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"LET KNOWLEDGE GROW FROM MORE TO MORE
AND THUS BE HUMAN LIFE ENRICHED."

A New Survey of Universal Knowledge

ENCYCLOPÆDIA BRITANNICA

Volume 18

PLANTS *TO* RAYMUND OF TRIPOLI

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Volume 18

PLANTS TO RAYMUND OF TRIPOLI

PLANTS AND PLANT SCIENCE. Living things (organisms) are commonly divided into two general groups—the animal kingdom and the plant kingdom. With higher organisms the difference between plants and animals is quite obvious: it is simple, indeed, to distinguish seaweed. ferns and trees from fish, birds and man However, in the case of the lower forms of life—bacteria, fungi, slime molds, protozoa. sponges—the distinction often is not so evident, and indeed, it is an artificial one since plants and animals probably had common ancestors in evolution (see ANIMAL).

The biologist recognizes no definite line separating animals and plants, or for that matter separating life and nonlife (see VIRUSES). But on the basis of certain fundamental differences in (1) mode of nutrition; (2) scheme of growth; (3) cell wall composition; and (4) locomotion, higher organisms may be placed in either the animal kingdom or in the plant kingdom.

1. Plants generally manufacture their own food, a process (see *Photosynthesis* below) directly associated with the presence in plant cells of tiny bodies or plastids containing chlorophyll, a vital green pigment. Animals, on the other hand, generally lack chlorophyll and are unable to manufacture their own food; they depend ultimately upon plants for food.

2. Embryonic tissues remain extremely active in plants and result in what is termed unlimited growth; as tissue dies it remains in place and the young, active tissue grows away from it Thus each apex of the root or shoot system consists of an aggregation of embryonic cells, an apical meristem, which persists throughout the life of the plant unless it changes into a reproductive cone or flower, or is destroyed by accident or disease; in some higher plants, especially treelike forms, lateral meristems (vascular and cork cambia) produce a growth in girth (see Tissues below). A mature animal, however. usually attains a maximum size and a characteristic form, that is, it has a limited growth pattern.

3. Almost all plants have cells whose walls contain cellulose and are, therefore, more or less rigid. Animal cells generally lack cellulose, and their cell walls are usually elastic.

4. Higher plants are anchored to the soil or to some other solid surface from which they cannot move by their own power. Most animals, on the other hand, are capable of considerable movement and make rather rapid changes to new locations when this is necessary.

Of course there exist plantlike animals such as the sessile marine corals, graptolites, anemones, sponges; and there exist also animallike plants such as bacteria, fungi and certain stages of algae and of higher plants. Nevertheless, when all characteristics are considered, it is relatively easy to determine whether an organism should be listed as a plant or as an animal. For the really difficult cases—slime molds, euglenoids, chlamydomonads, etc.—some biologists have advocated a separate kingdom, the protista (see PROTOZOA).

This article is divided into the following sections:

- B. Transpiration
  1. Physiology of Stomates
  2. Environmental Influences on Transpiration
  3. Significance of Transpiration
  4. Guttation
- C. Translocation of Water
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V. Plant Ecology
- A. Environment and Species (Autecology)
  1. Habitat and Structure
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- B. Regional Floras (Floristics)
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- C. Ecological Plant Geography
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  2. Limiting Factors
- F. Applied Plant Ecology

I. CLASSIFICATION OF PLANTS

A census of living things indicates that there exist today more than 300,000 species of plants and more than 1,000,000 species of animals. In the evolutionary sequence of the rise and fall of living things. many more have had their golden ages, and whole groups have either disappeared or exist today only as minor elements of the earth's flora and fauna. Knowledge of these relict or extinct groups of organisms is limited either to studies of the few representatives remaining or to the discovery of fossils.

Man has always been curious about his environment. History points to his efforts at identifying, naming and using the living things around him for his own ends. As man's knowledge grew, he has devised numerous systems of classification. The early systems for classifying plants are now little more than historically important (see BOTANY). With the general acceptance of the doctrine of evolution another point of view was added to the classification of organisms, namely, the understanding of relationships and origins of plants and plant groups as well as animals and animal groups. Clearly the evolutionary system is a natural system in that it occurred in nature over geological time; it contrasts with the artificial systems set up for identifications only.

Man, appearing late in the evolutionary system, has had to rebuild the natural system for himself from available evidence. Certainly an understanding of this system has become a major end of classification for both plants and animals. Here the accumulative evidence from comparative morphology and comparative anatomy; the contributions from embryology; the findings from paleobotany; the results from experimental studies in genetics, cytogenetics and morphogenesis; and the more recent additions from comparative physiology and biochemistry have helped clarify the issues and have pointed up the problems inherent in any attempt to duplicate the natural system. As a result certain areas of evolutionary relationship are now established. Many areas, however, remain conjectural and controversial. The present objective of investigators in diverse fields of botany is to narrow down or fill in these controversial gaps of knowledge.

Efforts at artificial classifications of plants need not concern us in detail here except insofar as terms employed in them have been carried over into present usage. The major divisions of the plant kingdom in the artificial system set up by Linnaeus (1754) were Cryptogamia and Phanerogamia, terms derived from the Greek meaning hidden marriage and visible marriage.

The phanerogams include what we know as flowering plants, or, as conceived then, seed plants. These have seemingly visible sexual organs in the flower. The cryptogams encompassed the nonflowering plants with inconspicuous sexual cells. It is now known that the plants in each group were misunderstood by Linnaeus and his followers. Actually the cryptogams, though their sexual cells are not advertised by showy flowers and are therefore not immediately evident, have the more obvious sexual reproduction on closer examination; the phanerogams, with their flowers making known the presence of sexual cells within, do by this device conceal them, rendering it difficult to detect and understand the details of sexual reproduction. Even though the Linnaean system has been superseded, the term phanerogam is still sometimes employed to cover all plants which reproduce by seeds, and cryptogam is frequently used for those that do not. The term vascular cryptogam is often used in current writings to indicate those vascular plants that do not bear seeds: the spore-producing clubmosses, horsetails and ferns.

After the artificial system of Linnaeus, classification turned in the direction of a natural system, one such system being that largely attributed to Eichler (1886). Under this system, the plant kingdom was considered to consist of four divisions:

1. Thallophyta, the algae and fungi.
2. Bryophyta, the liverworts and mosses.
3. Pteriodophyta, the clubmossrs, horsetails and ferns.
4. Spermatophyta, the seed plants (gymnosperms and angiosperms).

Until recently, the Eichler system had persisted generally; at the present time, however, it is largely replaced by a more natural arrangement (see the outline below). The tremendous strides made during the first half of the 20th century in paleobotanical investigations of Devonian and even Silurian fossils have produced a picture of an early, apparently world-wide flora of vascular plants with considerable diversification. While their beginnings are not clear, the different phyletic lines (lines of descent) already established in this flora by the mid-Devonian must have originated at a much earlier geological period.

Available evidence supports the premise of an origin for vascular plants from the green algae (Chlorophyta), but whether they descended from one line of green algae (monophyletic) or from more than one line (polyphyletic) is not clear. In the face of this irresolution, it has seemed wise for the present to hold to the conservative premise of a monophyletic origin for vascular plants. Pending further information, the phylum, or division, Tracheophyta is maintained for all vascular plants, and supersedes the divisions Pteridophyta and Spermatophyta of the Eichler system. This classification of the vascular plants, foretold by E. C. Jeffrey (1899–1910), took firmer form during the period 1917–1930; since 1930 it has slowly replaced the Eichler system.

With regard to Eichler's Thallophyta, students of algae (algologists) and of fungi (mycologists) have demonstrated it to be a cover-all group, including numerous phyletic lines. The number of these lines in the algae is generally agreed upon. By contrast, in the Eumycota, or true fungi, current opinion tends to favour a single origin directly from colourless flagellate organisms rather than multiple origins from algal groups, as advocated earlier.

Another body of opinion deserves mention: that both algae and fungi descended from colourless flagellate ancestors termed Protista initially by Haeckel in 1866. The term has been extended by adherents of this thesis beyond the limits set up by Haeckel until it includes all flagellated groups and their presumed early evolutionary progenitors. Therefore the Protista is presently conceived of as the first kingdom, ancestral to all living beings.

An increasing tendency among mycologists to question the grouping of the fungi with green plants must be considered.

These students, who doubt that fungi and green plants were ever related, conclude that fungi may well have arisen directly from the colourless Protista. The whole outlook of these mycologists depends upon an ecological and physiological approach; they base the classification of living beings upon nutritional modes of life. By this viewpoint the Protista are considered as having given origin to (1) a producing group of organisms that live by manufacturing their own food through photosynthesis — the plant kingdom; (2) an ingesting group that live by devouring organisms — the animal kingdom; and (3) an absorbing group that live by absorbing nourishment from either living or dead organisms — the fungal kingdom (R. H. Whittaker, 1959).

The place of the bacteria is as yet unresolved. It may be within the fungal groups or, in close alliance with the blue-green algae, either in the Protista or in a separate phyletic line from the supposed colourless flagellated ancestors. Preponderant opinion among bacteriologists separates the bacteria from the fungi.

The outline provided below attempts to produce an approach to the natural system of classification of plants; certain portions appear sound from the available facts and other portions are tentatively set forth as reasonable evaluations of data in hand. Since each scheme results from the interpretations of evidence by one man, or at most a few men, differences of opinion are to be expected. It is even more to be expected that the system of classification as set forth in this article will be changed as more information becomes available. The present offering is conservative and, with only minor variations, currently in wide use.

KINGDOM PLANTAE

Current System — Phylum or Division | Eichler System — Class | Phylum or Division

1. Chlorophyta* -- green algae
   Chlamydomonas, Oedagonium, Ulva, Spirogyra, etc.
2. Euglenophyta — euglenoid algae
   Euglena, etc.
3. Chrysophyta — yellow-green algae, golden-brown algae and diatoms
   Tribonema, Dinobryon, Navicula, etc.
4. Pyrrhophyta — dinoflagellates, desmokonts
   Peridinium, Ceratium, etc.
5. Phaeophyta — brown algae
   Ectocarpus, Lanzinaria, Fucus, etc.
6. Cyanophyta — blue-green algae
   Anacystis (= *Chroococcus*), *Oscillatoria, Nostoc,* etc.
7. Rhodophyta — red algae
   Nemalion, Polysiphonia, Corallina, etc

Algae

8. Schizomycota — bacteria†
   Streptococcus, Bacillus, Spirillum, etc.
9. Myxomycota — slime molds
   Physarum, Stemonitis, Dictyostelium, etc.
10. Eumycota — true fungi
    Class Phycomycetes — algal fungi
    Mucor, Pythium, Phytophora, etc.
    Class Ascomycetes — sac fungi
    Saccharomyces, Aspergillus, Neurospora, etc.
    Class Basidiomycetes — club fungi
    Puccinia, Amanita, Polyporus, etc.
    Fungi Imperfecti

Fungi

Thallophyta

11. Bryophyta
    Class Hepaticae — true liverworts
    Class Anthocerotae — horned liverworts
    Class Musci — mosses

Bryophyta

12. Tracheophyta
    Class Psilopsida
    Order Psilophytales
    Psilophyton, Rhynia, Asteroxylon, etc.
    Order Psilotales
    Psilotum and *Tmesipteris*
    Class Lycopsida
    Order Lycopodiales — club mosses
    Lycopodium and *Phylloglossum*
    Order Selaginellales — little club mosses
    Selaginella
    Order Lepidodendrales — tree club mosses
    Lepidodendron, Sigillaria, Bothrodendron, etc.
    Order Pleuromeiales
    Pleuromeia
    Order Isoetales — quillworts
    Isoetes
    Class Sphenopsida
    Order Hyeniales
    Hyenia, Calamophyton, etc.
    Order Sphenophyllales
    Sphenophyllum, etc.
    Order Equisetales — horsetails
    Equisetum, Calamites, etc.
    Class Pteropsida
    Subclass Filicinidae — ferns
    Order Coenopteridales — early fossil ferns
    Botryopteris, etc.
    Order Marattiales
    Marattia, Danaea, Angiopteris, etc.
    Order Ophioglossales
    Ophioglossum, Botrychium, Helminthostachys
    Order Filicales — "true" ferns
    Osmunda, Gleichenia, Dryopteris, Pteris, etc.

Pteridophyta (Continued)

    Subclass Gymnospermidae — gymnosperms
    Order Cycadofilicales — pteridosperms, or seed ferns
    Order Bennettitales — fossil cycads
    Williamsoniella, Wielandiella, Cycadeoidea, etc.
    Order Cycadales — cycads
    Cycas, Zamia, Dioon, Bowenia, etc.
    Order Ginkgoales — ginkgo, maidenhair tree
    Ginkgo
    Order Cordaitales
    Cordaites, etc.
    Order Voltziales — early fossil conifers
    Lebarhia, Walchia, Pseudovoltzia, etc.
    Order Coniferales — conifers
    Pinus, Sequoia, Taxodium, Thuja, Araucaria, etc.
    Order Gnetales‡
    Ephedra, Welwitschia and Gnetum

Gymnospermae

    Subclass Angiospermidae
    Dicotyledones — 44 orders, with over 250 families §
    Ranunculus, Quercus, Rosa, Malus, Taraxacum, etc.
    Monocotyledones — 11 orders, with 45 families §
    Triticum, Avena, Lilium, Musa, Cocos, etc.

Angiospermae

Spermatophyta

BIBLIOGRAPHY.—C. A. Arnold, *An Introduction to Paleobotany* (1947); Lyman D. Benson, *Plant Classification* (1957); A. W. Eichler, *Syllabus der Vorlesungen über specielle und Medicinsh-pharmaceutische Botanik,* 4th ed. (1886); A. Engler and L. Diels, *Syllabus der Pflanzenfamilien,* 11th ed (1936); E. C Jeffrey, "Morphology of the Central Cylinder in the Angiosperms," *Trans Canadian Inst. Sci.,* 6:599–636 (1900); O Tippo, "A Modern Classification of the Plant Kingdom," *Chronica Botanica,* 7.203 (1942); R. H. Whittaker, "On the Broad Question of Organisms," *Quart. Rev. Biol.,* 34:210–226 (1959); G. M. Smith, "The Classification of Algae," in *Manual of Phycology*, pp. 13–19 (1951); G N Papenfuss, "Classification of the Algae," in *A Century of Progress in the Natural Sciences, 1853–1953,* pp. 115–224 (1955); E. A. Bessey, "Mycology," in *A Century of Progress in the Natural*

*For the first seven phyla some algologists prefer Chlorophycophyta, Euglenophycophyta, Chrysophycophyta, etc , the addition "phyco" designating alga. At present no universal agreement on the designations of the phyla exists, and the more common usage is followed †The bacteria are sometimes omitted from the fungi completely ‡This group of plants may represent more than one order of plants In the absence of significant fossil evidence, existing information does not yet justify this separation. §Totals of orders and families were taken from Engler and Diel s *Syllabus der Pflanzenfamilien,* 11th *ed.* (1936).

Sciences, 1853–1953, pp. 225–265 (1955) ; R. Y. Stanier, M. Doudoroff and E. A. Adelberg, *The Microbial World* (1937) ; C. B. van Niel, "Classification and Taxonomy of the Bacteria and the Blue-green Algae," in *A Century of Progress in the Natural Sciences, 1853–1953,* pp. 89–114 (1955) ; A. J. Eames, *Morphology of the Vascular Plants: The Lower Groups* (1936) ; A. S. Foster and E. M. Gifford, *Comparative Morphology of Vascular Plants* (1959); E. Haeckel, *Das Protistenreich: Eine populare Gbersicht über das Formengebiet der niedersten Lebenwesen* (1878) ; R. C. Moore, "Kingdom of Organisms named Protista," J. *Paleont.,* 28:588–598 (1954). (R. H. WE.)

II. MORPHOLOGY OF PLANTS

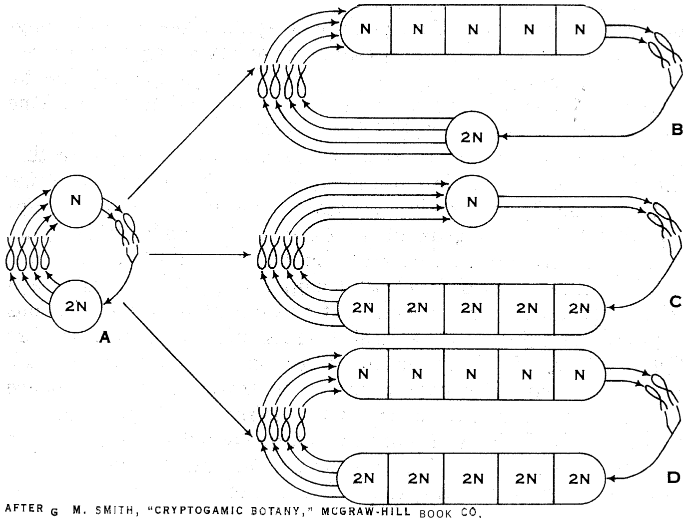
Plant morphology is concerned with the form and structure of plants and of their parts, and with the relation of parts to one another and to the whole, Morphology is thus fundamentally descriptive. A morphological study may be merely the determination of the facts of the history of an organism through all stages of development and reproduction; that is, it may be a purely descriptive life history study. As commonly understood, however, morphology has a broader basis: its object is to trace the underlying similarities in form between various plant groups; it is comparative in its nature, and its comparisons are considered in the light of evolutionary modification and development. Morphology thus conceived aids in the establishment of a natural classification of plants and in the reconstruction of their evolutionary history (phylogeny).

The methods used in morphological studies are: (1) comparison of adult forms of living plants; (2) comparison of living plants with fossils of ancient extinct forms (paleobotany) ; (3) observations on development of the individual (ontogeny). Morphology is generally subdivided into external morphology which deals with the external form, and anatomy, the study of the external and internal structure of plants. Cytology, study of the cell. arose as a subdivision of morphology concerned nith internal structure, but it has become an independent branch of biological science. A morphological study may assume a somewhat specialized aspect. Thus it may deal with the early development of an individual (embryogeny) ; with the causes that determine form and structure (morphogenesis); or with plant parts considered as organs carrying out certain distinct functions (organography).

1. Alternation of Generations. — The phenomenon of alternation of generations is so prominent and important a feature of the morphology of plants that for many years it has been one of the main objects of morphological studies. The term alternation of generations is used to designate the occurrence of two distinct phases in the life history of the plant, each of which produces the other. One is the sexual phase, the gametophyte, that bears male and female organs (gametangia) and gametes (sperms and eggs) and in which fertilization (syngamy) is effected The fertilized egg (zygote) develops into a nonsexual phase. the sporophyte. which produces a large number of single-celled spores. The latter develop directly into new gametophytes. The two phases of the life cycle are commonly referred to as generations. though actually they are two phases of one generation if the latter concept is used in the same sense as in zoology.

At fertilization the number of chromosomes is doubled through the union of two gametes. At some other point of the life cycle this number is again halved through reduction divisions (meiosis) (see FERTILIZATION; CYTOLOGY). The phase of the life cycle in which all cells have a double complement of chromosomes (diploid) and which begins with the fertilization and ends nith the reduction divisions is the sporophyte. The phase characterized by a single complement of chromosomes (haploid), from reduction division to fertilization, is the gametophyte. The character and relative extent of these two phases differ considerably in different groups and show great variability in the lower plants. .In many of the thallophytes (algae and fungi) almost the entire life cycle is gametophyte, since the first divisions of the zygote are meiotic; in others it is almost all sporophyte. Still others show varying degrees of relative development of these two phases, and often both are vegetative plants entirely similar in everything except the method of reproduction.

The diagrams give examples of different types of life cycles. The simplest possible life cycle occurs in the unicellular green alga *Chlamydomonas* (phylum Chlorophyta). It consists of an alternation of a one-celled haploid phase with a one-celled diploid phase (fig. 1[A]). In the somewhat higher Chlorophyta vegetative cell divisions occur in one or the other or in both phases. In the haplont type, as seen in the green algae *Spirogyra* and



AFTER G. M. SMITH, "CRYPTOGAMIC BOTANY," MCGRAW-HILL BOOK CO.

FIG. 1.—VARIOUS TYPES OF LIFE CYCLE AMONG THE CHLOROPHYCEAE (GREEN ALGAE)

(A) chlamydomonad; (B) haplontic; (C) diplontic; (D) diplohaplontic

Oedogonium, a multicellular haploid phase alternates with a unicellular diploid one (fig. 1[B]). In the diplonts, the green alga *Codium,* the life cycle consists of an alternation of a diploid coenocyte (the morphological equivalent of a multicellular diploid generation) with a unicellular haploid phase (fig. 1[C]). Certain other green algae, *e.g., Ulva,* are diplohaplonts and have an alternation of a many-celled haploid generation with a many-celled diploid generation (fig. 1[D] j (see also ALGAE).

The gametophyte is the dominant phase or "the plant" of the mosses (Bryophyta), whereas the sporophyte is merely a spore-bearing structure that develops from the zygote and remains attached to the gametophyte (fig. 2). In contrast. the vascular plants (Tracheophyta) have a large and conspicuous sporophyte with roots, stems and leaves and predominates in the life history. The fern sporophyte bears the spores on the backs of its leaves. Each spore may develop into a small but independent generation, the gametophyte or prothallus. on which the sex organs are borne (fig. 3). In the conifers and their allies (gymnosperms) and in the flowering plants (angiosperms) the gametophyte generation is extremely reduced. The spore (megaspore) producing the female gametophyte (megagametophyte) remains attached to the sporophyte after germination. Other spores (microspores) germinate to form the male gametophytes (pollen grains), which are liberated and carried (by wind, rain or insects) to or near an ovule containing the female gametophyte. One of the two male gametes (sperms) produced by the male gametophyte fertilizes the egg. The zygote grows at once into the embryo (fig. 4).

Two theories have long existed concerning the nature and origin of the sporophyte of vascular plants: the antithetic theory and the homologous theory. The first assumes that the two phases are essentially distinct, that the sporophyte is a new phase introduced into the life cycle of vascular plants in relation to life in air. It is supposed to have evolved from the zygote of an ancestral algal form through a stage in which it was merely a spore-bearing structure wholly dependent upon the gametophyte.

According to the homologous theory (which is supported by modern morphological and paleobotanical studies), the sporophyte and gametophyte are fundamentally alike in nature; they are correlative phases in the life cycle of plants that have arisen by modification of an original single sexual phase. In several interpretations the homologous theory places the differentiation of the gametophyte and sporophyte in ancient algal stocks and assumes the origin of land-living independent sporophytes directly from independent aquatic sporophytes.

2. Plant Body.—In the simplest plants the body consists of a single cell nithin which all life activities are carried on. According to the evolutionary concept, the simple cells united into colonies forming at first a loose, later a more intimate. union. until a multicellular plant arose. With the advent of "division of labour" between the different parts of the multicellular body, a morphologic differentiation of these subdivisions occurred, so that a very complex plant body appears in the higher plant groups. In the lowest plants any part may perform all functions. whereas in the highest the various functions have organs devoted to their performance, and in these the cells are grouped in definite and very specialized tissues. The lower plants (Thallophyta) show various degrees of complexity of form and structure. Certain groups of red and brown algae somewhat resemble the higher plants in the formation and arrangement of the members of their bodies. The progressive differentiation of the thallus of the liverworts and mosses (Bryophyta) presents an even closer parallel to the organization of the higher plants. Some of these have stemlike and leaflike body parts resembling organs of the most highly organized plants. True roots, stems and leaves, honever, do not occur in either thallophytes or bryophytes. These are characteristic organs of the vascular plants (Tracheophyta). According to a modern concept, these organs evolved with the invasion of the dry land by plants that formerly inhabited only the sea.

The nature of the plant body and its parts in vascular plants has long been a basic morphological problem. As was shown in the preceding section, it is the body of the sporophyte that is so complex in the higher plants. The gametophyte is extremely simple. In early days of morphological study the sporophyte body was looked upon as constituted of organs that were of different fundamental nature The number of these organs was at first large; for example, stem, root, leaf, ovule, sporangium. sporangiophore, emergence, hair. With the development of the concept of homologies, the interrelation of parts of a plant body began to be recognized. Comparative and developmental studies suggested that differently appearing parts may bear the same relation to the whole plant body, that. in other words, they may be homologous. For example, the floner appeared homologous with the shoot. the floral members with leaves. In contrast, if parts differ in their relation to the whole, but are similar in function and structure. they are analogous. Thus the flattened green stems of many plants of dry habitats are analogous with leaves. With increase in comprehension of the relationship between parts. the units of structure became reduced to three: stem. leaf and root.

The later discoveries of early land plants and studies in development have indicated that even these three categories of parts are not absolute, but are results of evolutionary development and cannot be clearly separated morphologically. The general nature of the plant body seems to be that of an axis. Under this interpretation there are no fundamental parts Roots and leaves, as elaborated organs. are secondary structures that differentiated on an originally primitive axis. The leaf may have arisen in two ways: (1) as a lateral emergence of the axis; and (2) as a branch system that became flattened and expanded. nith a webbing of tissue uniting the branches into one. The view upon the relation of the angiospermous flower to the other plant parts is also in a state of flux. The concept of the flower as a modified shoot. and particularly that of the homology between the leaf and the carpel, is being contested. The complex problem of the nature of the plant organs is still anaiting its final clarification. A judicial use of data on ontogeny. vascular anatomy. paleobotany and comparative morphology should eventually bring about such clarification. See ROOT; LEAF; STEM; FLOWER.

BIBLIOGRAPHY.—A. Arber, "The Interpretaticn of Leaf and Root in the Angiosperms," *Biol. Reviews, 16*:81–105 (1941); F. O. Bower, *Size and Form in Plants* (1930); D. H. Campbell, *Tlze Evolution of the Land Plants* (1910); 3. J. Eames, *Morphology of Vascular Plants, Lower Groups* (1936); E. A. Gaumann and C. W. Dodge, *Comparative Morphology of Fungi* (1928); K. E. Goebel, *Organography of Plants, Especially of the Archegoniatae and Spermatophyta* (1900–05); G. M. Smith, *Cryptogamic Botany*, vol. i, *Algae and Fungi*, vol. ii, *Bryophytes and Pteridophytes* (1938); W. Troll, *Vergleichende Morphologie der höheren Pflanzen*, 3 parts (1935, 1937); R. C. McLean and W. R. Ivimey Cook, *Textbook of Theoretical Botany (1951)*; H. C. Bold, *Plant Morphology* (1957); A. S. Foster and E. M. Gifford, Jr., *Comparative Morphology of Vascular Plants* (1959).

III. ANATOMY OF PLANTS

Anatomy deals with structure, gross and minute. external and internal. A special field of anatomy is histology, nhich is concerned nith the minute structure of organisms. If an anatomical study deals nith the structure of cells. particularly nith the protoplast, it enters the field of cytology. Thus anatomy merges with cytology and only an arbitrary limit may be set up between the two.

A. MINUTE STRUCTURE

1. The Cell.—An account of the anatomy of plants naturally begins nith the cell. which is the smallest physiological unit of organisms The cell is essentially an integral mass of protoplasm, of small dimensions and containing many specialized structures, chief among which is the nucleus. Other protoplasmic bodies. knonn as plastids. and inanimate matter. are present. The different living bodies and nonliving inclusions are dispersed within the more or less fluid living substance called cytoplasm. Among the nonliving inclusions are starch grains, crystals of various shapes and compositions, oil globules, tannins and food masses of different sorts. Much of the inanimate matter occurs in a n atery solution forming the cell sap. All cells that are permanent tissue

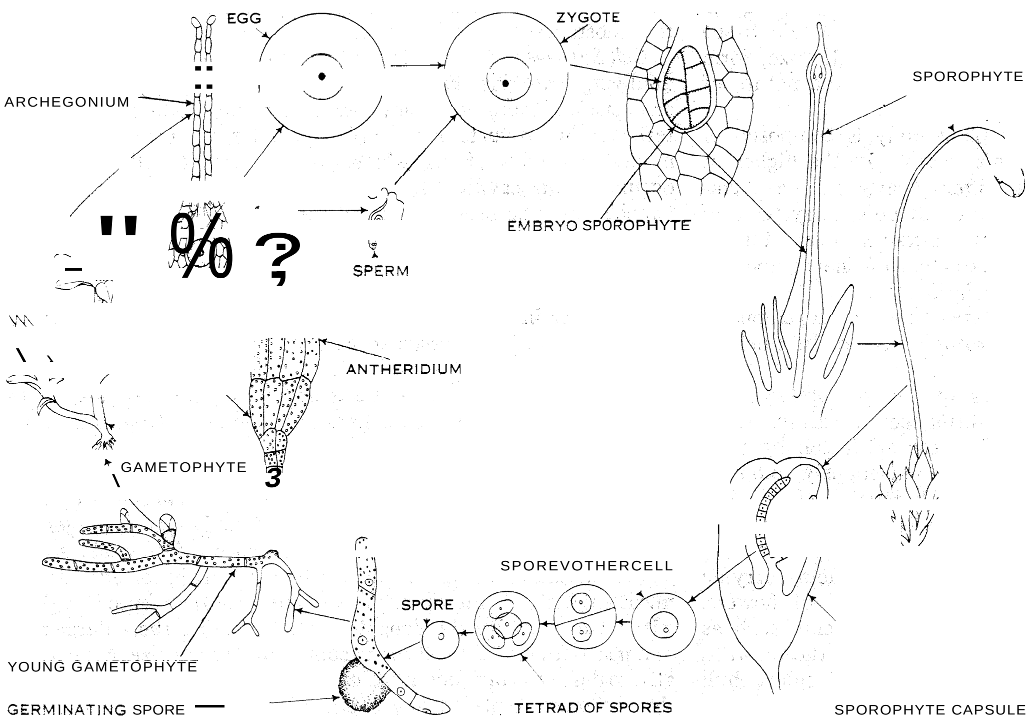


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FIG. 2.— LIFECYCLE OF A MOSS (FUNARIA)

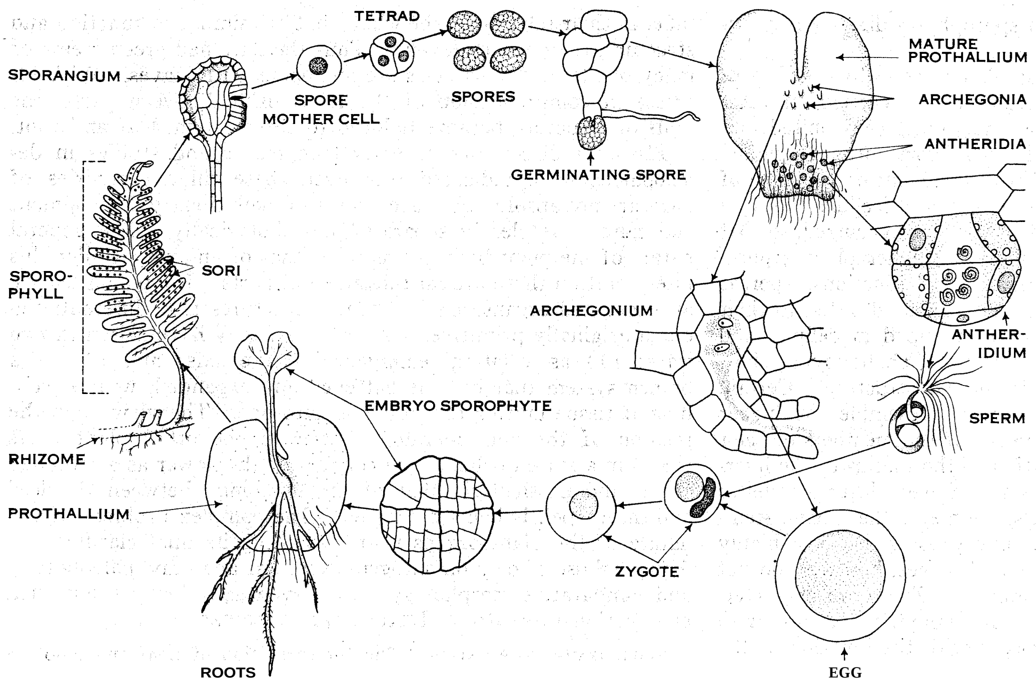

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FIG. 3.— LIFE CYCLE OF A FERN (POLYPODIUM)

elements of the plant body possess a more or less rigid limiting membrane or cell wall, consisting primarily of cellulose or some allied substance excreted by the living cell body. As mentioned above, the presence of plastids in the protoplasm and the existence of the cell wall are the two main characteristics that differentiate plant cells from those of animals.

The walls of adjacent cells are cemented together so that the cells are united into more or less coherent masses or tissues. Upon the characters of constitution, thickness and sculpture of the cell walls, the qualities of a plant tissue largely depend. The life of all the cells in a plant body may be prolonged, or a number of the cells may die and their protoplasm be removed. Thus a tissue may consist of living cells combined with an inanimate framework of cell walls, enclosing in their cavities solely liquids and gases. In such cases the characters of the adult tissue largely depend on the proportion and distribution, the size, form and contents of the living and dead units, and on the nature of their walls.

In all but the simplest forms the plant body is composed of cells associated in more or less definite ways. In the higher or more complicated plants the cells differ greatly among themselves so that the adult body is composed of definite systems of units, the tissue systems. Each system has its own characteristic structure, depending partly on the characters of the component cells and partly on the method of association.

For a detailed consideration of the structure and development of the plant cell with regard to the protoplasm and the nucleus, see **CYTOLOGY**.

Plastids.—The plastids are portions of the protoplasm that have become specialized for the performance of certain functions. They are readily distinguished in the adult cell by their size and definite form, and they are often conspicuously coloured. Leucoplasts are colourless and occur in the cells of the deeper lying tissues where light cannot penetrate—if exposed to light they often become green. They are frequently concerned with the formation of starch grains. Chromoplasts are colour-carrying bodies giving red and yellow colours to the petals of flowers, ripe fruits, etc.; they contain yellow and red pigments such as xanthophyll and carotin. The most important of all the plastids, however, are the green chloroplasts. These contain chlorophyll and are of universal occurrence throughout the plant kingdom with the exception of the important groups of fungi and bacteria. By means of this pigment the plastids are enabled in the presence of light to form carbohydrates from water and carbon dioxide. The chloroplasts are extremely variable in shape, particularly in the algae. In the higher plants the chloroplast is disc-shaped and, according to the prevalent view, consists of a mass of somewhat dense colourless cytoplasm, the stroma, and of granules containing chlorophyll. Chloroplasts frequently contain starch grains.

The differentiated plastids seen in mature tissues may be traced back to plastid primordia, or proplastids, in the youngest tissues (meristems) or embryo. The proplastids appear in the cytoplasm of the young cells as minute bodies grading off to the limit of visibility. At all stages of development from proplastids, and at maturity, the plastids may divide by simple constriction. These divisions are sufficiently numerous to account for the large numbers of plastids in mature cells. It has not been disproved, however, that plastids arise also anew (de novo) in the cytoplasm. The problem of individuality of the plastid is mainly one of determining whether they are continuous or not through the critical stages in the life cycle, the gametes and spores. They have been shown to be present in the gametes and spores of some plants and are, in these instances, apparently passed on'from one generation to another.

Mitochondria.—In addition to the plastids there are other bodies in the cytoplasm which are very minute and appear as tiny granules, rods or threads and whose nature and function are not well understood. They are called chondriosomes or mitochondria. According to one opinion. mitochondria are the bodies from which plastids develop; according to another, the proplastids and mitochondria are distinct structures. Mitochondria are thought to be concerned with respiration and accumulation of certain substances.

Cell Sap.—All living cells in plants contain variable amounts of nonliving materials that are collectively designated as inclusions or ergastic substances. They include storage products, waste material, or by-products of protoplasmic activity. One of the commonest examples of ergastic substances is the cell sap, which occurs nithin cavities or vacuoles of the cell. One or more vacuoles may be present in a cell, their number and shape varying from time to time in the same cell. The total vacuolar system of a cell or other protoplasmic mass, whether this system consists of one or more vacuoles, is called the vacuome. The cell sap is water in which are dissolved substances of various kinds, some being food materials, others products of the metabolism of the protoplasm. Its composition is constantly changing, but among the substances of constant occurrence are inorganic salts, carbohydrates such as the sugars and soluble nitrogenous compounds.

Vacuoles appear to be universally present in living plant cells. In the youngest or meristematic cells, which by continual division form the tissues and organs of the plant body, the vacuoles are rather numerous, small, spherical or drawn out into other shapes by the streaming cytoplasm in which they are dispersed. As the meristematic cells multiply, the vacuoles are distributed. with or without division, to the daughter cells. During the enlargement and maturation of the cell the vacuoles increase in size and eventually coalesce to form one large central vacuole, and the cytoplasm thus becomes displaced to a comparatively thin layer closely applied to the cell wall.

Cell Wall.—The cell wall in young, active cells (meristematic cells) is thin and extremely delicate; however, upon completion of the growth of the cell, the cell wall becomes thicker and may undergo considerable modification. It is commonly regarded as a secretion of the protoplasm and is, in living cells, in intimate relation with the protoplasm which may interpenetrate the particles of its substance. This close relation can be readily appreciated when the process by which the wall is first laid down is considered From the beginning of the plant's existence as a single cell, all new cell formation consists in the division of a pre-existing cell into two halves by the formation of a dividing wall. In this process the cytoplasmic spindle, which functioned in the preceding nuclear division (see CYTOLOGY), plays an important part. The new wall begins with the appearance of a cell plate dividing the spindle in two halves. If the spindle does not reach to the side walls of the dividing cell, new fibres arise on its periphery and extend the cell plate to the side walls. The cell plate is a fluid layer appearing first as minute droplets that unite to form a continuous layer. Some interpret these small units as droplets of pectic substances. The fluid cell plate apparently soon solidifies and becomes part of the wall. The two daughter protoplasts that resulted from the division of the original cell secrete additional wall substances. These are deposited among the existing particles (intussusception) and also over the inner surface of the new wall (apposition). The amount of wall material deposited varies in different kinds of cells. One extreme is cells with walls that are a little thicker than those of the meristematic cells from which they arose; the other, cells nhose interior spaces (lumina) are almost filled nith wall material.

Commonly the wall does not appear homogeneous, but shows layering. The layers may differ in origin, in appearance when viewed in polarized light. and in chemical and physical structure. Three main types of layers exist: intercellular substance, prrmary wall and secondary wall. The intercellular substance is composed of pectic substances and is isotropic (i e., dark or nonrefringent when viewed under polarized light). This substance acts as a cementing material binding together the walls of adjacent cells. Some regard it as being derived from the cell plate formed during cell division.

The primary wall consists largely of cellulose and pectic substances and is anisotropic (i e., bright or refringent when viewed under polarized light). It occurs next to the intercellular substance. Many thin-walled tissues contain only primary malls. In other tissues, however, these primary walls may be comparatively thick. They are formed while the cell is still enlarging during differentiation from a meristematic cell.

The secondary wall is extremely complex, physically and chemically, and strongly anisotropic Cellulose is its basic component and it is formed after the cell attains its final size and shape. The secondary wall of plant cells is rarely continuous over the entire surface of the underlying primary wall It may develop as separate rings. spirals, bars. or as complex network or mesh; or it may cover most of the primary wall except for small interruptions or cavities called pits (fig. 5). All three uall layers may become modified by impregnation with a variety of inorganic and organic substances, notably lignin, which renders the walls firm and hard.

The anisotropy of the primary and secondary walls indicates that they are crystalline in nature. The crystalline properties are imparted to the wall by cellulose, a carbohydrate with the general formula $(C_6H_{10}O_5)n$. The units $C_6H_{10}O_5$ (anhydrous glucose residues) are combined into long chains—the cellulose molecules.

These chain molecules occur in bundles, the microfibrils, in parts of which the molecules are arranged parallel to one another with characteristic spacings betneen the chains. The molecules and their aggregations are too small to be seen through a light microscope and are studied by the use of X-rays, polarized light and electron microscope.

The microfibrils appear to overlap each other and form a coherent system perforated by a continuous system of spaces. Within these spaces substances other than cellulose (e g , lignin, fatty substances, water) are deposited. As seen through the light microscope the cellulose wall also appears as a continuous system of fibrils, the macrofibrils, interpenetrated by a system of porosities. The macrofibrils are aggregations of submicroscopic microfibrils.

Many conspicuous differences in the optical and mechanical properties of cell walls are correlated with variations in the orientation of the microfibrils. If the microfibrils are oriented parallel to the long axis of the cell, the wall or layer in which they occur does not contract longitudinally in drying. The opposite is true if the walls have transversally oriented microfibrils. Various intermediate conditions occur in walls whose microfibrils are oriented in a spiral in relation to the long axis of the cell. To further complicate the system microfibrils may be differently oriented in

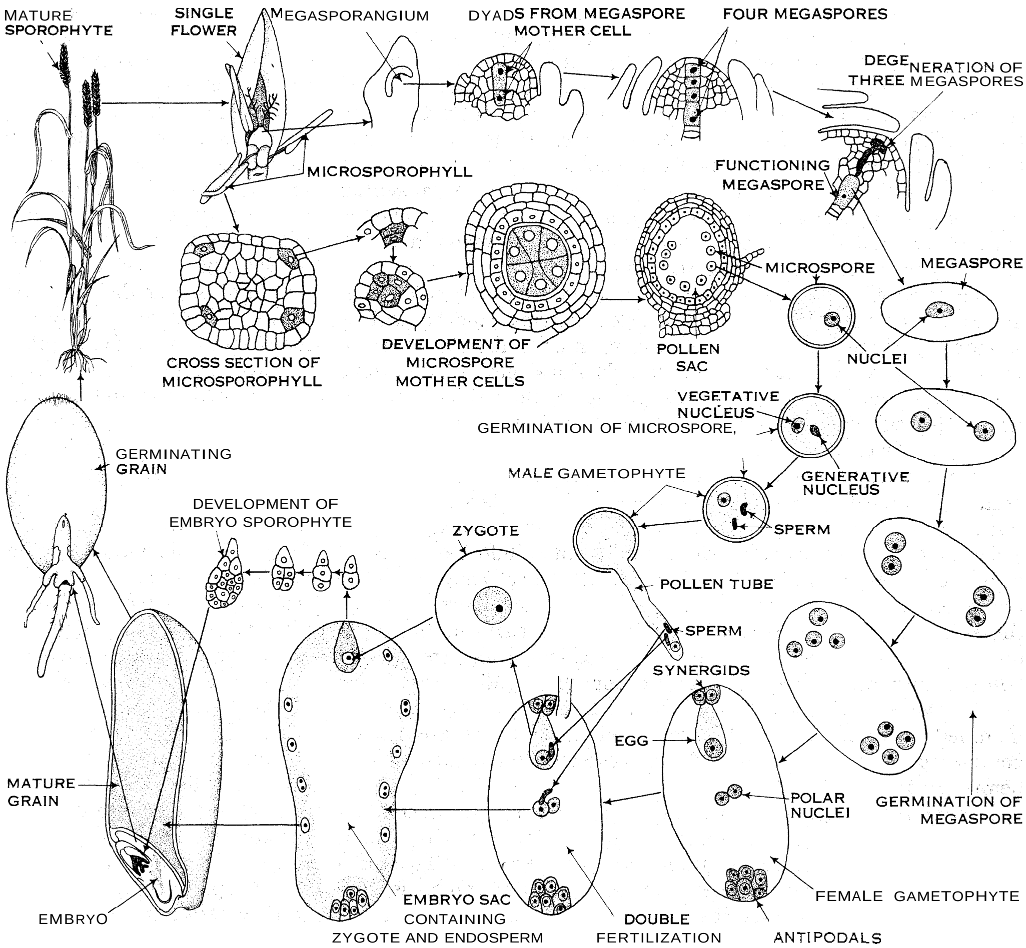

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FIG. 4.—LIFE CYCLE OF WHEAT (TRITICUM)

the various wall layers of the same cell.

Plasmodesmata.—The living cell in a complex multicellular plant body is not a completely independent unit, and its functions are conditioned by, and related to, the activities of the organism as a whole. This must involve a close connection between the living protoplasm of neighbouring cells, and this is effected by delicate connecting strands, the plasmodesmata. which traverse the walls. The connecting strands may be scattered singly throughout a wall or may be aggregated in thinner places of the wall, the pit areas. Plasmodesmata may represent the persistence of the original continuity of the protoplasm of two sister cells, but also are established after growth is completed. These delicate connections seem to occur universally in the higher plants. They play a part in the correlation of the functions of the cells and may also provide the means by which stimuli can be conveyed through long tracts of tissue.

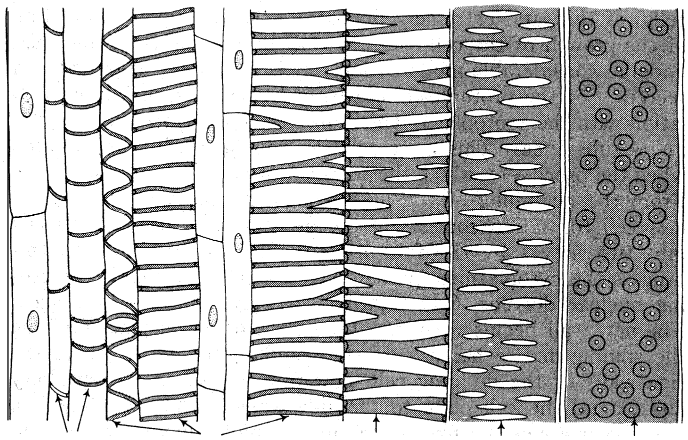
2. Cell Types **and** Tissues.—As plants increased in complexity the component cells also came to differ greatly among themselves. Plant cells may vary in size, shape, contents and wall structure. and may be highly specialized with regard to function.

Parenchyma. — Parenchyma cells are commonly more or less isodiametric in form, have thin walls and active protoplasts. A certain degree of variation in characteristics occurs with relation to the functions performed by parenchyma. Thus the parenchyma cells of the photosynthetic tissue of a leaf are rich in chloroplasts and may be considerably elongated or lobed; the parenchyma cell of a potato tuber contains leucoplasts that store starch; the parenchyma cells within the water-conducting tissue (xylem) may have thick secondary walls. The retention at maturity of living protoplasts is one of the most important characteristics of parenchyma cells. These cells are regarded as the least differentiated, the least specialized, and they make up the entire plant bodies of most of the Thallophyta (algae and fungi).

Collenchyma.—Collenchyma cells occur in layers or strands in the subsurface region of many stems. petioles and ribs of leaves where they serve as a supporting tissue. Like the parenchyma, this tissue retains living protoplasts at maturity. The shape of the cell varies from nearly isodiametric to a very much elongated (prosenchymatous). The principal characteristic is the thick cellulose wall, the thickening being irregular and massive. The thickenings occur in strips along most walls, or the tangential walls or only in the corners. The walls are very strong but plastic, and do not hinder the elongation of the growing organs in which collenchyma is the chief supporting tissue.

Sclerenchyma.—Sclereids and fibres are often treated as elements of one type of tissue called sclerenchyma (mechanical or supporting tissue), because both have thick walls, lack protoplasts and serve for support. Sclereids show similar variations in shape as the parenchyma cells but have very thick lignified walls with tubular pits. The protoplasts are usually lacking at maturity. One of the best-known examples of a sclereid is the stone cell that is a common component of the flesh of the pear fruit. The hard shell of the walnut is made up largely of sclereids. Fibres are elongated cells, sometimes very much so, with thick pitted secondary walls which may be of cellulose or lignified cellulose. The protoplasts usually die when the cells mature. The two main groups of fibres are those that occur in the wood tissue, the xylem fibres, and those located in various parts of the plant outside the xylem, the bast fibres. The xylem fibres are usually lignified and are chiefly responsible for the rigidity and hardness of the wood. Some bast fibres are lignified, others have unmodified cellulose walls. The latter kinds of fibres are valued commercially and occur in such well-known fibre plants as flax, hemp and ramie.

Conducting Elements.—Tracheary elements are water conductors located in the xylem or wood. The vascular plants are called Tracheophyta because they contain tracheary elements. Two principal types of tracheary elements occur in plants: tracheids (fig. 6[A]) and vessel elements (fig. 6[B], 6[C]). Both of these are commonly prosenchymatous with oblique or transverse end walls. They have secondary walls of lignified cellulose that are deposited as rings, spiral bands, bars, a network, or as pitted layers upon the thin primary wall. At maturity the protoplasts are lacking.



AFTER E. W. SINNOTT, "BOTANY PRINCIPLES AND PROBLEMS," MCGRAW-HILL BOOK CO.

FIG. 5.—CELL WALL TYPES IN PRIMARY XYLEM SHOWN IN A LONGITUDINAL SECTION OF VASCULAR BUNDLE IN A STEM

The principal distinction between the two types of tracheary elements is that the tracheid is an imperforate cell with a continuous primary wall, whereas a vessel element has openings or perforations usually located in the end walls of the cell. The vessel elements are combined into longitudinal pipelike units, the vessels, in which water passes freely through perforations from element to element. Water moving through tracheids passes from one cell into the other through places where the secondary wall is discontinuous but the primary wall is present. Often these places are very restricted and are then called pits. The water passes through the exposed part of the primary wall of the pit, the pit membrane.

In the wood of gymnosperms (firs and their allies) the pits show very elaborate structure. The pit membrane has small but numerous perforations and is reinforced by a primary thickening, the torus, in the middle. The secondary wall overhangs the pit cavity as a border (hence bordered pit), leaving a small opening (pit mouth) at the entrance into the pit cavity (fig. 6[D]). The pit membrane is flexible and can bulge one way or the other within the cavity formed by two communicating bordered pits of the adjacent cells. The torus may become appressed to the mouth of one or the other pit, obstructing the entry into the pit cavity. Thus, apparently by changes in the position of the pit membranes of bordered pits, some control is exercised over the passage of fluids in the xylem.

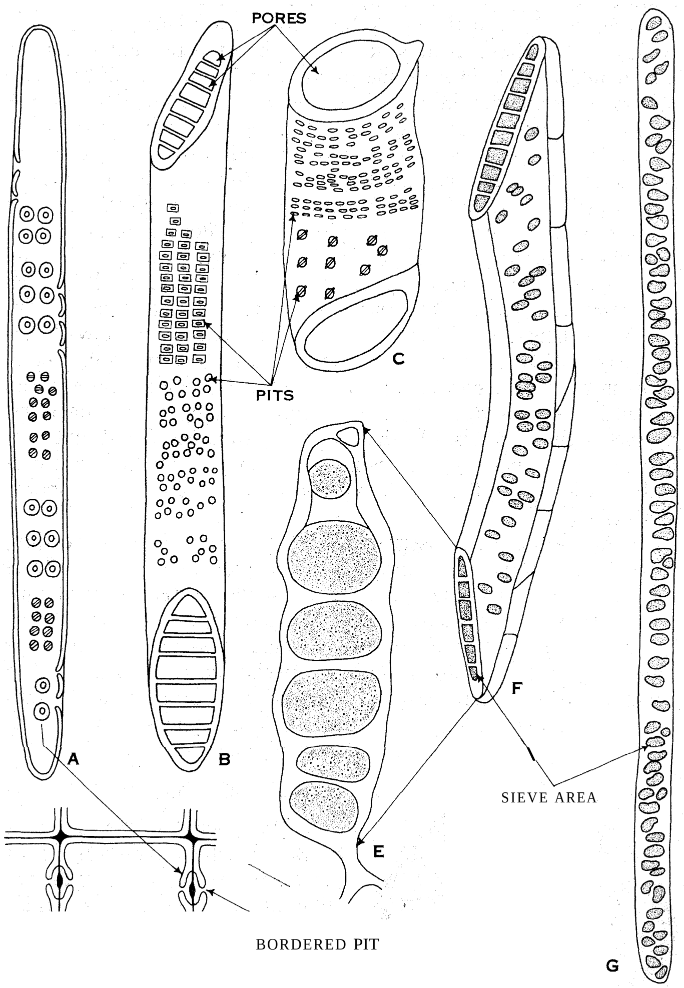
Sieve cells (fig. 6[G]) and sieve-tube elements (fig. 6[F]) are the characteristic components of the phloem, a tissue outside the xylem and concerned with the conduction of food (chiefly sugars and protein) manufactured in the leaves. The sieve-tube elements occur in the angiosperms (plants having their seeds enclosed in an ovary), whereas sieve cells are typical of gymnosperms and ferns. The sieve-tube elements have specially modified walls or portions of walls called sieve plates (fig. 6[E]). The essential feature of a sieve plate is the presence of perforations (sieve-plate pores) in the wall through which the protoplasts of two adjacent or superposed elements are continuous. These connecting strands are comparable with plasmodesmata but tend to be thicker than ordinary plasmodesmata.

In the sieve plate a special kind of carbohydrate, callose. surrounds each strand. In other words. each strand is enclosed in a tube or cylinder of callose, the callose cylinder. As the sieve tube ages, the callose becomes more massive. Since each callose cylinder thickens, the strands are constricted and, furthermore, callose bulges and spreads over the surface of the plate until the latter appears completely buried within the callose. The bulging callose masses on both sides of the sieve plate are referred to as callose plugs, though it is not known whether they actually plug the sieve plate. The appearance of the callose plugs indicates that the sieve-tube element has ceased to function. Therefore, the final callose masses developed at the end of the active period of the conducting element are also called definitive callose.

As it matures the protoplast of the sieve-tube element loses its nucleus. but the cytoplasm is retained until the cell ceases to function. Some studies indicate that this cytoplasm is peculiar: it appears to be very fragile. The contents of the vacuole are often slimy and readily coagulate when the tissue is killed. The so-called slime plugs often seen on sieve plates result from such coagulation. The sieve-tube elements of the angiosperms tend to have their sieve plates on the end walls. The sieve plate may cover the wall uniformly or may be broken up into more or less clearly defined sieve areas. The lateral walls show similar sieve areas, but with thinner strands (fig. 6[F]).

Series of sieve-tube elements are combined into longitudinal series, the sieve tubes. Each sieve-tube element is closely associated aith one or more slender parenchyma cells called companion cells (fig. 6[F]). These arise by division from the same mother cell as the sieve-tube element. The sieve cell of the gymnosperms and ferns shows no differences betneen end and lateral walls. All bear sieve areas of similar nature with rather thin connecting strands. Furthermore, sieve cells are not arranged in vertical superposed series and have no companion cells. Otherwise the sieve cell resembles the sieve-tube element in having callose associated with the connecting strands of the sieve areas and containing no nucleus in the mature protoplast.

Tissues.—The different types of cells characteristic of the plant body are combined into tissues in various manners. For example, only one kind of cell may form a tissue, as in parenchyma or collenchyma tissues. The fibres also may be aggregated into a simple mechanical or supporting tissue. These are simple tissues. In other instances many different kinds of cells are combined to make a complex tissue. The best examples of complex tissues are the xylem and phloem, which together constitute the vascular or conducting tissues. The xylem is concerned principally with the conduction of water and inorganic solutes and contains vessels and tracheids (or only tracheids), xylem fibres of different kinds, xylem parenchyma, and ray parenchyma in different proportions and combinations. The phloem translocates various organic solutes and contains sieve tubes and companion cells (or sieve cells), phloem parenchyma, ray parenchyma and bast fibres. The vascular tissues. notably the xylem, function also as supporting tissues because of the presence of fibres. The parenchyma that occurs in these tissues commonly serves for storage of different ergastic substances, particularly starch. The vascular tissues together form an elaborate system, the vascular system. Parenchyma is the principal tissue that surrounds and interpenetrates the vascular system. It may be spoken of as ground tissue.



(A) AFTER E. C. JEFFREY. "THE ANATOMY OF WOODY PLANTS,' THE UNIVERSITY OF CHICAGO PRESS; (B, C, F, G) AFTER A. J. EAMES AND L. H. MACDANIELS, "AN INTRODUCTION TO PLANT ANATOMY," MCGRAW-HILL BOOK CO.; (E) FROM K. ESAU, "HILGARDIA"

FIG. 6—TYPES OF CONDUCTING ELEMENTS IN XYLEM AND PHLOEM

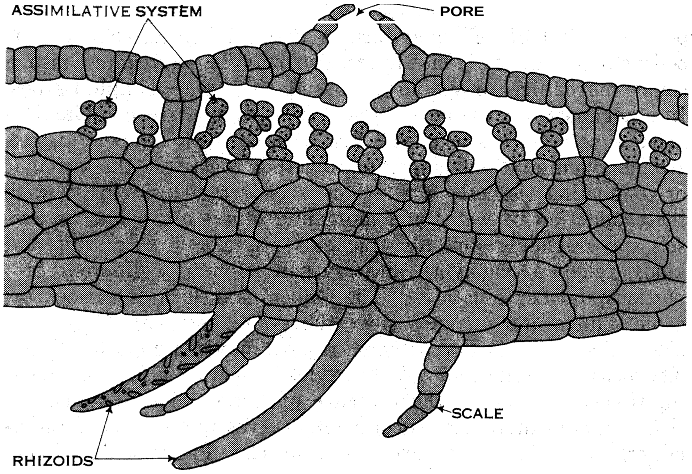
(A) Tracheid of a gymnosperm; (B and C) vessel elements; (D) transverse section of tracheid showing two bordered pits; (E) sieve plate from a sieve-tube element like that shown in (F); the light spots in each sieve area in (E) are callose rings with the cytoplasmic connecting strand in the centre of each. The small cells attached to the right side of the sieve-tube element in (F) are companion cells; (G) sieve cell of a gymnosperm

B. Organization of the Plant Body

1. Nonvascular Plants.—The reader is referred to special articles on the anatomy of the lower plants (Thallophyta: ALGAE and FUNGI; and BRYOPHYTA: mosses and liverworts) in which the tissues are rather undifferentiated. Suffice it here to mention that both algae and fungi range from the simplest unicellular forms with no external differentiation of the body to forms of larger size and greater complexity of organization. The progress in complexity is closely associated with division of physiological labour among the component cells and with the adaptation of the multicellular organism to its environment. But whatever are the various states attained by individual genera, the majority of the cells of the adult bodies of both algae and fungi remain alive and the tissues are essentially parenchymatous.

In accordance with the greater complexity in the conditions of life on land for self-supporting plants, considerably more advanced tissue differentiation is exhibited by the mosses, liverworts. etc. (Bryophyta). which are mainly terrestrial plants. In a general way this greater complexity consists (1) in the restriction of regular absorption of nater to those parts of the plant body which are in close contact with the soil; and (2) in the more regular evaporation of water from the parts exposed to the air. In the higher vascular plants these two principles find their full expression, whereas in the bryophytes water is still absorbed (as, for example, from rain or dew) by the general plant surface.

The lowest liverworts have an extremely simple vegetative structure comparable to that of many of the simpler algae. Since their bodies are small and normally live in damp air, the demands of terrestrial life on them are at a minimum. Their bodies consist of true parenchyma, and the vast majority of the component cells remain alive. Rooting and absorbing threadlike cells (rhizoids) universally occur on their lower surfaces in contact with the soil. and considerable tissue differentiation may occur within the body. Thus some possess a distinct assimilative system consisting of branched chains of thin-walled cells packed with chloroplasts and arising from the bases of large cavities directed toward their upper illuminated surfaces (fig. 7). These cavities are completely roofed by a layer of surface cells pierced by pores through nhich aeration and evaporation are freely maintained. In certain forms in which the body consists of thick midribs and delicate lateral leaflike appendages, strands or bundles of long thick-walled fibrelike prosenchymatous cells with pointed ends are arranged longitudinally within the midribs. which are devoid of special assimilative tissue. The walls of these cells are strongly lignified and are irregularly thick and thin so as to be closely studded by simple pits The latter are usually arranged in spirals and are often elongated in the direction of the spiral There is much variety of detail in the differentiation of the tissues of the liverworts, but the general plan of construction resembles that characteristic of the leaves of higher plants.



AFTER TH. HERZOG, IN LINSBAUER'S "HANDBUCH DER PFLANZENANATOMIE," GEBR BORNTRAEGER

FIG. 7.— SECTION OF THALLUS OF A LIVERWORT (MARCHANTIA)

In the mosses the plant body is generally more elaborate. There is a radially organized supporting and conducting axis (stem) bearing laterally through most of its length thin, flat assimilating and transpiring appendages (leaves). Branched rhizoids are attached to the base of the stem or to parts in contact with the soil. In some instances the stem possesses a special surface or epidermal layer of cells, but usually all the outer layers of the stem (the outer cortex) are composed of brown, thick-walled, lignified. prosenchymatous. fibrelike cells forming a peripheral sclerenchyma (fig. 8). This passes gradually into the thinner walled parenchyma of the inner cortex. The entire cortex is generally alive, and its cells often contain reserve foods in the form of starch. The centre of the stem. in the forms which live on soil, is composed of a strand of narrow, elongated. thin-walled, unlignified, dead cells, which are commonly interpreted as water-conducting elements (hydroids). This hydrom strand has in most cases no connection with the leaves, but forms a straight column in the stem and branches locally below the reproductive organs. In the aquatic and semiaquatic forms, and in those mosses which live under conditions of extreme drought, the entire plant surface absorbs water. In all such forms the hydrom strand is either slightly developed or altogether absent. The leaves of most mosses are flat plates, each consisting of a single layer of square or oblong assimilating cells containing chloroplasts. The marginal cells of the plates are frequently produced as teeth, and their walls are thick. The centre of the leaf is often occupied by a midrib consisting of several layers of parenchymatous cells elongated in the direction of the long axis of the leaf and poor in chloroplasts. This midrib is usually considered a primitive conductive foliar strand or leaf bundle. Hydroids, like those of the central strand of the stem, are frequently associated with this conducting parenchyma, and in some instances are continued into the cortex of the stem as a leaf trace bundle (the anatomically demonstrable trace of the leaf in the stem) (fig. 8). In several forms the leaf trace extends vertically downward for some distance in the outer cortex and ends blindly in a fan-shaped expansion; in others it joins the central hydrom strand so that a connected system is established between stem and leaf.

Further differentiation of tissues characterizes the highest family of mosses, the Polytrichaceae. In these, elongated, living, nucleated cells with a thin lining of protoplasm surround the dead central strand and form the phloemlike tissue, commonly called leptom. Between the hydrom and leptom is a cylinder of cell layers that may serve for the temporary storage and distribution of carbohydrates, since they sometimes contain an abundance of starch. The underground portion of the stem (rhizome) bears rhizoids and simple scales. The aerial parts bear leaves, each nith a simple midrib several cells thick and with a strong band of sclerenchyma above, and below a bundle of leptom, hydrom and starch cells, all of which join the central cylinder of the stem. Each midrib bears two wings, one cell thick, while above the midrib is a series of closely set, vertical, longitudinally arranged plates of green assimilative cells.

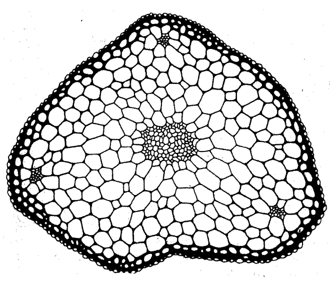
2. Vascular Plants. — The greatest anatomical complexity occurs in the vascular plants, which comprise the psilopsids, lycopods, horsetails. ferns and seed plants. The vascular plants are not exactly comparable with the bryophytes for while the body of the latter bears the sexual organs and is called a gametophyte, the vascular plant is a sporophyte. Nevertheless the gametophytic brpophyte and the sporophytic vascular plant have similar physiological needs and are both fixed to the soil. The chief new feature in external conformation of the body of a vascular plant compared with that of a bryophyte is the presence of "true" roots, the first formed of which is the downward prolongation of the primary axis of the plant. From this and from various parts of the shoot system, other roots originate. The roots of ferns are structurally simple and uniform compared with those of seed plants, but all manifest a primary plan of construction in direct relation to their normally subterranean life and fixative and absorptive functions; they differ from aerial stems in the characters of their surface tissues, in the absence of the green assimilative pigment chlorophyll, in the arrangement of their vascular systems, and in their mode of apical gronth. Great variety in stem and leaf form and structure is shown by the vascular plants.

Evolutionary Trend. — In spite of the many differences of detail betneen ferns and seed plants, we can trace, alike in root, stem and leaf. a threefold division of tissue systems, already indicated among the bryophytes, and expressive of the fundamental conditions of evolution of the bulky body of a land plant. Thus there is (1) a specialization of a surface layer of cells that regulates the immediate relations of the plant with its surroundings, while varying in expression in the subterranean and aerial parts. In the former the surface layer is pre-eminently absorptive whereas in the latter it is protective and is concerned with the gaseous interchange of oxygen and carbon dioxide involved in respiration, and in such vital functions as assimilation and transpiration. This surface layer is known as the epidermis. Then there is (2) an internal differentiation of conductive tissue, presaged in the bryophytes, and collectively known in the vascular plants as the vascular system. The vascular structures are imbedded in (3) fundamental or ground tissue. The latter may show differtnt distribution and may be combined with other types of tissue. Thus in the axis a cortex appears betneen the epidermis and the vascular tissues and, in the stem, a pith usually occurs enclosed by the vascular tissues. In the root the pith is usually absent. In leaves the vascular system is imbedded in parenchyma which is called mesophyll. The mesophyll is especially adapted for photosynthesis.

Besides absorption, assimilation, conduction and protection, plant tissues serve for support and the storage of food. Thus locally in the cortex, mesophyll and vascular system, special supporting tissues (sclerenchyma) may be developed, and living cells of both the ground tissue and the vascular system may serve for temporary storage of foods and are specialized accordingly. The functions of aeration. assimilation and transpiration are maintained by an extensive system of intercellular spaces communicating with the external air.

C. Tissues

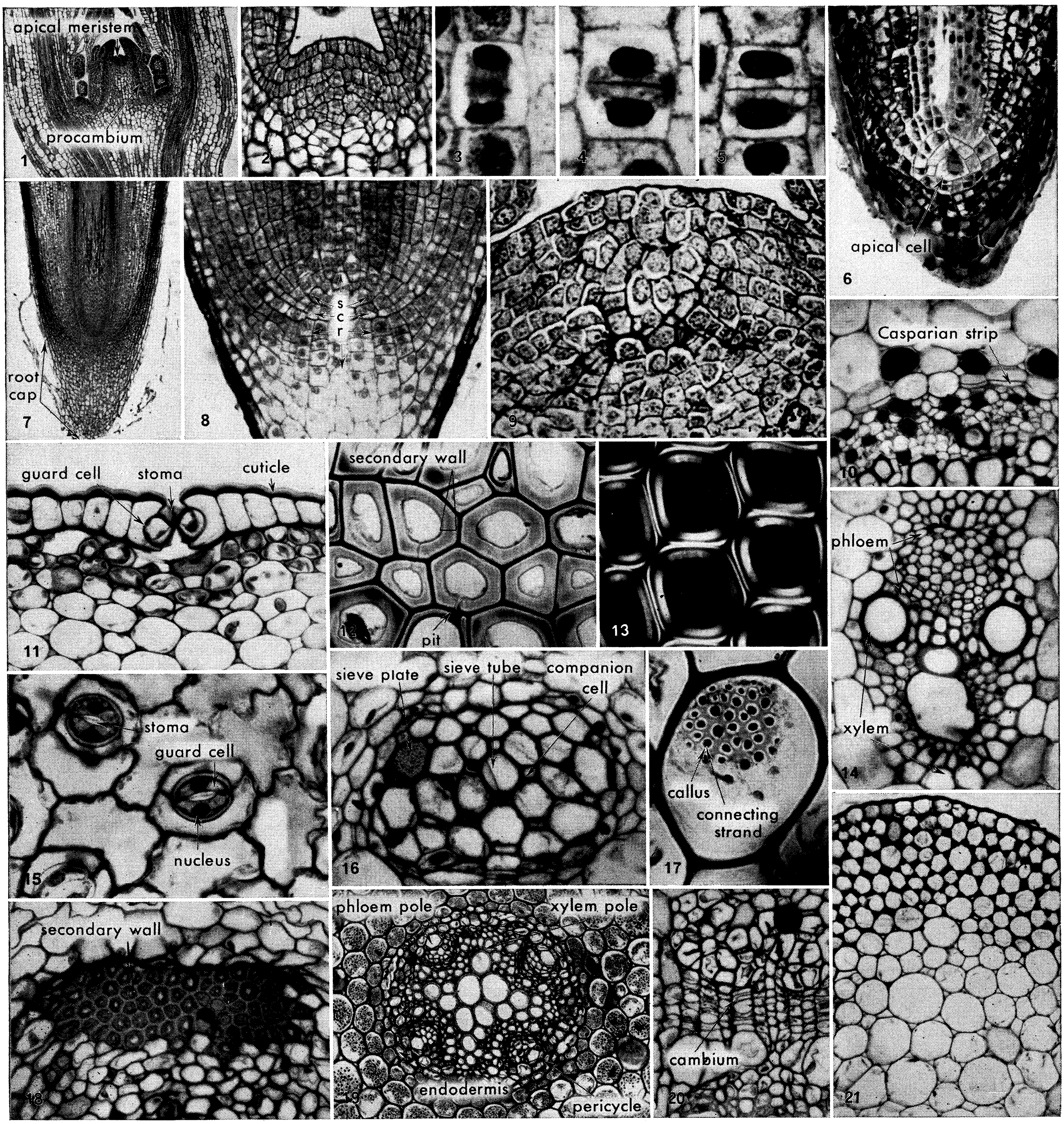
1. Meristems.—The different types of cells characteristic of the body of higher plants are alike at the beginning of their existence. They arise together from meristems, and only through subsequent differentiation in development become unlike. A meristem is best defined as a specific region in the plant body where cells are engaged chiefly in division and enlargement Meristems can be conveniently classified according to position as apical



AFTER W LORCH, IN LINSBAUER'S 'HANDBUCH DER PFLANZENANATOMIE GEBR BORNTRAEGER

FIG 8 —TRANSVERSE SECTION OF STEM OF A MOSS (MNIUM)

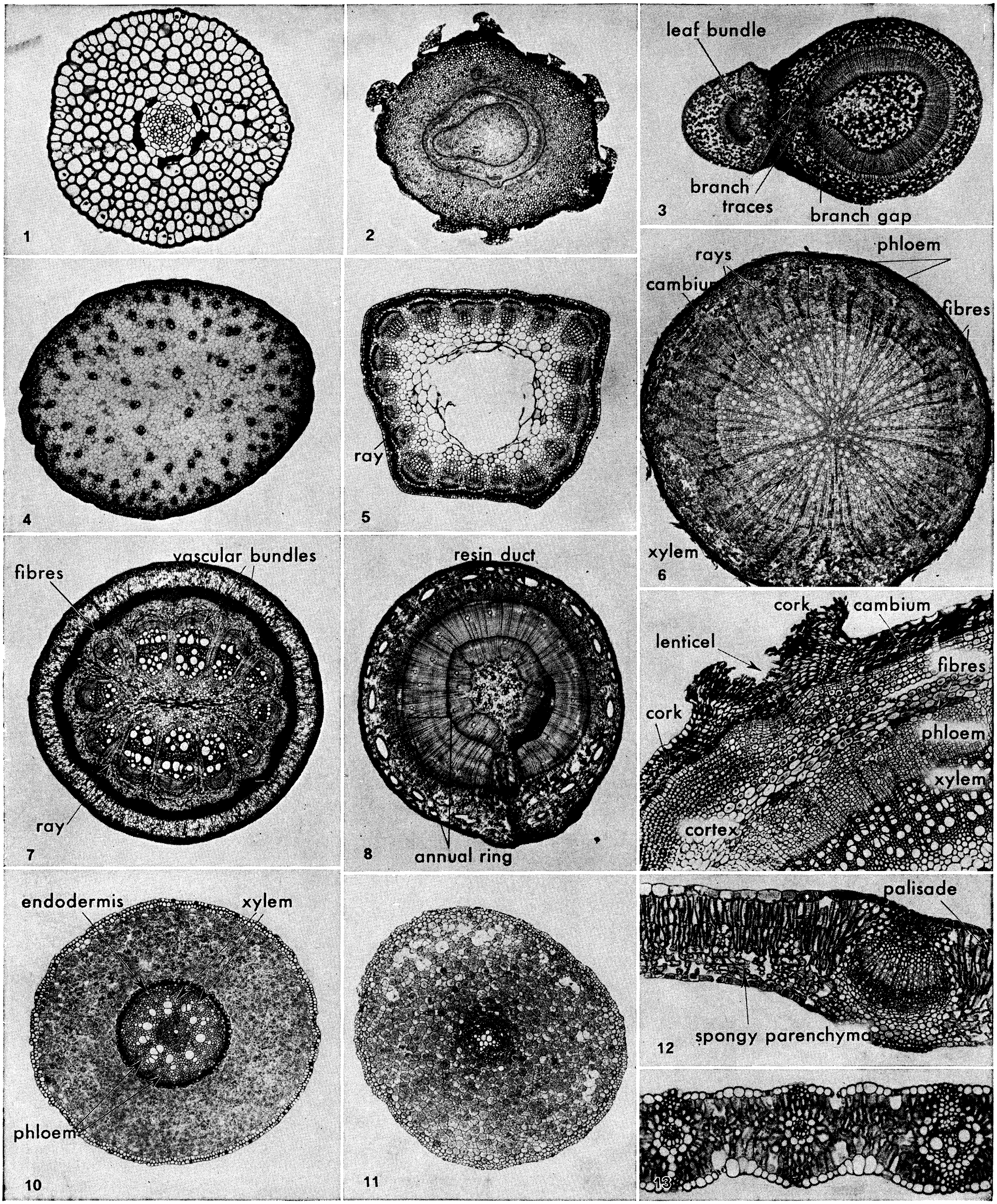
Sclerenchyma in the outer cortex, central strand in median position, blind leaf traces in the corners



COURTESY OF (1, 2) G. L. CROSS. "TORREY BOTANICAL CLUB BUL."; (9) A. S. FOSTER. "TORREY BOTANICAL CLUB BUL."; (12, 13) I. W. BAILEY, "JOUR. OF THE ARNOLD ARBORETUM" AND "AMERICAN JOURNAL OF BOTANY" (17) A. S. CRAFTS, "AMERICAN JOURNAL OF BOTANY" (19) O. H. CONANT; (7, 14, 16) FROM KATHERINE ESAU, "HILGARDIA"; (3, 4, 5, 6, 8, 10, 11, 15, 18, 20, 21) ORIGINALS BY KATHERINE ESAU

EXAMPLES OF PLANT TISSUES

1. Shoot apex of Vinca with two leaf primordia on the flanks of the apical meristem. 2. Apical meristem of *Vinca* shoot with two layers of tunica covering the corpus. 3, 4 and 5. Stages of cell-plate formation in cells from onion root tip. 6. Root tip of a fern (*Adiantum*). 7. Root tip of a pear tree. 8. Root tip of tobacco showing the initial regions of the stele, or vascular cylinder (*s*), of the cortex (*c*), and of the root cap (*r*). 9. Apical meristem of Ginkgo shoot. 10. Transverse section of portion of *Myriophyllum* rhizome showing endodermis with Casparian strips between cortex and vascular tissues. 11. Transverse section of part of Asparagus stem showing epidermis and cortex. 12. Transverse section of the xylem of *Trochodendron;* the dark material between the secondary walls consists of primary walls and interceliuiar substance. 13. Transverse section of the xylem of *Taxodium* photographed in polarized light between crossed Nicols; it illustrates double refraction of layers of secondary walls. 14. Vascular bundle from transverse section of Zea (corn) stem. 15. Surface view of epidermis of a *Convolvulus* leaf. 16. Transverse section of phloem from a vascular bundle of Zea. 17. Transverse section of sieve tube of Cucurbita (pumpkin) showing, above, part of sieve plate. 18. Transverse section of root tip of *Pisum* (pea) showing, in the centre, a bundle of fibres. 19. Transverse section of Ranunculus root showing the vascular cylinder and some cortical parenchyma. 20. Transverse section of vascular tissues of Sambucus stem showing cambium in the middle, some phloem and xylem above and below, respectively. 21. Transverse section of beet petiole showing, from top to bottom, epidermis, collenchyma and parenchyma



COURTESY OF (2) R. H. WETMORE, (3) I. W. BAILEY, (4, 7, 8, 9, 10, 11, 12) G. H. CONANT; (6) FROM KATHERINE ESAU, "HILGARDIA"; (1, 5, 13) ORIGINALS BY KATHERINE ESAU

EXAMPLES OF STRUCTURE OF DIFFERENT PLANT ORGANS

Transverse sections of: 1. ***Tmesipteris*** (a primitive vascular plant) stem; 2. ***Adiantum*** (fern) stem; 3. ***Illicium*** (a dicotyledon) stem; 4. ***Zea*** (a monocotyledon) stem; 5. ***Medicago*** (a dicotyledon) stem; 6. ***Pyrus*** (pear) root with secondary growth; 7. ***Aristolochia*** (vine) stem; 8. ***Pinus*** (a gymnosperm) stem; 9. Portion of ***Sambucus*** (elderberry) stem; 10. ***Smilax*** (a monocotyledon) root in primary state; 11. ***Ranunculus*** (a dicotyledon) root in primary state; 12. ***Syringa*** (a dicotyledon) leaf: 13. ***Triticum*** (wheat, a grass) leaf and lateral meristems. The apex or growing point of the root or shoot illustrates the former type, the vascular and cork cambia the second. The localization of the regions of cell formation in the plant body distinguishes the plants from the animals, whose parts grow through their whole extent. Also. unlike animals, the higher plants have a continuous formation of new tissues and organs throughout the life of the individual. A meristem is described as undifferentiated embryonic tissue exhibiting juvenile characteristics in contrast with the differentiated or mature tissues that arise from it. Meristems. however, differ morphologically and physiologically from each other and are not sharply separated from those differentiated tissues that retain protoplasts at maturity, particularly the parenchyma tissue. The living mature tissues are potentially meristematic. and resume meristematic activities when appropriately stimulated. Furthermore, cells of a given meristematic region may vary among themselves in many features.

Apical *Meristems*.—These meristems are usually composed of approximately isodiametric cells with prominent nuclei. The cytoplasm is often dense but may be also conspicuously vacuolated. The dense cells have many small vacuoles dispersed in the cytoplasm. The walls are commonly thin, and the cells are closely packed without intercellular spaces among them. The architecture of the apical meristems varies in different groups of plants. In most ferns, in the horsetails and in some other vascular plants, all tissues of the stem and root are derived from single apical cells located at the apices of these organs. The apical cell, which may be termed also initial cell, is usually tetrahedral in shape. Its base occupies the surface of the apical mound of tissue, and the apex points inward. By definite and regular divisions of such a cell, a mass of still undifferentiated cells is produced immediately below the apex that is continuously occupied by a residual apical cell. From these undifferentiated cells the different tissues sooner or later arise by further growth, divisions and differentiation. In the seed plants a few to many cells at the apex of shoot and root initiate the body tissues, and these cells function in different manners. In angiospermous shoots one or more superficial layers and a central core of the apical mound have independent initials. The peripheral layers (tunica) are characterized by surface growth, that is, anticlinal divisions predominate. The underlying core (corpus) shows divisions in all planes and thus grows in volume. The two zones are interdependent and their extent and behaviour fluctuate. They are not at all specific as to the tissues that originate from them. The peripheral zone may be concerned with the production of the epidermis only, or it may give rise to one or more of the underlying regions. Similarly, the central zone may produce pith only or also the vascular tissues and even the cortex. In the gymnosperms a peripheral and central zone may also be distinguished but here they appear to be more interdependent than in the angiosperms: a superficial group of initials divide anticlinally and periclinally and give rise to both the external and the internal cells of the apical mound.

The root and shoot apices differ from each other in several fundamental features. The shoot apex is concerned with the production of the lateral organs of the stem axis, that is, the leaves; the root apex produces no lateral organs: the lateral roots arise some distance from the apex and not superficially (like the leaves) but in the deeper layers of the axis. Thus the lateral roots have an endogenous origin in contrast to the leaves, whose origin is described as exogenous. The shoot apex is exposed to the outside and cuts off cells only toward the axis. The root apex is covered with a protective tissue. the root cap. produced by cells that are cut off away from the axis of the root. Thus, strictly speaking, the apical meristem of the root is subterminal, whereas that of the shoot is terminal. The initial cells of the root apex of angiosperms are commonly arranged in two or more tiers. One tier may form the root cap, epidermis and cortex, the other the central cylinder containing the vascular tissues. In other species the root cap arises from a separate initial layer (calyptrogen). the cortex and epidermis from another, the central cylinder from a third; or the epidermis and root cap have common origin. Sometimes all four root regions arise from separate sets of initials. In some roots the apical meristem appears generalized and shows no distinct tiers of initials. The study of a root having separate initials for the various regions of the root axis might give the impression that the regions are predetermined in the apical meristem. Such a view has been actually held and the supposedly independent meristematic regions, the histogens, have received special names: dermatogen. periblem and plerome, the precursors of the epidermis, cortex and central cylinder, respectively. Since in some roots. and apparently in all shoots, the regions of the axis cannot be traced back to separate sets of initials, the deterministic scheme of apical structure cannot be accepted.

2. The Primary **Plant** Body.—The apical meristem of shoot and root produce a complete plant body with all its vegetative and reproductive organs. This body is spoken of as the primary body. and the tissues composing it as primary tissues in distinction from the secondary body or secondary tissues that are later added to the primary body by the two lateral meristems, the vascular cambium and the cork cambium. The primary tissues result from progressive differentiation of the cell masses produced by the apical meristems, and the latter may be traced back to the embryo and the zygote. As previously stated, the various tissues or regions of the plant body do not appear to be predetermined in the initial regions of the apical meristems. The first certain evidence of tissue differentiation occurs in the subapical regions. There some cell masses show speeded up vacuolation of their protoplasts, others remain dense somewhat longer, but divide largely by longitudinal walls and soon become longer than wide. The more highly vacuolated parts of the subapical meristem later differentiate into the cortex and pith (if the latter is present) and are termed the ground meristem; the meristem part composed of the dense elongated cells is the precursor of the primary vascular system called procambium. It forms the primary xylem and primary phloem. A young plant organ, or part of it, composed of these partly differentiated but still meristematic tissues, is covered on the outside by a discrete meristematic layer, the protoderm, which later matures into the epidermis. These three meristems, the ground meristem, the procambium, and the protoderm, as well as the apical meristems, are the primary meristems whereas the two cambia are secondary meristems.

3. Epidermis.—The epidermis of the aerial stems and leaves is primarily a covering layer which protects against harm from loss of water and against mechanical injury. It usually consists of a single layer of living cells devoid of chloroplasts, and with thickened and waterproofed (cuticularized) outer walls. At intervals the epidermis is interrupted by small pores (stomata or stomates) leading from the outer air to the system of intercellular spaces in the underlying tissues, and serving for gaseous interchange between these tissues and the outer air. Each stoma or stomate is surrounded by a pair of peculiarly modified epidermal cells called guard cells. which possess chlorophyll and open and close the pore in accordance with the changes in water content (turgidity). The stomates of leaves are generally much more numerous in the lower epidermis than in the upper, and even may be absent in the upper epidermis. They are often situated at the bottom of pits in the leaf surface. Thus loss of water (transpiration) is checked by the creation of a still atmosphere in the pit above the pore. Such an arrangement of the stomates is found especially in plants adapted to gron th in regions where the supply of available water is deficient. In some angiosperms the epidermis is doubled or trebled by tangential divisions in the original layer, resulting in a multiple epidermis, which functions as a water-storage tissue. In many vascular plants epidermal organs, known as hydathodes, are developed, especially on foliage leaves, and serve for excretion of water in liquid form.

Hairs *and* Scales.—The epidermis of many species of vascular plants bears hairs or scales of varied form and function. The simplest hairs consist of single elongated cells projecting above the general surface of the epidermis, whereas others consist of simple or branched cell chains. The more complex scales are flat plates of cells commonly inserted on mounds or stalks, and may be placed parallel to the leaf surface or projecting directly from it. In other instances the hairs are glandular and excrete volatile oils, or they may be stinging, as in the common stinging nettle, in which the top of the hair is brittle, and when touched penetrates the skin, breaks and injects a poisonous liquid into the wound thus formed. In many plants both hairs and scales are shed before the stems and leaves are mature; in others they are retained throughout the life of the plant.

Epidermis of Root.—The epidermis of the root is different from that of the stem or the leaf. In relation to its normal function of water absorption its cell walls are not conspicuously cuticularized. and usually remain thin. The absorbing surface is increased because many of the cells expand their outer walls into tortuous, delicate, one-celled tubes (root hairs) which aid in anchoring the root, and readily absorb the surface films of water from the soil particles. A root hair thus corresponds in function with a rhizoid of a moss. The hairs are normally definitely restricted to a more or less definite zone of the root a little removed from the growing root tip. At the lower limit of this zone hairs are constantly being formed as the root advances in the soil, while at the upper limit they have passed maturity, are dying and are being destroyed. Thus beyond the zone which at any moment bears living absorbing hairs the epidermis is extensively or completely destroyed, and its place is taken by the immediately subjacent cortical layer, which is not absorptive, but becomes protective like the epidermis of the stein or leaf.

4. Cortex.—The cortex consists primarily of living parenchyma, but its differentiation may be extremely varied, and in the complex bodies of vascular plants its functions also are varied and may be modified. The cortex of a young stem is usually green—for its cells possess chloroplasts—and a fine system of intercellular spaces communicates with the external air through stomates. With age the inner cortical layers may lose their chlorophyll and become merely storage tissue, and the outer layers may be extensively modified. In many ferns and lower vascular plants the mature outer cortical layers of the stem and root are hard sclerenchyma with thick brown walls, but in flowering plants, while the stems are still slender, the cells of the outer cortical layers elongate and become cylindrical or spindle-shaped and develop localized cellulose thickenings; that is, this part of the cortex differentiates as collenchyma. It provides peripheral support for the growing stem, and as its cells are alive, is open to later modifications with changing conditions in stems that undergo annual increase in girth. On the other hand sclerenchyma is commonly dead, and provides a more rigid but usually unmodifiable supporting tissue. Its adequacy will be evident for stems such as those of modern ferns, which do not increase annually in girth. Less commonly, scattered cells or cell groups which increase little in length may become stone cells. with irregularly but inordinately thickened hard walls. Various secretory cells may occur in the cortex, usually lining cavities or canals which arise through a breakdown of certain cells (oil cavities in a citrus stem or fruit) or through enlargement of intercellular spaces (resin canal in pine stem). The cortex of the stem shows more modifications than that of the root. In the dicotyledons the root cortex commonly remains entirely parenchymatous and is early shed in connection with secondary growth, whereas in the monocotyledons and in the ferns it is more or less sclerified at maturity.

Endodermis.—The innermost layer of the living cortex investing the centrally located vascular system of the axis may be early and peculiarly modified as a continuous cylinder called the endodermis. Throughout its extent the endodermal cells are in close contact, so that the system of intercellular spaces in the cortex is not continued into the central cylinder of conductive tissue. In the absorbing region of angiospermous roots the endodermis shows a very characteristic structure. A band of wall material impregnated with fatty substances and lignin extends completely about the inner surface of the lateral longitudinal and end walls of each cell. These bandlike thickenings of the wall are known as Casparian strips. This kind of endodermis is thought to play a role in the regulation of the transfer of solutes from the cortex into the vascular system: the presence of the fatty substances in the Casparian strip and the firm connection between the strip and the cytoplasm of the cell apparently force the soil solution to move through the cytoplasm and be subjected to the protoplasmic control of the endodermal cells. In older roots that cease to absorb the endodermis may develop thick lignified walls; or it is torn and shed because of secondary increase in thickness of the central vascular cylinder.

The stems of seed plants rarely show peculiar morphologic characteristics in the innermost layer of the cortex. In the youngest part of the stem this layer is commonly differentiated as a starch sheath, which may be regarded as an equivalent of the endodermis. It is rich in starch and forms a continuous layer around the vascular system. In the more mature regions of the stem starch is absent. In most ferns the endodermis appears as a morphologically distinct layer throughout the stem and the root. Casparian strips and more generally corky (suberized) endodermal cells have been observed in this group of plants.

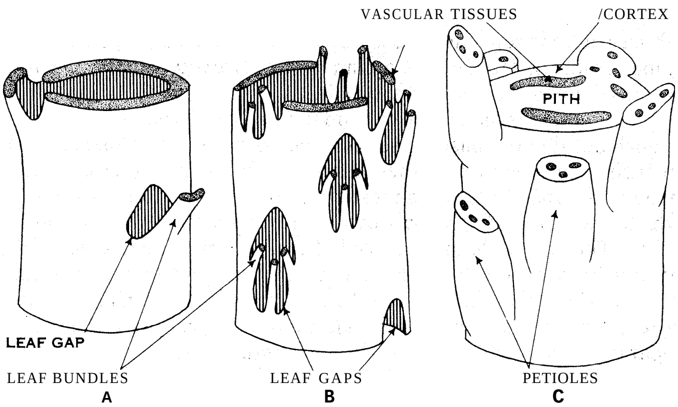
5. **Mesophyll.**—The mesophyll of the leaf is primarily concerned with the fundamental function of manufacture of carbohydrates (carbon assimilation), and to the active performance of this function the maximum exposure of living parenchymatous tissue containing chloroplasts is necessary. Thus the mesophyll is essentially a green expanse of thin-walled parenchyma and is penetrated by a large and elaborate system of intercellular spaces which serve at one and the same time for the promotion of transpiration and respiration. The pathways for the gases between the mesophyll and the outer air are the stomates which are in direct communication with the ample system of intercellular spaces in the mesophyll. The lower layers of the mesophyll are loosely arranged as spongy tissue with extensive intercellular spaces. This is the main transpiring tissue of the leaf, and in it chloroplasts may be comparatively few. It is protected from direct illumination and is at the same time liable to overevaporation. The main assimilating tissue, on the other hand, is under the upper epidermis and it is well illuminated; its cells are densely packed with chloroplasts, and are commonly oblong, with their long axes perpendicular to the leaf surface. The intercellular spaces in this upper epidermis are narrow, as between sticks in a bundle, and are in open communication with the intercellular spaces in the spongy tissue below. By reason of its resemblance to the boards in a fence, when viewed in a transverse section of the leaf, this portion of the mesophyll is called the palisade tissue. Leaves with blades held in a vertical position commonly possess palisade tissue on both sides or have little or no distinction in the form and arrangement of the cells of the mesophyll, since there is no difference in the illumination or other external conditions, while cylindrical or approximately cylindrical leaves may have palisade tissue all around. The leaves of shade plants have little or no differentiation of the palisade tissue. In fleshy leaves, which contain a great bulk of tissue in relation to their chlorophyll content, the central mesophyll contains little or no chlorophyll and may consist of water-storage tissue. while locally a layer or mass of subepidermal cells may be thick-walled and fibrous.

The cortex of the leaf stalk or petiole is transitional in structure to that of the stem and leaf blade. The petiole is traversed by one or more vascular strands connected below to the central conductive system of the stem, and leading forward in the leaf blade to a complex system of minor strands which ramify in the mesophyll where the spongy and palisade tissues meet. The layer of mesophyll immediately investing each bundle (bundle sheath) usually has the form of a special parenchymatous sheath of elongated cells. In dicotyledons the sheath cells commonly have fewer chloroplasts than the rest of the mesophyll. The bundle sheaths are considered important in the conduction of carbohydrates from the manufacturing (assimilative) cells to the conductive strands and in the supply of water from the latter for transpiration. Their function is thus considered in some measure comparable with that of the endodermis.

6. Vascular System.—Among the most striking characters of vascular plants is the possession of a double (xylem-phloem) conducting system, such as has been presaged in the higher mosses, but with more sharply defined and specialized features. This is the vascular system, and associated with it are other tis-

sues consisting of parenchyma and sclerenchyma. The primary vascular system together with the associated tissues is known as the stelar system (from the way in which in its simpler forms it traverses the whole axis of the plant as a column). When it is remembered that the moss plant is a gametophyte while the vascular plant is a sporophyte, it will be realized that the vascular system of the latter is not the result of elaboration of the conductive system of the former, but that these vascular systems are most readily interpreted as somewhat similar products of differentiation in plants adapted to life on land.

Arrangement of the Vascular System.—In the vascular system the xylem and phloem are nearly always found in close association in strands or bundles, but as is to be expected the arrangement of such bundles is by no means stereotyped either in the given plant group or in the different parts or members of the plant body. A connected vascular system penetrates, however, the entire body. When the vascular system of the axis appears in the form of a solid central rod. with a core of xylem ensheathed by phloem, it is termed protostele. Usually a discrete parenchymatous layer, the so-called pericycle, surrounds the phloem and lies directly beneath the endodermis. The evidence from comparative anatomy and paleobotany indicates that protostele is the primitive type of vascular system. It occurs in both the stem and root of many lower vascular plants, but is restricted to the root of seed plants. In the advanced ferns the vascular system of the juvenile stem is a solid protostele, but that of the more bulky portions of the adult plant shows a somewhat different arrangement.



AFTER Y. OGURA, IN LINSBAUER'S "HANDBUCH DER PFLANZENANATOMIE." GEBR. BORNTRAEGER

FIG. 9.—TYPES OF VASCULAR SYSTEM IN HIGHER PLANTS

(A) Siphonostele; (B) dictyostele; (C) tissues other than the vascular in connection with a dictyostele

If the xylem core is not solid but contains parenchyma (pith or medulla), the stele becomes a medullated protostele or siphonostele (fig. 9[A]). In the protosteles the vascular system is not interrupted, at least not markedly so, where a vascular bundle, the leaf trace, diverges to a leaf. Siphonosteles usually show breaks in the continuity of the vascular tissues above the departure of a leaf trace, these breaks being called leaf gaps. The gaps are filled with parenchyma, which connects the pith with the cortex. In cross sections of internodes such a stele appears as a continuous circle but shows breaks in the nodal region. If the leaf gaps overlap in their longitudinal extent in a siphonostelic vascular system, the stele is a dictyostele which, in cross section of both nodes and internodes, appears composed of several portions (fig. 9[B]). This kind of dictyostele may be found, for example, among ferns. In a dictyostele breaks other than leaf gaps—the parenchymatous medullary rays—may be present. A stele of this type should be visualized as a tubular network, the meshes representing the vertical leaf gaps and parenchymatous rays. The stems of seed plants usually have similar steles. Thus the vascular system of the axis (root and stem) commonly has the shape of a solid rod or a tube with or without perforations.

The leaves, if small as in the lower Tracheophyta (*e.g.*, *Selaginella*, Equisetum) or the conifers (*e.g.*, firs), have a very simple system which typically consists of one unbranched vein. The large-leaved ferns have complex systems of bundles in the petioles and rachises (extension of petioles to end of leaf) with branches given off into the leaflets (pinnae). The flowering plants (angiosperms) commonly have rather large leaves with complex vascular systems (see below. Vascular System of Leaf). The xylem and phloem show two types of arrangement in siphonosteles. If the phloem appears only on the outside of the xylem the stele is ectophloic, if on both sides, amphiphloic. If the ectophloic stele is a much dissected siphonostele the individual strands making up such a stele are collateral bundles, having xylem on one side, phloem on the other. The component parts of an amphiphloic siphonostele are bicollateral bundles having phloem on both sides of the xylem.

The Vascular System in the Stem of Seed Plants.—In this group of plants distinct vascular bundles traverse the axis and connect or anastomose with each other (very much dissected siphonostele). At certain intervals one or more bundles diverge into a leaf, and it appears that all bundles of the stem are directly or indirectly related to the leaf bundles. In other words, the vascular system may be regarded as made up of leaf traces and their fusions. The number of leaf traces to a given leaf varies. Common numbers are one, three and many. If the trace is single only one leaf gap or lacuna is associated with the given leaf and the node is called unilacunar. If there is more than one trace the node may be trilacunar (three gaps) or multilacunar (more than three gaps). The unilacunar node associated with two leaf traces to one leaf is primitive in the angiosperms. The development of axillary buds further complicates the vascular anatomy of the node. The vascular bundles connecting the bud with the vascular system of the main axis are known as branch traces, which are usually two in number. Branch gaps or parenchymatous areas in the vascular system of the main axis occur above the divergence of the branch traces.

In the gymnosperms and dicotyledons the vascular bundles are usually arranged in one circle, with parenchymatous rays separating the bundles from each other. The monocotyledons typically possess large leaves with broad sheathing bases containing numerous bundles. Therefore the number of bundles present at any given level of the stem is high. They are arranged in more than one circle or are scattered in a definite, though not superficially obvious, order throughout the cross sectional area of the stem so that the delimitation of cortex and stele is difficult or impossible. The bundles are surrounded by large-celled ground tissue and around each bundle there is a fibrous investment or sheath.

Vascular System of Root.—The stele of the primary root of a gymnosperm or angiosperm is of radial structure. There are usually two or more xylem strands radially alternating with as many phloem strands, and the first formed xylem groups (protoxylem) are peripheral. Depending on the number of the xylem strands, the root is called diarch, triarch, tetrarch or polyarch. The centre of the stele is either solid xylem or is pithed, and sclerotic cells are in the ground tissue. Thus the vascular system of the root in seed plants is much simpler than in the stem. It forms a protostele, though not of the most primitive kind: the phloem does not completely ensheath the xylem but appears in strands alternating with the protoxylem groups.

Vascular System of Leaf.—In the leaf of the average seed plant the vascular tissue appears as a number of branching or approximately parallel, and usually anastomosing, strands. Above and below the larger strands the leaf parenchyma is raised so as to produce the so-called veins. The vein system is typically very elaborate, and the bundle system is concentrated in the petiole as the tributaries of a river are massed in the main stream. The leaf bundles are usually collateral (the phloem being turned downward and the xylem upward), and the whole bundle may be protected above and below by fibrous cells. As the bundles are followed toward their blind endings in the mesophyll the fibres first disappear, the sieve tubes are replaced by narrow elongated parenchyma cells which disappear before the end of the bundle is reached. The bundles usually end in short or long spiral or reticulate tracheids covered by the bundle sheath.

Ontogeny of the Vascular System.—The primary vascular system in the various organs of the plant is first delimited in the form of a meristem called procambium. The procambium assumes similar aspect as the mature vascular system with its continuities and interruptions. gaps, traces. bundles and other details. But all parts of the procambial system are short. The elongation of these parts is one of the phases in the maturation of the procambium into the vascular system. In a given transverse section of the procambium the vascular elements differentiate not all at once. but gradually. The first primary xylem elements (protoxylem) may appear on the periphery of the xylem system, and the subsequent primary elements (metaxylem) toward the centre. Such order of differentiation is spoken of as centripetal and the xylem of this kind is exarch; or the protoxylem occupies the innermost position in the xylem system and the further xylem differentiates centrifugally. Such primary xylem is endarch.

The first phloem is termed protophloem; then follows the metaphloem. The phloem located on the outside of the xylem differentiates centripetally. The internal phloem, as in an amphiphloic siphonostele, differentiates centrifugally.

A good example of exarch xylem is found in the roots of seed plants. Here the starting points of xylem differentiation. the protoxylem poles. occur on the periphery of the stele and alternate with the protophloem poles. Both metaxylem and metaphloem differentiate toward the centre of the root, but the phloem remains essentially peripheral, whereas the metaxylem frequently reaches the centre. The xylem in the stems of seed plants is typically endarch. The protoxylem occurs on the periphery of the pith in each major subdivision of the dictyostele. Opposite each protoxylem strand on the periphery of the stele is the protophloem bundle. The metaxylem and metaphloem differentiate toward each other, that is, the xylem shows a centrifugal, the phloem a centripetal order of development. The leaf bundles commonly show the same order of differentiation as the stem bundles.

The longitudinal course of differentiation in the root is from the more mature toward the younger parts of the root. that is, the differentiation is acropetal. In the stem, however, xylem and phloem, as far as known, differ from each other in their initial course. The phloem differentiates acropetally from the lower regions of the axis toward the apex and into the leaf primordia, whereas the xylem is initiated at the base of the leaves or in the leaves and then differentiates toward the apex of the elongating leaf and downward (basipetally) into the axis toward the junction with the mature xylem below.

The primary xylem is simpler in structure than the secondary. The protoxylem contains only one or two kinds of tracheids or vessels (commonly with annular and spiral secondary thickenings) and some parenchyma. The metaxylem shows greater variety of elements and often contains fibres. The primary phloem also is simpler than the secondary. The protoxylem and protophloem mature before the organ in which they occur completes its elongation.

Since the water-conducting elements are dead at maturity and the sieve tubes or sieve cells have enucleate protoplasts. these vascular elements cannot respond with growth to the continued division and elongation of the adjacent tissues. For a while the protoxylem and protophloem elements, which have no rigid walls, are passively stretched, then they are torn and more or less completely obliterated while new conducting elements differentiate to take the place of the old ones. Consequently in mature plant organs the protophloem and protoxylem may appear much modified as compared with their original state. This is particularly true of the protophloem in which fibres (bast fibres) or collenchymalike cells often differentiate after the obliteration of the conducting elements. The fibrous or collenchymatous protophloem appears like a region very distinct from the rest of the phloem and has often been called the pericycle The metaxylem and metaphloem remain longer intact, though they too become functionless when secondary vascular tissues are formed. In plants having no secondary growth, the metaxylem and metaphloem are the main conducting tissues of the mature plant.

7. Laticiferous Tissue.—In certain families of angiosperms there are peculiar tissues that do not occur in the ferns and their more primitive relatives. Such, for example, is the laticiferous tissue found in many composites (Compositae) and spurges (Euphorbiaceae). nhich appears in the form of long, usually branched tubes penetrating the other tissues of the plant in a general longitudinal direction. The tubes possess a delicate layer of protoplasm with numerous nuclei lining the walls, whereas the interior of the tube (corresponding with the cell vacuole or cavity) contains a fluid called latex. consisting of an emulsion of fine granules and drops of various substances, suspended in a watery medium, in which other substances (salts, sugars, rubber producers, tannins, alkaloids and various enzymes) are dissolved. Of the suspended substances, grains of caoutchouc. drops of resin and oil, proteid crystals and starch grains may be mentioned. Of this varied mixture of substances some are undoubtedly plastic (*i.e.*, of use in constructing new plant tissue), while others are apparently endproducts of metabolism, secreted within the plant body. The latex may be milky in appearance or nearly colourless. The use of certain plants as rubber producers (notably Hevea *brasiliensis*, the Para rubber tree). depends on the property of coagulation of the latex. The trees are regularly tapped and the coagulated latex which exudes is collected and worked up into rubber. Opium is obtained from the latex of the opium poppy (*Papaver somniferum*), which contains the alkaloid morphine.

Laticiferous tissue is of two kinds: (1) laticiferous cells, which branch but do not anastomose, and the apexes of which keep pace in their gronth with the other tissues of the plant, as seen in dog bane (Xpocynaceae) and in most spurges; (2) laticiferous vessels, which are formed from rows of actively dividing (meristematic) cells. The end walls of these cells break down so that a network of laticiferous tubes arises (Papaveraceae. Hevea). In some plants, as in onion (*Allium*) and in morning glories (Convolvulaceae) roms of cells with latexlike contents occur. but the walls separating the individual cells do not break down.

8. Cambium and Secondary Growth.—Most of the modern ferns. horsetails and herbaceous monocotyledons, and many of the annual dicotyledons, are composed of primary tissues only. The gymnosperms and many dicotyledons, particularly the treelike forms (arborescent). have, in roots and stems, large amounts of secondary vascular tissues added to the primary so that the axis becomes many times thicker than it was in the primary state. These tissues are formed by the vascular cambium. In the stems this merrstem arises partly from the procambial cells that remain in meristematic state after the primary xylem and phloem of the bundles mature, and partly from the ray and gap parenchyma cells located between the bundles. Because of this double origin it is customary to speak of fascicular cambium, if it arises within the bundle, and interfascicular, if it is formed between the bundles. The tno, however, form one continuous meristem, circular in cross section In the roots, the cambium arises first on the inside of the phloem strands. Then these strips of cambium become connected with each other by cambial cells that arise within the parts of pericycle located outside the protoxylem poles. Thus in both the stem and root a continuous cambial cylinder is formed, which produces secondary xylem toward the centre of the axis, secondary phloem toward the periphery.

It is difficult to indicate precisely when procambium becomes cambium. Generally, one might say that the procambium exists and produces the primary vascular tissues as long as the primary organ is still elongating by continued cell division and cell enlargement. After this gron th ceases, the remaining vascular meristem assumes the characteristics of the cambium. The latter thus functions in the part of the body that attained its final length. Therefore, if the elements produced by the cambium elongate, they do so not in harmony with the adjacent tissues but by a kind of sliding gronth in ahich the elongating cell intrudes among other cells.

In a wide range of dicotyledons and gymnosperms the vascular cambium shows certain common characteristics. It is composed of two kinds of initials: (1) the elongated, prosenchymatous, sometimes spindle-shaped, fusiform initials. and (2) the prismatic parenchymatous ray initials. Both kinds of initials are highly vacuolate. The fusiform initials form such elements as tracheids, vessels, fibres. wood parenchyma and sieve tubes, that is, vascular elements that are disposed vertically in the axis of the plant. The ray initials are points of origin and propagation of the radially disposed xylem and phloem rays. There is only one layer of initials around the circumference of the axis but the immediate products of this layer cannot be distinguished anatomically from the initials. The initials and their nearest products (the xylem and phloem mother cells) together form a few layered cylinder of thin-walled vacuolate cells between the xylem and the phloem.

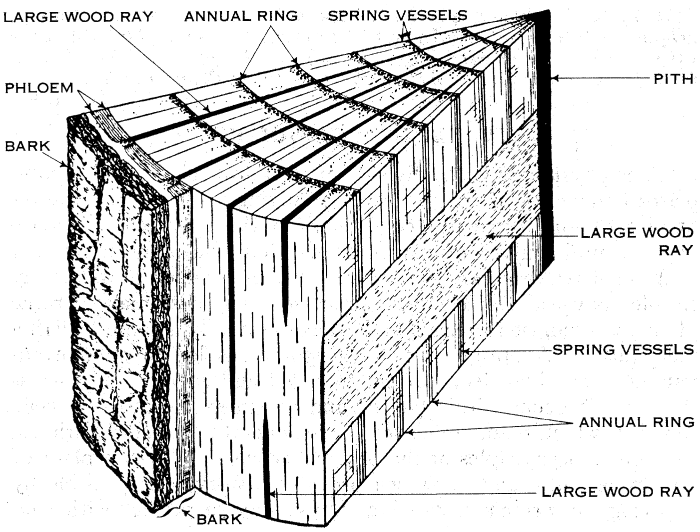
Through secondary growth the primary xylem is buried in the centre of the stem or root, while the primary phloem is pushed outward. The cambial cylinder itself moves outward because of the accumulation of secondary xylem inside of it. As it does so, it also increases in circumference. The divisions that add to the xylem and phloem are tangential, but those that cause the increase in girth of the cambial cylinder are either radial longitudinal (anticlinal) or oblique radial divisions, followed by such elongation of the daughter cells that they appear to slip past each other and eventually lie side by side, at least part of their length.

9. Secondary Vascular Tissues.—The secondary xylem and phloem are highly complex tissues composed of many kinds of cells. As in the cambium, two systems of cells may be distinguished in the secondary tissues, the radial or transverse formed by rays. and the vertical or longitudinal made up of various cells having their long axes parallel with the axis of the organ (fig. 10). The xylem and phloem rays are usually parenchymatous, but may contain ray tracheids in the xylem of gymnosperms. The longitudinal system of the phloem contains sieve cells, phloem parenchyma and fibres in the gymnosperms; sieve tubes with companion cells, phloem parenchyma and fibres in the dicotyledons. The vertical system of the xylem in gymnosperms may contain only tracheids or also fibres and xylem parenchyma. The dicotyledons have a more complex longitudinal system, the complexity varying in different groups. Vessels, tracheids, several kinds of fibres. and xylem parenchyma are common components. The patterns of distribution of the different elements of the secondary phloem and xylem vary greatly and serve as useful criteria in the recognition of relationships among plants.

The secondary vascular tissues in roots and stems are fundamentally similar, but often the root contains a higher proportion of storage parenchyma. The fascicular and interfascicular cambium portions of stems may produce essentially the same kinds of tissues, as in most trees; or the interfascicular cambium forms only ray parenchyma, as in woody vines. In the former case the secondary xylem and phloem form continuous cylinders; in the second the vascular system is broken up into blocks or large strands, each associated with a primary xylem strand next to the pith. Similarly in the roots, the cambium arising in the pericycle may form parenchyma only; or the cambium produces a continuous vascular cylinder.

Annual Rings.—In those plants whose annual activity is interrupted by a regular winter or dry season the limit of each year's increase of secondary wood is marked by a more or less distinct line which is produced by the sharp contrast between the elements formed in the late summer of one year and those produced in the spring of the next. Frequently large vessels are produced by the cambium in the spring. while as summer advances the vessels formed are narrower, and then fibres with greatly reduced cavities arise. In gymnosperms containing no vessels the tracheids formed in the spring have much thinner walls and wider interiors (lumina) than those produced during the summer. Thus in a single season of cambial activity a rough outward progression may be traced in the secondary wood of that season from wide vessels or tracheids to narrow fibres, beyond which the transition to the wide vessels or tracheids of the succeeding spring is sudden. Each zone thus recognized in a cross section of the stem is called an annual ring, and the lines of separation of successive rings mark the temporary cessation of cambial activity at the end of successive seasons.

Sapwood and Heartwood.—The older wood of large trees, forming a cylinder in the centre of the trunk, frequently undergoes marked changes in character. The wood parenchyma and medullary rays die, and the walls of all the cells often become greatly hardened, because of the deposit in them of special substances. Wood thus altered is called heartwood or duramen, as distinguished from the younger sapwood or alburnum, which is nearer the cambium, carries on the active function of conduction, and retains its parenchymatous cells in life. The heartwood ceases to be of any use to the tree except as a support.



AFTER E. W. SINNOTT, "BOTANY PRINCIPLES AND PROBLEMS," MCGRAW HILL BOOK CO.

FIG. 10.— SEGMENT OF OAK LOG

(Right) radial cut; (top) transverse cut; (left) surface of log with a portion of the phloem and bark cut away showing a tangential view of the wood underneath

10. Phellogen and **Periderm.**—The secondary increase of xylem and phloem involves an outward movement of the primary phloem and of all the elements which surround the latter. The cortex, and particularly the epidermis, must accommodate for this movement, either yielding passively to a limit and being injured or destroyed by the outward pressure, or being to some extent modified so as to persist. Mostly the epidermis is unable to maintain the active radial division of its cells necessary for such expansion, is soon stretched to its limit, dies and is destroyed. Extensive radial division in the cortical cells is progressively less essential as the inner cortex is followed inward, and as a rule, by a combination of radial and tangential divisions, the integrity of the cortex is maintained. Toward the periphery of the cortex, and commonly by modification of its outer layer, a secondary meristem arises and produces external and internal secondary tissues. This meristem is the cork cambium or phellogen, and the whole of the tissue it gives rise to is known as periderm.

Cork and Bark.—The phellogen is simple in structure as compared with the vascular cambium; it is composed of one kind of cell which is rather short and prismatic. The external product of this meristem is the characteristic tissue known as cork. This consists typically of closely fitting layers of cells which quickly die, and when mature, have completely suberized walls. The cork serves to replace the epidermis as an external protective layer when the former is ruptured. The outer layers of the cork are constantly being destroyed, but new layers are in progress of formation within. The internal tissue sometimes formed by the phellogen is known as phelloderm; it augments the cortex, and typically consists of living parenchymatous cells to some extent capable of further division. Indeed, an inward succession of phellogens may arise in the phelloderm and in even more deeply seated living layers. The phellogens arising deeply may cut off parts of cortex and even phloem. These tissue parts then die and together with the cork form the rough bark on the surface of the tree. In certain plants the epidermis becomes the phellogen. To the great activity of the phellogen, and to the power of formation of a series of phellogens in deep layers, the value of the cork oak as a source of cork is due. Certain regions of the periderm show loosely arranged cells whose walls are not suberized. These regions are the lenticels through which gaseous interchange between the stem tissues and the outside air is possible.

BIBLIOGRAPHY.—A. De Bary, *Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns* (1884) ; A. J. Eames, *Morphology of Vascular Plants, Lower Groups* (1936) ; A. J. Eames and L. H. MacDaniels, *An Introdzcction to Plant Anatonzy*, 2nd ed. (1947); A S Foster, *Practical Plant Anatomy* (1942) ; G Haberlandt, *Physiological Plant Anatomy* (1911) ; H E. Hayward, *The Structure of Economic Plants* (1938) ; E C. Jeffrey, *The Anatomy of Woody Plants* (1917) ; K Linsbauer, ed., *Handbuch der Pflanzenanatomie* (monographs on special phases of plant anatomy) ; K. Esau, *Plant Anatomy* (1953), *Anatomy of Seed Plants* (1960); A. S Foster and E. M. Gifford, Jr., *Comparative Morphology of Vascular Plants* (1959).
(K. E.)

IV. PLANT PHYSIOLOGY

Plant physiology is the division of botanical science which comprises knowledge of the processes occurring in plants and the influence of environmental conditions on those processes. Since experimental analysis of plant processes has invariably shown that each such process can be resolved into a number of relatively simpler physical and chemical processes. it is customary for the plant physiologist to regard a plant as essentially a complex living mechanism. Adoption of this viewpoint has led to notable advances in our knowledge of the material and energy transformations which occur within plants, and no exception has ever been found in which plant processes do not operate in accord with the fundamental principles of the physical sciences. Given a plant of known heredity. and of known previous history, it is possible by applying the principles of plant physiology to predict with considerable certainty the physiological reactions which will be evoked in that plant upon its exposure to a given complex of environmental conditions.

The following discussion is largely restricted to the physiology of seed plants.

A. Physiology of the Plant Cell

Although from one point of view all plant physiology is cellular physiology, most plant processes are considered in relation to larger structural units such as tissues, organs or the entire plant body. Certain topics. however, can most conveniently be discussed under the above heading.

1. Organization of the Plant Cell.—Essential to the discussion that follows is a review of cell structure as given earlier in the *Anatomy* section. The typical mature plant cell is a tiny many-sided compartment enclosed by a cell mall. Lining the inside of the wall is a thin layer of protoplasm. which is the seat of physiological processes. Present as a part of the protoplasm of each cell is a more or less spheroidal body called the nucleus, which appears to exert a controlling influence on the processes of the cell. The remainder of the protoplasmic layer is called the cytoplasm. Within the cytoplasm are present other organized bodies, smaller than the nucleus. The most important of these are the plastids. The great bulk of the cell cavity or lumen is the vacuole, which contains a complex watery (aqueous) solution called the cell sap. Present as solutes in the cell sap are sugars, salts and many other compounds.

Plant cells of higher plants vary greatly in size and configuration. Some are essentially spheroid (isodiametric), others are considerably or greatly elongate. They range in size from $\frac{1}{250}$ to $\frac{1}{2,500}$ in in rough diameter; a cubic centimetre of compact plant tissue may contain 1.000.000 or more cells. The protoplasts of individual cells are not entirely isolated from each other by the imprisoning walls, but are interconnected by minute strands of cytoplasm called plasmodesmata, which extend from protoplast to protoplast through pores in the separating wall.

The cell wall between two adjacent cells consists of tno or more layers: (1) the middle lamella; (2) the primary cell wall of each cell; and (3) secondary layers which are not present in all cells. The middle lamella is the first cell wall layer formed in the process of cell division and is bounded on each side by the primary walls of tno adjacent cells. This layer is composed of pectic compounds of mhich calcium pectate is one of the more important. The primary cell wall, mhich also develops largely during and immediately subsequent to cell division, is composed of cellulose and pectic compounds which are water-saturated. The basic structural framework of such walls is composed of long chainlike cellulose molecules, which. in portions of the wall at least. are bound together into bundles (micelles) of 100 to 170 parallel molecules. The pectic compounds in the primary wall apparently occupy only the irregular spaces between the micelles. In some kinds of cells a secondary wall may be formed on the inner surface of the primary wall. Unlike primary cell walls, secondary walls lack elasticity, and fail to manifest reversible changes in thickness which are characteristic of many primary walls. Secondary cell walls often contain a smaller proportion of pectic compounds to cellulose than primary cell walls. A number of other constituents are also found in plant cell walls. The most important of these are lignin, suberin and cutin. Lignin, the characteristic constituent of the walls of the cells of woody tissues, is a brownish substance whose exact chemical composition is unknown. It occurs in the intermicellular spaces of the cellulose-containing wall. Suberin is a fatlike substance which is the characteristic constituent of cork cells; cutin is another fatlike substance which occurs as a thin "varnish" over the epidermis of most aerial plant organs.

2. Protoplasm.—As observed at high magnification in an ordinary optical microscope protoplasm appears as a clear fluid in mhich are suspended numerous granules or droplets of insoluble materials. This visible gross structure of the protoplasm does not, however, represent the physical organization which accounts for its unique properties. Portions of the protoplasm mhich contain no suspended granules exhibit all of its fundamental properties. Hence the ultimate structure with which most of the distinctive properties of protoplasm are associated is beyond the limit of the optical microscope: it is ultramicroscopic and resides in the hyaline. optically empty fluid which is its basic constituent.

Chemical analyses of protoplasm tell us no more of its organization than the analysis of a ground-up match would tell us of its mechanical construction. The protoplasmic system is destroyed the moment it is subjected to chemical analysis. Nevertheless such analyses do yield the best available information on the proportionate amounts of various ingredients present in protoplasm. Water is the chief component of the protoplasm of all active cells, usually constituting 90% or more of its total weight. Most detailed chemical analyses of protoplasm have been made upon the formless ameboid bodies (plasmodia) of slime molds. These are inconspicuous naked masses of flowing protoplasm often found creeping imperceptibly over rotting logs in damp woods. Because of the absence of cell wall material, and because the protoplasm can be collected in relatively large quantities. such plasmodia have been favourite materials for chemical analyses of protoplasm. Analysis of such a plasmodium shows that proteins and chemically related substances constitute about 67%, lipids about 11%, minerals about 4%, and sugars about 14% of the total dry weight. The sugars, however, appear to be entirely restricted to the vacuoles. as is also true of a part of the minerals and some of the nitrogenous compounds, especially the amino acids.

The properties of protoplasm are clearly as much a function of its ultimate physicochemical organization as of the specific compounds of which it is composed. A number of the properties of protoplasm are similar to those of gelatin, agar and other water-absorbing colloids (hydrophilic colloids). Among these are its elasticity. its variable viscosity, its capacity to absorb water, its capacity for reversible gelation, and the fact that its physical state may be markedly influenced by mechanical disturbances, high or low temperatures, or certain concentrations of various salts (electrolytes). Although protoplasm appears to have the organization of a hydrophilic colloid, its structural and dynamic complexity far transcends that of nonliving hydrophilic systems such as agar or gelatin sols or gels. William Seifriz and others postulated that protoplasm has a basically fibrillar structure, the submicroscopic fibrils (composed largely or entirely of complex proteins) overlapping and interlocking through molecular side chains within an aqueous medium. Electrolytes, carbohydrates, lipids and other constituents of the system may be dissolved or dispersed in the aqueous medium, dissolved in water held within the fibrils, or adsorbed at interfaces within the system. For a detailed treatment of the physics and chemistry of protoplasm see PROTOPLASM.

Protoplasmic Streaming. — In many plant cells the protoplasm is in active motion, the exact mechanism of which is unknown. In the simplest cases this movement consists of a rotation around the inner surface of the cell wall. Rates of streaming may range up to at least 19 in. per hour. Cyclosis is accelerated by increases in temperature up to the point at which injury occurs, and is retarded at lower temperatures, ceasing just above freezing. Protoplasmic streaming also ceases in the absence of oxygen.

3. Permeability. — Unlike the cell walls, which in most living cells are quite freely permeable to water and solutes, the cytoplasmic layer is more permeable to some substances than to others. In other words, cytoplasm is differentially permeable. This property of differential permeability resides largely in the surface layer of the cytoplasm in contact with the cell wall (plasmalemma), and the surface layer in contact with the vacuole (tonoplast). The cytoplasmic layers are usually relatively permeable to water and to certain solutes such as dissolved gases, and to some types of organic compounds. On the other hand, they are usually much less permeable to sugars and mineral salts. The permeability of the cytoplasmic membranes is a variable property, however, and under certain conditions solutes which ordinarily penetrate through these membranes slowly or not at all may enter or leave cells very rapidly.

4. Osmotic Relations. — If a flabby or flaccid plant cell (*i.e.,* one in which the cell sap exerts no pressure against the encompassing protoplasmic layer and cell wall), is immersed in pure water, inward diffusion of water (osmosis) occurs into the cell sap. Diffusion of the water takes place because the diffusion pressure of the water in the cell sap is less than that of the surrounding pure water by the amount of its osmotic pressure. If the osmotic pressure of the cell sap is 12 atm. (atmospheres, each of which is equivalent to a pressure of 14.7 lb. per square inch or 14.7 lb./inch^2) the diffusion pressure of the water in the cell sap is 12 atm. less than that of pure water at the same temperature and under the same pressure. The lo er diffusion pressure of the water in the cell sap results from the presence of solutes. As water enters the cell it exerts a turgor pressure against the protoplasm and cell wall, a pressure which also prevails throughout the mass of water within the cell. If the cell wall is elastic, as it usually is, some expansion will occur in the volume of the cell. As diffusion of water into the cell continues, turgor pressure gradually increases until eventually it is equal to the final osmotic pressure of the cell sap. At this point of dynamic equilibrium the diffusion pressures of the water in the cell sap and the surrounding water are equal, and the number of molecules entering the cell exactly equals the number passing out of the cell per unit of time. Subjection of water to an imposed pressure increases its diffusion pressure by the amount of the imposed pressure. In this example, disregarding the usually small effect of sap dilution as the cell expands, the diffusion pressure of the water in the cell sap is reduced 12 atm. because of the presence of solutes (the osmotic pressure is the index of this effect) and raised 12 atm. by the turgor pressure; hence its equilibrium diffusion pressure is the same as that of the pure water bathing the cell. If the same cell in a flaccid condition is immersed in a solution with an osmotic pressure of 5 atm., inward diffusion of water occurs but does not continue as long as in the preceding example.

Disregarding dilution, dynamic equilibrium is attained when a turgor pressure of 7 atm. prevails within the cell, because at that point the diffusion pressure of the water in the cell sap and that of the water in the solution are equal. As exemplified in the preceding examples, the effective physical quantity determining the direction of osmotic movement of water from cell to cell in plants or between a cell and an external solution is the diffusion pressure deficit of the water. This value is equal to the osmotic pressure of the contained water (which tends to hold the water in) less the turgor pressure to which it is subjected (tending to push the water out). In an unconfined solution (no membranes) the diffusion pressure deficit is equal to its osmotic pressure, since there is no turgor pressure. In a fully swollen or turgid cell the diffusion pressure deficit is zero, and the turgor pressure equals the osmotic pressure, and as much water leaves the cell as enters it; in a fully flaccid cell the turgor pressure is zero. and the diffusion pressure deficit is equal to the osmotic pressure; therefore much more water diffuses into the cell than goes out.

The osmotic pressures of plant cell saps mostly lie within a range of 5–40 atm. Much higher values occur in some halophytes, the maximum on record being 202.5 atm. in the leaf cells of saltbush (Atriplex confertifolia). The osmotic pressures of the cells of a given plant tissue may vary considerably with environmental conditions and the metabolic status of the cells; more or less regular diurnal or seasonal variations in osmotic pressure occur in the cells of many tissues.

In some kinds of cells water may, under certain conditions, pass into a state of tension (negative pressure). In such cells the diffusion pressure deficit is equal to the osmotic pressure plus the tension imposed on the water, and sometimes far exceeds the osmotic pressure of the cell sap. Osmotic movement of water always occurs from the cell of lower to the cell of greater diffusion pressure deficit unless some interfering or offsetting condition or mechanism prevents or counteracts such movement. Movement of water in plant tissues commonly occurs from cell to cell along diffusion pressure deficit gradients. The osmotic pressure, diffusion pressure deficit and turgor pressure are called the osmotic quantities of plant cells; all three of these physical quantities are necessary in any critical evaluation of the water relations of cells.

5. **Plasmolysis.**—If a partially turgid plant cell is immersed in a solution with a higher osmotic pressure than the cell sap, a slow shrinkage in the total volume of the cell ensues; *i.e*, water moves from the cell sap to the surrounding solution. When the lower limit of elasticity of the rigid cell wall is reached the protoplasmic layer begins to recede from the wall because of continued loss of water from the cell sap. This recession often continues until the protoplasm has shrunk to a more or less rounded sack in the centre of the cell, the space between the wall and the protoplasm becoming filled with the external solution. This phenomenon is called plasmolysis. Since immersion of a cell in a solution with an osmotic pressure just barely exceeding that of the cell sap should just initiate withdra al of the protoplasm from the cell wall, this phenomenon is the basis for one of the methods of measuring the osmotic pressure of plant cells.

6. Enzymes. — Numerous kinds of chemical transformations are constantly occurring in physiologically active plant cells. Many of these chemical reactions can be accomplished artificially, if at all, only by subjecting the reactants to drastic conditions such as high temperatures or extreme degrees of acidity or alkalinity. Yet these reactions occur efficiently and rapidly at ordinary temperatures in a protoplasmic medium which is neither strongly acid nor strongly alkaline. This is possible because of the accelerating effect of certain organic catalysts called enzymes, which are synthetic products of the protoplasm.

Two principal groups of enzymes occur in plants. Hydrolytic enzymes catalyze certain hydrolytic decomposition reactions such as digestive processes and also condensation reactions in certain synthetic processes. Desmolyzing enzymes catalyze various kinds of reactions such as those that involve breaking the bonds between carbon atoms, adding or removing atoms or atomic groups, and shifting atoms or groups of atoms from one part of a molecule to another. The enzymes participating in the various chemical steps of respiration are of the desmolyzing type (see below, *Respiration*). A very small amount of an enzyme can catalyze the transformation of an enormous quantity of substrate. The enzyme sucrase, for example, can catalyze the hydrolysis of 1,000,000 times its own weight of sucrose into glucose and fructose and still retain its catalytic properties.

Many enzymes catalyze the same reaction in both directions, but this is not true of all of them. Most enzymes are thermolabile and in a liquid medium are chemically destroyed at temperatures between 140° and 158° F. Some enzymes appear to consist solely of protein molecules; others of protein molecules to which some nonprotein (prosthetic) group is attached. The prosthetic groups of some enzymes appear to exist in the protoplasm apart from the protein fraction, in which case they are called coenzymes. Some coenzymes are related chemically to the vitamins. See also ENZYMES.

B. TRANSPIRATION

In spite of the indispensability of water for their growth and metabolism. most kinds of land plants—excepting only certain species native to arid habitats—are extremely inefficient in their utilization of water. An overwhelmingly large proportion of the water absorbed from the soil is not retained within the plant or used in metabolic processes but escapes in the process of transpiration. essentially a modified kind of evaporation. Although loss of water vapour, at least in limited amounts, can occur from any part of the plant exposed to the atmosphere, in general most transpiration occurs from the leaves. Leaf transpiration is of two types: (1) stomatal transpiration, in which water vapour loss occurs through the stomates; and (2) cuticular transpiration, in which evaporation of water takes place directly from the surface of epidermal cells through the cuticular layer which, although relatively impervious to water, does permit the passage of limited quantities. In most species stomatal transpiration accounts for 90% or more of the water vapour loss from leaves. Through the investigations of Stephen Hales, in 1i27, transpiration was the first major plant process studied from essentially a modern experimental viewpoint.

1. Physiology of **Stomates.**—The stomates are minute, elliptical pores which occur in the epidermis of plants, being most abundant in leaves. Every stomate is surrounded by two distinctive epidermal cells called guard cells. Open stomates are the principal pathways through which gaseous exchanges occur between a leaf and the atmosphere.

The principal gases which diffuse into or out of a leaf through the stomates are water vapour, carbon dioxide and oxygen. When the stomates are closed all gaseous exchanges between a leaf and its environment are greatly retarded. The size of a fully open stomate varies greatly according to species. Among the largest knoan stomates are those of Zebrina *pendula* whose axial dimensions average $31 \times 12\mu$ ($1\mu =$ ——— in.). The number of stomates may range from a few thousand per square centimetre of leaf surface in some species to over a hundred thousand per square centimetre in others. In many kinds of plants stomates occur in both the upper and lower epidermis, usually being more abundant in the lower. In numerous other species, especially trees and shrubs, they are present only in the lower epidermis. In aquatic plants with floating leaves stomates occur only in the upper epidermis.

The total combined area of the fully open stomates is only 1%–3% of the total leaf area. Despite this fact, rates of stomatal transpiration are often 50%, and sometimes more, of the evaporation from a free water surface under comparable conditions. Much more important is the fact that the rate of diffusion of carbon dioxide, essential in photosynthesis (see below), into the leaf through the stomates is much greater than through an equivalent portion of the area of a fully exposed carbon dioxide absorbing surface. H. T. Brown and F. Escombe in 1900 showed that the high diffusive capacity of stomates in proportion to their area is in accord with the principles of the diffusion of gases through multiperforate septa. Diffusion rates through small openings vary as the perimeter, not the area; therefore. the smaller the aperture the greater its diffusive capacity relative to its area. As a result a gas may diffuse nearly as rapidly through a septum pierced with a number of small apertures. whose combined area represents only a small proportion of the septum area, as through an open surface equal in area to the septum. Since diffusion of gases through stomates is proportional to the perimeter of the pore, diffusion rates through a partially open stomate are almost as great as when the stomate is fully open.

Increase in the turgidity of the guard cells results in opening of the stomates; decrease in their turgidity results in their closure. In general stomates are open in the daytime and closed at night. although there are many exceptions. The mechanism whereby stomates open in the light and close in its absence seems to be principally an osmotic one. Upon illumination the hydrogen ion concentration of the guard cells decreases. This favours the conversion of insoluble starch in the guard cells into soluble glucose-1-phosphate by the enzyme phosphorylase. The resulting increase in the osmotic pressure of the guard cells causes an increase in their diffusion pressure deficit. Osmotic movement of water from adjacent epidermal cells, in which there is no appreciable daily variation in osmotic pressure, takes place in the guard cells. A thicker ridge of cell wall occurs on the stomate side of the guard cells, and as the turgor of the guard cells increases the cells "buckle" and part, thus opening the stomate. With the advent of darkness or even of a markedly reduced light intensity. the reverse train of processes is induced in the guard cells, leading to stomatal closure. Since light of low intensity is relatively less effective in inducing stomatal opening, stomates usually do not open as wide on cloudy as on clear days and often do not remain open for as much of the daylight period. Deficiency of water within the plant induces partial to complete closure of the stomates. During periods of drought stomates therefore remain closed much or all of the time regardless of the light intensity to which the plant is exposed. Stomatal opening does not occur in most species at temperatures approaching 32° F. Therefore in cold or even cool weather stomates may remain closed even when other environmental conditions favour their opening. Nocturnal opening occurs at times in some species, but the conditions resulting in such stomatal behaviour have not been adequately investigated.

Dynamics of Stomatal Transpiration.—In most kinds of plants the cells of the mesophyll do not fit together tightly and the intercellular spaces between them are occupied by air. A labyrinth of these air-filled spaces is thus present in a leaf, bounded by the water-saturated cell walls of the mesophyll. Evaporation of water takes place from the wet cell walls into the intercellular spaces. If the stomates are closed the only effect of this evaporation is the saturation of the intercellular spaces nith water vapour. When the stomates are open, homever, diffusion of water vapour may occur through them into the outside atmosphere. Such diffusion always takes place unless the atmosphere has a vapour pressure equal to or greater than that within the intercellular spaces. an uncommon condition during the daylight hours of clear days. The physical processes of evaporation of water from wet mesophyll cell malls and its subsequent diffusion from the intercellular spaces through the stomates into the atmosphere are, therefore. the tno main steps in stomatal transpiration.

2. Environmental Influences on Transpiration.—Because of its usually controlling influence on the opening and closing of stomates, light is a factor of prime importance in influencing the rate of transpiration. Stomatal transpiration is largely restricted to the daylight hours; hence daytime transpiration is usually many times greater than nighttime transpiration, which is largely or entirely cuticular. Light also has a secondary effect on transpiration through its influence on leaf temperatures, since leaves in direct sunlight usually have temperatures one to several degrees higher than that of the surrounding atmosphere.

The rate of diffusion of water vapour through open stomates depends upon the steepness of the vapour pressure gradient betneen the intercellular spaces and the atmosphere. Assuming open stomates. therefore, the greater the atmospheric humidity (vapour pressure) for any given vapour pressure just below the stomatal pores in the intercellular spaces. the less the rate of transpiration. Temperature affects the rate of transpiration principally because of its differential effect upon the vapour pressures in the intercellular spaces and the atmosphere.

Although leaf temperatures do not follow atmospheric temperatures exactly, in general, increase of atmospheric temperature results in a rise of leaf temperature. Assuming a warm, clear day and an adequate soil water supply, increase in temperature results in an increase in the vapour pressure in the intercellular spaces. Such a rise in vapour pressure occurs because the vapour pressure necessary to saturate air increases with rise in temperature, and the extensive evaporating surfaces of the cell walls bounding the intercellular spaces make it possible for the intercellular spaces to be maintained in an approximately saturated condition most of the time. Rise in temperature ordinarily has little or no effect on the vapour pressure of the atmosphere. Consequently the vapour pressure gradient through the stomates is steepened and the rate of outward diffusion of water vapour increases.

Transpiration rates on windy days are usually greater than on otherwise comparable but quiet days. A gentle breeze is relatively more effective in increasing the transpiration rate than winds of greater velocity. In very quiet air local regions of relatively high humidity may build up in the vicinity of transpiring leaf surfaces. Such localized zones of relatively high vapour pressure retard transpiration unless the air movement is adequate to prevent such an accumulation of water vapour molecules. The bending. twisting and fluttering of leaf blades, and the swaying of branches in a wind also contribute to increasing the transpiration rate.

Soil water conditions also influence the rate of transpiration. Whenever soil conditions are such that the rate of absorption of water is retarded, a corresponding diminution in transpiration rate soon follows.

3. Significance of Transpiration. — Transpiration rates of temperate zone plants may range up to values of about 5 g. per square decimeter (about $15\frac{1}{2}$ sq.in.) of leaf area per hour. Considerable interest also attaches to the quantities of water transpired per acre of crops. grassland or forest. An acre of corn, for example, transpires water equivalent to 15 acre-inches in a growing season. Tremendous variations occur in such values from season to season, however. depending upon climatic conditions. The quantities of water vapour transpired by vegetation-covered areas of the earth's surface are often of sufficient magnitude to have important effects on meteorological conditions.

Much fruitless discussion has raged over the question of whether transpiration is detrimental or beneficial to plants. The extreme viewpoints are (1) that the process is an unavoidable evil; and (2) that it is a physiological necessity. Some of the incidental effects of transpiration are advantageous to the plant, but none is indispensable for its survival or even for its normal physiological operation. Likenise, some of the incidental effects of transpiration are detrimental to the plant, but plants have transpired and survived for untold centuries.

Transpiration is a necessary consequence of the relation of water to plant structure. Terrestrial green plants cannot survive unless they obtain carbon dioxide from the atmosphere. Whatever course the evolution of green plants might follow, their structure must always remain such that carbon dioxide can reach interior cells of the leaf. The principal carbon dioxide absorbing surfaces of terrestrial vascular plants are the moist mesophyll cell walls bounding the intercellular spaces of the leaves. Ingress of carbon dioxide to these spaces occurs almost entirely through open stomates. When the stomates are open. outward diffusion of water vapour is unavoidable, and this process of stomatal transpiration accounts for most of the loss of water by plants. Transpiration is, therefore, in itself an incidental phenomenon. Despite this fact it often has marked indirect effects on other physiological processes occurring in the plant, especially photosynthesis and gronth, because of its influence on the internal water relations of the plant.

4. Guttation. — The exudation of drops of water at the tips or margins of the leaves of many species of herbaceous plants can often be observed, especially in the early morning on a spring day. This phenomenon, called guttation, also occurs in some woody plants. The exuded water is not pure but contains traces of sugars and other solutes. Guttation occurs from special glands called hydathodes, which resemble enlarged stomates. In most species water loss by guttation is negligible compared with water loss by transpiration.

C. Translocation of Water

In land plants the water absorbed from the soil moves to all living parts of the plant. The most striking examples of upward translocation of water occur in trees. One of the tallest known living trees is a specimen of coast redwood (Sequoia sempervirens) which has attained a height of 364 ft. In this tree water ascends to an elevation of nearly 400 ft., since the roots extend for at least several feet into the soil. Many other individual trees of this species and of several others exceed 300 ft. in height. The mechanism of the ascent of sap in plants, and especially in tall trees, has long been one of the classical problems of plant physiology.

1. Mechanics of Water Movement. — The upward movement of water in plants occurs in the xylem, which in the stems of trees and shrubs is identical with the wood. In the trunks and larger branches of a tree, however, sap movement is restricted to a few of the outermost annual layers of wood. For this reason hollow trees, in which most of the central core of heartwood has disintegrated, can remain alive indefinitely. The xylem of any plant constitutes a unit system which extends from just back of every root tip through all the intervening root and stem branches to the mesophyll of the leaves. In angiosperms most translocation of water occurs through vessels. which are elongated tubelike structures in which cross walls are of relatively infrequent occurrence. In gymnosperms movement of water occurs solely through spindle-shaped cells called tracheids, which may be as much as five millimetres in length. Small. often rounded, thin areas occur in the malls of vessels and tracheids which are contiguous with other vessels or cells; these pits are structurally of several types but all of them appear to facilitate passage of water from one xylem element to adjacent ones.

Root Pressure. — If the stem of an herbaceous plant is cut off, a slow exudation of sap often occurs from the xylem tissues at the cut surface of the stump. A similar phenomenon occurs in many woody plants, such as the maple, birch, currant and grape, especially in the spring. A vigorous grapevine often loses a quart or more of sap per day after spring pruning. The exudation of sap results from a pressure originating in the roots, called root pressure. There are several reasons, however, why root pressure cannot be the principal mechanism operating in the upward transport of water in plants: (1) there are many species in which this phenomenon — the exudation of sap — does not occur; (2) the magnitude of measured root pressures seldom exceeds 2 atm. (about 30 lb. per square inch), which could not motivate a rise of water for more than about 60 ft.; (3) known rates of flow under the influence of root pressure are inadequate to compensate for known rates of transpiration; (4) root pressures are usually present in woody plants only in the early spring; during the summer period when transpiration rates, and therefore rates of sap transport, are greatest, root pressures are negligible or nonexistent. Root pressure does account for some upward movement of water in certain species of plants at some seasons, but it represents only a secondary mechanism of water transport.

Ascent of Sap. — Molecules of water, although ceaselessly in motion, are also strongly attracted to each other. This property of a liquid is called cohesion. The cohesion of water is the cornerstone of an important theory of the ascent of sap in plants. The postulated mechanism is relatively simple. Evaporation of water from the walls of the mesophyll cells of leaves results in an increase in the diffusion pressure deficit of the mesophyll cells. Resulting intercellular movements of water cause an increase in the diffusion pressure deficit even of those mesophyll cells not directly exposed to the intercellular spaces. The increased diffusion pressure deficit of the cells abutting directly upon xylem elements in the veinlets of the leaf induces movement of water from the vessels or tracheids into the adjacent cells. Whenever transpiration is occurring at appreciable rates, water does not enter the lower ends of the xylem conduits in the roots as rapidly as it passes out of the xylem vessels or tracheids into mesophyll *cells at the upper end of the* water-conductive *system, consequently the* water *in the xylem ducts is stretched into taut threads; i.e., passes into a state of tension. Each column of* water *behaves like a tiny steel wire which is stretched. Because of their saturated condition, cross* walls *in the xylem do not interfere* with *the continuity of the water. The tension is propagated along the entire length of the water columns to their terminations just back of the root tips, causing entry of water from adjacent root cells (see below. Absorption of Water). The tension can be sustained by the water threads because of the cohesion between the water molecules, operating in conjunction with adhesion of the boundary layers of* water *molecules to the walls of the xylem ducts. The existence of* water *under tension in vessels and tracheids has been confirmed by direct microscopic observation and in other ways. Conservative calculations indicate that a cohesion of 30 to 50 atm. would be adequate to allow conduction of water to the topmost leaf of the tallest known tree. However, under conditions of internal water deficiency, tensions considerably in excess of 50 atm. probably prevail in the water columns of many plants. Actual measurements of the cohesion of water in physical systems indicate* with *a high degree of probability that tensions of this magnitude can develop in the water columns of plants.*

2. *Absorption of Water.* — *Soil Water Conditions.*—Since *soil particles never fit together tightly, there is a certain amount of space betneen them. This pore space varies from about 30% of the soil volume in sandy soils to about 50% in clay soils. The pore space may be occupied entirely by air, as in dried soils, or entirely by* water. *as in saturated soils. but is commonly occupied partly by air and partly by* water. *In a soil in which the mater table lies relatively close to the surface, considerable quantities of water may rise into its upper layers and become available to plants. In many soils, especially in arid regions. there is no water table, and in many others. even in humid regions, the* water *table is continuously or intermittently too far below the soil surface to be an appreciable source of water for most plants. In such soils the only water available to plants comes through natural precipitation or artificial irrigation.*

If rain falls on a dry, homogeneous soil the water will become rapidly distributed to a depth which will depend on the amount of water which falls per unit area and the type of soil. After several days, further deepening of the moist blanket of soil extending down from the ground surface will virtually cease because downward *capillary movement of water has become extremely slow* or *negligible. The boundary between the moist layer of soil and the drier zone underneath will be quite sharp. At this equilibrium condition the water content of the moist soil layer is essentially uniform throughout. The water content of a soil in* this condition *is termed the field capacity. A soil at its field capacity, although relatively moist, is also well aerated; hence soil water contents in the vicinity of the field capacity are the most favourable for the development of most kinds of plants.*

A considerable proportion of the water in any soil is unavailable to plants. The permanent wilting *percentage, an index of the soil water unavailable in growth, is measured by* allowing *a plant to develop with its roots in soil enclosed in a waterproof pot until the plant passes into a state of permanent wilting. The water content of the soil at this point is its permanent wilting percentage. The range of permanent wilting percentages is from* less *than 5% in very sandy soils to about 20% in clay loams. Therefore, sandy soil gives up a greater portion of its moisture; only about 5% of its total moisture content is unavailable to plants. The permanent* wilting *percentage of a given soil is about the same, regardless of the kind of test plant used.*

The diffusion pressure deficit of the water in soils varies with the soil water content. In most soils it is virtually zero at saturation, less than 1 atm. at the field *capacity, and about* 15 *atm. at the permanent wilting percentage. As the water content of a soil drops below its permanent wilting percentage, its diffusion pressure deficit increases at an accelerating rate, soon attaining a value of hundreds of atmospheres; it is for this reason that the permanent wilting percentage is an index of the soil water which is unavailable in plant growth.*

Relation of Root Growth to Water Absorption. — *The successively smaller branches of the root system of a plant ultimately terminate in the root tips, of which there may be thousands or millions on a single plant. The term root tip refers to the region extending back from the actual termination of the root for a distance of several to many centimetres. The terminal zone of a root tip is the dome-shaped root cap, just back of which are the regions of cell division and elongation (see below, Growth). Just back of these regions, in most species. is the root hair zone. Each root hair is a projection from an epidermal cell of which it remains an integral part. A single root tip may bear thousands of root hairs, each of* which *may be from a few millimetres to a* centimetre *or more in length. A root hair is generally a short-lived structure. but* new *ones are constantly developing as the root advances through the soil.*

Most absorption of water occurs at the root tips, especially in the root hair zone. since the older portions of roots become covered with *cutinized or suberized layers which are virtually impermeable to water. Whenever the diffusion pressure deficit of root hairs and other peripheral cells of the root tip exceeds that of the soil water, movement of water into the root cells occurs. If the soil is above the field capacity, water may move from more remote portions of the soil by capillarity toward the region of absorption; the supply of* water *to root tips is largely or entirely maintained in this* way. *Elongation of the root tips, although slower in most species in relatively wet soils. also helps maintain their contact with untapped portions of the soil water. Many plants* grow *for a great part of the time in soils* with *a water content* between *the field capacity and the permanent wilting percentage. In this range of soil* water *contents, capillary movement of mater is too* slow *to maintain an adequate supply of* water *to rapidly absorbing root tips, and after most of the nater on the soil particles in contact with a root tip is absorbed, it cannot be replaced in significant quantities. In such soils it is the continued elongation of the root tips which maintains their contact with available soil water. The numerous root tips may be pictured as slowly progressing through the soil, absorbing* water *from the particles* with *which they come in contact. The aggregate increase in length of the root system of a rye plant averages 3.1 mi. per day. Calculations show that daily root growth of this plant would permit sufficient absorption of water from soils at the field capacity to compensate for daily transpirational water loss.*

Mechanism of Water Absorption.—The *tension generated in the* water *columns of a plant as an indirect result of transpiration is propagated to the terminations of the xylem ducts in the root* tips. *As soon as the tension in the* water *columns exceeds the diffusion pressure deficit of adjacent cells in the root tip, water passes from those cells into the xylem. This engenders further cell to cell movement of water in a lateral direction across the root tip* with *the presumable result that a gradient of diffusion pressure deficits. consistently increasing from the epidermal cells to the root xylem, is established. As soon as the diffusion pressure deficit of the peripheral cells of the root exceeds that of the soil* water. *entrance of mater from the soil begins. Essentially, the long chain of* water *molecules is "drawn" upward by transpiration in the leaves, and water from the soil is "taken in" through the root hairs.*

The process just described accounts for most of the absorption of water by plants. The phenomenon of root pressure, previously described, involves an absorption mechanism which is localized in the roots. Absorption of this type occurs only when transpiration is low *and the soil is relatively moist. Although xylem sap is relatively dilute, its osmotic pressure is often greater than the diffusion pressure deficit of the soil water. This leads to the establishment of a gradient of diffusion pressure deficits across the cortex and other tissues of the root tip along which water moves from the soil to the xylem.*

Environmental Factors *Influencing* Water Absorption. — *Because of their reciprocal relation any factor* which *influences the rate of transpiration influences the rate of absorption; the converse is also true. In addition the rate of absorption is also influenced by* certain soil conditions. Within limits the greater the available soil water supply the greater the possible rate of absorption. Extremely high soil water contents decrease absorption rates in many species because of deficient soil aeration. Low soil temperatures retard the rate of absorption of water by many species. The rate of water absorption by sunflower plants, for example. is rapidly reduced as the soil temperature drops below 55° F. Deficient aeration. characteristic of wet soils, retards water absorption in many species. In such soils the oxygen concentration is lower and the carbon dioxide concentration is higher than in the atmosphere. This retarding effect on water absorption is correlated with a retardation in the rate of root respiration. The presence of solutes in appreciable concentrations in the soil solution also retards or checks water absorption by roots. In most soils the solute concentration is too low to have any appreciable effect on water absorption, but in saline or alkaline soils the influence of this factor may be so pronounced that only a few species of plants are able to survive.

Relative Rates of Water Absorption and Transpiration.—On a clear, warm day, when transpiration rates are high, the rate of water absorption usually lags behind the rate of transpiration, largely because of the resistance of the root cells to the passage of water. As a result there is a gradual increase in the tension in the water columns and a gradual diminution in the water content of the plant, especially of the leaves, during the day. This leads to the partial loss of turgor pressure by the leaf cells, a condition called incipient wilting. Sometimes, especially on clear, hot summer afternoons, the decrease in water content of the leaves is sufficient to induce visible wilting. If the soil water supply is adequate, absorption of water during the night exceeds nocturnal transpiration loss, and the leaf cells gradually regain their turgor. Visible wilting caused by a temporary excess of transpiration over absorption is called temporary wilting, which is distinguished from permanent wilting, caused by a soil water deficiency. Plants automatically recover from temporary wilting during the night, but will not recover from permanent wilting unless the soil water supply is replenished.

D. Metabolism

1. Carbohydrate Metabolism.— The dry matter content of a plant tissue can be determined by drying it at 212° F. The dry residue remaining after the evaporation of water can be further separated into two fractions by incinerating it at about 1,100" F. The bulk of the dry matter, representing combustible organic constituents, disappears, leaving only a small mineral residue called the ash, which is derived from mineral salts absorbed from the soil.

An adequate explanation of the origin of the bulk of the dry matter of plants long eluded students of plant life. As a result of the investigations of Joseph Priestley, Jean Senebier, Jan Ingen-Housz, N. T. de Saussure and others in the late 18th and early 19th centuries, the gaseous exchanges between green plants and the atmosphere were first clearly envisaged. Green parts of plants, exposed to light, were found to utilize carbon dioxide and release oxygen. Nongreen parts, whether in light or dark, and green parts in the dark were found, like animals, to release carbon dioxide and consume oxygen. These gaseous exchanges are the external manifestations of the processes now known as photosynthesis and respiration, respectively. Photosynthesis occurs only in green plant organs exposed to light. Respiration occurs in all living plant tissues, green or nongreen, in light or dark. The fact that green plants usually lose oxygen and use carbon dioxide in the light does not mean that no respiration occurs in such organs in the light, but merely that the rate of photosynthesis exceeds the rate of respiration. Although De Saussure in 1804 recognized that utilization of carbon dioxide by plants contributed to their increase in dry weight, it was not until Julius von Sachs, in 1862, discovered the appearance of starch in the chloroplasts of leaf cells as an accompaniment of the consumption of carbon dioxide that the relation of the gaseous exchanges of plants to their carbohydrate metabolism began to be adequately realized.

2. Photosynthesis.— In the process of photosynthesis certain carbohydrates are synthesized from carbon dioxide and water in the chloroplasts of living plant cells, oxygen also being a product, and light the source of energy. The summary chemical equation for the process is:

$$6CO_2 + 6H_2O + 673 \text{ kg.cal. of radiant energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

A hexose sugar is conventionally considered to be the basic carbohydrate product of photosynthesis, although in actuality the situation is much more complex. Most of the carbon dioxide used diffuses into the leaf through the stomates and dissolves in wet cell walls bordering the intercellular spaces, from where it diffuses in solution to the chloroplasts. In most species less than 1% of the water absorbed is used in photosynthesis. Most of the oxygen liberated passes out of solution into the intercellular spaces, from where it diffuses through the stomates into the atmosphere. For details of the synthesis of carbohydrates see PHOTOSYNTHESIS.

Plant *Pigments.*—In the higher plants photosynthesis occurs only in the chloroplasts, which are green ellipsoidal bodies about 5 μ in diameter. A single mesophyll cell may contain hundreds of chloroplasts. The green colour of chloroplasts and of leaves is because of the presence in the plastids of chlorophyll, of which there are two kinds: chlorophyll a ($C_{55}H_{72}O_5N_4Mg$) and chlorophyll b ($C_{55}H_{70}O_6N_4Mg$). Most leaves contain from two to three times as much chlorophyll a as chlorophyll b. Both chlorophylls have been extracted in pure form from the leaves of over 200 species. The structural formulas of the chlorophylls were determined in 1936 by H. Fischer and S. Breitner. In the angiosperms chlorophyll is, with rare exceptions, synthesized only in the light; in plants of all other groups it can be made either in light or dark. Among the substances which must be present in the cells for normal chlorophyll synthesis are oxygen, carbohydrates, nitrogen, magnesium, iron and water.

The role of chlorophyll seems to be a twofold one: it absorbs light of certain wave lengths, principally in the blue-violet and short red regions of the spectrum. which is used as a source of energy in photosynthesis, and it is a transitory participant in some step of the reaction, presumably acting as a catalyst (see also CHLOROPHYLL, CHEMISTRY OF).

The chloroplasts also contain the yellow pigments carotene ($C_{40}H_{56}$), and the xanthophylls (mostly $C_{40}H_{56}O_2$). The leaves of any angiosperm which have developed in the dark are yellow as a result of the presence of these pigments. Carotene is the precursor of vitamin A. one molecule of carotene being split into two molecules of vitamin A by a simple hydrolysis reaction. Carotene, the xanthophylls and certain other chemically related red and yellow pigments are collectively called the carotinoids. In some plant organs, such as carrot roots, carotinoid pigments occur in the amorphous or crystalline state. The cell sap anthocyanins constitute the other principal group of plant pigments; they are responsible for most of the red, blue and purple colorations of flowers, fruits and other plant parts. Both the carotinoids and anthocyanins play a prominent part in the autumnal coloration of leaves (see ANTHOCYANINS AND ANTHOXANTHINS; PLANT COLORATION).

Factors *Influencing the* Rate of *Photosynthesis.*—F. F. Blackman's (1905) "principle of limiting factors" has assisted materially in the interpretation of the effects of various factors on the rate of photosynthesis. This principle was stated by its author as follows: "When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the 'slowest' factor." This principle, which also holds for other physiological processes, does not admit of too rigorous an application, but in general the concept is valid that the rate of a physiological process is largely controlled by the factor present in relative minimum, the so-called "limiting factor."

Carbon dioxide constitutes only 0.03% by volume of the atmosphere. marked deviations from this value seldom occurring. In the air stratum just above the suriace of rich forest or agricultural soils, however, concentrations several times the usual one sometimes occur, as a result of the upward diffusion of carbon dioxide released in the respiration of soil organisms. With increase in the carbon dioxide concentration of the atmosphere, the rate of photosynthesis increases until some other factor becomes limiting. If the natural concentration of carbon dioxide in the atmosphere were higher than 0.03%. most plants, much of the time, would photosynthesize at a more rapid rate than they do. Very high concentrations of carbon dioxide (15% or more), however, cause a retardation in photosynthesis.

Photosynthesis can occur in visible light from any source, provided its intensity is sufficiently great. The minimum light intensity at which sufficient photosynthesis occurs during an average day's length to be in excess of the consumption of carbohydrates in respiration during 24 hours—no plant can long survive at intensities less than this—differs according to species. In tree seedlings this minimum light intensity ranges from about 1% of full sunlight intensity in some shade species to about 5% in some sun species; in larger plants the minima are probably greater. For measurements made on a leaf or group of leaves, all of which are well exposed to light, the rate of photosynthesis rises with increase in light intensity until some other factor becomes limiting. At the atmospheric concentration of carbon dioxide, maximum rates of photosynthesis in single leaves are attained in many species at one-fourth to one-third of full sunlight intensity, and in some shade species at still lower values. Very high light intensities cause a retardation in photosynthesis, a phenomenon termed solarization.

The rate of photosynthesis for an entire tree, or for a plot of vegetation, increases consistently with increase in light up to the maximum sunlight intensity, which at noon on a clear summer's day in mid-temperate latitudes approximates 1.3 g.cal. per square centimeter per minute (equivalent to about 9,000 foot-candles). Even in full sunlight many interior leaves of an apple tree, for example, cannot photosynthesize at their maximum capacities because they are shaded by peripheral leaves. The lower the light intensity, the greater the proportion of the leaves of which this will be true. Hence the greater the intensity of the light, the greater the average photosynthesis per unit of leaf area and the greater the total photosynthesis per tree up to the limits of sunlight intensity. All wave lengths of light are not equally effective in photosynthesis. For equal intensities of light incident on the leaf, maximum photosynthesis occurs in the orange—short red region, with a secondary maximum in the blue. Rates in the green and yellow regions are lower, but still very appreciable.

The daily rate of photosynthesis is also influenced by the daily duration of the light period (photoperiod). One reason certain crops can develop to maturity during the short growing seasons of high latitudes is that more sugar can be synthesized during the long photoperiods than during the shorter photoperiods of lower latitudes (see below, *Photoperiodism*).

Photosynthesis occurs over a wide range of temperatures, but in temperate zone plants this process takes place at relatively rapid rates in the temperature range 50°–95° F. Increase in temperature. in general, results in an increase in the rate of photosynthesis, if no other factors are limiting the process. In nature, however, the effect of an increase in temperature on the rate of photosynthesis is often not fully realized because of the limiting effect of some other factor. Very commonly the factor which prevents a temperature rise from being fully effective in increasing the rate of photosynthesis is the carbon dioxide concentration of the atmosphere. but low light intensity and low water supply also often act as limiting factors.

Reduction in the water content of a plant causes a retardation in the rate of photosynthesis. This effect is not primarily a result of a deficiency of water as a raw material used in photosynthesis, but of certain indirect effects such as a reduction in the diffusive capacity of the stomates, and a decrease in the hydration of the protoplasm. In young apple trees marked diminution in the rate of photosynthesis occurs long before wilting is apparent, although even in wilted leaves some photosynthesis continues. When uater is applied to the soil, wilted apple leaves recover their turgidity in a few hours, but the original rate of photosynthesis is not regained for several days (G. W. Schneider and N. F. Childers, 1941).

Conditions within the plant also affect the rate of photosynthesis. Among the internal factors which may influence photosynthesis are peculiarities of leaf anatomy, chlorophyll content of the cells, hydration of protoplasm, other "protoplasmic factors," and the accumulation of carbohydrates within the cells.

Mechanism of Photosynthesis.—From the standpoint of fundamental chemistry photosynthesis is, in essence, an oxidation-reduction reaction between carbon dioxide and water. The carbon dioxide is reduced and the water is oxidized, largely as a result of the transfer of hydrogen atoms from water to carbon dioxide. Because the energy content of the products (carbohydrates and oxygen) is greater than that of the reactants (carbon dioxide and water), energy must be supplied from an outside source. In actuality the energy source is light, and the process is thus a photochemical one. As is true of many metabolic processes, photosynthesis is a complex process, embracing numerous sub-reactions, and is by no means entirely understood. Three major sub-reactions which are generally recognized are: (1) photolysis (splitting by light) of water; (2) photosynthetic phosphorylation; and (3) carbon dioxide fixation. All three of these reactions occur in the chloroplasts (D. I. Arnon, 1958).

Substantial evidence exists that the light energy is used in splitting the water molecules and that chlorophylls play a role in this stage of photosynthesis. R. Hill (1937) showed that illumination of a suspension of chloroplasts in water in the presence of certain hydrogen acceptors results in the evolution of oxygen. This phenomenon, now generally called the Hill reaction, can be represented chemically as follows, *A* representing a hydrogen acceptor:

$$2H_2O + 2A \xrightarrow[\text{chloroplasts}]{\text{light}} 2A\ H_2 + O_2$$

The Hill reaction has also been shown to occur in suspensions of grana from disintegrated chloroplasts, as well as in suspensions of intact chloroplasts. It has been shown experimentally that the oxygen released in this reaction comes from the water molecules. The Hill reaction appears to represent, in essence, the photolysis of water stage of photosynthesis.

Photosynthetic phosphorylation is a process in which adenosine diphosphate is converted into adenosine triphosphate in the chloroplasts. This compound and triphosphopyridine nucleotide, which is reduced simultaneously with the synthesis of adenosine triphosphate, provide the necessary "assimilatory power" used in the final step in photosynthesis, which is the fixation of carbon dioxide. M. Calvin and A. A. Benson (1949) and others consider that the compound phosphoglyceric acid is a key intermediate compound in the fixation of carbon dioxide stage of photosynthesis. (See PHOTOSYNTHESIS.)

Biologzcal Significance of *Photosynthesis*.—World-wide cessation of photosynthesis would soon result in the disappearance of all plants and animals, including man, with the negligible exception of a few species of autotrophic bacteria, because this process provides both the energy and organic substance capital of the biological world. Directly or indirectly, all plants and animals, with the minor exception just noted, obtain from green plants oxidizable carbon compounds ("food"). which alone can be used as a source of energy (see below, Respiration) by living organisms in growth, movement and the accomplishment of metabolic processes. All such oxidizable carbon compounds are the direct or derivative products of photosynthesis. Carbohydrates, fats and proteins all are synthesized by chains of chemical transformation from the hexose sugars produced in photosynthesis, and retain within their molecules chemical energy primarily incorporated in hexose molecules by the transformation of radiant energy from the sun. In some food chains carnivorous animals prey upon smaller or weaker carnivorous animals, which in turn prey upon smaller or weaker animals, but ultimately all such chains always lead to animals which obtain their food from green plants. Photosynthesis not only supplies the energy upon which living organisms operate, but all of the organic substance out of which bodies of plants and animals are constructed consists of the direct or derivative products of photosynthesis.

Magnitude and *Efficiency* of *Photosynthesis*.—Under favourable conditions rates of photosynthesis often approximate 10–15 mg. of hexose per square decimeter of leaf surface per hour. Corn plants yielding 100 bu to the acre synthesize about 8,700 kg. (nearly 10 tons) of sugar in a growing season. This represents the transformation of about 33,000,000 kg cal. of radiant energy into chemical energy Nearly one-fourth of this is oxidized in respiration and most of the rest has been transformed into starch, cellulose and other compounds before the plants are mature. The world production of sugar by land plants has been estimated by H. Schroeder (1919) at 4×10^{13} kg. annually which represents the transformation of 1.6×10^{17} kg.cal. of radiant energy into chemical energy.

Despite the utter dependence of the entire organic world upon photosynthesis, only a relatively small percentage of the light incident on plants is used in the process. Of the radiant energy falling on the acre of corn mentioned above only 1.6% is utilized in photosynthesis. Under certain conditions, particularly nhen the light intensity is low, the efficiency of the process in utilizing incident light may be as high as 5%, but rarely, if ever, is greater than that under natural conditions. From a theoretical standpoint the quantum yield of photosynthesis is of considerable significance, but this question has not been settled with finality. Results of various investigators are not in agreement on the magnitude of this quantity, values ranging from 0.1 to 0 25 molecule of carbon dioxide reduced per quantum of light absorbed having been recorded.

Synthesis of Other *Carbohydrates*.—Sucrose is universally present in plants, and is the most abundant of plant sugars. In some plant tissues (sugar cane, sugar beet) it may constitute as much as 20% of the fresh weight, but its concentration is usually lower. Upon hydrolysis sucrose yields an equal number of glucose and fructose molecules, both hexose sugars. In rapidly photosynthesizing leaves the sucrose content usually increases during the daytime; during the night hours the concentration decreases because of its continued translocation out of leaves to other parts of the plant.

Starch is a complex, insoluble carbohydrate which is synthesized in many, but not all, species of plants. In green leaves starch synthesis occurs in the chloroplasts and apparently is initiated whenever the concentration of hexoses exceeds a certain critical value. Starch is a long chainlike carbohydrate molecule composed of hundreds of α D-glucose residues. It is synthesized in plant cells from glucose-1-phosphate by a specific enzyme Considerable quantities of starch accumulate in green leaves during the occurrence of photosynthesis, but most of it is converted into soluble carbohydrates and translocated out of the leaves at night. Starch is also synthesized in many other organs of plants, as for example in potato tubers, from soluble carbohydrates translocated from the leaves. In the nongreen organs of plants, starch synthesis occurs in the colorless leucoplasts. Starch usually occurs in plant cells as microscopically visible starch grains.

Cellulose, the importance of nhich as a cell wall constituent has already been mentioned, is also synthesized from glucose. Cellulose molecules are long chainlike molecules built up from hundreds of β D-glucose molecules. Cellulose is the most abundant organic compound present on the earth. Among the other more important carbohydrates synthesized in plants are pentosans, dextrins, inulin, hemicelluloses, pectic compounds, gums, mucilages, glycosides and tannins.

3. Fat Metabolism.— Fats and fatlike substances, collectively called lipids, are universal constituents of plant cells. All lipids contain the elements carbon, hydrogen and oxygen; some of the more complex ones, the phosphatides, also contain phosphorus and nitrogen. Phosphatides and perhaps other lipids are essential ingredients of the protoplasm. Fats (called oils in the liquid state) accumulate in various organs of plants, especially in seeds and fruits, in which they constitute a reserve supply of food. Upon germination of fatty seeds the oils are digested and used in the processes of respiration and assimilation. Many vegetable oils are important items of commerce; among these are castor bean, rape, sunflower, linseed, peanut, corn, cotton, coconut, palm and olive oils. Lipids apparently can be synthesized in any living plant cell.

Only the synthesis of the fats is well enough understood to warrant discussion. There are three main steps in this process: (1) synthesis of glycerol from carbohydrates; (2) synthesis of fatty acids from carbohydrates; and (3) condensation of glycerol and fatty acid molecules. The detailed chemistry of the first two steps is not known, except that in both there is a chemical reduction with the result that both glycerol and fatty acids contain more energy than the carbohydrates from which they are made. This energy is derived from respiration. The condensation of fatty acids and glycerol to form a fat, using palmitic acid as an example, proceeds as follows under the influence of the enzyme lipase:

$$\underset{\text{palmitic acid}}{3C_{15}H_{31}COOH} + \underset{\text{glycerol}}{C_3H_5(OH)_3} \longrightarrow \underset{\text{palmitin}}{(C_{15}H_{31}COO)_3C_3H_5} + 3H_2O.$$

In this condensation reaction there is very little energy change, but because of the endothermic nature of the reactions by which fatty acids and glycerol are made, a fat contains about $2\frac{1}{4}$ times as much energy as an equal weight of carbohydrate.

4. Mineral Metabolism.— Although many other chemical elements are constituents of plants, only 15 are definitely known to be necessary in chemically detectable quantities for most kinds of plants. These are: carbon, oxygen, hydrogen, nitrogen, magnesium, potassium, calcium, phosphorus, sulfur, iron, boron, manganese, zinc, copper and molybdenum. The first three of these elements are obtained by plants from atmospheric gases or soil water. The remainder are obtained from mineral salts which are absorbed from the soil. The last six of the elements listed above are often called micrometabolic (or trace) elements because they constitute only a very small proportion of the necessary mineral ration of plants. In agricultural soils the elements most likely to be deficient are nitrogen, phosphorus and potassium; hence most commercial fertilizers consist of mixtures of compounds of these three elements. There are many soils, however, to which one or more of the other essential elements, including some of the micrometabolic ones, must be added if satisfactory growth of plants is to be obtained.

Absorption of Mineral Salts.— A part of the mineral salts used by plants is absorbed from the soil solution. Another and, at least for cations, more important source of mineral elements is the clay fraction of the soil. The clay particles are largely of colloidal dimensions and bear negative charges, having associated with them certain cations in large numbers, the commonest of nhich are hydrogen, calcium, magnesium, potassium and sodium ions. Of all these cations the hydrogen ion is held most tenaciously by the clay particles. As a result of respiration, carbon dioxide is continuously being generated in root cells. Part of this carbon dioxide reacts with water, forming carbonic acid, which in turn dissociates, forming hydrogen ions. If a root hair or root epidermal cell is in intimate contact with a clay particle, hydrogen ions from the cell exchange places with cations associated with the clay particles. This process of cation exchange is one of the mechanisms of absorption of ions by the roots of plants. Similar cation exchanges often occur following the addition of a fertilizer to a soil, the displaced cations passing into the soil solution.

Some of the absorption of mineral salts from the soil solution undoubtedly occurs by a simple diffusion, but a larger proportion of the absorption results from the operation of a more complex mechanism, called accumulation of salts. Many of the kinds of ions in the cell sap of large-celled species of submersed water plants such as *Nitella*, *Chara* and *Valonia* are present in a much greater concentration than in the water in which the plants live. A similar situation appears to exist in cells of root tips, which contain various kinds of ions — apparently in a freely dissolved state — each in a concentration much greater than in the medium from which they have been absorbed. Many kinds of plant cells, including those of root tips, appear to possess such a capacity of accumulating salts, *i.e.*, in causing their net movement from a medium of their lesser concentration to one of their greater concentration, which is directly opposite to the direction in which they would move if simple diffusion were the mechanism of movement. Furthermore. such cells possess the capacity of retaining accumulated salts in the cell sap in a higher concentration than in the surrounding medium. In this process, unlike the cation exchange process, both the anions and cations of a salt usually pass into a cell in electrostatically equivalent quantities. The accumulation of salts and their retention in the cell in a higher concentration than in the surrounding medium is correlated with an adequate rate of aerobic respiration within the cells. Presumably energy released in respiration is utilized in the process. Absorption of water and absorption of mineral salts both occur principally through the root tips although the mechanisms of the two processes are entirely different. Continued growth of the root tips through the soil is an important factor in the absorption of mineral salts. particularly in soils at water contents below the field capacity.

Roles of Mineral *Elements* in Plants.—Plants absorb many kinds of ions which are not necessary for their development, and commonly absorb necessary ions in quantities greater than are utilized in the metabolism of the plant. Absorption of ions, therefore, is not necessarily followed by their utilization. Generally speaking, however, most of the ions of essential elements which are absorbed are utilized in one manner or another in metabolic processes, or else have important influences upon physiological conditions within the plant. Many of the mineral elements are important constituents of protoplasm, cell walls or accumulated foods within the plant. The osmotic pressure, hydrogen ion concentration, buffer action and permeability of plant cells are all influenced by mineral salts or their constituent ions. Some mineral elements act as catalysts in the plant. Others have, in certain concentrations. toxic effects which often may be offset by the presence of other ions, a phenomenon known as antagonism. Examples of specific roles of most of the essential mineral elements are given at other places in this article.

Absence or deficiency of any of the essential mineral elements sooner or later becomes apparent in the plant as aberrations in growth or pigmentation. Characteristic visible symptoms of the deficiency of each of the essential elements have been recognized for a number of kinds of plants. Ability to identify such symptoms is of value in diagnosing developmental disorders in plants under natural or cultural conditions.

Hydroponics.—J. von Sachs in 1860 and W. Knop in 1863 were the first to use the method of water culture (solution culture) for studying the mineral salt relations of plants. In this method the plants are grown with their roots immersed in dilute solutions containing dissolved salts (so-called nutrient solutions). An alternative procedure is to grow plants with their roots in pure quartz sand or gravel which is kept moist with the solutions. By comparing the development of plants in solutions containing different kinds and proportions of ions, or the growth reactions of plants in a solution markedly deficient in one of the necessary elements with its growth in a complete solution (one containing all necessary elements) many important facts concerning the mineral nutrition and metabolism of plants have been discovered.

Solution and sand cultures have been used by plant physiologists as a laboratory technique for many years, but it was not until about 1936 that the extension of these methods to the commercial culture of plants in large tanks was attempted, a procedure for which the name hydroponics has been proposed. In one such method plants are supported in a matrix of peat, excelsior or some similar material on a wire screen with their roots projecting into a tank of solution below. Provision for adequate aeration of the solution is necessary if suitable development of the plants is to be insured. In another method the plants are rooted in a medium of coarse sand. gravel or haydite (fused shale) contained in large shallow tanks into which the solution is automatically pumped at intervals from a reservoir. to which it drains back after each cycle of pumping. Considerable success in the culture of certain greenhouse crops by these methods has been reported by commercial growers. The principal salts used in preparing solutions suitable for use in soilless plant culture are potassium dihydrogen phosphate, calcium nitrate, potassium nitrate, magnesium sulfate, ammonium sulfate and iron tartrate. (See HYDROPONICS.)

5. Nitrogen Metabolism.—Proteins, as already noted, are, next to water, the most abundant constituent of protoplasm. Proteins also accumulate in certain plant organs in considerable quantities, especially in the seeds of legumes. Upon germination of such seeds the proteins present are digested and utilized in the processes of assimilation and respiration. All molecules of plant proteins contain the elements carbon, hydrogen, oxygen and nitrogen. Sulfur also appears always to be a constituent, although present in relatively small quantities. Phosphorus is also a component of certain plant proteins.

In spite of the fact that nitrogen gas constitutes about 79% of the atmosphere, green plants are not able to utilize nitrogen from this source. Leguminous plants. an apparent exception to this statement, obtain atmospheric nitrogen indirectly through metabolic activities of symbiotic bacteria living in nodules on their roots. The well-known influence of legumes in enhancing the nitrogen content of soils is dependent upon the action of these bacteria. Most green plants obtain their nitrogen as a constituent of the nitrates or ammonium compounds which they absorb from the soil.

Protein molecules are synthesized by the condensation of large numbers of molecules of amino acids. More than 15 different amino acids occur in plants. The simplest amino acid is glycine:
$$\begin{array}{l} CH_2.COOH \\ | \\ NH_2 \end{array}$$
Most amino acids have a more complex molecular structure; at least one plant amino acid (cystine) also contains sulfur. Amino acids are apparently synthesized from organic acids derived from carbohydrates and from the nitrogen absorbed as nitrates or ammonium compounds. The sulfur present in cystine and possibly other amino acids is absorbed by the plant as sulfates. In some species of plants (apple, asparagus, certain grasses) synthesis of amino acids occurs principally in the roots, while in others (pea, soybean, tomato) it occurs principally in the aerial parts. The principal regions of protein synthesis do not necessarily correspond with the principal regions of amino acid synthesis. Amino acids may be made in one part of a plant, translocated to other parts. and used there in protein synthesis. Condensation of amino acids resulting in the formation of proteins occurs chiefly in the meristems and in certain storage tissues, especially in seeds. The condensation of amino acid molecules occurs mainly by their union through the peptide linkage. Using two glycine molecules for illustration, this process occurs as follows:

$$\begin{array}{l} CH_2-COOH \\ | \\ NH_2 \end{array} + \begin{array}{l} CH_2-COOH \\ | \\ NH_2 \end{array} \longrightarrow \begin{array}{l} \qquad\qquad\quad CH_2-COOH \\ \qquad\qquad\quad | \\ CH_2-CO-NH \\ | \\ NH_2 \end{array} + H_2O.$$

By the linking together of at least several hundred amino acid residues in this fashion the long, complex molecular chains characteristic of proteins are built up. A number of different kinds of amino acids enter into the constitution of each protein molecule; these are not arranged in a haphazard manner, but according to definite linear sequences, which are different and characteristic in each kind of protein. Many of the proteins found in the nuclei of plant cells contain phosphorus. Such proteins are complex compounds formed by the combination of proteins and the phosphorus-containing nucleic acids. Among the compounds important in the protein metabolism of plants are asparagine and glutamine. chemically very closely related to aspartic acid and glutamic acid, respectively, both of which are important plant amino acids. Organic nitrogen is often translocated from one part of the plant to another as asparagine, and this compound also commonly occurs as a temporary storage food. Alkaloids, complex nitrogen-containing compounds. very different in chemical constitution from the proteins, occur in some species of plants. Examples are nicotine, quinine, strychnine and morphine. These compounds are apparently only incidental products of plant metabolism; many of them, however, are important in therapeutics.

E. Translocation of Solutes

1. Organic **Solutes.**—*Downward* Translocation.—Organic solutes, principally carbohydrates synthesized in the leaves, are translocated in a downward direction in plants to the tissues of stems and roots through the phloem. In the stems of noody plants downward translocation occurs only in the youngest layers of phloem. corresponding roughly to the inner bark adjacent to the cambium. In tall trees the carbohydrates entering the root tips may have moved hundreds of feet through the continuous phloem from the leaf cells in which they were made. Most of the translocation of solutes through the phloem occurs in the sieve tubes, which consist of linear series of elongate cells joined together end to end. The exact mechanism of the downward translocation of solutes through the phloem is not knoun. One theory is that it is accomplished by cyclical streaming of the cytoplasm in the sieve tube cells, the solutes passing from one cell to the next by diffusion. Another theory is that there is a mass flow of solution in a downward direction through the phloem, movement from cell to cell being assumed to occur through the interconnecting cytoplasmic strands. There are a number of objections to both of these theories. one of the most serious being that neither of them can account for the rapidity with which translocation occurs in some plants. There are indications that the movement of solute molecules is in some manner greatly accelerated by the metabolic activity of the phloem cells through which translocation occurs, and that energy is actually expended in the accomplishment of solute movement (H. F. Clements, 1940).

Upward *Translocation.*—Under certain conditions considerable quantities of carbohydrates and other soluble foods are translocated in an upward direction through plants. This occurs, for example, in the stems of woody species when the buds resume growth in the spring. The tissues of the shoots formed shortly after initiation of growth are constructed largely from foods nhich move in an upward direction from storage tissues of the older stems. Translocation of foods in an upward direction also occurs toward developing flowers or fruits located in a terminal position, in seedlings as food moves from the endosperm or cotyledons toward the apical growing regions, and during the earlier stages in the development of leaves or shoots from bulbs. corms, rhizomes and tubers. Upward translocation of organic solutes occurs largely in the phloem. It is not certain nhether solutes can move simultaneously in the phloem in both directions or can only move in an upward direction under certain conditions and in a downward direction under others. The comments previously made regarding lack of knonledge of the mechanism of downward translocation apply equally well to upward translocation of organic solutes.

2. Mineral Salts.—The mineral salts absorbed from the soil by the roots are mostly translocated in an upward direction in plants, a large proportion of them ultimately reaching the leaves. Considerable controversy has flourished over whether upward movement of the mineral salts occurs principally in the xylem or principally in the phloem, but the preponderance of the evidence at present indicates that the xylem is the chief tissue through which mineral salt transport occurs (P. R. Stout and D. R. Hoagland. 1939). The dissolved mineral salts. generally in very low concentration, are passively carried in an upward direction through the ascending streamlets of water in the xylem ducts. The possibility of some upward movement of certain mineral elements in the phloem. particularly if in organic combination, cannot, however, be entirely excluded. Not all of the mineral salts translocated into a leaf or other lateral organ of a plant necessarily remain in that organ permanently. Re-translocation of certain mineral elements either as ions or as constituents of organic compounds out of the leaf and their subsequent distribution to other organs, often younger leaves, is of frequent occurrence in plants. Just prior to the abscission of leaves or floral parts a considerable proportion of the nitrogen, phosphorus, potassium, sulfur and magnesium present is translocated back into the stems. Such movements of minerals out of leaves occur through the phloem. There are also indications of a periodic daily "circulation" of at least certain of the minerals in the plant. Mobile phosphorus compounds, for example, apparently can move from root to leaf through the xylem, and from leaf to root through the phloem within a 24-hour period (O. Biddulph, 1941).

F. Respiration

The gaseous exchanges—consumption of oxygen and release of carbon dioxide—accompanying respiration are only external manifestations of this process.

1. Aerobic Respiration.—The essential and only invariable feature of respiration in green plants is that this process results in the oxidation of foods in living cells. The summary equation for the most usual course of respiration is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 673 \text{ kg.cal.}$$

This process is often termed aerobic respiration because it proceeds only in the presence of atmospheric oxygen. Hexose sugars are most commonly the substrate of respiration and the equation given above, representing their complete oxidation, is the exact opposite of the photosynthetic equation. Fats and proteins can also be oxidized in plant cells after conversion into soluble hydrolytic products. Oxidation of fats usually is not initiated until the soluble carbohydrates in the cell are exhausted. Oxidation of proteins apparently seldom occurs until the cells have been depleted of both carbohydrates and fats. The respiratory ratio (ratio of volume of carbon dioxide released to volume of oxygen consumed) of a plant tissue depends upon the type of substrate being oxidized. Oxidation of carbohydrates results in a respiratory ratio of approximately 1, of fats a ratio of about 0.8, of proteins about 0.9, and of certain organic acids, such as oxalic and malic acids, a ratio of more than 1. The occurrence of anaerobic respiration in a tissue also results in a respiratory ratio greater than 1. That heat energy is released in respiration can be demonstrated by placing a mass of germinating seeds in a calorimeter and measuring the rise in temperature with a thermometer. The energy which escapes as heat is entirely lost to the plant. An important fraction of the energy released is not transformed into heat, but is used in endothermic synthetic processes, in various translocation phenomena. in protoplasmic streaming, in the accumulation of ions or molecules by plant cells, in various stages of growth and in other ways. All of the energy made available by respiration represents radiant energy previously entrapped in the process of photosynthesis.

Factors *Influencing the* Rate of Respiration.—In general, young meristematic tissues, relatively rich in protoplasm, have higher rates of respiration than older tissues in which the proportion of cell walls and dead cells is greater. Opening leaf or flower buds, growing root tips and germinating seeds all have relatively high rates of respiration. Germinating poppy seeds at 61" F. may lose 122 cc. of CO_2 per gram of dry weight in 24 hours. The respiration rates of meristematic plant tissues are of the same order of magnitude as the rates in warm-blooded animals. Rates in dormant seeds or other dormant organs, and mature or senescent leaves. fruits or other organs are much lower. Within a temperature range of about 32"–113" F., increase in temperature usually causes an increase in respiration rate (an approximate doubling for each 18° F. rise in temperature), although at the higher temperatures the increased rate often diminishes with time. Starved plant cells respire relatively slowly, and in general, with increase in the soluble carbohydrate content of the cells there is an increase in the rate of respiration up to the point at which some other factor becomes limiting. Very high oxygen contents of the atmosphere result in increased rates of respiration, very low ones result in decreased rates. The oxygen content of the atmosphere can, however. deviate considerably from the usual atmospheric concentration without any pronounced effect on the rate of respiration. An increased carbon dioxide content of the atmosphere results in a decrease in the rate of respiration of some plant tissues and an increase in others. The effect of a shift in the hydration of the tissues on the rate of respiration is exhibited most clearly in seeds. The respiration rate of dry seeds is often vanishingly small. but immediately upon the imbibition of water, the first step in germination, it increases markedly.

Influence oj Respiration Rafe on Net Rate of Photosynthesis.—The average quantity of hexose produced in photosynthesis by a corn plant during its life history is about 9 g. per photoperiod, while the average amount of hexose consumed in respiration during its life history by the entire plant is about 2 g. per 24-hour day. The difference between these two quantities is the net daily rate of photosynthesis and represents the amount of hexose which can be utilized by the plant in assimilation or which may accumulate as unused food. The average net daily rate of photosynthesis is an important consideration in evaluating the survival and development of plants, as, in general, the greater this quantity the larger the plant can grow and the more food that can accumulate. Temperature has an important effect on net daily photosynthesis because of its differential influence on the rates of respiration and photosynthesis.

In many and perhaps all species the temperature optimum for respiration is higher than the optimum for photosynthesis. In the potato, for example, the temperature optimum for photosynthesis, under otherwise favourable conditions, is about 68° F.. while the optimum for respiration, at least of the leaves, is about 95° F. Hence, the higher the temperature above the photosynthetic optimum, the greater the proportion of the photosynthate which is consumed in respiration in one part of the plant or another. and the smaller the daily net photosynthesis. At relatively high temperatures, therefore, there is relatively less food which can be used in the construction of new tissues and which can accumulate in the tubers or other organs. This is the explanation of the well-known fact that the potato is a cool climate crop. The same principle also applies to other species, although the temperature which results in maximum daily rates of net photosynthesis varies with other environmental factors and with the species, being in general higher in species indigenous to warm climates than to those indigenous to cool climates. Analysis of this effect of temperature on plants is complicated by the fact that plants in nature are exposed to a daily cycle of temperature variations, the general pattern of which varies from season to season and habitat to habitat.

2. Fermentation.— When a dilute sugar solution becomes inoculated with yeast cells the process of alcoholic fermentation ensues:

$$\underset{\text{hexose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{ethanol}}{2C_2H_5OH} + 25 \text{ kg.cal.}$$

This process proceeds as a series of sub-reactions, each catalyzed by a specific enzyme. The over-all series of reactions in which the compound pyruvic acid is formed from a phosphorylated hexose sugar is called glycolysis. Although an oxidation reaction, glycolysis can occur in the complete absence of atmospheric oxygen; *i.e.,* it is anaerobic. The further steps in the conversion of pyruvic acid to ethanol are also anaerobic. Even when oxygen is present yeast cells carry on very little aerobic respiration, still obtaining most of their energy from the relatively less efficient process of fermentation.

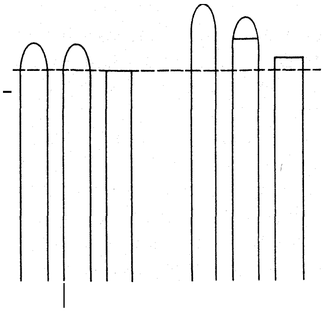
A process identical with or at least very similar to alcoholic fermentation occurs in the tissues of green plants under certain conditions. If kept in an atmosphere devoid of oxygen many plant tissues continue to release carbon dioxide while ethanol or other chemically related compounds accumulate in them. In some plant organs such anaerobic respiration occurs even in the presence of oxygen. This is true in the earlier stages in the germination of some kinds of seeds and grains (pea, oat, sunflower) because of the virtual impermeability of the coats to oxygen. The skin of the grape and some other fruits is also highly impermeable to oxygen, and considerable anaerobic respiration undoubtedly occurs in such organs. Many tissues of higher plants are soon injured by prolonged anaerobiosis. Within a day signs of injury appear in corn seedlings which have been deprived of oxygen. The injurious effect of anaerobic respiration on many plant tissues is undoubtedly in part a result of the low-energy output of this process and in part a result of the accumulation of ethanol or other toxic products within the cells. Some aging (senescent) plant tissues, on the other hand, such as apple and pear fruits, continue to release carbon dioxide and remain uninjured for months when stored in pure nitrogen or hydrogen.

Mechanism of Respiration.—Like fermentation. the process of aerobic respiration proceeds as a complex series of sub-reactions. The earlier steps in fermentation and respiration appear to be identical. By means of the glycolytic series of reactions pyruvic acid is formed in the cells of plants. Glycolysis may occur either in the presence or absence of oxygen. In the presence of oxygen fermentation is usually inhibited and the further aerobic oxidation of the pyruvic acid to water and carbon dioxide takes place through another complex series of reactions known as the Krebs cycle. Most of these reactions in this cycle are catalyzed by specific enzymes. Energy transfers from molecule to molecule during respiration are accomplished through the intermediation of certain complex molecules of which adenosine triphosphate is the best known. Compounds formed during the intermediate steps of respiration are the starting points for many metabolically important chains of reactions. The biochemical pathway along which respiration proceeds appears to be the same or very similar in most kinds of plant and animal cells.

G. Growth

The co-ordinated development of plant organs and tissues is just as clearly a type of physiological activity as relatively simpler processes such as photosynthesis and respiration. The tissues and their constituent cells resulting from the complex of physiological processes referred to as growth in turn become factors influencing subsequently occurring physiological processes in those tissues. Growth of plants occurs primarily in meristems, which are tissues in which the cells retain a capacity for cell division. The principal meristems of a vascular plant are the apical stem meristems, the apical root meristerns and the cambium (not present in ferns or monocots). An embryo plant has only one apical stem meristem. but with the development of the branching stem system there comes to be such a meristem at every growing stem tip and in every bud. Hence there may be thousands of apical stem meristems on any plant with an extensive system of branching. Likewise there is only one apical root meristem on an embryo plant, but with the branching of the root system the number of such meristems on a single plant may exceed many thousands or even millions, since one is present at every root tip.

Growth of any meristem proceeds by successive microscopically visible stages of cell division, cell enlargement and cell maturation. which are the three principal morphological phases of gronth. The terms for the first two stages of growth are self-explanatory. Cell maturation refers to the final stage in growth during which most of the distinctive structural and chemical differences in the walls of the various kinds of cells develop. It is also the stage in which the protoplasm disappears from many kinds of cells as, for example, most cells of the xylem. An actively growing meristem is a centre of intense assimilatory activity, assimilation being the term used to refer to the construction of new cell walls and protoplasm from foods. Protoplasmic proteins are made by the condensation of amino acids, principally during the cell division stage of growth. Cellulose, pectic compounds and other cell wall constituents are synthesized by the condensation of soluble carbohydrates, principally during the cell division and cell enlargement phases of growth. Water is incorporated into the cells in considerable quantities during both cell division and cell enlargement, some entering into the hydration of newly formed cell walls and protoplasm, and larger quantities entering into the expanding vacuoles, particularly during cell enlargement. Translocation of water and soluble foods is, therefore, constantly in progress toward growing meristems. Translocation of essential minerals, as soluble compounds of one kind or another, is also continually occurring toward growing meristems. Certain growth substances must also be present if growth is to occur. Regions of cell division and cell enlargement are also centres of intense respiratory activity, considerable quantities of carbohydrates being oxidized in such cells, much of the resulting energy being utilized in various dynamic and metabolic processes which are integral phases of growth. Respiration rates during the maturation phase are distinctly lower than during the tno preceding stages of the growth process.



A B C A B C

FIG 11 — EFFECT OF DETIPPING OAT COLEOPTILE ON ITS SUBSEQUENT

(A) intact coleoptile; (B) tip severed and replaced; (C) tip removed. At right, differences in subsequent elongation of coleoptiles treated as shown at left

Growth from primary meristems is called primary growth and results in all increase in the Itngth of stems and roots. in the development of their branching system, in the development of the primary tissues of such organs, and in the production of all lateral appendages. such as leaves, floral parts and root hairs. Primary growth of plants is not a continuous but a periodic phenomenon, periods of growth having in general a correlation with favourable seasons. but varying greatly from one species of plant to another. The periodicity of root growth in a given species is usually different from the periodicity of stem growth often beginning earlier in the season than stem growth and continuing after the latter has ceased. Most of the secondary growth of plants is initiated in the cambium. which is a uniseriate layer of cells located between the xylem and phloem. In most plants in which it occurs the cambium is present as an almost continuous layer of cells extending from just back of every root tip to just below every stem apex. As a result of secondary gronth in a lateral direction xylem cells (secondary xylem) are formed on the inner side of the cambium and phloem cells (secondary phloem) on its outer side (the first layers of these tno tissues. primary xylem and primary phloem develop during primary growth). In woody perennials secondary tissues may develop from the cambium for hundreds of years cambial activity being resumed periodically nith the advent of each growing season The diameter of the woody cylinder is thus increased from growing season to growing season, and commonly each season's layer of xylem (wood) can be distinguished in cross sections of the wood as a definite annual ring As new layers of phloem form adjacent to the cambium, the older phloem is displaced outward and in most woody species, becomes part of the bark. which eventually sloughs off.

Leaves develop from the leaf primordia, small protuberances of meristematic cells nhich originate laterally in apical meristemi. The zone of attachment of a leaf to a stem is called a node; in most kinds of plants the !eaves become more or less regularly spaced along the stem axis by elongation of the internodes In the axil of each leaf an offshoot of the terminal meristem develops which in turn becomes a terminal meristem Such meristems are essentially rudimentary side branches and are called lateral buds, usually being covered nith bud scales in woody species. The branching stem system of the plant is a result of the development of the lateral buds into side branches. Branch roots, on the other hand, develop from meristems ahich originate in interior pericycle tissue. In many woody plants scale-enclosed terminal buds form annually at the tip of each stem axis In the woody plants of temperate regions resumption of growth from the terminal buds and from some of the lateral buds occurs each spring. continuing for a few weeks to several months, depending upon the species of plant and

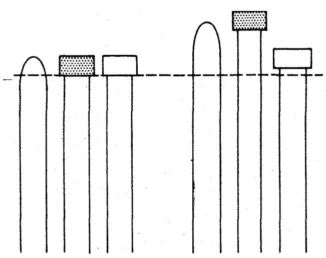


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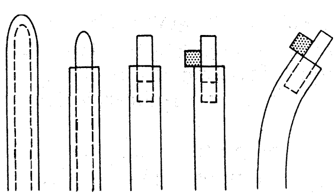
FIG 12 —EFFECT OF AN AGAR BLOCK CONTAINING AUXIN ON OF OAT COLEOPTILE

(A) Check or control; (B) block containing agar placed on detipped coleoptile; (C) block of pure agar placed on detipped coleoptile. At right, differences in elongation of the coleoptiles treated as shown at left

the environmental conditions. In most species of plants some of the apical stem meristems sooner or later become differentiated into flower primordia from which develop flowers and, ultimately, fruits and seeds.

1. Hormones. — Hormones are substances synthesized within an organism which, in very minute concentrations: exert profound effects on its metabolism or growth, often after translocation to parts or organs remote from their centre of production. Although the existence of such substances in plants had been suspected for many years. the first convincingly clear demonstration of the presence of growth hormones (growth substances) in plants was not made until the investigations of F. W. R'ent in 1928.

The auxins have been the most thoroughly studied of the plant hormones. Their action has been investigated mostly in the coleoptile of the oat, which is the first part of the plant that emerges above the ground in germination. This is a cylindrical structure several centimetres in height, which encloses the first leaf. If the tip of an oat coleoptile is removed, elongation of the stump is greatly retarded as compared with an intact coleoptile. If the cut off tip is replaced on the coleoptile. nearly the original rate of elongation may be regained (fig. 11). Furthermore. if the cut off tip be placed with its cut surface in contact with a small block of agar gel for about an hour. and the agar block then be affixed on the cut surface of a detipped coleoptile, that coleoptile will elongate at nearly its usual rate. No such effect will be obtained if a block of pure agar is used (fig. 12). Cell divisions cease very early in the development of coleoptiles and their elongation in length is restricted to the basal portion. The facts just cited indicate that the tip exerts a controlling influence on the elongation of basal cells of the coleoptile and, furthermore, as shown by the agar block experiment, this controlling influence must be ascribed to some diffusible substance or substances which move from the tip toward the base through the coleoptile. These substances are called auxins. If an agar block containing auxins from one source or another is affixed one-sidedly on a detipped coleoptile. cell elongation is found to be more rapid on a side of the coleoptile below the portion of the tip on which the block is located, resulting in curvature of the coleoptile (fig. 13). Translocation of the auxin is almost strictly longitudinal, the elongating cells on the side of the coleoptile below the block receiving much more than cells on the opposite side, with a corresponding differential effect on growth. Within limits of 0° to 20°, curvature resulting from the eccentric attachment of agar blocks containing auxin to detipped coleoptiles is proportional to the concentration of auxin in the blocks. This proportionality between auxin concentration and coleoptile curvature has made it possible to use the bending of oat coleoptiles as the basis for a quantitative and extremely sensitive biological test for auxins. Auxins are essential for the occurrence of cell elongation in all plant cells. In their absence elongation ceases; in their presence elongation occurs if no other factors are limiting, and within limits, elongation is proportional to auxin concentration. Relatively high concentrations of auxins inhibit cell elongatipn. and the concentration most favourable for elongation is different in different tissues. being, for example, much higher in stems and coleoptiles than in roots. The only auxin definitely known to occur in the tissues of higher plants is the compound indole-3-acetic acid. although the presence of others, probably chemically similar. is suspected. A number of synthetic compounds, not known to occur in plants, have been discovered to have many of the same effects on plants as the naturally occurring auxins.



A B C D E

FIG. 13. — STEPS IN TESTING FOR AUXINS QUANTITATIVELY BY DEGREE OF BENDING OF AN OAT COLEOPTILE

(A) , Intact coleoptile enclosing the primary leaf; (B) tip of coleoptile removed; (C) primary leaf pulled loose and its tip cut off; (D) agar block affixed to one side of detipped coleoptile; (E) curvature resulting from movement of auxin into side of coleoptile below block. Within limits, this curvature is proportional to the concentration of auxin in the agar block

More roots form on cuttings of many kinds of plants if they are first treated with an auxin. Some of the synthetic auxins, notably indole-butyric acid and a-naphthalene acetic acid, are especially effective in inducing root formation. The hormone may be applied in solution. in a paste, as a vapour or in a powder. Detailed information on the rooting of cuttings of many species by treatment with auxins is given by G. S. Avery, *et al.* (see Bibliography, below).

The detachment of leaves, fruits and certain other parts of plants from stems usually occurs by the process of abscission. The first step in the abscission of leaves or fruits is the formation of an absciss layer across the base of the petiole of the leaf or the peduncle of the fruit. The absciss layer is a transverse zone consisting of several layers of parenchymatous cells. It may form weeks or months before detachment of the leaf or fruit occurs. Abscission proper, which in the leaves of deciduous trees of temperate regions occurs principally in the autumn, takes place as a result of dissolution of the middle lamella between layers of cells in the absciss layer. Artificial introduction of auxin into leaf petioles at a time when they would ordinarily abscise within a short period materially delays the time of abscission. A practical application of this discovery is to spray apples with a solution of a-naphthaleneacetic acid shortly before harvest in the fall. Aplication of such a spray delays abscission of the fruits and makes it more likely that they can be picked before they fall to the ground and deteriorate in quality.

Usually fruit development ensues only after pollination and subsequent fertilization have occurred. *If*, however, pollination is prevented and any one of several of the auxins is introduced into the pistil by a suitable technique, development of the fruit will occur (F. G. Gustafson, 1936). Such parthenocarpic fruits are seedless.

One of the seemingly paradoxical developments from the study of auxins which. in general, are growth hormones par excellence. is that some of them also exert such toxic effects on plants that they are widely used as weed killers. The best known of such auxins is 2.4-dichlorophenoxy-acetic acid (2,4-D). Such auxins exert their toxic effects only when employed at considerably higher concentrations than those at which they exert growth-promoting effects.

Other growth reactions of plants which are influenced by auxins include cambial activity, abscission, initiation of flowers, gromth correlations and tropisms.

The auxins are by no means the only hormones which occur in plants. Many vitamins of the so-called B-complex appear to operate as hormones in plants. Thiamin, for example, is synthesized principally in the leaves! whence it is translocated to other parts of the plant (J. Bonner. 1942). The same situation appears to prevail with respect to some of the other B vitamins.

The kinins constitute another group of plant hormones. These compounds are purine derivatives, the most thoroughly investigated of which is 6-furfurylaminopurine (C. O. Miller, et *al.*, 1956). The kinins were originally considered to be primarily cell division promoting hormones, but have also been found to favour certain other growth reactions of plants such as expansion of leaf blades.

The gibberellins constitute still another group of plant hormones. the best known of which is gibberellic acid. This compound has the molecular formula of $C_{19}H_{22}O_{11}$ and has the basic ring structure of the compound fluorene. One of the principal effects of the gibberellins is that of promoting elongation of various plant organs. In this respect they resemble the auxins, but they are not to be classed with the auxins because their effects on many plant growth reactions are quite different from those of the auxins. Among other growth reactions of plants influenced by gibberellins are induction of flowering in certain species. shifting the growth cycle of some biennials to annuals. induction of parthenocarpy. enhancing cambial activity, and overcoming the dwarf habit of growth in some species (B. B. Stowe and T. Yamaki, 1957)

2. Factors Influencing Growth. — The process of growth is so complex that it is impossible to characterize it by any single index. Quantitative measurements may readily be made of such aspects as increase in lengths of stems or roots, increase in diameter of a stem, increase in volume of a fruit, or increase in dry or fresh weight of a plant organ. However! qualitative differences in growth are often of greater significance than quantitative differences. The relative development of vegetative and reproductive growth, for example, or whether the vegetative growth is soft and succulent or hard and woody are often of greater import from a physiological or practical standpoint than the absolute development of any plant organ or organs, measured as length or weight. Such developmental differences must be characterized largely in descriptive terms rather than in quantitative measurements.

The growth and reactions of a plant are the result of the coordinated interplay of its hereditary factors and the environmental conditions to which it is exposed upon its internal physiological processes. Genetic factors have as much influence on the development of a plant as environmental factors, but a detailed consideration of their effects cannot come within the scope of this article. The environment of plants is too complex to be subjected to any completely logical analysis, but the following are the principal factors of the physical environnient which have effects upon the rate and type of growth of plants: radiant energy (intensity, quality, duration). temperature of air and soil, atmospheric humidity, soil water supply, soil aeration, supply of available minerals in the soil, concentration of gases in the atmosphere, gravity and atmospheric pressure. Since an individual factor can vary in more than one way, since various interrelations exist among the different factors, and since each factor can induce various chains of reactions in a plant, interpretation of the effects of an individual environmental factor on the growth of plants is usually a complex problem. The principle of limiting factors can be applied in the approximate analysis of many growth phenomena. In this epitomized discussion the influence of only a few of these environmental conditions can be considered in detail.

Photoperiodism.—The reaction of plants to the length of the daily period of illumination is called photoperiodism. The daily length of the photoperiod varies from latitude to latitude and from season to season in the same latitude. In the tropics, seasonal variations in the photoperiod are small, day lengths approximating 12 hours the year round. In mid-temperate regions, photoperiods vary in length from 8 or 9 hours in December to 15 or 16 hours in June. In arctic regions the photoperiod drops to a zero value in December, and is of a 24-hour duration in June. Although the length of the photoperiod has certain effects on the vegetative development of plants, its most noteworthy influence is upon reproductive development. The foundations of our knowledge of photoperiodism in plants were laid by W. W. Garner and H. A. Allard, beginning in 1920. Originally four categories of plants, in terms of their photoperiodic reaction, were recognized: short-day plants, long-day plants, indeterminate plants and intermediate plants. Further investigations have shown that all plants belong basically to the two categories of long-day plants and short-day plants. Long-day plants require a certain minimum length of photoperiod (which varies considerably from one species or even variety of plant to another) out of each 24-hour day for the induction of flowering, but flower under any longer photoperiod, up to and including continuous light. Short-day plants, on the other hand, require an alternation between a dark period and a light period during each 24-hour day if flowers are to be induced. The dark period must be of a certain minimum length (which varies considerably from one species or even variety of plant to another) but flowering also occurs under dark periods which are considerably longer than the minimum. In the Biloxi soybean, for example, a dark period at least 11 hours (but which may be considerably longer) must alternate with photoperiods which may be from 4 to 18, but optionally from 10 to 12 hours in length if flowers are to be initiated (K. C. Hamner. 1940).

Examples of short-day plants include: cocklebur. salvia, aster, dahlia, poinsettia, chrysanthemum and violet; examples of long-day plants include spinach. radish, dill. lettuce, grains, timothy and hibiscus. Spring-flowering plants of temperate zones are mostly of the short-day type, the flower primordia having been formed during the shortening days of the preceding late summer and autumn. Temperate zone autumn flonering plants mostly fall into the same category, except that flowers are initiated during the current instead of the preceding season. Most summer-blooming plants are of the long-day type.

The daily length of the photoperiod is an important factor influencing the distribution of crop plants and of plants in nature. Species of the pronounced long-day type cannot survive in nature in the tropics. Similarly species of the pronounced short-day type cannot survive under natural conditions in more northern latitudes, excepting only those nhich are maintained by vegetative propagation. Short-day Biloxi soybeans, for example, fruit readily in the gulf states of the United States. but not in the latitude of Washington. D C. In the latter region days short enough to induce flowering come so late in the season that fruits are killed by frost before they can ripen. Long-day species with a short critical photoperiod (indeterminate plants) can complete their life cycle over such a nide range of day lengths that their ecological distribution and season of blooming are controlled by factors other than length of the photoperiod.

When the leaves of short-day Biloxi soybean are exposed to short photoperiods while the apical growing regions are kept under long photoperiods or in total darkness. initiation of flower primordia occurs. If the growing tip of the plant is exposed to short photoperiods and the leaves to long photoperiods, no such initiation occurs (H. A. Borthwick and M. W. Parker. 1938). Similar results have been obtained with other short-day species and also with long-day species. These facts indicate that the leaves are the loci of the reactions which lead to the flowering of plants, and that the effects of processes which occur in the leaves are transmitted to the apical meristems, causing them to differentiate into flower primordia. Under the influence of photoperiods of the proper duration it seems likely that a substance (or substances) is made in the leaves. whence it is translocated to the terminal meristems. inducing floner formation. The name florigen has been proposed for this postulated flower-inducing hormone.

It is not necessary for plants to be exposed continuously to photoperiods of the proper length for the initiation of flowers to occur. Short-day Biloxi soybeans, nhich have been growing under long days, will initiate flower primordia after exposure to only two short-day cycles and a return to long days. Similarly four long-day cycles are sufficient to initiate flowering in long-day dill plants which are kept under short days before and after exposure to long days. The existence of this phenomenon of photoperiodic induction has also been demonstrated in a number of other species of both long-day and short-day types.

When a typical short-day plant is kept under a distinctly short-day cycle, such as 8 hours of light alternating with 16 hours of dark, initiation of flowers soon ensues. If. however. the dark period is interrupted at somewhere near its mid point by a short period of relatively low-intensity light flowering is inhibited. When a long-day plant is kept under such a short-day cycle flowering does not occur. If, however. the dark period to which such a plant is exposed is interrupted at approximately its mid-point by a short period of relatively low-intensity light, flowering is induced. In both short-day and long-day plants the usual photoperiodic reaction is reversed by such a treatment. The same effect can be achieved by folloning the 8-hour photoperiod, which must be of relatively high light intensity, with a 6- to 8-hour exposure to low-intensity light.

This low-intensity light reaction of photoperiodism (which must be distinguished from the "high intensity" reaction of the photoperiod proper) has been investigated from the standpoint of the relative effectiveness of different spectral bands of light. A narrow band in the red vicinity of 6500 Å (1 Å or Angstrom unit = $\frac{1}{10,000,000}$ mm.) wave length has been found to operate most effectively in the low-intensity light reaction. Furthermore. a closely adjacent band in the far red, at about 7.300 Å wave length reverses the effect of the red band. This reversible far red reaction affects a number of other growth phenomena in plants in addition to the photoperiodic reaction. These include germination of seeds, elongation of stems, expansion of leaves, germination of fern spores and the formation of certain pigments. Many of these growth reactions apparently can be reversed an indefinite number of times by alternately exposing the plant first to the effective red band, then to the effective far red band of light.

Temperature Effects on Growth—Within limits a rise in temperature favours increased rates of elongation or enlargement of plant organs. The range of temperatures within which this occurs is usually higher in tropical than in temperate zone species, and higher in plants of the latter group than in subarctic species. In temperate zone species, the temperature range over which such an effect occurs approximates 40°–95° F. With further rise in temperature above the optimum. elongation or enlargement rates decrease. falling to zero at about 105°–115° F. The temperature most favourable for one stage of development of a plant is often not the most favourable for another stage.

Relatively low temperatures favour initiation of flowers in some species relatively high temperatures favour floner initiation in other species, and dowers are initiated in still other species over a wide range of temperatures (H. C. Thompson, 1939). Celery plants which have been exposed to a temperature range of 40°–50° F. or 50°–60° F. for 10–15 days will develop flowers, fruits and seeds if subsequently grown at 60°–70° F., a range of temperatures too high for the initiation of flowering. On the other hand, lettuce plants (White Boston) develop flowers, fruits and seeds without forming heads if grown at 70°–80° F Similar plants grown at 60°–70° F first form heads and subsequently go to seed. Other species for which exposure to a relatively low temperature seems essential to induction of flowering include rutabaga, onion, cosmos and stock; other species for which exposure to a relatively high temperature seems essential to induction of flonering include pepper, phlox and cleome.

Growth Correlations—The influence of one part of a plant upon the development of another part of the same plant is called a growth correlation. The harmonious development of the plant body as a whole is controlled by correlative influences operating reciprocally from organ to organ, tissue to tissue, and cell to cell. Innumerable examples of growth correlations can be cited. A familiar one is the phenomenon of apical dominance. 4s long as the terminal bud on a woody stem remains intact or continues to gron, development of lateral buds, at least on the current season's shoots. fails to occur. If the terminal bud is injured or destroyed, however, development of the lateral buds usually ensues. Obviously the terminal bud has some sort of an influence on the lateral buds which prevents their development. Apical dominance also occurs in the groaing shoots of herbaceous plants. When the terminal bud is removed from a broad bean and replaced with a biock of agar gel containing auxin *b* or heteroauxin, inhibition of lateral bud development continues just as if the terminal bud remains intact. If the terminal bud is replaced with a block of plain agar, however. lateral buds begin to develop immediately. It is obvious that auxins play a role in apical dominance. but the exact mechanism of their action has not been worked out. Many, but not all correlative influences of one plant organ on another result from the action of growth substances. One part of a plant often has an influence on the relative quantities of certain foods, of mineral compounds, or of water which reach other parts of the plant. and correlative influences on growth often result from such effects. For example, if the nitrate supply is low, the root system of a plant is large in nroportion to its top. Under such conditions absorbed nitrates are largely used in the synthesis of amino acids in the roots and these amino acids are used in protein synthesis accompanying root growth. Only small quantities of nitrogenous compounds escape utilization in the roots and are translocated to the tops. Hence the growth of the tops is checked by a deficiency of nitrates or amino acids, even though they may contain an abundance of carbohydrates, some of which are translocated downward and used in amino acid synthesis and other processes in the roots. If the supply of nitrates is more abundant, however, more nitrogenous compounds are translocated to the tops, where most of them are used in the synthesis of protoplasmic proteins. The resulting enhanced vegetative growth of the tops results in a greater proportionate development of the aerial portions of the plant as compared with the roots than occurs when the nitrogen supply is deficient.

Dormancy.—Many kinds of seeds. apparently mature, fail to sprout even when brought under environmental conditions favourable for germination. This state of internally inhibited growth of seeds or other plant organs is called dormancy. The following are the main causes of dormancy in seeds: (1) seed coats impermeable to water; (2) seed coats mechanically so strong that they cannot be ruptured by swelling of the embryo; (3) seed coats impermeable to oxygen; (4) seed coats containing a specific chemical inhibitor of germination; (5) embryos in a rudimentary state at the time seeds are shed; (6) embryos fully formed at seed maturity but in such a physiological condition that they will not develop further until they have passed through a period of "after-ripening." More than one of these conditions is present in some kinds of seeds. Methods of "breaking" the dormancy, or at least shortening the period of dormancy, have been devised for a number of kinds of seeds and are of considerable practical utility. The method used with a given kind of seed depends upon the cause of dormancy in that particular seed.

The phenomenon of dormancy is also exhibited by buds. The buds on stems of woody temperate zone species ordinarily do not develop during the summer in which they are formed. even under favourable environmental conditions. This condition of dormancy is maintained in most such species until the following autumn or winter. Exposing stems to vapours of ether, ethylene chlorohydrin or ethylene dichlorid is an effective method of breaking bud dormancy in many woody species. The buds of many kinds of tubers, rhizomes, corms and bulbs likewise may remain dormant for a considerable period. Freshly harvested potato tubers, for example, ordinarily do not sprout at once because of bud dormancy. The duration of dormancy in potato tubers can be greatly curtailed by treatment uith certain chemicals

Vernalization.—This term refers to a low-temperature treatment given seeds before sowing which results in shortening the time until flowering of plants that develop from them. Less commonly, it is also applied to treatment of seeds at relatively high temperatures, or to temperature treatments of plant organs other than seeds (H. H. McKinney, 1930). Although seeds of a number of kinds of plants can be vernalized. this technique is employed principally with cereals, and especially with winter wheats. Vernalization of the grains of a winter wheat so speeds up the completion of its life cycle that it can be grown as a spring wheat. Grains of the Turkey Red variety of winter wheat, for example, are vernalized by soaking to a moisture content of about 60%, which just permits initiation of germination, holding them at approximately that water content, and exposing them to a temperature of 33°–37° F. for 9–10 weeks before sowing. The plants developing from these seeds reach the heading stage in 110–120 days from the beginning of the cold treatment. Unvernalized seeds of the same variety require 150 days from sowing to attain the same stage of development in the same environment. This effect of low temperature treatments on pre-germinated seed, now called vernalization, has been known for many years, but gained new prominence beginning about 1930 because of its advocacy as a practical measure by Russian agriculturalists. Because of the particular climatic conditions prevailing over large portions of the U.S.S.R., the vernalization of winter wheats has proved an advantageous agricultural procedure in some parts of that country. In other parts of the world, however, vernalization has not proved to be a practice of commercial value.

H. Plant Movements

The existence of autonomous movements in plants usually escapes notice because most of them occur too slowly to permit their detection by casual observation. That movements of plant organs actually do occur can be readily confirmed by a series of observations of certain plant organs under suitable conditions. The reality and vigour of plant movements can also be demonstrated strikingly by time lapse motion-picture technique in which pictures of the moving plant organs are taken at relatively long intervals and the resulting film projected at such a speed that the movements are greatly accelerated. Most movements in the vascular plants may be classified into growth movements or turgor movements.

Growth movements, many of them curvatures of plant organs, result from differential rates of growth. Growth movements may be classed as tropic movements. nastic movements and nutations.

1. Tropisms.—Tropic movements such as phototropism and geotropism occur under the influence of an environmental factor acting with greater intensity from one direction than another.

Phototropism—When a plant. such as a potted plant on a window sill, is illuminated more strongly on one side than on others, the stems usually bend toward the brighter light. Two mechanisms of this phenomenon of phototropism have been recognized. One is a retarding effect of light on the elongation of the cells. Hence the cells on the more brightly illuminated side of the stem elongate less than cells on the opposite side, and the stem bends toward the light. The other mechanism of phototropism has been studied principally in the coleoptiles of grasses. Charles Darwin showed many years ago that, although bending occurs in the basal portions of a coleoptile, shading its tip with a tin-foil cap prevents curvature of the coleoptile when unilaterally illuminated. Detipped coleoptiles likewise evince little or no phototropic reaction. Bending of the basal portions of the coleoptile is, therefore, subject to a controlling influence of the tip. Subsequently it was shown that auxin in the tip of an oat coleoptile migrates laterally across the tip from the more strongly illuminated to the shaded side. Some inactivation of auxin on the illuminated side may also occur. Since downward translocation of the auxin is almost strictly longitudinal. the cells on the shaded side of the coleoptile receive more auxin than those on the lighted side. The cells on the shaded side therefore elongate more than those on the illuminated side, and the coleoptile bends toward the light.

Geotropism.—If a potted plant be placed in a horizontal position, the stem bends upuard away from, and the root bends downward toward, the force of gravity. These are examples of negative and positive geotropism, respectively. In a horizontally oriented oat coleoptile, auxin migrates from the upper to the lower side of the tip and thence longitudinally in the usual manner. The greater concentration of auxin on the lower than on the upper side induces greater elongation of cells on the former. and the coleoptile bends upward. In a horizontally oriented root tip, auxin also migrates from its upper to its lower side. Elongation of root cells is favoured by much lower concentrations of auxins than favour elongation of coleoptile cells, and root cell elongation is retarded at all higher concentration. A relatively high auxin concentration on the lower side of the root therefore results in a smaller elongation rate of the cells on the lower as compared with the upper side, and a downward bending of the root results.

2. Nastic Movements and **Nutations.**—Nastic movements are those in which the direction of the movement is limited by the structural symmetry of the plant organ. The more rapid growth of the upper side of a plant organ such as a leaf or flower part is called epinasty; the more rapid growth of its lower side hyponasty. Opening of flowers is caused by epinastic movements of the sepals and petals; closing of flowers, such as occurs in some species at night or at low temperatures, results from hyponastic movements of the floral parts. Careful observation of a growing stem tip reveals that it does not grow straight ahead through space, but moves in an irregular spiral pathway as it elongates. Such growth movements are called nutations.

3. Turgor Movements.—Turgor movements are those caused by reversible changes in cell volume. Many such movements result from turgor changes in structures called pulvini, located at the base of the blade or petiole, or both in some kinds of plants. The well-known and spectacular reactions of the sensitive plant result from turgor changes in cells of pulvini located at the base of the petiole and the base of each leaflet.

Bibliography.—W. Ruhland (ed.), *Encyclopedia of Plant Physiology*, 18 vol (1955–); B. S. Meyer and D. B. Anderson, *Plant Physiology*, 2nd ed (1952); J. Bonner and A W Galston, *Principles of Plant Physiology* (1952); D. I Arnon, *Science*, 127 (1958); L J Audus, *Plant Growth Substances* (1953); G. S. Avery *et al.*, *Hormones and Horticulture* (1947); E. Baldwin, *Dynamic Aspects of Biochemistry*, 3rd ed. (1958); J. A. Bassham and M. Calvin, *The Path of Carbon in*

Photosynthesis (1957); O. Biddulph, *Amer. J. Bot.*, 28 (1911); J. Bonner, *Amer. J. Bot.*, 29 (1942); J. Bonner, *Plaizt Biochemistry* (1950); H. A. Borthwick and M. W. Parker, *Bot. Gaz.*, 100 (1938); A. Burgerstein, *Die Transpiration der Pflanzen*, 3 vol. (1901, 1920, 1925); M. Calvin and A. A. Benson, *Science*, 107 (1948); A. C. Chihnall, *Protein Metabolism in the Plant* (1939); H. F. Clements, *Plant Physiol.*, 15 (1940); A. S. Crafts *et al.*, *Water in the Physiology of Plants* (1950); W. Crocker and L. V. Barton, *Physiology of Seeds* (1953); O. F. Curtis, *Translocation of Solutes in Plants* (1935); H. Davson and J. F. Danielli, *The Permeability of Natural Membranes* (1943); Henry H. Dison, *Transpiration and the Ascent of Sap in Plants* (1914); H. R. Downes, *The Chemistry of Living Cells* (1955); C. Ellis and M. W. Swaney, *Soilless Growth of Plants*, 2nd ed., rev, by T. Eastwood (1947); J. Franck and W. E. Loomis (eds.), *Photosynthesis in Plants* (1949); A. Frey-Wyssling, *Submicroscopic Morphology of Protoplasm and Its Derivatives* (1948); F. G. Gustafson, *Proc. Nat. Acad. Sci., Wash.*, 22 (1936); K. C. Hamner, *Bot. Gaz.*, 101 (1940); E. J. Hewitt, *Sand and Water Culture Methods Used in the Study of Plaizt Nutrition* (1952); R. Hill, *Nature*, 139 (1937); D. R. Hoagland, *Lectures on the Inorganic Nutrition of Plants* (1944); W. O. James, *Plaizt Respiration* (1953); P. J. Kramer, *Plant and Soil Water Relationslzips* (1949); A. C. Leopold, *Auxins and Plant Growth* (1933); J. V. G. Loftfield, *Tka Behavior of Stomata* (1921); t\'. E. Loomis (ed.), *Growth and Differentiation in Plants* (1949); H. H. McKinney, *Bot. Rev.*, 6 (1910); C. O. Miller, *et al.*, *J. Amer. Chem. Soc.*, 78 (1956); A. E. Murneek *et al.*, *Vernalization and Photoperiodisnz* (1948); M. W. Onslow, *The Anthocyanin Pigments of Plants* (1925); E. Rabinowitch, *Photosynthesis and Related Processes*, vol. 1, 2 (1945–56); J. Russell, *Soil Conditions and Plant Growth*, 8th ed. (1950); G. W. Schneider and N. F. Childers, *Plant Physiol.*, 16 (1941); H. Schroeder, *Naturwissenschaften*, 7 (1919); B. T. Shaw (ed.), *Soil Physical Conditions and Plaizt Growth* (1952); F. Skoog (ed.), *Plant Growth Substances* (1951); P. R. Stout and D. R. Hoagland. *Amer. J. Bot.*, 26 (1939); B. B. Stowe and T. Yamaki, *Ann. Rev. Plant Physiol.*, 8 (1957); J. B. Sumner and K. Myrbäch (eds.), *The Enzymes*, vol. 1, 2 (1950–52); H. C. Thompson, *Proc. Amer. Soc. Hort. Sci.*, 37 (1939); E. Truog (ed.), *Mineral Nutrition of Plants* (1951); H. B. Tukey (ed.), *Plant Regulators in Agriculture* (1954); T. A. Wallacc *et al.*, *Trace Elentents in Plant Physiology* (1950); R. Willstätter and A. Stoll, *Investigations on Chlorophyll* (1928); R. B. Withrow (ed.), *Photoperiodism* (1959).
(B. S. M.)

V. PLANT ECOLOGY

Plant ecology is the science which deals with the interrelationships between plant life and environment. It is a segment of general ecology, the empirical basis of which lies in the common observation that living organisms vary with environment. and whose deeper foundations rest upon the fact that life and environment are inseparable parts of a greater whole. Other aspects of general ecology are animal ecology, human ecology and bioecology. which is defined provisionally as the ecology of plant and animal interrelations. Actually, plants, animals and men are so intimately associated that it is seldom possible for the ecologist to confine his attention to any one of them, although each special field has its own core of knowledge and technique.

This last statement can be emphasized by noting the following subdivisions or facets of plant ecology: (1) autecology, the relation of the individual species or plant to its environment: (2) floristics, the distribution in time and space of the various kinds (*i.e.*, species, genera, etc.) of plants; (3) ecological plant geography, the distribution of plant communities; (4) plant sociology, or synecology, the characteristics of plant communities; (5) ecological measurement or habitat analysis, the analysis of the nonliving environment; (6) applied plant ecology.

Throughout the following discussion of these phases of ecology it should be kept in mind that earth, atmosphere, individual organism and communities of organisms all represent dynamic systems, or processes, whose mutual interplay is the concern of the ecologist.

A. Environment and Species (Autecology)

This subject deals with the types of plant structure and behaviour characteristic of different habitats, and the capacity of plants to adjust themselves to various conditions. These are problems of structure and behaviour as well as of ecology, hence they involve the techniques of morphology and physiology. Genetics is also involved, since the attributes in question depend upon the inherited make-up of the individual.

1. Habitat and Structure. — It is a matter of common observation that plants of arid regions are gray, thick-leaved or leafless, succulent and often thorny. in contrast to those of humid regions nhich have delicate, bright green, abundant foliage. Every gardener is familiar with the fine texture of lettuce or tobacco leaves grown in moderate light, as against the woody, coarse leaves produced in strong sunlight. Travelers have also noted the rapid decrease in height of nheat and corn in passing from Iowa to Colorado In a given field of alfalfa, some plants will be killed by winter temperatures which leave others unharmed, partly through local differences in soil moisture, etc., but also in part through inherited differences in different individuals. A field of cabbage or flax may be swept by disease which kills some plants, leaves others unharmed. Such are a few of the countless problems with which autecology must deal.

Every species of plant inherits certain potentialities of adjustment to external conditions. The range of tolerance may be nide or narrow, and differs as regards different factors. The dandelion. which occurs under a nide range of temperature and moisture conditions, has been observed to bloom during ten months of the year at Lincoln, Neb. But along the shore of Lake Michigan it thrives only on clay or where lime-bearing clays are mixed with beach sand.

Within the species are to be found varieties with special limits of tolerance. Upon these, as upon the species. environment may act selectively, eliminating in one place, sustaining in another.

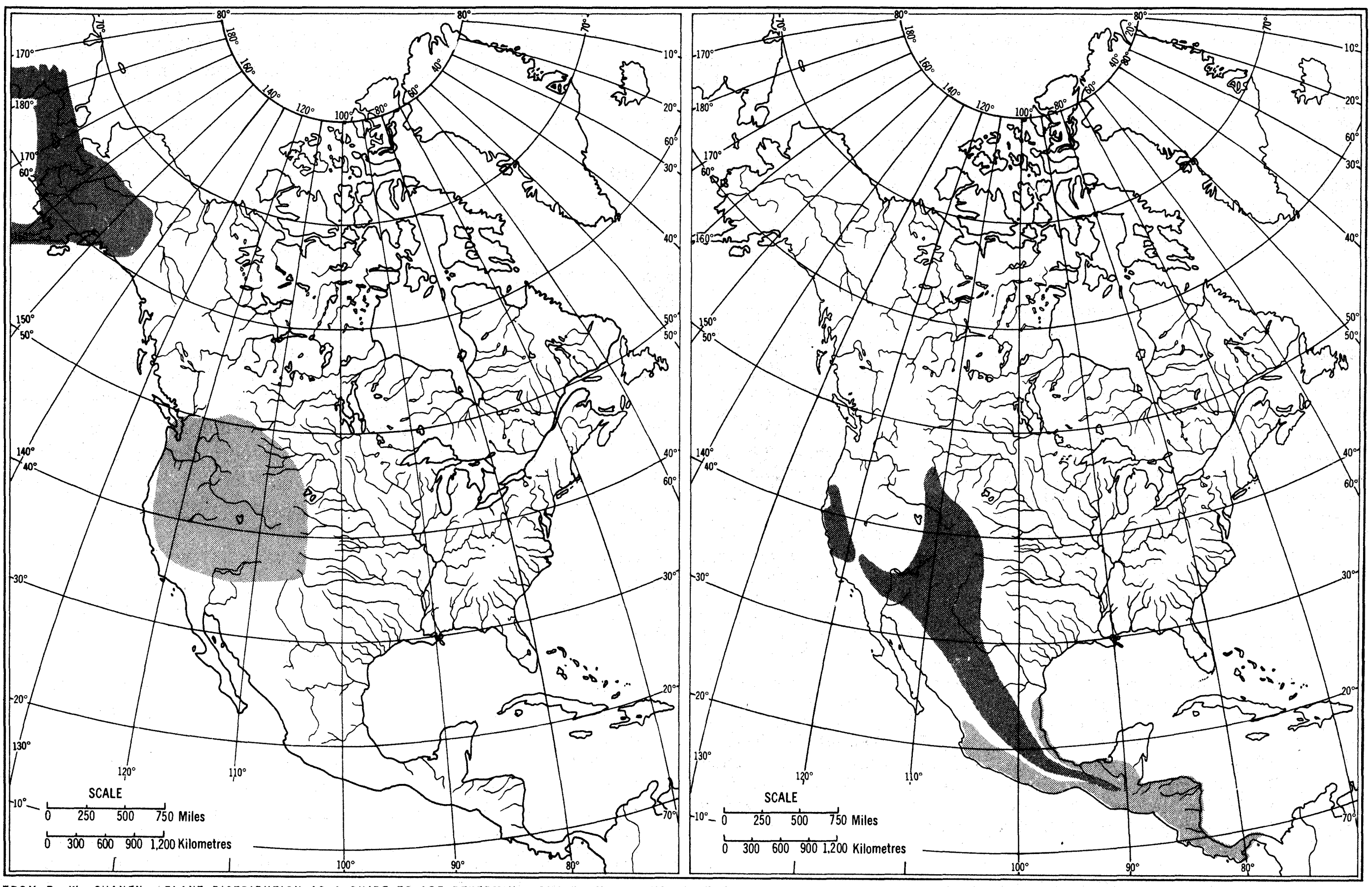
A given factor, such as temperature or moisture. does not always act in absolute fashion. The reaction of a plant with respect to it may vary nith other conditions. Thus by regulating water supply, etc., a plant may be hardened to resist cold.

2. Plant **Adjustments.**—Autecology also considers the numerous specialized adjustments of behaviour between different species of plants, or between plant and animal species. Into this category fall such problems as insect pollination, parasitism and mutual relations between legumes and nitrogen-fixing bacteria.

The course of organic evolution has led not merely to increased specialization of animals and plants, but to increasingly specialized relations between and among species of both. Thus the class of insects. although older than flowering plants, has developed to its present amazing complexity (over 500.000 species) along with the flowering plants, with which insects sustain a wide variety of intimate, often mutual relationships. Unquestionably the development of the flowering plants has been, in its turn, profoundly affected by the activities of these invertebrates. Similarly, the rise of hoofed grazing animals mas conditioned by the evolution of grasses and the consequent origin of great continental steppes. The grasses, in turn, have become adjusted to grazing as a factor in their normal environment.

Among the interrelations of plants none is more important than competition. The consequences of competition are evident in all plant communities, but the source and means of competition are a part of the subject matter of autecology. The general principle involved is that the intensity of competition increases as requirements become more nearly alike. This implies that competition should be most intense between individuals of the same species, which have practically identical requirements. Especially is this true of plants, since mutual benefit within the species does not appear so clearly among plants as among animals. Some measure of the intensity of competition can be seen in any normal woodland by comparing the density of seedlings, saplings and mature trees of any species. A single mature tree is likely to be the sole survivor of many thousand seedlings. Since the most critical competition is for light, water and soil nutrients, the ultimate adjustment among individual plants is attained through spacing, both of roots and tops. Secondary species commonly root at shallower depths and branch at lower levels than dominant forms.

The absence of mutual aid within the plant species is compensated for in part by the usually prodigious output of reproductive bodies, e.g , seeds, and by the development of often highly specialized means of dissemination, whose study is an important phase of autecology. Seed transport by wind, water and animals is a phenomenon familiar to anyone with the slightest knowledge of



FROM R. W. CHANEY, "PLANT DISTRIBUTION AS A GUIDE TO AGE DETERMINATION" FROM "JOURNAL OF THE WASHINGTON ACADEMY OF SCIENCES"

FIG. 14 — DISTRIBUTIONOF SUBTROPICAL AND TEMPERATE FOREST UNITS DURING THE CENOZOIC ERA OF WESTERN AMERICA (BEGINNING ABOUT 70.000,-000 YEARS AGO)

(Left) Eocene epoch; (right) recent epoch. In both maps, the lighter area indicates a subtropical, and the darker area a temperate forest

plants, and often attains great effectiveness. Hard seeds of edible fruits not only pass through the digestive tract of animals without injury, but may actually germinate better for doing so. The eccentrically weighted fruit of maple acquires in falling a spin which may project it to a considerable distance from the parent tree. The coconut, although it cannot germinate after prolonged immersion in salt water, appears to have been transported, by means of ocean currents, to every oceanic isle capable of growing it.

The term adaptation is frequently used with respect to autecological adjustments. It should be employed. however, in such a way as not to confuse (1) the fitness of plants which have become adjusted by selection to a given environment; and (2) the plastic adjustments which a given species can make to variations within an environment to which it has long since been generally fitted by selection.

Autecology has numerous practical applications; *e.g.,* in the selection of drought-, frost-, and disease-resistant varieties of economic plants. It is also of value in diagnosing the character of a habitat under conditions where instrumental studies are not available. Commercial use has been made of it in selecting sweet corn strains with very tight husks through which the larvae of the European corn borer cannot penetrate to the tender grains within.

B. Regional Floras (Floristics)

With the possible exception of certain microscopic plants, every species has a limited and characteristic range, although there is wide variation among species in extent and continuity of their range. The same statement may be made of larger groups, the genera and, to a considerable degree, of families. Groups with greatly restricted range, such as the genus *Sequoia* which is confined to California, are known as endemic. The opposite extreme is represented by cosmopolitan forms such as the common dandelion.

1. Pattern of Distribution. — The pattern of distribution of plant families and their subdivisions finds its explanation in terms of organic evolution and subsequent migration. This migration, in turn, has been subject to changing conditions of earth, climate and biological influence. Theoretically, the older a group. the more extensive should be its distribution; but this principle is subject to so many modifications that every instance has to be investigated on its merits. For example, the present genus *Sequoia* referred to above was once widespread.

Thus a study of floristic patterns must take account of the past as well as the present. It draws upon geology and climatoiogy for explanations, and in turn is a source of valuable clues to students of these subjects by suggesting the position, in time and space, of pathways and barriers. These latter are dependent upon changes of land and water area, changes in land elevation, and shifts in climatic centres.

The term continental pairing is sometimes employed to describe the rather frequent appearance of a genus. or even a species, on two continents. Thus closely related forms are to be found in eastern Asia and in North America — a fact correlated with the existence of a land bridge in the Bering region and a uniform, favourable circumpolar climate. Similar relationships exist between the floras of Europe and North America and those of Asia and Africa.

On the other hand, members of families common to Africa and South America, or to Australia and other continents of the southern hemisphere, exhibit more distant relationship and hence point to more remote opportunities for migration and to barriers of greater antiquity. These facts are parallel nith data obtained from animal distribution — for example. the relatively ancient separation of old and new world marsupials and primates.

2. Factors Influencing Distribution. — The most obvious climatic influence on plant distribution is that of temperature. Few species of seaweeds, if any, have a zone of distribution exceeding a difference of ten degrees in mean annual isotherm. Land species are subject to similar limitations, plus those caused by differences in supply of available moisture. Hence continental desert areas may form barriers as effective as mountain ranges or seas.

Numerous biological factors also influence migration of plant species. Apparently the Yucca (*q.v.*) will tolerate a wider range of conditions than the *Pronuba* moth which is essential to its pollination and seed formation. Thus its natural range is limited to that of the symbiotic insect. Again, the evolutionary development of more efficient species will drive older, less efficient species from areas to which they are well adjusted, and hinder their return. This is exemplified in the relation between conifers and deciduous trees in the humid temperate parts of the northern hemisphere. The former, though quite capable of growing in such regions, have been relegated to the less productive margins. Also, the presence of lethal parasites may exterminate a particular species throughout a portion of its natural range especially favourable to the parasite. and thus establish a lacuna or barrier.

The reciprocal relation between human cultures and plant species is of extreme importance. The three great centres of primitive agriculture — eastern Asia. Asia Minor and Central America — are correlated with the original location of three grasses — rice, wheat and maize. respectively. In the subsequent migrations of these and other economic plants, and of numerous ruderals, is to be found much of the record of the shifting of human cultures.

While the subject of floristics deals with the distribution of all species of the plant realm, the greatest interest attaches to seed plants, which are the dominant forms of modern plant life. Considerably more than half the known families are represented within the tropics. which have afforded more or less continuous refuge during periods of climatic stress in more temperate regions. Flowering plants, well established during the Cretaceous, evolved into a wealth of species during the ensuing Tertiary and became widely distributed during that period of comparatively widespread favourable climate. Present patterns of distribution of this great group and the somewhat older conifers are largely the result of the impact of glacial Pleistocene conditions upon this Tertiary pattern.

Pleistocene glaciation involved at least four major advances of continental ice sheets, with three more or less prolonged interglacial periods. The comparatively brief time since the last retreat (about 15,000 years). although usually referred to as postglacial, has exhibited some of the qualities of an interglacial period, and at no time since the Tertiary have the mild conditions of that period been attained.

During the Tertiary a remarkably rich temperate flora had become diffused to high latitudes in both hemispheres and may properly be described as circumpolar. This flora was compelled to retreat toward the tropics by the advance of Pleistocene ice. With each glacial recession some of the lost territory was reoccupied. to be lost again with successive advances of the ice. The effect of this upon the Tertiary flora was less disastrous in North America than in Europe, where southerly retreat encountered obstacles, and where now the deciduous forest flora is relatively poor in species.

Glaciated portions of the northern hemisphere exhibit three groups of disjunct species of great interest: (1) boreal species in now temperate southerly regions; (2) southern plants occurring in isolated stations north of their present main range; and (3) continental steppe or grassland species in more humid or oceanic regions than they normally occupy. The boreal species, notably bog plants, are now usually regarded as true relicts left behind following the last glacial retreat. The northern outliers of southern plants are still a subject of controversy. One school holds that they represent vegetation which persisted in place on nonglaciated elevations or nunataks throughout glaciation. Critics of this belief hold that this was impossible, questioning the nunatak nature of the areas in question and also the ability of southern plants to survive the glacial climate. Both botanists and geologists are divided in opinion.

In view of this problem, the third group of disjunct species takes on considerable interest. There is a growing belief that they represent relicts from a postglacial time that was warmer and drier than the present — a so-called xerothermic period or periods. Given such climatic conditions and a suitable pathway for migration — for example, the formerly elevated but now submerged Atlantic coastal shelf — southern plants may well have moved northward, leaving relicts behind them during the subsequent cooling and subsidence. At any rate evidence is accumulating from a variety of sources, including modern glaciers and microfossils in peat deposits. to substantiate the existence of postglacial xerothermic conditions.

While the chief contributions to floristics are made by students of plant classification (taxonomy), the knowledge itself is an essential segment of ecology. For example, composite maps of the ranges of characteristic plants of great formations reveal with clarity the dynamic centres of climate and plant distribution in such regions as the eastern deciduous forests and tall-grass prairies of North America and the Mediterranean zone of Europe.

Moreover the Danish botanist C. Raunkiaer has developed a method of climatic analysis through floristic lists of any region. He has classified plants according to the depth of burial or height of exposure of their delicate perennial growing points. Each species falls into a definite category according to the degree of exposure or protection, and the percentage of species in each category constitutes what he calls the "biological spectrum" of a given regional flora. By comparison with a standard spectrum which he devised, inferences may be drawn concerning the climatic characteristics of a region whose flora has been thus analyzed.

C. Ecological Plant Geography

Much that has been said concerning the distribution in space and time of species will apply to communities of plants as well. For a discussion of the nature of communities, see Plant Sociology (Synecology) below.

1. Major Communities. — The major communities of the earth can be grouped roughly as follows: (1) tundra, or treeless, largely moss and lichen vegetation found in the arctic and above timberline on mountains; (2) taiga, or coniferous evergreen forest, ranging from sparse and stunted to dense and thrifty, characteristic of cool regions bordering the tundra; (3) forests of other types, including temperate-deciduous and evergreen forests, tropical rain forest and tropical monsoon (deciduous) forest; (4) grassland, including subhumid and dry steppe or prairie and shortgrass; (5) scrub, or woody, semiarid shrub vegetation; (6) desert. Transitions of course are common — for example, savanna between forest and prairie.

The major communities are known as formations. They are regarded, with reason. as expressions of major climatic types. Allowance must be made, however, for variations caused by physiographic conditions which modify the impact of the general climate, thus producing microclimatic differences, and for soil (edaphic) conditions which modify the availability of water and nutrients or impose unusual chemical limitations.

For such reasons, the actual boundaries between formations are seldom smooth and unbroken. Rather they are lobed and interdigitated, resembling peninsulas and chains of islands. As Asa Gray put it, there must be debatable borders between regions where slight incidents will throw the balance either way. Climates fluctuate in the intensity of their expression from year to year. and consequently in their marginal effects.

Rapid increases in elevation result in a telescoping of climates within comparatively small areas. Thus in ascending a mountain one may pass through plant communities expressing climates which on level terrain might encompass many hundreds of miles.

Any map of world formations must be generalized to a high degree, yet inspection of such a map reveals the transitions from extreme oceanic to extreme continental climates except in circumpolar regions where temperature becomes the limiting factor. The failure of such maps, in temperate and tropical regions, to correlate more exactly with conventional rainfall maps is caused by evaporation, a quantity not generally measured by the meteorologist, but one of critical importance to vegetation.

Ecological plant geography is a subject of the highest utility in its bearing upon world resources and industries and in its indication of proper types of land use and management. It is likewise a factor in military strategy.

D. Plant Sociology (Synecology)

In its broad sense this term is equivalent to synecology, or the study of vegetation rather than the individual plant, or the physical factors of the environment. It is sometimes employed to indicate particular techniques of statistical study. Whereas flora represents the sum total of plant species, vegetation refers to the aggregate of plant life in terms of the communities into which it is organized. Beginning with the great formations already referred to, vegetation may be subdivided into communities of descending rank and of distinctive character at each level.

Difficult problems of nomenclature and classification are involved here, including the old Aristotelian problem of the specific thing and the form which it represents. The deciduous forest of eastern North America may be designated as the oak-beech formation, which in turn includes the maple-beech, oak-hickory, and oak-chestnut associations. These associations again may be divided into faciations (white oak–black oak), consociations (bur oak), and these latter into societies of subordinate species. More formal systems, involving Latinized terms, are also employed. In general the more refined a subdivision, the more homogeneous its character.

1. Community Structure and Evolution. — The attributes of a plant community are structure (the growth forms present—*e.g.*, trees, shrubs, grasses — and their relative arrangement), composition (the species present), and development (life history or succession). Thus a forest is dominated by trees of one or more species, the individuals exhibiting definite spatial relations to each other. In the environment thus controlled, characteristic undershrubs, seedlings, vines and herbs occupy suitable niches. Equally essential, although less conspicuous, are the fungi and bacteria which utilize the materials formed by the dominant vegetation and by decay return these materials for re-use by green plants. Characteristic parasites and symbionts are also part of the community structure, and so are its animals as well. Such a structure may vary greatly in Aoristic composition, depending upon the species present in the region. The deserts of Asia and North America are similar in structure, but composed of different plant families.

One of the most fruitful discoveries in connection with plant communities is the fact of succession or development. This can be simply illustrated by the changes which occur on an abandoned field, a bare rock surface, or a sand dune from the first invading pioneers to the final stabilized forest or prairie. Succession involves change in both structure and composition and moves toward a condition of relative equilibrium characterized by little change in either respect, and known as a climax community. The test of a climax community lies in the ability of the species composing it to reproduce themselves under the conditions which they so largely determine. Pioneer and subclimax species do not have this power. In principle a climax community, once established, maintains itself unless disturbed by physiographic, climatic, or biological (biotic) change. Such disturbance for example would result from serious erosion, uplift or depression, shift in available moisture or temperature patterns. evolution or immigration of new species, fire, clearing, drainage, disease, etc.

Succession represents a process of increasing integration between life and environment. It apparently tends to follow the principle of Le Chatelier as developed by Bancroft; *i.e.*, heterogeneous systems tend progressively toward a condition of minimum disturbance by external forces and internal stresses. So far as the somewhat limited evidence goes, succession also tends toward a progressively more efficient use of energy. The climax community is a close-knit and delicately balanced system which stores and uses solar energy. So intimately adjusted are the nutrient and reproductive cycles of its constituent organisms that the minimum of useful energy is wasted in the chain of metabolic relationships. Thus the climax community represents the maximum in organic economy, as contrasted with the extreme of energy waste in a bare area which receives solar energy only to dissipate it into space without benefit to living organisms.

Representing thus the maximum capacity of a landscape for sustained production, the climax community affords a scientific norm of great value to man in the planning of land use and management and. by analogy at least, in the organization of his own communities. For this reason, quite as much as for sentimental and aesthetic considerations, it is important that in civilized and heavily populated areas substantial remnants of natural vegetation should be set aside, preserved and permanently protected from disturbance. Such reserves or nature sanctuaries are to be distinguished from parks set aside for recreation, and from public forests managed for economic yield.

There is, unfortunately, some difficulty among ecologists in arriving at an agreement regarding the exact meaning of the word climax. For practical purposes the climax plant community might be regarded as the limit toward which the vegetation of a given climatic area and a given evolutionary composition tends. This definition is chiefly convenient because the changes in climate and evolution are slow in terms of human experience. Against them as a background, succession involves the operation of three other dynamic processes: (1) changes in the landscape; (2) soil development; and (3) biological interaction.

2. Changes in the Landscape. — The youthful landscape is typically marked by strong contrasts of elevation, which for a time are increased by the rapid downcutting of narrow stream valleys. This tends to diversify the effect of climatic conditions. producing extremes of shelter in ravines and depressions, of exposure on uplands, and marked differences in available soil moisture throughout. As topography matures, valleys widen, depressions fill and uplands are lowered, thus lessening the initial contrasts. The limit of this process is represented by the peneplain, a generally uniform physiographic system over which local modifications of climate are at a minimum. Until this mature stage of topography is reached, the stability of any community within the landscape is provisional, and its climax character is relative, subject to completion of the erosion cycle.

Actually the peneplain condition is not often attained. Tilting, warping and uplift often interrupt the orderly progress of the erosion cycle, rejuvenating the landscape and interrupting the course of plant succession. Morever, the rate of erosion and deposition is significantly modified by the presence of vegetation. This can be observed by comparing the sharp and rugged topography of a thinly clad desert or semiarid terrain with the gently rounded hills of a heavily vegetated humid region. By removing natural vegetation and substituting clean-tilled fields, man has become a prime agent of geological change, inducing as much erosion in a few decades as might occur in a millennium under natural conditions.

3. Soil Development. — Soil represents not merely the finely divided rock of the earth's surface, but the underground extension of community action and influence. This activity results in a physical, chemical and biological organization of the soil of which the structural expression is the soil profile. The soil profile is studied by means of trenches, or along road and stream cuts, and accurately records the character of the particular climate and vegetation. Thus a forest soil profile is characterized by a thin, very rich and acid surface layer of black humus formed by the fungus decay of fallen leaves and other organic debris. Beneath is a light layer from which the acids have leached soluble mineral material, and below that the layer occupied by tree roots, from which they draw mineral nutrients that are subsequently dropped on the surface by falling leaves, branches, fruits, etc. By comparison, a grassland soil profile exhibits a dark humus layer often 36 in, or more in thickness, measuring the depth of penetration of the abundant fibrous roots and the accompanying microorganisms and fauna. In consequence of these differences cleared woodland soil quickly loses its shallow, rich surface layer with careless handling, while prairie soil can endure longer periods of exploitation. The latter, on every continent, is particularly suited to cereal production, and from it comes the bulk of such staple foodstuffs.

Thus the soil profile is an expression of the energy which activates the living community, and the organization of the profile indicates the capacity of the area to sustain life under current conditions. It should be noted that this organization represents an accumulation of solar energy, inanifesting itself in the accumulation and mobilization of materials, and facilitating the work of living organisms. The accumulated energy in soil is analogous not so much to the power which runs a factory, as to the energy used in its construction and equipment. Soil development is clearly a most important phase of community succession. And in the same way that physiographic processes tend to minimize the initial differences of a given climatic area: soil development tends toward uniformity throughout such an area.

4. Biological Interaction. — The influences of vegetation and habitat are mutual and continuous. Yet it may be said that the influence of the physical environment is at a maximum under pioneer conditions, while that of vegetation is greatest at climax. The pioneers in a new or raw habitat usually encounter extremes of physical and chemical conditions, and frequently violent fluctuations in those conditions. For example, successful pioneer plants must be adapted to withstand high intensities of light usually characteristic of such habitats. But these plants produce shade, which is unfavourable to their own seedlings, and they are replaced by species more tolerant of shading.

Pioneer habitats likewise often present extremes of moisture or dryness. The growth of pioneer plants, adjusted to such extremes, increases humus and modifies the local water balance, a circumstance which operates in favour of plants which, while less hardy than the pioneers, are much more efficient than their predecessors under the new conditions which those predecessors have brought about.

An exceedingly important aspect of this process is the role played by animals and microorganisms, through competition and through the mutual adjustments between dominant and secondary species belonging to the same stage of succession. Like the processes of physiographic change and soil development, biological interaction is convergent in character, leading from initial heterogeneity to ultimate homogeneity. Thus, in the north central states, such varied habitats as dunes, ponds, bare rock and clay ridges have their distinctive pioneer vegetation. Each passes through a characteristic sequence beyond this stage, approaching in structure and composition the beech-sugar maple forest—a relatively stable and self-perpetuating community. Numerous instances are on record of beech-maple climax forests which have deveioped on each of these types of initial areas; on the other hand a lag in physiographic change or soil development may arrest the sequence for a long period at some subclimax level. Thus the moist shaded northern face of a steep hill may reach the climax condition while the hot dry southern exposure remains covered with the subclimax oak and hickory.

Problems of technique in the field of plant sociology have been quite as troublesome as those of nomenclature. Mapping, both topographic and two-dimensional, is of course essential. Aerial photograph>·has been an invaluable aid.

Within the community itself the problem of expressing quantitatively the relationships which exist is extremely complicated. In addition to relative abundance of various species, their cubic magnitude, both above and below ground, may bc significant. Typical concepts used are frequency, coverage, constancy, presence. Since the end of quantitative study is always a qualitative judgment, the choice of particular techniques of counting and measuring varies widely with workers and with the nature of the communities studied. Thus in grassland and herbaceous communities the use of standard quadrats, or squares of uniform size for sampling and comparison, has been extensively developed. In forest regions quadrats of larger size are necessary to give adequate sampling.

Since plant succession is at best a slow process, it must ordinarily be demonstrated by a combination of more or less indirect and inferential methods. Prevalence of vigorous juveniles of species different from the existing dominants is strong evidence of the direction of succession. The zonal distribution of plants, as, for example, about a senescent lake, often indicates the sequence of advance of land vegetation into the lake bed. Comparison of numerous related communities in different stages of development is also a fruitful method. Records, whether paleobotanical, archaeological, or historical, often afiord valuable clues. Direct proof is increasingly afforded by the growing length of scientific records.

E. Nonliving Factors of the Environment

1. Ecological Measurement, or Habitat Analysis. — These terms are employed in the absence of better ones to designate evaluation of the nonliving factors of the environment. The ecologist here depends upon techniques borrowed from sciences which deal with earth and atmosphere. Not infrequently he contributes to these sciences in return, as is evidenced by the groming attention given to evaporation by meteorologists.

It is an axiom that the living community is the most perfect expression or integration of the physical environment. This has led to considerable use of plant communities as indicators of conditions which cannot conveniently be measured otherwise, as for instance, depth of water table. Individual species are also used as indicators.

It is essential, however, that the physical environment be understood as accurately and completely as possible. This is well exemplified by the problem of the Korth American prairie. For a century able scientific men had propounded explanations as to the absence of trees on the prairie. More than a score of theories were advanced, including such suggestions as fire and soil. It was not until after 1910, and then as a result of patient instrumental studies, that proof was obtained that the lack of available moisture is the limiting factor for tree growth in the main body of the grassland. This had been frequently surmised, but never before established.

For the greatest value, ecological measurements should be continuous and inclusive. Light. humidity, precipitation, temperature, evaporation, wind movement and direction are the atmospheric factors most important. Moisture, temperature, texture and chemical composition are the corresponding soil properties. Automatic recording instruments, such as the hygrothermograph, must be employed, supplemented by frequent determinations for such factors as are not adapted to automatic measurements.

The earlier ecological methods of studying light only measured the intensity of actinic rays. improved means are now available which measure both intensity and quality for a wide range of the effective spectrum. Also important is the photoperiod, or relative length of day and night. Measurements for evaporation have until recently given only relative figures, which could not be integrated with rainfall data. Improvements under way promise to give means for direct and absolute determination of the evaporating power of the air.

2. Limiting Factors. — In the study of environment the principle of limiting factors must constantly be borne in mind. It is empirically expressed in the proverb "a chain is no stronger than its weakest link," and was recognized by Baron Justus von Liebig in his study of soil fertility by his "law of the minimum." In 1905 it was placed upon precise experimental basis for plant metabolism by F. F. Blackman, who stated that the rate of photosynthesis mas conditional upon the least favourable of the several factors necessary. Depending upon local conditions, moisture, acidity, nutrients, temperature, light. etc., may be the controlling or limiting factor in a given habitat for given plants. The object of much ecological measurement is to determine limiting factors.

Ecological measurement has been sufficiently perfected to give material aid in predicting the hazards to be encountered in critical areas under various types of land use and management. This technique can be of the greatest economic importance in semiarid regions, such as the high plains of Korth America.

F. Applied Plant Ecology

Illustrations of the economic uses of ecology have been given in the preceding sections. With few exceptions, however, such applications have been sporadic. At the first Imperial Botanical conference, held in London in 1924, systematic plans were laid for the employment of ecology in developing new parts of the empire. With the encouragement of Gen. Jan Smuts, this conference has borne fruit in Africa. The Russians have made intelligent use of ecology. although there is reason to believe that parts of the steppe area have suffered unduly from exploitation. The Gnited States department of agriculture, including the soil conservation service organized in 1935, is making increasing use of ecology.

Yet it is probably fair to say that among public men, and among the general population, there is yet little realization of the basic importance of this subject in establishing permanent and healthful relations between landscape and population.

In the problems of land use and management, ecology occupies a role analogous to that of physics and chemistry in modern industry. Such problems must increasingly be solved by the rigorous application of the principles of ecological science.

Man is the beneficiary not only of a prolonged process of organic evolution which has provided him a great variety of useful plants and animals, but of prolonged and continuous activity by plant and animal communities. This has resulted in the development of fertile soil, as well as in forests and grasslands whose products are no less essential to man than those of his cultivated fields. Moreover, natural vegetation maintains a cover which stabilizes the earth beneath him and retards the violent action of erosion.

Natural communities are characterized by a positive or favourable energy budget. Many, perhaps most, areas controlled by man are exploited, resulting in a negative energy budget, the final mark of which is unproductiveness and abandonment. The fundamental problem of applied ecology therefore is to assay various landscapes occupied by man and determine whether they are registering a net loss or gain in efficiency. The simple criterion of cash returns cannot be applied here. The next problem of the ecologist is to assist in devising methods of land use suited to the character of the locality so that a favourable energy budget may be maintained or restored.

Because of the character of our political system and our long habit of using science chiefly where immediate problems of health or profit are involved. the fundamental application of ecology cannot be hastily achieved. In practice, however, growing numbers of civil servants — foresters, county agents, agricultural engineers, entomologists. etc.—are acquiring some understanding of ecology. The same thing is true to a lesser extent of farmers and farm owners. As this knowledge becomes more general, it will materially affect practice and planning, and has in fact already done so in favoured localities.

In the field of land management, or actual operation, ecology also has important functions, some of which have been suggested in preceding sections.

See PLANT DISEASES; *see* also Index references under "Plants and Plant Science" in the Index volume.

BIBLIOGRAPHY.—J. Braun-Blanquet, *Pflanzensoziologie* (1927), (authorized. English trans. by George D. Fuller and Henry S. Conard under the title *Plant Sociology, the Study of Plant Contmunities,* 1932); Ralph W. Chaney, "Paleobotany — Plant Distribution as a Guide to Age Determination," *Jour. Wash. Acad. Sci.* 26 (8): 313–24 (1936); Frederic E. Clements, *Plant Succession and Indicators* (1928); C. Raunkiaer, *The Life Fornzs of Plants and Statistical Plant Geography,* being the collected papers of C. Raunkiaer (Oxford, 1934); E. J. Russell, *Soil Conditions and Plant Growth* (1942); E. J. Salisbury, "The Geographical Distribution of Plants in Relation to Climatic Factors." *The Geographical Journal,* 312–42 (1926); Paul B. Sears, "Xerothermic Theory," *Bot. Review* 8 (10): 708–36 (1942) and *Life and Environnzent* (1939); A. G. Tansley and T. F. Chipp, *Aims and Methods in the Study of Vegetation* (1926); C. Warren Thornthwaite, "The Climates of the Earth," *Geographical Review* 23(3):433–40 (1933); E. H. Transeau, H. C. Sampson and L. H. Tiffany, *Textbook of Botany* (1940); E. Warming (assisted by M. Vahl; trans. by P. Groom and I. B. Balfour), *Oecology of Plants* (Oxford, 1909); John E. Weaver and Frederic E. Clements. *Plant Ecology,* 2nd ed. (1938); S. A. Cain, *Foundations of Plant Geography* (1944); H. J. Oosting, *The Study of Plant Communities* (1957); E. V. Wulff, *An Introduction to Historical Plant Geography* (1943). (P. B. S.)

PLANUDES, MAXIMUS (c. 1260–1330), Byzantine grammarian and theologian who flourished during the reigns of Michael VIII and Andronicus II Palaeologi, spent the greater part of his life as a monk in Constantinople On entering the monastery he changed his original name Manuel to Maximus. Possessing a knowledge of Latin remarkable for his time he was sent by Andronicus II in 1327 on an embassy to remonstrate with the Venetians for their attack upon the Genoese settlement in Pera. Planudes, especially by his translations, paved the way for the introduction of the Greek language and literature into the west.

He is the author of a Greek grammar, a biography of Aesop and a prose version of his fables, certain scholia, various original poems. His numerous translations from the Latin included Cicero's *Somnium Scipionis* with the commentary of Macrobius: Caesar's *Gallic War;* Ovid's *Heroides* and *Metamorphoses;* Boetius, *De consolatione philosophiae;* Augustine, *De trinitate.* He also edited a supplement to the Anthology known as *Appendix Planudea*

PLASKETT, JOHN STANLEY (1865–1941), Canadian astronomer, discoverer of the dual star known as "Plaskett's twins," was born Nov. 17, 1865, near Woodstock, Ont. Me graduated from the University of Toronto in 1899. In 1905 he was made astronomer of the Dominion observatory at Ottawa, and remained in that position until 1917, nhen he was placed in charge of the Dominion Astrophysical observatory in Victoria, B C. After his retirement in 1935, he supervised the grinding and polishing of the 82-in mirror for the telescope of the McDonald observatory of the University of Texas.

Plaskett was one of the most noted astronomers of his time Of his many important discoveries, one of the first came in 1922 when he found that what had for years been considered a large single star was actually two stars. The stars, although clearly visible to the naked eye, had not been identified as tuins until Plaskett studied them through the Dominion observatory's 72-in. telescope. which he had been instrumental in persuading the government to install.

The stars were subsequently given his name and are known as "Plaskett's tnins" He also made valuable studies on the motions of stars, on the Milky Way and its movements and on the rotation of the galaxy.

Of his numerous papers. the most important include *Star Image in Spectroscopic Work; Design of Spectroscopes; The Rotation of the Galaxy; Diffuse Matter in Interstellar Space;* and several on the 0-type stars.

He was the recipient of a number of honorary degrees and awards for his distinguished services to astronomy. He died at Esquimault. B C., Oct. 17. 1941.

PLASSEY (PALASI), a village of Bengal, scene of Robert Clive's victory on June 23, 1757, over the forces of the nawab Suraj-ud-Dowlah. Clive, with a force of about 3,000 men and 8 fieldpieces, took the field against the nawab, who had about 60,000 men, 53 heavy guns and some French artillery under St Frais. Only the Bhagirathi river separated Clive's force from the entrenched camp of the enemy, when the English leader, for once undecided. called a council of war. Clive and the majority were against fighting; Maj. Eyre Coote, of the 39th foot, and a few others were for action. Coote's soldierly advice powerfully impressed Clive, and after deep consideration he altered his mind and issued orders to cross the river. After a fatiguing march, the force bivouacked in a grove near Plassey early on June 23. The nawab's host came out of its lines and was drawn up in a huge semicircle almost enclosing the little force in the grove. and St. Frais's French gunners on the right wing opened fire. Clive replied and was soon subjected to the converging fire of 50 heavy guns. For hours the unequal fight was maintained, until a rainstorm stopped it. The English covered up their guns, but the enemy took no such precaution.

Mir Mudin, the only loyal general of the nawab's army, thinking that Clive's guns nere as useless as his own, made a disastrous cavalry charge upon them; he lost his own life, and his colleagues then had the game in their hands. Mir Jafar persuaded the nawab to retire into the entrenchments.

But the rank and file of the Indians, ignorant of the treachery of

Mir Jafar, who went over to Clive, made a furious sortie. Clive, noticing that Mir Jafar's division in his rear made no move against him, led his troops straight against the works.

After a short resistance, made chiefly by St. Frais, the whole camp fell into Clive's hands. At a cost of 22 killed and 50 wounded this day's work decided the fate of Bengal. Although the historic grove has disappeared, a monument has been erected to commemorate the victory.

PLASTERING is one of the most ancient building techniques. Evidence indicates that primitive peoples plastered their reed or sapling shelters with mud, thus developing more durable structures and more effective screens against vermin and inclement weather. More lasting and sightly materials in time replaced mud. Some of the earliest extant plastering is of a quality that compares to that used in modern times. The pyramids of Egypt contain plasterwork executed at least 4,000 years ago which is still hard and durable. The principal tools of the plasterer of that time were in design and purpose like those used today. For their finest work the Egyptians used a plaster made from calcined gypsum which is identical with plaster of paris. In other respects also the materials and the procedures used by the Egyptians 4,000 years ago were identical with those of today.

Very early in the history of Greek architecture (*e.g.*, at Mycenae) plaster of a fine white lime stucco mas used. The art of plastering reached a high degree of perfection in Greece more than five centuries before Christ, and plaster was frequently used to cover temples externally (stucco) and internally, in some cases even when the building was made of marble. The stucco and the plaster of the interior provided an excellent ground for decorative painting. The temple of Apollo at Bassae, built of yellow limestone about 450–420 B.C., is an excellent example of Grecian skill and artistry in the use of decoration on stucco and plaster. The ornamental plaster ceilings of England during the reigns of Henry VIII, Elizabeth I and James I still are admired. Earlier extant specimens of the plasterers' skill in England are the pargeted and ornamented fronts of half-timber houses. Plaster as a medium of artistic expression waned by the 19th century, when imitation and mechanical reproduction all but displaced this creative art. As a surface material for interior walls and ceilings and to a lesser degree for exterior walls, plaster has become common. It facilitates cleanliness and sanitation in building and is a retardant to the spread of fire.

Base.—A surface is usually prepared for plastering by first providing a base to which the lath is applied. The base may be an integral part of the structure or a separate framework attached to the walls and ceilings. The purpose of the base is to correct minor deviations from a true surface that may be present in the structure and to provide additional attachment for the lath. In wood-frame structures the walls are usually constructed so as to provide a true surface while the ceilings for the most part require a base. On masonry walls the base also provides a necessary air space and a separation between the plaster and the dampness which might penetrate the masonry. Furring may consist of strips of wood or light steel structural shapes fastened to the walls or ceilings of masonry or wood-frame buildings.

Wood Furring.—Wood furring consists of strips of wood usually surfaced on one or both faces to a thickness of $\frac{3}{4}$ in. and having a width of two or three inches. The strips are spdced 12 or 16 in. on centres to conform with the dimensions of the lath which are 48 in. or a multiple of 48 in. in length. Wood furring strips on exterior masonry walls are placed vertically and are securely attached with galvanized nails driven into the mortar joints or into plugs provided for that purpose. On wood floor joists and rafters the furring strips (or strapping) are run crosswise to the direction of the joists and nailed securely to the underside of each joist.

Steel Furring.—Steel furring, consisting of light channel sections or rods, may be used on exterior masonry walls. The channels or rods should be galvanized or painted as a protection from corrosion and securely attached with galvanized staples driven into galvanized metal plugs set in the mortar joints of the wall. In fireproof construction, where plastered ceilings are installed, steel furring may be suspended from the flanges of the beams or soffits of the floor construction by means of clips or metal hangers.

Grounds.—Grounds are strips of soft wood surfaced to a uniform thickness corresponding to the combined thickness of the lath and plaster. These strips surround all openings in the plastered areas and provide a stop at the boundaries of the plasterwork. They must be set accurately for line, and they must be level and plumb, since they serve as guides for the finished plaster surface. The grounds must be set carefully with respect to the interior finish so that they are covered by the door casings, the window trim, the baseboards and all other interior finish. At the intersection of plastered surfaces forming an external angle, a metal corner bead serves as a ground and a protection for the otherwise exposed plaster. In fireproof construction where interior partitions are masonry or steel stud walls the grounds may be an integral part of the metal frames. The thickness of the ground varies with the type of lath and the number of coats of plaster required. With metal lath and three coats of plaster the grounds are $\frac{3}{4}$ in, thick; with gypsum lath and two coats of plaster the same thickness is required and with wood lath and three coats of plaster $\frac{7}{8}$ in. thickness is required.

Lathing.—Lathing provides the structural base or reinforcement for the plaster and is the means of attaching it to the wall and ceiling furring. The plaster may be keyed to the lath and held mechanically, as it is when used with wood lath or it may be bonded to a surface by adhesion as it is when used with gypsum lath.

Until the end of World War I wood lath was extensively used in the U.S., but it has largely been displaced by plasterboards and metal lath.

Wood lath is usually sawn, straight grain spruce, free of bark and live knots and measuring $1\frac{1}{2}$ in. wide by $\frac{1}{4}$ in. thick and 48 in. long. In wood-frame buildings having studs spaced 12 or 16 in. on centres the laths are nailed on the walls in parallel horizontal rows with their edges not less than $\frac{3}{8}$ in. apart so that the mortar may be pressed through to form a key which clinches it to the lath. The laths are laid with end joints meeting on the supports, but should not be permitted to butt or overlap, nor should continuous joints occur on one support. The joints of every eight or ten laths should fall on alternate supports in order to avoid a line of weakness where the plaster might crack from shrinkage. The wood laths are secured to the studs or furring with a threepenny large-headed nail at each end of the lath and at each intermediate stud or furring strip.

Metal lath is usually some form of expanded metal or woven wire mesh which is protected against corrosion by galvanizing or painting. The expanded metal lath is available in standard lengths of 8 ft. and widths of 24 in., and the wire mesh is available in rolls of 100 ft. or more and in various widths. Because of their fireproofing quality metal laths are used extensively in all types of buildings. Expanded metal lath should be applied to the walls with the long dimension running horizontally, starting at the bottom, with each successive sheet overlapping the one below. The end joints should also be lapped and securely stapled or wired to the supporting furring or studs. Additional ties should be provided between supports along the overlapped edges so as to prevent sagging nhen the weight of the wet plaster is applied.

Gypsum lath consists of a sheet of gypsum plaster enveloped in a protective paper covering and available in units 16 in. wide by $\frac{3}{8}$ in. thick and 4 ft. long. These units are nailed to the base with joints breaking on alternate furring strips or studs. To protect against cracks caused by shrinkage narrow strips of metal lath may be applied at the intersection of the ceiling and walls as well as at the interior corners. As a substitute for wood lath this type of lath requires less plaster and has a somewhat better insulating value.

Plaster.—Plaster materials used in the composition of plastering mortars include a cementing agent, an aggregate and a binder. The aggregates and binders are inert materials while the cementing agent, in the form of a paste, has the property of setting or hardening. 4 properly proportioned mixture of these components results in a workable mortar which sets and hardens. Mortar is usually designated according to its cementing material, such as lime, gypsum or cement mortar. The aggregate most commonly used is a fine-grained, sharp and angular sand, clean and free of all traces of clay, loam or organic matter. The binder may be long, clean cattle hair or jute fibre in two- to three-inch lengths. For interior work lime or gypsum plasters are most commonly used.

Lime.—Lime is made by heating limestone at a sufficiently high temperature to eliminate the carbonic acid and water. At this temperature the limestone is said to be calcined. The resulting white product is called quicklime or lump lime.

Lime in this form must be slaked and reduced to a paste before being mixed with the aggregate to form a mortar. Slaking takes place when water is sprayed on the quicklime. causing it to generate heat as a result of a chemical action. The lime swells to about two and one-half times its original bulk and breaks down into a powder at first and later into a paste. This process is usually carried out at the place of manufacture, and the product appears on the market in the form of a fine powder called hydrated lime. Two grades of hydrated lime are available. One, known as mason's lime. is gray-white; the other, finishing lime, is snow-white and has a finer texture.

Gypsum.—When gypsum rock is heated to a sufficiently high temperature its water of crystallization is expelled. leaving a white powder. This powder, plaster of paris, hardens rapidly after it is mixed with water into a paste. In order to use this material as a cementing agent, a retarder is mixed with the powder to control the time of hardening. With further preparations and additions, including jute fibre, it is known as prepared gypsum cement. This cementing agent. with its aggregate, known as gypsum plaster, is used extensively in the U.S. for interior plasterwork. Because it is soluble in water it cannot be used for exterior work.

Application.— Plasterwork is designed according to the number of applications or coats involved. such as one-coat. two-coat and three-coat work. Two-coat and three-coat work, finished to a thickness. including the lath, of $\frac{3}{4}$ in. is commonly specified for interior work. Three-coat work is usually applied to wood and metal lath and two-coat work is applied to gypsum lath.

Scratch Coat.—The first coat or scratch coat is applied to wood and metal lath, but omitted on the gypsum lath. The mortar for the scratch coat is rich in cementing material and binder using one part by weight of prepared gypsum cement to two parts of sand mixed dry to a uniform colour before the water is added. The mortar should be plastic enough to be worked through the openings to form a key when laid on with some pressure. The scratch coat should be as thin as possible (not over $\frac{1}{4}$ in.) but sufficiently strong to serve as a foundation for the subsequent coats. It is laid on with a steel trowel starting as the grounds near the floor and working upward with overlapping diagonal applications of mortar. When the mortar is set and somewhat hardened the surface is thoroughly scored to provide an adequate bond for the second coat.

Brown Coat.—The second coat, called the brown coat in the U.S. and the floating coat in England, is less rich in cementing material. The proportion of cementing material to aggregate by weight is about one to three when prepared gypsum and sand are used. The cement and sand are thoroughly mixed to a uniform colour in a dry state; water is added to the mixture, and the whole is worked to the desired consistency. Because of the greater proportion of sand in the brown-coat mortar: there is less danger of excessive shrinkage and resultant cracks in the finished plaster surface. The brown coat should not be less than $\frac{1}{4}$ in. thick. It should be laid onto a straight, smooth surface, using the grounds as the guides for establishing the true surface. When the area to be brown coated is large, additional guides may be established by setting points of reference from the grounds. These points of referende, called dots, are used in establishing vertical and horizontal bands of mortar that are six to eight inches wide. These bands, called screeds, divide the area into panels which are then filled in with mortar and brought to a true surface with a straight edge. using the screeds and grounds as the guides. After this operation, which is known as rodding, the surface is smoothed with a two-handed float, called a darby, and further packed and smoothed with a small wooden float. A well-packed and relatively smooth surface is essential to a satisfactory brown coat. When properly packed and smoothed the surface should be scored to provide a bond for the hard finish or white coat.

White Coat.—The third coat consists of a lime paste into which plaster of paris is worked at the time of application. In its preparation hydrated lime is mixed with sufficient water to bring the mixture to a thin paste consistency. It is then permitted to stand for a few days for complete soaking. At the end of this period the paste is mixed with plaster of paris and applied to the brown coat, which should be firm and nearly dry. The mixture of lime and plaster of paris, called gauged stuff, should be applied at once. The gauged stuff may be prepared by the plasterer in small batches to avoid the danger of setting due to the presence of plaster of paris.

The final coat is applied in three operations starting with a thin coat applied with a steel trowel and well bonded to the brown coat. This operation. called scratching in, is followed by a second coat, called doubling-up, that brings the finish surface to its final true plane. The third operation consists in working over the surface with a steel trowel and damp brush correcting minor inequalities and producing a smooth polished surface.

Ornamental Plaster.—Ceiling ornaments and cornices constitute the major part of ornamental plasterwork. Cornices are usually run in place using a metal molding tool which is a reverse profile of the desired cornice. The molding tool is guided by running rods attached for their temporary use to the ceiling and wall. Gauged stuff, consisting of lime paste and plaster of paris, is laid on to meet the profile which is worked to and fro until the cornice is formed. The miters at the corners have to be formed by hand and decorative elements such as egg and dart, rope moldings and other decorative elements are precast and stuck in place with plaster of paris.

Stucco.—Plaster coating of exterior walls is commonly known as stucco. Since the stucco surfaces are exposed to the inclemencies of the weather the choice of cementing material is of great importance, especially in areas where the climate is rigorous. Strength, durability and weather resistance are essential qualities. Mortars with portland cement and other admixtures that improve its workability and reduce its porosity are most commonly used. Stucco may be applied directly to concrete, brick, tile and other masonry malls, or it may be applied to a supporting metal lath base. When the mortar is applied directly to masonry walls the surfaces should be sufficiently rough to form a key for the plaster and properly wetted to prevent excessive absorption. When metal lath is used as a supporting base, the procedures are essentially the same as those used for interior work. Various types of finish. including colours and textures, may be incorporated or applied to the finish coat. White portland cement used with white sand provides a durable surface with a fine texture resembling stone. Splatter dash and pebble dash are textured surfaces resulting from throwing mortar or pebbles with some force on the finish coat while it is still soft. When skillfully done these methods produce interesting variegated surfaces. Colour pigments and finishing techniques may be incorporated in the finish coat with pleasing effects. One of the oldest techniques for decorative plasterwork used for interior and exterior embellishment is sgraffito. Colour coats are applied to the area to be decorated, which is finished with a skim coat of fine cement. The outer coat or coats are scratched away, exposing the coloured layers that make up the decoration.

Plaster Substitutes.—After World War I many composition boards and sheets became available as substitutes for plaster. These substitutes have many desirable characteristics such as insulation, sound absorption, durability as well as ease of application. To this might be added the advantages of a dry construction. which permits an uninterrupted building program and reduces building costs. The disadvantages stem from the inherent difficulties with joints and with application to nonplanar surfaces. Much improvement has been made in dealing with the joints. Most of the sheets manufactured in the U.S. have standard widths of four feet and lengths of eight feet (with some exceptions). Some of the compositions available include wood products, pressed or laminated, asbestos-cement, gypsum and variations under many trade designations.

BIBLIOGRAPHY.—F. Van Den Branden and M. Knowles, *Plastering Skill and Practice* (1953); W. Millar, *Plastering, Plain and Decorative* (1927); O. Hering, *Concrete and Stucco Houses* (1922). (E. N. G.)

PLASTER OF PARIS (GYPSUM PLASTER), $2CaSO_4.H_2O$, a hemihydrate of calcium sulfate made by heating gypsum. When mixed with water it quickly sets to a mass of gypsum crystals with an increase in volume. It is used in making molds, casts and finishing plaster. See CEMENT; SCULPTURE TECHNIQUE.

(J. B. Ps.)

PLASTICS. The term plastic, derived from the Greek *plastikos,* appears to have been used first as a suffix implying growing, developing and forming. Later it was used as an adjective meaning capable of being formed. The manufacture of pottery and earthenware depends on the plastic qualities of the clay; the making of glass and plastics and the use of putty. asphalt and cement are all dependent upon the plasticity of the product. Properly speaking, all these products should be considered in any description of plastics and the plastics industry, but the term is much more highly restricted. Today it is used to describe a product of synthetic origin which is capable of being shaped by flow in some stage of manufacture and which is not rubber, wood, leather or metal.

Before the introduction of manufactured plastics, almost any material was pressed into service, especially those materials which could be cut easily and which would take on a high lustre on polishing. Among the products found useful were ivory, coral. tortoise shell. mother-of-pearl, amber, bone and horn. Numerous intricate carvings aere made out of ivory during all periods of history. Ivory lends itself readily to the manufacture of handles for cutlery, for brushes, combs, balls, toys and models. Amber was used in the form of beads and turned into ornaments and holders of various types. Buttons and handles were made out of bone; and combs, handles, drinking cups, powder horns and musical instruments were fabricated out of horn. Although these natural products do not require plasticity in their fabrication, they are consciously or otherwise classed with plastics; they may possess a type of residual plasticity or thermoplasticity which enables them to flow slightly from the heat generated during the polishing operation.

While the designation "plastic" is broader generically than the word "resin" (*q.v.*), both terms are used indiscriminately with respect to synthetic products. It is worthy of note, however, that general usage refers to cellulose derivatives as plastics and not as resins; and conversely, the synthetic resinous products, particularly those entering into the surface-coating field, are referred to as resins and not plastics. Doubtlessly, this distinction is again based on usage, since products of the resin class were primarily employed in the surface-coating field and the plastic characteristics were achieved by solution rather than by heat. The articles called plastics generally require shaping by heat during their fabrication by moulding or extrusion. Since the newer synthetic products can frequently be used interchangeably as coatings or as mouldings, the distinction between resins and plastics becomes less pronounced. Moreover, modern technology shows that the materials which are designated as rubber, fibres, resins and plastics are of a similar molecular structure, and by appropriate chemical and physical treatment it is possible to interconvert any one of these materials. It follows that certain structural features are common to all these products, and, being common, they relate to similarity in physical properties between materials which are not necessarily chemically related.

It might be argued that rubber is a plastic, since it can be fabricated by procedures similar to those employed in moulding plastics, but rubber is not generally considered to be a part of the plastics industry. Moreover, synthetic rubber is in a similar category, even though the preparation of the polymeric rubber molecule employs many of the processes developed for the preparation of resinous polymers. Similarly, the fibre industry is considered to be independent of the plastics industry, and here again the same raw materials, polyamides (nylon), cellulose and cellulose acetate are used by both industries. Plastics are also divorced from the self-supporting type of film production such as the manufacture of photographic film and cellophane. The term plastic, therefore, is essentially a commercial classification to which no strictly scientific definition can be applied.

HISTORY OF DEVELOPMENT

The modern plastics industry is an integration of many different and unrelated bodies of knowledge. One part of the development is derived from the fundamental investigations which were made into the chemistry, physics and biology of such high-molecular-weight natural products as natural resins, rubber, gutta-percha, cotton, cellulose, ramie, pectins, chitin, starch, glycogen, wool, silk and hair. Initially, optical methods were used in order to investigate the nature of these products, and later ultramicroscopy was brought into play. Somewhat later colloidal chemical methods were developed and used in the study of the gross morphology of these substances. X-rays indicated that some of these natural products. such as cellulose, gutta-percha and silk, were crystalline; other materials were amorphous; and still others were both crystalline and amorphous depending on the state of the product. Natural rubber (hevea) in the unstretched state was amorphous when examined by X-ray diffraction methods but it became crystalline when in the stretched state. As new technological tools were developed, they were also brought into use, and among the more powerful of these methods were the measurements of viscosity and the sedimentation of the products when they were subjected to extremely high centrifugal forces such as those developed by the ultracentrifuge. The idea grew that the natural products must of necessity be of a very high molecular weight.

Causes of **Resinification.**—In the preparation and synthesis of new compounds, materials would often resinify through unknown and uncontrollable reactions either during the course of the preparation or spontaneously after the product was formed and isolated. Other compounds were made where the transformation to the resinous and polymeric state could be followed and the various stages studied.

J. J. Berzelius in an article in the *Jahresbericht* of 1833 introduced the term "polymer." Naturally the definition which Berzelius presented underwent some later change. Initially, a polymer indicated the presence of the same atoms in the same proportion in compounds having different molecular weight. These conditions satisfy many compounds which are no longer considered polymers. The term "high polymer" is now restricted to high-molecular-weight compounds which are composed of simple molecules while the term "polymerization" (*q.v.*) relates to the process by which large molecules are synthesized from smaller ones.

In the same year (1833), nitrocellulose was prepared; H. Regnault in 1838 noted that vinyl chloride polymerized in sunlight and in the following year E. Simon polymerized styrene; J. Redtenbacher prepared acrylic acid in 1843; W. Caspary and B. Tollens in 1873 synthesized the methyl, ethyl and allyl esters, whereas G. W. A. Kahlbaum prepared the polymer of methyl acrylate in 1880. It is known that isoprene was prepared by G. Williams in 1860, and that it was polymerized by G. Bouchardat in 1879. R. Anshutz prepared polymers of itaconic-acid esters in 1881, and E. Frankland and B. F. Duppa discovered a method of making ethyl methacrylate from hydroxyisobutyric esters in 1865. Many condensation-type resins were also discovered during this interval, and many polyesters were also prepared, particularly those derived from glycerol and dibasic acids (*see* RESINS). The transformation of ethylene oxide from monomer to polymer was studied by M. A. von Lourenço, who showed that the boiling point and the viscosity increased progressively with molecular weight of the polymer. I. Ostromislensky maintained that there was a stepwise synthesis of rubberlike substances. Similarly it was observed that when glycine was condensed, there was obtained a series of products in which there was a regular change in the physical properties. The classical work of Emil Fischer in synthesizing numerous polypeptides out of simple amino acids is well known. Although Fischer showed that his synthetic product possessed many of the properties of the hydrolytic products of naturally occurring proteins, it was generally considered that the natural products such as proteins, cellulose and rubber possessed unique properties of their own and one that was not shared by the products of the laboratory. The so-called "association theory" was advanced to account for the behaviour of the natural products.

Part of the dilemma of the different behaviour shown by natural and synthetic products was resolved by Hermann Staudinger in **1926.** He demonstrated the inter-relationship existing between the structure as determined physically by X-rays and the size and structure of the polymer as determined chemically from analysis, as well as the size of the molecule determined by the nature and number of end groups existing in the high-molecular-weight compound. These various ideas were consolidated by Staudinger in his book which has now become a classic, *Die hochmolekularen organischen Verbindungen-Kautsckuk und Cellulose.* In this treatise he shows the similarities which exist between polystyrene, a synthetic substance, and rubber (*Kautschuk*) and between the polyoxymethylenes and naturally occurring cellulose. He demonstrated that the products of the laboratory have many properties in common with the natural products and that the synthetic materials can be used as prototypes in evaluating the natural materials.

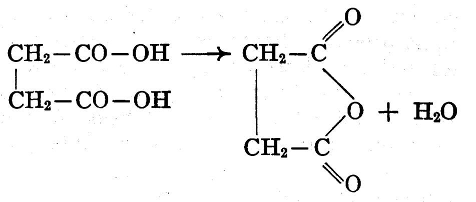
The causes of resinification of organic compounds remained obscure for a long time. The chemical reactions which led to resinification were unknown and the development was empirical. It was recognized very early that unsaturated compounds yielded resins and when the phenol-formaldehyde resins were first introduced, the same unsaturation hypothesis was advanced. The resin formation of phenol-formaldehyde resins was attributed to the polymerization of methylene quinones. Somewhat later the concept of "resinophoric" groupings (*e.g.*, azomethine$-C{=}N-$, carbodiimide $-N{=}C{=}N-$, conjugate unsaturation $-CH{=}CH-CH{=}CH-$, $-CH{=}CH-CHO$) was introduced by W. Herzog and I. Kreidl, and although the theory was shown to be untenable, it focused attention on the relationship of structure and it led to studies which revealed that there were essentially two chemical reactions responsible for resinification: one involving a condensation reaction, where the polymer differs from the starting material by the elements eliminated in the condensation; and a second involving a polymerization reaction, where the polymer and starting material have the same chemical composition. *(See* **POLYMERIZATION.)**

About the same time that Staudinger was conducting his investigations in Europe, studies were being made in the United States on various condensation-type resins, and the foundation was laid for the so-called functionality concepts which enabled a clear distinction to be made between the chemistry of the thermoplastic resins and the behaviour of the thermosetting type of product. Synthetic products made by W. H. Carothers using condensation reactions yielded fibrelike materials which possessed many of the crystalline properties which had been associated only with natural products.

In order that a chemical compound can be made to condense to a material of high molecular weight, it is necessary that each molecule of that compound contain two or more functional groups which can react with one another. When a compound contains molecules possessing only one functional group, these molecules on interaction will yield a product which can be, at best, twice as large as the molecules of the starting material. When a compound possesses molecules containing more than two functional groups, then each molecule can be joined to two other molecules. Preferably these functional groups should be at the ends of the molecule or at least so situated sterically that cyclization or intramolecular reaction cannot occur. These important steric or spatial configuration factors were first thoroughly evaluated by Carothers. When all of these requirements are met, it is possible for the functional groups to react with one another intermolecularly, leading to a reaction product containing long chains. These long chains are molecules of high molecular weight. When the product contains molecules having more than two functional groups, the reaction product which is formed by condensation leads to the formation of complex structures. It is such complex molecules which are responsible for the industrially valuable physical properties found in plastics.

The functional groups referred to above are simply any chemical groups which can react with others. For example, two organic acid molecules can react to form an anhydride (1, below). If the original starting molecule contains two acid groups and these groups are so situated sterically that ring formation can occur, then ring formation takes place without the formation of a high-molecular-weight compound; for example, succinic acid dehydrates to an anhydride (2). If, on the other hand, the acid groups are situated sufficiently far apart to preclude cyclization, such as are found in sebacic acid, polymeric, high-molecular-weight, linear anhydrides are formed (3).

$$2R-COOH \longrightarrow R-CO-O-CO-R + H_2O \qquad (1)$$



(2)

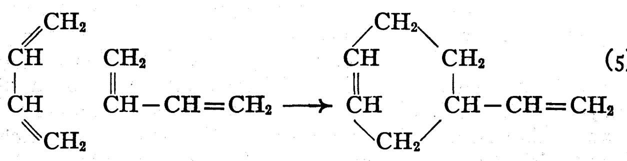
$$\begin{gathered} HOOC-(CH_2)_8-COOH \longrightarrow \\ HO-CO-(CH_2)_8-CO-O-CO-(CH_2)_8-COOH \end{gathered} \qquad (3)$$

Likewise, an alcohol and acid can react to form an ester. If a simple organic molecule contains an acidic group on one end and an alcoholic group on another, the initial condensation product that is formed still possesses a hydroxyl group and a carboxyl group which can react similarly to the starting materials (4).

$$\begin{gathered} HO-R-COOH + HO-R-COOH \longrightarrow \\ HO-R-CO-O-R-COOH \end{gathered} \qquad (4)$$

Such a condensation can proceed to yield a high-molecular-weight pclymer. The unreacted end groups left over at the ends of such large molecules are referred to as "end groups."

A similar situation exists with respect to polymerization products. Under these conditions, cyclization to a low-molecular-weight compound can occur (5); or if the conditions are properly selected, a polymer of high molecular weight may result (6).



(5)

$$CH_2{=}CH-CH{=}CH_2 \longrightarrow (-CH_2-CH{=}CH-CH_2-) \qquad (6)$$

Later studies gave some insight into the molecular size and structure of the large molecules that are found in plastic materials. Minor changes during the preparation, and the addition of small amounts of other chemicals, may markedly change both the proportion and the distribution of the molecular species with the result that a new product of differing physical properties may be formed. Moreover, the same materials may under different chemical processing yield resins and polymers of widely different physical characteristics. By means of these two procedures innumerable types of resinous compositions can be produced. Since most of the plastic products depend on the chemical industry as their source of raw materials, it follows that as soon as a new chemical is developed it is immediately tested by plastic manufacturers to determine whether this new material may serve as a partial or a total replacement for the material now employed. The new materials are quickly introduced into the plastics industry, allowing the preparation of new products with different structures and different handling characteristics.

FABRICATING TECHNOLOGY

The development of moulding technology parallels the study of resinification, since it was only by fabricating the synthetic laboratory products that these materials could be turned into articles of commerce. The art of moulding developed following Charles Goodyear's discovery of the vulcanization of rubber about 1839; this involved the use of a simple hand type hydraulic press. This type of press came into use for all types of moulding operations where the mould is sufficiently light to warrant manual handling. With the development of phenolic resins, larger objects could be moulded, and this necessitated the improvement of compression moulding in order to increase the output of any individual mould. Automatic presses were developed and pins were incorporated into the mould itself to permit automatic ejection of the pieces from the mould. Where metallic inserts had to be introduced into the specimen during moulding, semiautomatic presses were constructed, enabling the introduction of inserts in an efficient manner. To eliminate error further and to speed production, automatic presses were fashioned which can measure the charge, preheat the charge, load it into the cavity, close the mould, mould the object, open the mould and eject the final piece. Still greater mould efficiencies are achieved by electronic preheating of the plastic prior to its introduction into the mould.

The conventional type of compression moulding is both awkward and expensive when applied to thermoplastic materials. Where compression moulding is used on thermosetting materials the mould can be kept at a uniform and constant temperature. During the moulding and curing operations chemical reaction occurs, causing the plasticity to decrease, with the result that the product is sufficiently rigid while hot to be ejected from the mould. Thermoplastic resins, on the other hand, do not undergo any chemical change, and after fabrication of the piece it is necessary to cool the mould in order to decrease the plasticity to the point where the object can be taken out as a single entity. The idea arose that if it were possible to inject the hot plastic into a cool mould, utilizing the procedure used in the die-casting of metals, it would obviate the periodic heating and cooling of the mould. It is of interest to note that the first experiments directed toward injection moulding were made by John and Isaiah Hyatt, who were also instrumental in first commercializing nitrocellulose (see below); but they abandoned the work. Later the technique of injection moulding was again revived, this time in Germany. The first presses had an injection capacity of from about 0.5 oz. to 1.5 oz. per cycle and were useful only for the manufacture of small objects such as buttons, combs and costume jewellery. Once the value of these presses was demonstrated and a suitable plastic composition developed, larger and larger presses were designed until it became possible to inject 32 oz. of plastic into a mould in a single cycle.

The advent of the injection type of equipment speeded up the production of thermoplastic resins, and in order to increase the mould capacity of the thermosetting resins a type of injection moulding was developed for the thermosetting type of material. This is known as transfer moulding. Since thermosetting resins remain plastic for only a very short time, they cannot be preheated in the manner employed for thermoplastic resins; the heating chamber must be loaded afresh for each cycle and the heated charge forced into a hot mould. Not only does transfer moulding decrease the time of moulding of certain objects, but it allows the introduction of inserts which sometimes cannot be introduced into conventional compression mouldings. The plastic enters the mould in a highly fluid state and will not displace or break such fragile inserts as glass and fine metal parts. Moreover, the separation of resin and filler are minimized by this type of moulding, and the resulting moulded objects are stronger, of more uniform density and freer of gas pockets.

A third type of moulding is the so-called extrusion type, which was used for many years in the rubber industry before it was applied to thermoplastic resins. The resin is fed from a hopper, thence to a screw conveyor where the resin is heated, whereupon it emerges from a die in a continuous strip in the form of the die opening. In order to minimize distortion, the heated plastic is frequently caught on a belt which travels at the same rate as the extruded object. By this means rods and tubing of various sizes and shapes can be produced efficiently.

Still another type of plastic fabrication is the process known as "pulp-preforming." By means of this procedure, resin and filler are deposited on suitable forms prior to moulding.

CELLULOSE PLASTICS

Nitrocellulose. — In 1833 Henri Braconnot, a professor of chemistry at Nancy, described the preparation of a "xyloidine," which he considered similar to lignin, by treating starch, sawdust and cotton with nitric acid. He found that this material was soluble in wood vinegar and attempted to make coatings. films and shaped articles of it. For those who are concerned with origins, it is in these early experiments that one can see the beginnings of both the plastics and the lacquer-coating industry. Somewhat later, in 1846, C. F. Schoenbein nitrated cotton, using for this purpose a mixture of nitric and sulphuric acids. He also found that he could dissolve the nitrocellulose in a mixture of ether and ethyl alcohol and this solution came to be called "ether glue." At the time, Schoenbein made the prediction that this nitrated cotton or explosive cotton wool would make a substitute for gunpowder. The explosive nature of this product attracted the attention of militarists all over Europe, and many governments and private individuals started extensive tests to adapt this smokeless powder to explosive use since, unlike ordinary gunpowder, it left no black smudge after firing. Because crude preparatory methods were employed, disastrous explosions occurred in many countries, with the result that the manufacture of the product began to be looked upon with disfavour.

These explosions had a salutary effect, however, in that the pressure and stimulus were removed from production and allowed leisurely scientific research into processes and means of stabilizing the product.

Investigations into various methods of conducting nitration indicated that several types of nitrated cotton might be made. The nitrocellulose possessing the highest degree of nitration where the nitrogen content was more than 13%, was referred to as guncotton or explosive cotton; where the nitrogen content was from 12.6% to 12.8%, the material was referred to as pyrocollodion and where the nitrogen content was from 11.5% to 12% the materials were known as pyroxylin, collodion or photocotton. The nitration reaction is a very complicated one, involving a heterogeneous system of cellulose, nitric and sulphuric acids and water. Each constituent may play several roles which are both physical and chemical in nature, the reagents swelling as well as reacting with the cellulose.

While some attempts had been made to prepare coating compositions out of collodion, the first successful plastic was made by a young U.S. printer, John W. Hyatt. So great was the demand for ivory that the great elephant herds were being slaughtered in an attempt to supply the market. It was in 1863 that Phelan and Collander, manufacturers of ivory billiard balls, offered a $10,000 reward to anyone who might develop an adequate substitute for natural ivory. Working with his brother, Isaiah, John Hyatt prepared satisfactory billiard balls. Somewhat later the Hyatt brothers were granted a patent which described the process of dissolving nitrocellulose under pressure. Since very volatile liquids were employed as solvents, a great economy of materials resulted. Procedures for mixing the pyroxylin and camphor were disclosed in patents issued to the Hyatts between 1870 and 1872. Subsequently, 75 patents were taken out on various procedures for plasticizing nitrocellulose in order to produce the plastic. In 1870 the Albany Dental Plate company was organized by Hyatt and in 1871 the Celluloid Manufacturing company mas formed. The immediate use of this material was for dental plate blanks; later the plastic was used in sheet form for automobile side curtains as well as the well-known celluloid collars Toughness flexibility and good appearance were the properties which enabled the material to be used for a wide variety of items such as combs, brush handles, spectacle frames and various novelty and decorative items.

In 1884 Count Hilaire de Chardonnet, a pupil of Louis Pasteur, deposited with the French Academy of Sciences a document entitled. "Artificial Textile Material Resembling Silk." The paper, which was opened in 1887, described the method of transforming guncotton into fibrous. silklike material. At the Paris exposition in 1899 he was awarded the grand prize for his discovery. The fibre left much to be desired inasmuch as it was highly inflammable, but it focused attention on the possibility of manufacturing synthetic filaments from a vegetable source.

As noted above, it was possible to dissolve nitrocellulose in ether and alcohol. and such collodion solutions could be cast into films. In the early days of photography, it was necessary to prepare the plate prior to exposure. Many descriptions have been given of the methods employed by the early photographers using their so-called "wet" collodion plates. The solvent combination was extremely volatile. making it difficult to secure uniform films free from "blushing." After the development of the dry-process plate, the next logical step was the elimination of the glass support for the nitrocellulose. Such a nitrocellulose film was demonstrated at a photographic exhibition held in Paris in 1881.

The discovery by John H. Stevens that amyl acetate could be used as a solvent for nitrocellulose was made in 1882. This solvent proved to be far superior to anything used previously and enabled uniform films to be formed without haze. The first successful attempt to secure transparent flexible film for photographic purposes was made by H. Goodwin of Newark, S.J., during the years 1887–98. A somewhat similar process was developed independently by H. Reichenbach in 1889. Further work resulted in processes which allowed the nitrocellulose to be fabricated in continuous fashion, enabling the production of suitable base for both still and motion-picture photography. Another important use for nitrocellulose in sheet form was in safety glass. Sheet nitrocellulose was laminated between glass sheets forming a glass-plastic sandwich. The nitrocellulose film discoloured rapidly. however, and was eventually superseded by other, more light-stable plastics; but it served as an invaluable guide and established the importance of safety glass in the automotive industry.

Prior to World War I. Russia supplied the largest volume of fusel oil. This oil. remaining after the distillation of grain alcohol, was the raw material used in the synthesis of amyl acetate. Following the loss of this source of supply during the Russian Revolution. and with the loss of additional supplies caused by the enactment of the U.S. prohibition laws. the amount of this potential lacquer solvent became vanishingly small. New solvents for nitrocellulose were being developed rapidly, however. During 1920–23 the butyl-alcohol process was perfected by Chaim R'eizmann, and about the same time anhydrous ethyl acetate made its appearance. Moreover, other plasticizers than camphor were being developed. Tricresyl phosphate was prepared in 1920 and triacetin in 1921, and both materials weakened the grip of the camphor monopoly which had been notorious in manipulating the price of the product.

Since the theoretical nitrogen content for mono-, di- and trinitrated forms of cellulose are 6.77%, 11.3% and 14.16%, respectively, it can readily be seen from the nature of the manufactured products that the most valuable nitrocellulose plastic compositions contain from two to three nitrate groups per glucose residue in the cellulose molecule. Explosives are made from those materials having from 12.2% to 13.8% of nitrogen; lacquers and films from 11.5% to 12.2% and plastics from 10.5% to 11.5%. The properties of the nitrocellulose thus secured are dependent not only upon the degree of nitration but also on the uniformity of nitration of the cellulose molecule. Moreover, the length of the chain of the nitrocellulose molecule is very important since the longer the chain — that is. the larger the x in the equation below — the more viscous the solution of nitrocellulose in organic liquids. The reaction leading to cellulose trinitrate may be expressed by the equation:

$$[C_6H_7O_2(OH)_3]_x + 3x\ HNO_3 \longrightarrow [C_6H_7O_2(ONO_2)_3]_x + 3x\ H_2O. \qquad (7)$$

For coating applications high-viscosity lacquers are a disadvantage since only thin films can be deposited, and large and excessive amounts of solvent are required. The viscosity of the nitrocellulose can be controlled to some extent by selecting the source of the cellulose and by modifying the nature of the nitration. The most important means of controlling the viscosity of the nitrocotton, however, is by chemical treatment; and while it had been observed that certain materials such as ammonia and metallic salts had the property of decreasing the viscosity of nitrocellulose, it was found that the most certain method for securing a low-viscosity nitrocellulose was by treating the product with water under pressure.

Several factors contributed to the greatly expanded use of nitrocellulose immediately following World War I. Some idea of the expansion can be seen from the fact that the consumption of these materials jumped from 1,000,000 lb. in 1922 to more than 20.000,000 lb. in 1929. These developments could be traced to: (1) the availability of desirable solvents at relatively low cost; (2) the large quantities of nitrocellulose on hand following termination of the war; (3) the development of a method for preparing lacquers possessing a high solids content with relatively low viscosity; and (4) the tremendous demand for rapid-drying finishes by the rapidly expanding automotive industry. Through the use of a combination of nitrocellulose with alkyd resins, it was possible to decrease the time of finishing of an automobile body from weeks to a matter of hours.

For plastic manufacture, the nitrocellulose or pyroxylin is admixed with alcohol together with camphor, either natural or artificial, and kneaded into a doughlike mass. Colouring matter is added, either in the form of dyes for ,transparent colours, or as pigments for opaque colours. The coloured masses are rolled to discharge some of the volatile solvent, sheeted and pressed into blocks. After seasoning, the blocks are sliced; then they are either further fabricated, or the process is repeated for various mottled and variegated effects. The sheets may be moulded and when sufficiently soft may be fashioned by "blow moulding" into hollow objects. Rods and tubes are fabricated by extrusion, Artificial leather is made by painting fabrics with nitrocellulose solutions and then stamping or embossing the surface after discharge of the solvent.

Despite its obvious disadvantages of inflammability, discoloration on aging and limited tolerance to heat and to strong organic solvents such as alcohols, ketones and esters, the nitrocellulose plastic is colourful, tough! flexible, of good appearance and resistant to wear, water and humidity. It is easy to fabricate into many diverse forms and finds wide acceptance for billiard balls, piano keys, mirror and spectacle frames, combs, brush handles, machine keys, radio dials and various novelty and decorative items.

The various developments of nitrocellulose in fibres, films, coatings and plastics paved the way for further advances for newer materials which did not possess the disadvantages enumerated above, and the technology used in nitrocellulose was a useful guide in the processing of new products. Most important, the success of nitrocellulose indicated that a market existed for plastic products.

Cellulose Acetate. — The deficiency inherent in nitrocellulose for plastic use brought up the possibility of adapting other esters of cellulose, particularly the esters of organic acids. Paul Schutzenberger acetylated cellulose in 186j and A. Franchimont in 1879 found that the esterification reaction could be catalyzed by sulphuric acid. In 1894 C. F. Cross 'and E. J. Bevan, working in England, patented a process for preparing a chloroform-soluble type of cellulose acetate. The most important commercial development was made by G. W. Miles in 1903–05 with the discovery that if the highly acetylated cellulose was subjected to hydrolysis, it became transformed to a less highly acetylated compound which was soluble in cheap organic solvents such as acetone. In 1911 Henry Dreyfus perfected a manufacturing process for the preparation of the acetylated compound and its hydrolysis. The same basic process is employed in the manufacture of the cellulose acetate as that employed in the manufacture of a nitrate with the exception that the anhydride is used as the esterification reagent with the net result that acetic acid is the by-product rather than water.

$$[C_6H_7O_2(OH)_3]_x + 3x\ (CH_3CO)_2O \longrightarrow [C_6H_7O_2(OCOCH_3)_3]_x + 3x\ CH_3COOH. \quad (8)$$

The cellulose acetate with an acetate content of about 62.5% is then hydrolyzed, precipitated, washed and dried. This process of hydrolysis can be conducted on the acetate in the fibrous form or in solution. In order to bring out the full toughness of the product, the fibrous acetate is colloidized with plasticizers. These are high-boiling liquids possessing a low vapour pressure and having solvent or gelling action on the plastic. Among the more useful plasticizers are such materials as dimethylphthalate, diethylphthalate and dimethoxyethylphthalate. Depending on its ultimate use as a film, moulding powder or safety glass, different quantities, amounts and types of plasticizers are employed, allowing one type of polymer to fill many diverse applications.

The first use of this material was in the so-called "safety film" for photographic use. The acetone-soluble cellulose acetate found extensive use in World War I as the "dope" for coating aircraft wings because it was much less inflammable than nitrocellulose. After the war the excess plant capacity found a ready market for cellulose acetate as an acetate rayon. However, another very important development, the new procedure for moulding thermoplastic resins mentioned above, was occurring simultaneously. It was found that the acetate was particularly amenable to being moulded by injection, and the cellulose-acetate plastic was given a new impetus by this rapid and efficient means of fabrication. The acetate was preferred since the nitrate could not be subjected to the same temperature conditions required in injection moulding. Cellulose acetate became widely used in the automotive industry because of its mechanical strength, toughness, wear-resistance, transparency and ease of mouldability. The high resistance to impact made it a desirable material for protective goggles, tool handles. oil gauges and the like.

Since the cellulose acetate did not discolour as did the nitrate on exposure to light. it was far more suitable for safety-glass manufacture; and, while its resistance to water was not all that could be desired, the laminated safety glass found favour, especially when precautions were taken to edge-seal the assembly in order to prevent access to moisture. Such safety glass became accepted and in time definitely made the public safety conscious.

Cellulose Acetobutyrate and Other Esters.—Since one of the more serious limitations of cellulose acetate lies in its poor resistance to moisture and weathering. attempts were made to use longer, less water-soluble organic acids for esterification purposes. The use of mixed acids was not overlooked, with the result that it was found that a mixture of butyric and acetic acids (as anhydrides) yielded mixed esters which were very similar in properties to the acetate but possessed much better moisture resistance, better weathering and superior adhesion. When moulded by injection. cellulose acetobutyrate required somewhat less pressure than acetate and yielded better welded joints.

Other cellulose esters were prepared commercially. During World War II processes for the manufacture of propionic acid (and anhydride) were developed, and cellulose esters made from this acid appeared on the market. Since propionic acid contains three carbon atoms, it is intermediate between acetic and butyric acids. It follows that the cellulose propionate possesses many excellent properties similar to those exhibited by the acetobutyrate as well as many characteristics of its own, particularly a shorter moulding cycle and easier machining qualities. Cellulose benzoate was manufactured in Germany but the material did not find a market in the U.S.

Cellulose Ethers.—Since cellulose is a polyhydric alcohol, it can be made to undergo etherification reactions as well as the esterification reactions mentioned above. Ether linkages cannot be saponified; so it is not surprising to find that the cellulose ethers are among the more stable of the cellulose derivatives. The idea of ethylating cellulose was first conceived by W. von Suida in 1905 with the primary object of changing the affinity of cellulose for dyestuffs. The cellulose ethers were studied simultaneously by Leon Lilienfeld in Austria, Otto Leuchs in Germany and Henry Dreyfus in France. It was found that the cellulose ethers and in particular ethyl cellulose were soluble in organic liquids and possessed potentialities in plastic as well as in lacquer and in rayon applications.

Ethyl cellulose was first produced commercially in Germany and it was not until 1935 that large-scale production was undertaken in the U.S. The alkali cellulose—a mixture of cellulose and caustic soda—is reacted with either ethyl chloride or with ethyl sulphate until the desired ethoxy content is secured. While it is possible to introduce three ethoxy groups into each glucose segment in the cellulose molecule, it has been found that only those products which contain from 43.5% to 49.5% ethoxy content are of commercial interest. This degree of ethylation amounts to from 2.15 to 2.58 ethoxy groups per glucose residue. Those ethylcellulose derivatives possessing from 47.5% to 50% ethoxy content exhibit the greatest solubility in organic liquids as well as the best compatibility with other film-forming materials. However, ethyl cellulose possessing somewhat lower ethoxy content (from 45.0% to 47.5%) yields harder films and plastics which have less tendency to flow at elevated temperatures. The chief uses of ethyl cellulose are in coating, in adhesives and as plastics possessing a high degree of toughness over a wide temperature range.

Many other cellulose ethers are known. The methyl cellulose, glycol cellulose and cellulose glycolic acid prepared respectively from methyl sulphate (or chloride), from ethylene oxide (or chlorohydrin) and from sodium monochloroacetate are dispersible in water and have found use as sizing and finishing agents in the textile industry.

OTHER NATURAL PRODUCTS AS PLASTIC MATERIALS

Casein Plastics.—Casein (the protein derived from milk) was condensed with formaldehyde by A. Spitteler and W. Krische to form a tough, insoluble mass which could be fabricated readily. Production of this plastic was begun shortly after 1900 in Germany and France and in 1914 in England under the name of Galalith (milk stone). When the monopoly was broken during World War I, manufacture was undertaken in the U.S. in 1919. At the time the casein plastic came into prominence it possessed an immediate advantage over the competitive products inasmuch as it was much less inflammable than nitrocellulose and could be fabricated into objects of lighter colour than was possible with the phenolic resins. When an attempt was made to introduce the casein plastic into the United States, the limitations of the material became apparent, especially under the extremes of humidity encountered. The result was that the product was wholly unsuited for electrical fixtures and other applications requiring some degree of dimensional tolerance. The limitation of the composition, and the advent of synthetic resins which could be handled more rapidly and did not possess the limitations inherent in the protein plastic, gradually restricted the use of casein plastic until the only large outlet for the product was in the manufacture of buttons from alum-hardened casein.

Shellac.—This natural resin finds some use in the manufacture of moulding compositions. In many respects shellac is an ideal plastic binder for certain types of electrical equipment and for communication instruments. The resin is often used by itself as well as in combination with such fillers as flaked mica and asbestos.

SYNTHETIC RESIN PLASTICS

Synthetic resins can be grouped into many different arrangements but one generally accepted classification involves the designation "thermoplastic" and "thermosetting" types of resins. The thermoplastic resins are characterized by their ability to remain plastic after numerous heating treatments. while the thermosetting or thermocuring resins are not susceptible to repeated heating cycles and, once heated, are converted to a cured or infusible form which cannot be fused again without serious chemical degradation. From the molecular structural standpoint, the thermoplastic resins are characterized by molecules which are essentially linear or threadlike in form, while the thermocuring resins consist of molecules which are considered to be linked three-dimensionally into a network arrangement. Resins may also be classified by the chemical means employed to effect reaction. Certain resins formed without the elimination of volatile components are generally referred to as the polymerization type. Where volatile ingredients such as water and alcohol are formed during the resin preparation, this type of product can be considered a condensation resin. When the chemical and physical types are superimposed, it is possible to have the grouping:

1. Thermoplastic condensation resins
2. Thermoplastic polymerization resins
3. Thermocuring condensation resins
4. Thermocuring polymerization resins

The equations leading to the formation of these various types may be written schematically as follows:

$$2n\ H{-}R{-}OH \longrightarrow H{-}[R{-}O{-}R]_n{-}OH + n\ H_2O$$

Linear polymer formed by condensation reaction

$$n\ CH_2{=}\overset{R}{\underset{R_1}{C}} \longrightarrow -CH_2-\overset{R}{\underset{R_1}{C}}\left[-CH_2-\overset{R}{\underset{R_1}{C}}\right]_{n-2}-CH_2-\overset{R}{\underset{R_1}{C}}$$

Linear polymer formed by loss of unsaturation

$$2n\ \begin{array}{c}H-R-OH\\ | \\ H-R_1-OH\end{array} \longrightarrow \begin{array}{c}H-\\ \\ H-\end{array}\left[\begin{array}{c}R-O-R\\ |\qquad | \\ R_1-O-R\end{array}\right]\begin{array}{c}-OH\\ \\ -OH\end{array} + 2n\ H_2O$$

Ketwork polymer formed by condensation reaction

$$n\ \begin{array}{l}CH=CH_2\\ | \\ R\\ | \\ CH=CH_2\end{array} \longrightarrow \left[\begin{array}{l}-CH-CH_2-\\ \quad | \\ \quad R \\ \quad | \\ -CH-CH_2-\end{array}\right]_n$$

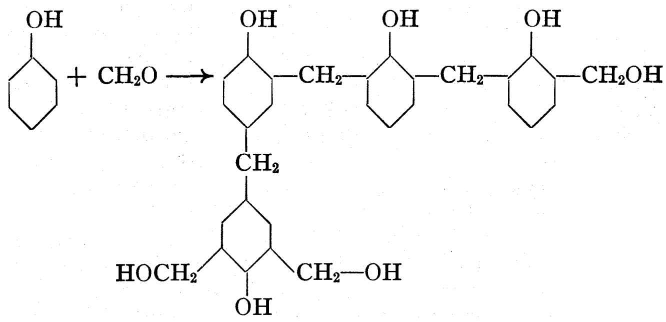
Network polymer formed by loss of unsaturation

Generally the thermocuring resins will tolerate substantial quantities of inert fillers such as cellulose flock, wood flour, asbestos and the like, whereas the thermoplastic resins are fabricated clear or when fillers or opacifiers are used, the quantity employed is much less than with the thermosetting type of resin. Different methods of iabrication are utilized with thermoplastic and thermosetting resins since chemical changes occur during the moulding of thermocuring resins, whereas physical changes predominate in the moulding and extruding of thermoplastic resins.

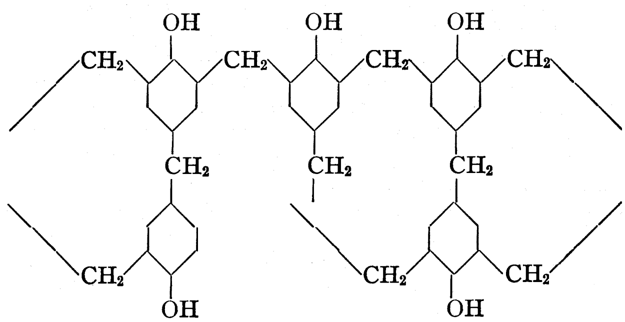
Thermosetting Resins.— Phenol-Formaldehyde Resins.— When Leo *H.* Baekeland offered the phenol-formaldehyde resins in 1909, the value of nitrocellulose plastics sold annually in the U.S. was more than $5,500,000. Irrespective of the fact that the pyroxylin plastic was well established, this new material found a ready market because, unlike the nitrocellulose product, the phenol-formaldehyde resin could be made insoluble and infusible. Moreover, unlike the thermoplastic material, the thermosetting phenolic condensation product would tolerate considerable amounts of inert ingredients or fillers and, in much the same manner that the thermoplastic materials could be changed by the incorporation of various plasticizers, the thermosetting resins could be modified through the incorporation of various fillers.

In some respects, this resin-filler combination was being exploited prior to Baekeland's entrance into the plastic moulding field. Various coal-tar residues were mixed with asbestos and silica and these resins were moulded under pressure and subsequently heated outside the mould to further the reaction. Since a great deal of curing does not occur, the strength of such cold-moulding compositions was not very high. When the phenolic binder became available, however, and when it was substituted for the bituminous binder, the moulded piece took on a much better finish and possessed increased strength.

In making phenolic moulding powders, phenol and formaldehyde are heated in the presence of suitable catalysts, generally acids. and the condensation is conducted to the stage where the water separates. The viscous phenolic condensation product on cooling to room temperature becomes hard and brittle. The resin at this stage is soluble and can be dissolved in various organic liquids; such solutions are employed for laminating and impregnating purposes. The structure can be represented schematically as follows:



Intermediate condensation product



Cross-linked

In order to make the moulding compound, the resin is ground and mixed with appropriate filler, lubricants and dyes. To render the combination as homogeneous as possible, the mixture is milled and then ground. For general use, wood flour is the preferred filler, but where heat resistance, impact strength or electrical characteristics are involved, other fillers such as cotton flock, asbestos and chopped fabric are used. The resin, because of its excellent insulating characteristics, enters into the manufacture of radio parts such as sockets, binding parts, knobs and dials, and into the electrical system of the automobile as distributor heads, coil parts, switches, magnetos, instrument-housing panels, etc.

Where the resin is to be cast, the initial condensation of the phenol and formaldehyde is heated with alkaline catalysts in such a way as to hold the water which is formed in the condensation as a suspension in the resin. The reaction mixture is subjected to reduced pressure whereby the water of condensation is removed without phase separation. Where opaque castings are desired, the viscous resin is poured directly into moulds made of either rubber or lead. Hardening is allowed to take place from one to two days at moderately elevated temperatures. During curing of the resin, the water which is evolved forms droplets which are large enough to interfere with the transmission of light. Where clear castings are required, suitable modifiers are added to the resin prior to the introduction into the mould. These modifiers cause the water which is formed in the final cure to assume a size smaller than the wave length of light and, being of such dimensions, the particles do not interfere with the transmission of light. Such castings are clear. Mottled effects can be secured by appropriate mixing of coloured viscous resins prior to the introduction into the mould. The castings are machined and polished to objects possessing a high degree of lustre and brilliance.

Certain developments in the foundry industry have involved utilization of phenolic resins. In powdered form they have been used to cement sand for making the so-called shell moulds. A large volume of resin was projected for this application, but the automatic or semi-automatic manufacture of shell moulding on any substantial scale remains in the future. Present indications are that resin-coated sand may prove more useful in larger scale applications of this process.

For laminated structures, the resin in alcoholic solution is used to impregnate either paper or fabric. After impregnation the sheets are dried, consolidated and subsequently heated under pressure to form a rigid, tough assembly of high strength and good electrical properties which can be machined and fabricated. Power transformers, timing gears, cams, clutches, fan belts and many other materials can be made from such structures. When fabric is substituted for the paper, similar laminated compositions are made which can be machined to form gears and bearings.

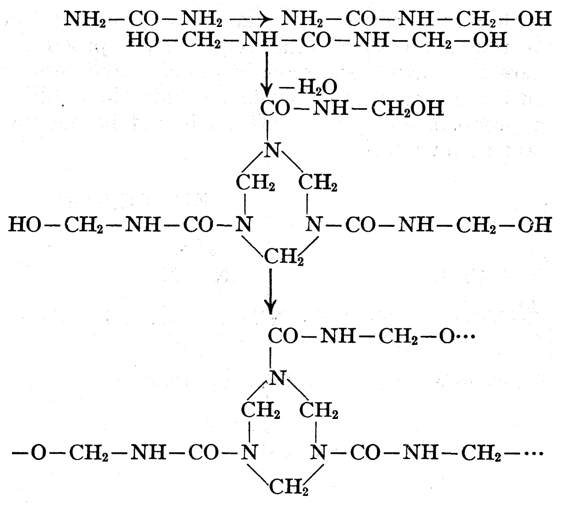
Lignin, which is the bonding agent of wood and other cellulosic derivatives. has been isolated from certain intermediates from paper manufacturing. The lignin resins have been used as extenders for phenolic resins. particularly those entering into varnishes, moulding resins and adhesives.

Phenol-Furfural Resins.—Furfural is an aldehyde which is derived from waste farm products such as the hulls of oats, rice and cottonseed and corn husks. This aldehyde will condense with phenol to produce a resin similar to that secured from phenol and formaldehyde. The plastic properties of the two compositions differ. however, in that the furfural product possesses a long period of flow at low temperatures; this property enables it to be used in certain types of intricate mouldings.

Urea-Fornzaldehyde Resins.—The resins derived from urea and formaldehyde have been considered truly synthetic materials inasmuch as all the basic materials are derived from gases. These gases are ammonia, carbon dioxide, carbon monoxide and hydrogen. Reaction of ammonia and carbon dioxide under pressure yields urea, whereas the reduction of carbon monoxide results in the formation of formaldehyde. Condensation of urea with commercial formalin (aqueous solution of formaldehyde) yields the water-soluble intermediate condensation products known as mono- and dimethylolurea, which on further reaction form water-soluble, resinous condensation products.

The intermediate water-soluble resins are starting materials for the production of resin, adhesives. surface coatings and moulding powders. Initially, glass-clear products were produced and extensively investigated as substitutes for glass and were often referred to as "organic glass." While the initial products were clear and brilliant, they quickly deteriorated on aging. Part of the difficulty resided in the ability of the plastic to absorb water from a humid atmosphere and then to release the water when the moisture content of the atmosphere decreased. This "breathing" of the plastic resulted in some loss of transparency and glasslike clarity. Furthermore, on prolonged standing, cracks and fissures developed in the surface of the resin, probably arising from liberation of water and formaldehyde through further condensation occurring in the colloidal mass; these fissures further decreased the transparency and limited the strength of the product since, on impact, the surface fracture acted as a focal point for the transmission of energy into the interior of the specimen. The glasslike product was extensively investigated by Hanns John and by Heiner Ramstetter and by Fritz Pollak and Kurt Ripper during the decade following World War I, but attempts to commercialize the product were unsuccessful.

The combination of the urea-formaldehyde resin with various fillers was investigated by many chemists, but the combination of cellulose and resin has been generally associated with the development work of Carleton Ellis in the U.S. A parallel development occurred in England, however. where because of lack of timber, Norwegian pulp was imported and used. The introduction of fillers destroyed the transparency of the product but the resin-filler combination. when suitably compounded with flow promoters, plasticizers, lubricants, accelerators and catalysts, could then be moulded in steel dies under heat and pressure to insoluble and infusible products possessing a wide utility. Manufacture of one of these materials began in the U.S. in 1929. The plastic can be produced in any colour, from translucent and colourless to ivory and pure white. through pastels and brilliant hues to jet black. In thin sections the natural uncoloured combination of urea and cellulose transmits light in a highly diffused state, and



Preparation of urea-formaldehyde resin

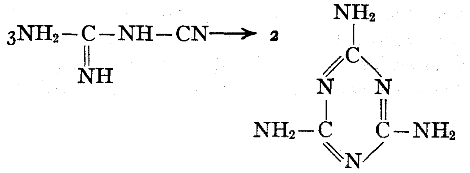
by altering the thickness and pigmentation, the reflection and transmission can be modified at will. Among the widespread uses of the moulded product. aside from its value in luminaries, are in the manufacture of closures, buttons, wall plates, instrument dials, display boxes, dress accessories and housings of all types.

The resin in solution form possesses many other applications aside from impregnating filler to make moulding compositions. The resin solutions are used in the preparation of cements which can be hardened hot or, through the proper addition of catalysts, may be set cold. When the water-soluble resin is suitably dispersed in organic solvents, it forms the basis of a very important class of resin finishes and enamels for metal coating. As an impregnant for wood veneer, the water-soluble condensation products serve both as a binder and a protective coating. Since the resin is colourless, the cured resin materially enhances the beauty of the wood. The solutions are also used to treat textiles in order to control their shrinkage and render them crease or crush resistant.

In the manufacture of laminated stock, sheets of absorbent paper are impregnated, dried and assembled to appropriate thickness and then heated between platens to yield a sheet stock which has found utility in lighting reflectors, signs, wall panels, table tops and decorative murals.

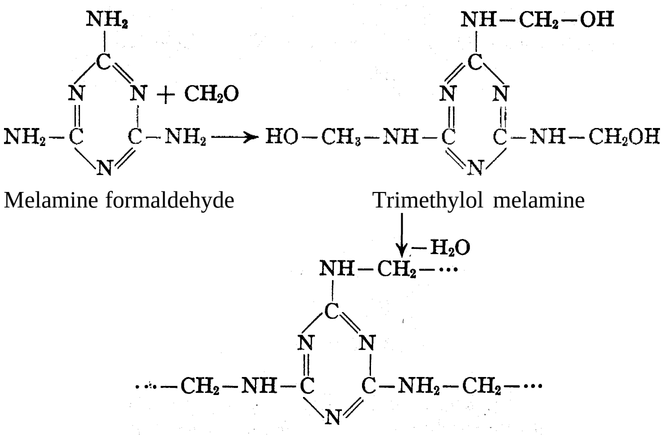
Melamine-Formaldehyde Resins.—Prior to 1939 melamine was practically an unobtainable rare chemical compound which could be secured only in limited amounts at $40 a pound. Although the compound was rare, it was not new and unknown. It had been known and characterized for more than 100 years and had been first prepared in 1834 by the famous chemist Justus von Liebig. After 1939, melamine became a commercial article made in ton quantities. and like urea it is secured from the air. Combination of the nitrogen in the air with calcium carbide yields calcium cyanamide, which can be hydrolyzed to cyanamide and dimerized to dicyandiamide. Under high temperature and pressure dicyandiamide is transformed to melamine, an extremely stable substance containing only carbon, hydrogen and nitrogen in its chemical structure. These reactions can be represented by the following chemical equations:

$$CaC_2 + N_2 \longrightarrow CaCN_2 + C$$
$$CaCN_2 + 2H_2O \longrightarrow Ca(OH)_2 + NH_2{-}CN$$
$$2NH_2{-}CN \longrightarrow NH_2{-}C({=}NH){-}NH{-}CN$$



Preparation of melamine from calcium cyanamide

Condensed with formaldehyde, melamine forms products which in superficial respects resemble the condensation products of urea but, where only mono- and dimethylolureas have been prepared, a much wider number of the initial melamine-formaldehyde condensation products are known. Di-, tri- and hexamethylol melamines have been prepared.



Network condensation of melamine with formaldehyde

The melamine resin is not so sensitive to alkalies and can tolerate fillers which cannot be used with the urea condensation product. One of these fillers is the mineral asbestos. Because of their excellent heat and arc resistance, good dielectric strength and low water pickup, mineral-filled melamines suitably modified with other resins were used in ignition systems, particularly in the large distributor heads in military aircraft where, under the reduced pressures at high altitude, flash-over and tracking are especially troublesome. The mineral-filled materials may also be used where other unusual performance characteristics are required such as in the automotive ignition parts of trucks, tractors and automobiles.

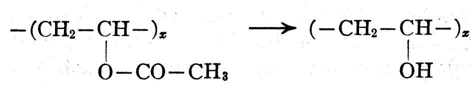
Cellulose-filled melamine plastics have been used in many of the applications already discussed for the urea resins. but since the melamine resin is more resistant to high temperatures, to boiling water and to more alkaline solutions, and since it does not retain food odours, it is particularly useful in tableware. The melamine resin possesses extreme hardness and this, together with its good colour and abrasion resistance, makes it an invaluable material for surfacing of laminated assemblies. Translucent mouldings may be made and are applied to button manufacture.

Anhydrous Thermosetting Resins.—The thermosetting resins used for laminating and moulding depend on the loss of water to effect insolubilization. In order that this water content be as small as possible, the resin is carried to an advanced stage of condensation where considerable heat and pressure must be utilized to cause the resin to flow sufficiently to fill the mould. During World War II, new types of products appeared which did not involve the loss of water to bring about insolubility and infusibility of the resin. These compositions have been referred to as anhydrous thermosetting resins and solventless varnishes, while the process has been called low-pressure or contact moulding. They belong to the class of thermocuring polymerization type of resins. Irrespective of the name, all of these resins have one characteristic in common: the polymerizable molecules possess a plurality of unsaturated groups and undergo reaction to insolubility quickly and exothermically without the evolution of low-molecular-condensation residues. The unsaturation can be introduced into the initial molecule by the incorporation of either unsaturated acid residue or unsaturated alcohol residues or both. The polymerization is generally catalyzed by peroxides. The physical state of the anhydrous thermosetting resins can be varied within wide limits; some are thin fluids, others viscous liquids. whereas still others are solid or greaselike in consistency. Since only low pressure is required in fabrication, comparatively inexpensive moulds can be utilized. In many instances, the fluid-moulding technique may be employed for making complex shapes; this procedure depends on delivering pressure uniformly over a large area through the use of rubber bags, and by such means large structural parts of aeroplanes and boats have been built. The most spectacular development in this field is the fibrous glass reinforced automobile body. In certain respects the high strength and the low weight of the plastic combined with its ability to recover practically undamaged from impacts and its higher resistance to corrosive atmospheres and moisture penetration have been assets. In large-scale production, however, the assembly could not compete with steel construction. Some efforts have been directed to the use of these reinforced resins as reinforcing agents in the manufacture of plastic pipe and in the manufacture of equipment for use in the chemical process industries. Here again the outstanding advantage arises from corrosion resistance. When such rigid sheets of plastics are laminated into a cellular or honeycomb core, highly rigid and lightweight combinations can be produced which possess good strength and insulating characteristics.

The anhydrous thermosetting products are frequently referred to as polyester resins. Structurally ester groups are present in the molecule. Another product designated as a polyester is the polyethylene glycol terephthalate. Again. ester linkages are present in the molecular pattern but the physical properties of the polymer are very different. Being of much higher molecular weight and crystalline in structure the product can be oriented into fibres and into sheet stock of exceptional clarity and strength.

Thermoplastic **Resins.**—*Vinyl Resins.*—As noted above, acetic anhydride is required in the manufacture of cellulose acetate. Following World War I various methods were investigated for processes which might be used to convert the acid to the anhydride since it was anticipated that large quantities of this cellulose plastic would be required in the manufacture of fibre, film and safety glass. Among the methods investigated for the manufacture of acetic anhydride was the reaction of acetic acid with acetylene to form ethylidene diaceiate, which in turn could be decomposed to acetic anhydride. In conducting the reaction between acetylene and acetic acid, investigators obtained substantial quantities of an organic liquid which was too low boiling to be the desired product. This liquid was monomeric vinyl acetate. Although the investigation was directed primarily to the preparation of an acetylating agent. vinyl acetate was in time destined to be the basis of the manufacture of most of the plastic for use in safety glass.

Polyvinyl Acetate Resins.—The transformation of vinyl acetate ($CH_2 = CH—O—CO—CH_3$) to a safety glass interlayer did not occur all at once, however. Manufacture of the early product was difficult because little was known concerning the chemistry of transformation of a vinyl monomer to its polymer. Moreover, the early development was hazardous from a commercial standpoint since there were no uses for such a resinous product. It was first investigated as a shellac substitute. but its remarkable adhesive properties, when hot, made it invaluable for uniting many diverse materials such as cloth, paper, leather. wood and glass. Compounded with fillers, glycerine, sugar and flavouring, polyvinyl acetate makes an acceptable chicle substitute in the manufacture of chewing gum. Hydrolysis of the polyvinyl acetate causes cleavage of the ester grouping resulting in the formation of polyvinyl alcohol,



a resinous polymeric alcohol that forms viscous solutions in water and finds some utility as a thickening agent for emulsions and in the preparation of plastics which, although sensitive to water. are highly resistant to oils. Polyvinyl alcohol can be spun into a fibre, and although the fibre is soluble in water, special uses can be made of this solubility in the weaving of sheer laces; fibres of polyvinyl alcohol and any other fibre can be woven and the synthetic water-soluble fibre dissolved, leaving a sheer fabric which would be difficult to approach by mechanical means alone. There have been a number of developments in Japan whereby polyvinyl alcohol has been cured with formaldehyde to yield a fibre material possessing excellent fibre characteristics. The major shortcoming appears to be in the heat resistance. On the other hand, the dry tenacity of the product is outstanding.

Many chemical transformations of polyvinyl alcohol are possible. It can be condensed with other low-molecular compounds, particularly aldehydes, to form new resinous materials. Condensation with, formaldehyde, acetaldehyde and butyraldehyde results, respectively, in polyvinyl formal, polyvinyl acetal and polyvinyl butyral. The polyvinyl formal finds use as a coating resin for electrical insulation; the acetal possesses potentialities as a photographic film base and as an injection-moulding material; but it is the butyral which possesses the most outstanding utility, and as much as 100,000,000 sq.ft. have been produced annually for safety-glass manufacture. The resin when suitably plasticized yields a tough, high-impact film which maintains its properties at low temperature, and when laminated between glass yields a composite assembly which possesses little tendency to yield flying splinters on impact.

Polyvinyl Chloride Resins.—Vinyl chloride is a gas at room temperature and can readily be prepared from either ethylene or acetylene. Addition of hydrogen chloride directly to acetylene yields the monomer, or ethylene can be chlorinated and dehydrohalogenated to vinyl chloride. The polymerization was extensively studied by Ostromislensky, who sought to dehalogenate the polymer to a rubberlike substance. Polyvinyl chloride was transformed to a rubber substitute about 20 years after these basic investigations but by an entirely different procedure.

Polymeric vinyl chloride, $—(CH_2—CHCl)_x—$, is practically infusible and for a long time proved to be a rather intractable substance. In efforts to plasticize the product it was milled and compounded with polyvinyl acetate, mentioned above, but with no great degree of success until it was found that by mixing the ingredients prior to polymerization and then chemically combining the two materials into a polymeric structure, it was possible to achieve in this conjoint polymer or copolymer a new type of product which was easier to handle and one which could be further flexibilized through the addition of high boiling liquids and plasticizers. By varying the ratio of acetate to chloride, resins of varying plasticity and stiffness can be secured.

Intensive investigations were made into the nature of plasticization methods and techniques of direct plasticization of vinyl chloride without the necessity of copolymerization. It was generally conceded, however, that the copolymer is amenable to plasticization by a larger number of widely diverse liquids than is the unmodified polymer. Both types, however, have found extensive use as sheet stock and as wire insulating compounds and as substitutes and replacements for rubber. Since these polymers possess considerable amounts of chlorine, they will not support combustion and they therefore possess distinct advantages in wiring where noninflammability is of importance. The halogen, however, is labile and when the resin is exposed to heat or to ultra-violet light, loss of hydrogen halide occurs, resulting in discoloration.

By the dry spinning of the vinyl chloride-acetate copolymer, it is possible to produce filaments which can be woven into chemically resistant fabric. In Germany fibres were fabricated directly from polyvinyl chloride and were known as PC-fibres.

Polyvinylidene Chloride Resins.—By doubling the amount of chlorine in vinyl chloride, a new chemical entity. vinylidene chloride, is obtained. Because of the symmetrical arrangement of the chlorine atoms in polyvinylidene chloride. $—(CH_2—CCl_2)_x—$, the polymer is crystalline. and advantage can be taken of this crystalline characteristic to form oriented filaments and tubing. Such oriented forms have the molecules arranged in an ordered manner with the result that in the direction of orientation the product is very strong. Extruded, quenched and drawn, the polyvinylidene chloride makes an excellent substitute for reed and rattan and a corrosion-resistant substitute for insect screening; in the form of tubing, the resin can be used to pipe many corrosive chemicals.

Acrylic Resins.—The term acrylic resin covers not only the acrylic esters but also the polymerizable derivatives of both acrylic and methacrylic acids as well as the acid chlorides, nitriles, amides and substituted amides. Acrylic derivatives generally involve cyanide in their synthesis, but investigations indicate that, at least in the case of the acrylic acid derivative, there inay be an alternative procedure involving carbon monoxide (in the form of a metallic carbonyl) and acetylene. Considerable investigation was also undertaken in an attempt to prepare acrylic esters from natural lactic acid derived from milk. but it remained to be demonstrated nhether the natural lactic acid could compete with the synthetic product. The names of Otto Rohm and Rowland Hill were associated with the preparation and polymerization of acrylic and methacrylic esters, respectively.

From the standpoint of plastic use of the methacrylic esters are preferred, since they are harder and more rigid than the corresponding acrylic esters. By changing the type of alcohol which is used in esterification of the original monomeric ester, it is possible to modify the hardness of the resulting polymer. Polymethyl acrylate is tough and rubbery; polyethyl acrylate is softer and more rubbery; polybutyl acrylate is sticky. If one continues up the homologous series of alcohol esters, the polymers become softer and more plastic until at polyoctyl acrylate, it is found that the polymer is almost liquid in consistency.

Polymethyl methacrylate,

$$\begin{array}{c} \quad CH_3 \\ \quad | \\ (—CH_2—\underset{|}{C}— \quad)_x, \\ \quad COOCH_3 \end{array}$$

is the hardest ester in the methacrylate series and. as in acrylates, introduction of alcohols possessing longer chains into the ester lowers the softening point of the plastic. Some idea of the relative hardness is seen in the fact that polyamyl methacrylate is about as hard as polymethyl acrylate. While polymethyl methacrylate is the preferred resin for injeciion moulding and plastic applications, it was found that cyclohexyl methacrylate was superior for lens casting, since this liquid undergoes less shrinkage during polymerization than does the methyl ester. Cyclohexyl methacrylate polymer, together nith styrene resin, was used in combination in the preparation of plastic achromatic lenses.

Without doubt the largest single outlet for the methyl methacrylate resin has been in sheet form for windows in aircraft, particularly in military aircraft. The resin was cast in moulds made of glass and the finished sheet could then be "post-formed" to a uide variety of shapes necessary for blisters, noses. cockpits, windshields and canopies of aircraft. The high clarity of these plastics. as well as the ability to transmit or "pipe" light, also favoured their use in surgical instruments, highway reflectors and edge-lighted advertising displays.

Whereas styrene was copolymerized with butadiene to form a general-purpose rubber, acrylonitrile, the nitrile of acrylic acid (CH, = CH—CN) was copolymerized with butadiene to yield a special 011-resistant rubber extensively used where rubber of necessity had to be in contact nith gasoline and other hydrocarbon liquids. Acrylonitrile forms conjoint polymers with many other vinyl compounds such as acrylic esters and styrene, but from all indications it promised to play its most important role as a polymer in the form of a synthetic fibre.

Polyamides.—By the condensation of diamines and dibasic acid. linear condensation products may be formed and by varying the nature of the acid and the amine, it is possible to produce products which are hard and tough or soft and rubbery. These linear condensation products are referred to as polyamides $[—NH—(R)—NH—CO—R'—CO—]_x$. Polyamides are most generally knonn in the form of fine and coarse filaments in such articles as hosiery, parachutes. bristles and brushes. As has been pointed out, however, high-molecular-weight organic resinous cornpounds of certain types can be converted into fibres. The polyamides were first offered commercially in the form of filaments but were later directed to the moulding trade. particularly toward the injection-moulding field where their toughness and ability to flow around complicated inserts are prime considerations. Polyamides, particularly those derived from primary *amines, are characterized by a high degree of crystallinity whether in the form of filaments or as mouldings. Under stress, orientation of molecules begins to occur and this orientation continues until the specimen is drawn to about four times its initial size; although this property is of outstanding importance in filaments, it is of more limited utility in moulded articles. The resin exhibits a sharp melting point, and on melting is more liquid and plastic than conventional resinous materials. The fluidity is both an advantage and a disadvantage: the high fluidity necessitates the use of specialized equipment but on moulding there is no need of using excessive pressure in injection moulding, since the liquid resin transmits its pressure on the moulded specimen hydrostatically.*

Inasmuch as adipic acid and hexamethylene diamine are the ingredients most often used in nylon synthesis, and since both of these ingredients contain six carbon atoms, this particular product has been referred to as Nylon-6,6. *There is another variety of nylon which can be made from amino caproic acid; this polymer is referred to as Nylon-6. However, a much easier and efficient preparation of Sylon-6 can be effected through the use of* caprolactam. *Extensive facilities are available both in Europe and in the United States for the manufacture of this polymer from this ingredient.*

Caprolactam is a 7-membered heterocyclic ring. More recently a 5-membered ring has been polymerized to a high-molecular-weight substance, polypyrrolidone, or in the alternative designation, Nylon-4.

A product somewhat similar to the polyamides, manufactured in Germany during World *War* II, *utilized isocyanates, particularly the diisocyanates. Reaction of these unsaturated compounds* with *glycols yielded polyurethanes* $[-NH-R-NH-CO-O-R'-O-]_x$ *which could be iabricated into bristles. A wide variety of other urethane products have been derived from isocyanates. When reacted* with *the appropriate alkyds, foamed resins are produced which have wide utility in the manufacture of laminates, upholstery, and in insulation. Reacted with another variety of alkyd resins, these same isocyanates yield synthetic rubbers having unusual abrasion resistance. Other uses for these isocyanate products are being discovered.*

Polymers From Cycloctabutanes.—From *pentaerythritol a cyclic monomeric chlorinated ether can be prepared which can be polymerized to a high-molecular-weight plastic containing a fair proportion of halogen. Because of the position of the chlorine in the polymer molecule, it is difficultto remove and consequently the product possesses unusual stability. Inasmuch as the groups are symmetrically positioned in the polymer, the product is crystalline and capable of being drawn.*

Polystyrene Resins.— That styrene or vinyl benzene would polymerize has been known for a long time. The designation "vinyl benzene" $(CH_2 = CH-C_6H_5)$ *immediately relates it to the other polymerizable vinyl compounds, such as vinyl chloride, fluoride and acetate. The designation "styrene" arose from the fact that this liquid was first prepared by heating the natural resin* storax. *The first patents on the possible uses of styrene were taken out by F. E.* Matthews *in 1911.* Monomeric *styrene is present in the light oils of coal-tar manufacture and in the drip oils condensed during the preparation of illuminating gas, and although extensive investigations were undertaken to remove styrene from this source, the processes proved too costly and could not compete economically* with *the synthetic methods. In order to secure a satisfactory plastic out of styrene, it is necessary that a highly purified product be subject to polymerization Where the monomeric styrene is of inferior quality, the resulting resin is too brittle and on aging the surface of the plastic becomes covered with fine hair lines similar in appearance to those appearing in an unfilled urea-formaldehyde resin. By using a reaction discovered by* M. *Berthelot in 1869. it was found that by dehydrogenating ethyl benzene catalytically at elevated temperatures and fractionating the resulting mixture, it is possible to secure a product which on polymerization under appropriate conditions yields a polymer possessing valuable chemical and physical properties. Chemically, the resin is highly resistant to both* weak *and strong acids, although oxidizing types of acids may lead to some discoloration. Alkalies and the lower alcohols do not attack the polymer, and the water absorption of the resin is extremely small. The resin can be dissolved in coal tar and in chlorinated solvents. In electrical characteristics, the plastic possesses an extremely low* power *(or loss) factor and,* when *the resin is properly prepared, this power factor remains substantially unchanged over a wide range of frequency. The low power factor combined* with *the low* water *absorption makes polystyrene an ideal material for various electrical and electronic applications. The presence of a multiplicity of aromatic rings in the polymer renders the product responsive to temperature, with the result that the resin can be handled expediently by the injection-moulding technique. Among the* noteworthy *applications of this plastic is the fabrication of battery boxes, ranging in size from those employed in a small automobile to the type that is ordinarily used in portable radio sets. It has found utility in manufacture of condensers, tube sockets, coil forms and switch plates. Since styrene was one of the components entering into the synthetic rubber GR–S. large facilities exist for the manufacture of the monomer. Some idea of the expansion that took place can be seen from the fact that the amount of polystyrene used rose from about 750,000* lb. *per month in 1937 to more than 20,000,000 lb. per month in 1951. During this period progress was made on the commercial casting of styrene in several forms. As a copolymer with divinyl benzene, the resin was employed for certain radar applications which involved operating temperatures higher than could be tolerated with polystyrene. The monomer was also cast directly for certain optical parts such as prisms and lenses.*

Since polystyrene possesses a high dispersion value, it could be combined with polycyclohexylmethacrylate *to make corrected plastic achromatic lenses.*

One of the limitations of polystyrene for many applications is its inability to tolerate excessive heat; and although the modification with divinyl benzene increases its resistance to heat distortion, it does so at the expense of mouldability. In order to increase the heat resistance of polystyrene and maintain mouldability, the monomer has been copolymerized with various nitrogen-containing compounds such as acrylonitrile, fumaric nitrile *and vinyl* carbazole. *The increase in softening point is attained at the sacrifice of colour. Consequently, extensive investigation was carried out in the direction of introducing various groups into the styrene nucleus in an attempt to improve the heat distortion directly. One of the methods that proved successful involves the introduction of multiple halogens into the aromatic nucleus. Another method of securing styrenelike plastics having softening points above that of boiling* water *involves the use of ring-substituted methyl groups in the monomer. Through the introduction of methyl groups into the benzene nucleus of the monomer one can, on polymerization, modify the properties of the resulting resin. Two syntheses based on alternative isomers are now being employed commercially. One procedure, based on the conventional dehydrogenation of the appropriate methyl ethyl benzene, yields a meta para mixture; the other process involves the decomposition of* diaryl *ethanes permitting the formation of* ortho *methyl styrenes.*

The presence of a methyl group. ortho *to the vinyl. imparts important heat resistant characteristics to the finished polymer; the composition comprising 67% of para and 33% of* ortho *yields derivatives* which, *on injection moulding, remain stable in boiling water.*

Isotaxic Polymers. — *Still another development having far reaching implications in the manufacture of plastic products is the observation made by Guilio Natta at Milan university that entirely new physical properties can be built into vinyl polymers through the use of their so-called heterogeneous catalysts.* When *these heterogeneous catalysts are utilized with styrene, propylene, and butylene the polymerization becomes directed in the sense that it permits arrangement of the monomer units in an ordered fashion in the chain.*

Through the use of these novel catalysts, one secures through the positioning a symmetry with a result that the new *products possess much higher melting points.*

Also, these catalysts have been utilized with diolefins yielding, under polymerization conditions, a different type of symmetry in the diene polymer. With isoprene it is now possible utilizing these more unusual catalysts, to arrange a very large proportion of the double bonds in a cis position yielding a synthetic rubber which closely simulates the physical and chemical properties of the natural *Hevea brasiliensis*.

Polyvinyl Carbazole Resins.—Reaction of acetylene with carbazole yields vinyl carbazole $\left[\begin{array}{l} CH_2=CH \\ \quad\ | \\ \quad\ N-C_{12}H_8 \end{array}\right]$, which can be converted to a plastic possessing high heat resistance and excellent electrical properties; but the brittleness of the product limits its uses to specialized industrial applications.

Polyethylene Resins.—Although ethylene is the simplest unsaturated compound, it proved to be one of the most difficult to convert into a high-molecular-weight polymer. The polymerization requires extremely high pressures and moderately high temperatures to effect conversion. As might be predicted from its structure, polyethylene, $-(CH_2-CH_2)_x-$, is completely nonpolar and possesses a low power factor and a low dielectric constant. Being highly symmetrical, it is also crystalline; and in common with other crystalline polymers, thin sheets of the resin exhibit high resistance to penetration by water vapour.

At ordinary temperatures the resin is highly resistant to attack by organic and inorganic reagents. At moderate temperatures, the resin can be dissolved in certain organic liquids and such solutions can be applied as a coating, but satisfactory results are obtained only by keeping the object coated in a heated condition until the solvent has evaporated. Polyethylene, however, can be applied more easily directly by extrusion of the molten plastic. It proved suitable for insulating high-frequency and high-voltage circuits. Because of its low water permeability, extensive tests were carried out with a view of using the resin in submarine cables.

A new type of polyethylene which takes on characteristics of a rigid plastic has created considerable interest in both industrial and in scientific quarters. It has been referred to as "linear polyethylene," "high density polyethylene" or "low pressure polyethylene." The term "low pressure" appears undesirable inasmuch as investigations have demonstrated that a high-density rigid polyethylene can be prepared utilizing high-pressure techniques. The term "linear polyethylene" appears to be most appropriate in that it refers to the fundamental architecture of the molecule. Perhaps the most important technical advantage from the standpoint of the consumer is that this linear polyethylene possesses a higher softening point permitting sterilization—a procedure which was impossible with the earlier type. Another advantage of the high-pressure linear polyethylene resides in the absence of a catalyst which, in certain highly selective electrical applications of polyethylene, may lead to difficulties.

Polyisobutylene Resins.—Isobutylene is a hydrocarbon boiling at about $-5°$ C., and when dimerized it can be converted by reduction to iso-octane. By conducting the polymerization at very low temperatures, using boron fluoride as a catalyst, a high-molecular-weight product is formed $\left[\begin{array}{c} \quad\ CH_3 \\ \quad\ | \\ -CH_2-C- \\ \quad\ | \\ \quad\ CH_3 \end{array}\right]_x$. This polymer is rubberlike but inasmuch as the material is saturated, it cannot be vulcanized. By conducting the polymerization of isobutylene along with a diene such as butadiene, isoprene or dimethyl butadiene, unsaturated residues are introduced into the polymer. These residues can act as nuclei for vulcanization with sulphur.

Polyvinylpyrrolidone.—The polymer secured from 1-vinyl 2-pyrrolidone is a water-soluble product, possessing many unusual characteristics and having a wide variety of pharmaceutical applications including that of blood plasma extender. It was used as a blood plasma substitute by the German army during World War II. The product is being manufactured in the U.S. chiefly for use in hair-spray lacquers and in detergents. The polymer has a high affinity for many dyestuffs and in many cases will prevent the bleeding of migrant colours from one garment to another. When hair is placed in contact with aqueous solutions of polyvinylpyrrolidone a certain amount of polymer enters into the hair shaft. Subsequent rinsing will not remove all of the polymer, leaving the hair with an improved appearance both from the standpoint of clarity and of natural colour. A number of preparations employ PVP as a retardant vehicle for drugs since it permits the drug to remain in the body for a longer period. The success of the pyrrolidone polymer as a blood plasma extender has stimulated research in other products possessing similar characteristics. One derivative which has found some interest is Dextran, a polymer of glucose.

Polyvinyl methyl ether.—Another high polymer possessing water-soluble characteristics and simultaneously dispersible in a number of organic liquids is the polymer secured from vinyl ether. Like PVP it is a derivative of the high-pressure synthesis of acetylene. The direct addition of methanol to acetylene under pressure using appropriate catalysts yields a monomer. When alcohols other than methyl are used with acetylene similar vinylization occurs yielding ethyl vinyl ether. Vinyl isobutyl ether and, if the alcohol is long enough, such as octadecyl alcohol, no excessive pressure is required to carry out the reaction. These vinyl ethers will polymerize among themselves or with other vinyl materials. One product possessing extensive uses as a water-soluble colloid is the copolymer of vinyl methyl ether with maleic anhydride, which has been designated as PVM/MA. Inasmuch as there are acidic groups still present in the polymer a number of esters may be prepared which vary widely in physical characteristics.

Polyacrylamide.—Still another polymer possessing water solubility in its resinous plastic form is polyacrylamide. The amide linkage is capable of reaction with formaldehyde yielding the intermediate which can undergo further condensation reactions.

Perhalogenated Plastics.—Several references can be found in the patent literature to the preparation of polymeric materials which possess only carbon and halogen in their molecular structure. One of the perhalogenated products, polytrifluorochloroethylene, $-(CF_2-CF-Cl)_x-$, is described in a patent issued to F. Schloffer and O. Scherer (1934), while another patent, that of R. J. Plunkett in 1941, refers to tetrafluoroethylene polymer $-(CF_2-CF)_x-$. The latter product was produced commercially in limited quantities and found its chief utility in the preparation of corrosion-resistant gaskets. Polymeric tetrafluoroethylene is a remarkably stable substance and is insensitive to all organic and inorganic liquids. As would be expected from its symmetrical structure, the polymer is crystalline and the resin on heating undergoes a phase transition at about 327° C., where the mouldings become transparent and the tensile strength decreases markedly.

Trade Names.—Plastics are known and sold commercially under various trade names. A single resin may be sold under a multiplicity of names arising from the fact that the resin manufacturer sells the resin under his own trade name while the moulder may offer this resin in its moulded form to the public under his own distinctive brand name. Moreover, the same chemical composition may frequently be offered to several different consuming industries under several different individual names. As knowledge gradually accumulates concerning the chemical nature and constitution of resins and plastic materials, the custom is becoming established of associating, directly or indirectly, the trade name along with the chemical constitution.

Bibliography.—C. E. H. Bawn, *Chemistry of High Polymers* (New York, 1948); R. H. Boundy and R. F. Boyer (eds.), *Styrene: Its Polymers, Copolymers and Derivatives* (New York, 1952); T. S. Carswell, *Phenoplasts: Their Structure, Properties and Chemical Technology* (New York, 1947); G. F. D'Alelio, *Fundamental Principles of Polymerization* (New York, 1952); C. Ellis, *The Chemistry of Synthetic Resins* (1935); Faraday Society, *Phenomena of Polymerisation and Condensation* (London, 1936); P. J. Flory, *Principles of Polymer Chemistry* (Ithaca, N. Y., 1953); R. Houwink, *Chemie und Technologie der Kunststoffe* (Leipzig, 1939); G. Kranzlein and R. Lepsius, *Kunststoff-Wegweiser* (Berlin, 1939); K. H. Meyer, *Natural and Synthetic High Polymers* (New York, 1942); R. S. Morrell *et al.* (eds.), *Synthetic Resins and Allied Plastics* (London, New York, 1937); J. Scheiber and K. Sändig, *Artificial Resins* (London, New York, 1931); C. E. Schildknecht, *Vinyl and Related Polymers* (New York, London, 1952); H. R. Simonds and C. Ellis, *Handbook of Plastics* (New York, 1943; London, 1944); H. Staudinger, *Die hochmolekularen organischen Verbindungen-Kautschuk und Cellulose* (Berlin, 1932); E. C. Worden, *Technology of Cellulose Esters* (New York, 1921); R. L. Wakeman, *The Chemistry of Commercial Plastics* (New York, London, 1947).
(E. L. Ka.)

PLASTIC SURGERY is that specialty of surgery which concerns itself principally with the improvement in appearance or function of the external tissues of the body. It is a formative or constructive discipline making use of the readjustment of local tissues or the transfer of tissues from a distance to effect a desired change for the better appearance of parts of the body. Early in its development, plastic surgery was limited to correction of facial deformities, but its scope has been expanded to include correction of defects of all external parts and, in a more limited fashion, restoration of function, as of the hands, not necessarily associated with abnormal appearance.

History.—Probably the earliest use of the term plastic surgery was that by Edward Zeis, author of the *Handbuch der Plastischen Chirurgie* (1838). But some of the techniques employed had their origin long before the publication of Zeis's book. As early as or earlier than 800 B.C. the Hindus restored missing facial features. For instance, the caste of potters advanced the tissues of one or both cheeks toward the midline of the face for the reconstruction of the nose; the need for this arose from the practice of slicing off the nose as punishment for various offenses. Some discussion of the same general type of surgery as that used by the Hindus was contained in Celsus' description of plastic procedures in his *De re medica* (1st century A.D.). Galen (2nd century A.D.) also was acquainted with these procedures. Thereafter, it was not until the middle of the 15th century and the work of Branca in Sicily that further development of plastic surgery occurred. Instead of using facial tissues for reconstructing the nose, Branca substituted the use of skin and fat from the arm. In 1597 Gaspar Tagliacozzi prepared a systematic treatise on plastic surgery. Then its development ceased again until the 19th century.

The first half of the 19th century mas marked by development and refinement of the established principles underlying the transfer of tissue still partially supplied with blood (pedicled flaps); the second half was marked by expansion of the newly evolved technique of transplantation of skin and other tissues completely separated from their original blood supply (grafts). One of the earliest descriptions of the use of 'grafts was that by J. Mason Warren of Boston in 1843. In fairly rapid succession, Jacques Louis Reverdin (1869), L. L. X. E. Ollier (1872), J. R. Wolfe (1876), Karl Thiersch (1886) and Wilhelm Krause (1893) elaborated and refined the principles involved in the free and unattached transfer of skin grafts, so that by 'the beginning of the 20th century grafting mas a well-recognized plastic surgical procedure. With the development of the Padgett dermatome, a mechanical device for cutting thin pieces of skin from a large area; in 1939, it became possible for surgeons to make use of skin grafts readily.

Techniques. — Autografting — The use of pedicled flaps and of free grafts has as its main purpose the addition of tissues to the region undergoing repair. Sometimes there is no need to supply new tissue; rearrangement of what is already there may be sufficient. The Z-plasty is one such local rearranging technique. In this, width may have to be sacrificed for length, but by so doing an improvement in appearance or function may be attained. Sometimes simple removal of tissue may be all that is needed to provide the desired effect. Very commonly the plastic surgeon employs two, three or all four of these major techniques.

The employment of a free graft entails relatively less surgical manipulation than that of a pedicled flap, for the tissue is simply removed from one part of the body and then reinserted into or applied upon another. The tissue of a pedicled flap, on the other hand, usually must be prepared for severance from its donor site by a series of incisions which progressively all but encompass the tissue and cause it to become wholly dependent upon the blood supply entering from one retained attachment or pedicle. In this manner a relatively great bulk of tissue can be made to live upon a relatively narrow stalk, and it becomes possible to move one extremity of the flap to a new site while the flap continues to be nourished through its stalk. Once the transplanted portion has healed to the margins of the defect to which it has been transferred. the sustaining pedicle can be divided and the tissue will live from the blood carried into it from the vessels of the recipient area.

The skin employed for grafting may include the entire thickness of the two layers of skin, the external epithelium and the deeper corium, or the skin may be reduced in thickness by inclusion of only part of the corium with the epithelium. The full-thickness graft does not have so good a chance for survival as the partial-thickness graft. but when it survives it retains more normally its original characteristics such as colour and texture and is not so subject to reduction in area. Split-thickness grafts, which have a better chance for survival, undergo more shrinkage and alteration of their original texture and colour. Full-thickness grafts find their principal use in the replacement of skin of, the face. where texture and match of colour with the surrounding normal skin are of paramount importance; partial-thickness grafts are employed on other parts of the body, particularly when extensive areas of skin are needed.

Homografting.—For many years efforts have been made to understand the physiological basis for the maintenance of survival of tissues transplanted from one human being into or upon another. Such tissues, called homografts (as opposed to autografts, or transplants from one part to another of the patient's own body), could be very useful. as for the skin grafting of extensive defects when the patient, for one reason or another, is unable to supply donor skin for himself. Permanent hoinografting of skin must await elucidation of the means whereby the graft can be induced to remain alive. In spite of their frailty, however, homografts of skin do survive for periods of several weeks. and this makes it possible to apply them, as a purely temporary measure, upon extensive burn wounds merely to obtain provisional coverage while the general condition of the patient improves.

Foreign Bodies as *Replacements* for Living Tissue. — Although the body usually can provide its own replacements, such as cartilage or bone, for the reconstruction of skeletal defects, there are times when the patient is unwilling to submit to the extra operation necessary for the removal of the graft. Homografts of cartilage or bone can be used, with less chance of success than with autografts, or foreign materials such as various plastics (polyethylene) may be employed. The indications for the use of foreign bodies are relatively few, because the chance for permanent retention is not great. On the other hand, foreign bodies do find a wide application as external prostheses. Whereas the reconstruction of a major defect of the face from living tissue may be indicated when the patient's life expectancy is considerable, an external prosthesis may be desirable for older persons who might not be willing to devote the time needed for the multiple operative stages necessary to rebuild a complicated anatomical part such as a nose or ear.

Deformities **and** Defects. — Congenital *Malformations.*— These constitute a very important segment of plastic surgical practice. Two of the commonest are harelip and cleft palate. Repair of harelip generally is carried out within the first few months of life, not only to restore an abnormal appearance toward normal but also to improve the sucking function. Harelip deformity may be seen as a notching of the vermilion border or may be present as a complete cleft of the upper lip. usually on the left side, but occasionally bilateral or on the right side alone. Both harelip and cleft palate may occur in the same patient, or only one may be present. The time for repair of the cleft palate is often said to be about the age of 18 months, but sometimes it is desirable to wait for several years, in which instance an artificial device may be provided to help separate the nasal and buccal cavities. The aim of surgical repair is to accomplish such separation by eradicating the longitudinal gap in the roof of the mouth, and so to aid in the development of better speech, the control of escape of ingested food via the nostrils, and the reduction of upper respiratory infections. For the maximal benefit from repair of harelip and cleft palate. in some instances a series of operative procedures must be performed.

Burns. — Although minor burns (*q.v.*) can be treated successfully by all surgeons, the techniques of skin grafting play such an important role in the treatment of major burns that plastic surgeons are frequently called upon to care for patients following destruction of extensive areas of skin. Burns usually are classified as first. second or third degree. In third-degree burns the entire depth of skin is lost, and unaided healing can occur only by the slow advance over the wound of skin from the margins of the defect. This process may take weeks, months or even years to be completed, depending upon the extent of the burned area. The patient's immediate welfare may be improved by the application of partial-thickness skin grafts, which also reduce the time required for wound healing as well as the amount of residual scarring.

After an interval of many years (approximately 10–40), the scars resulting from unaided healing of large third-degree burns may undergo chronic ulceration, perhaps related to an inadequate blood supply. Such unstable scars are subject to skin cancer. As a consequence, even though third-degree burns may have healed without skin grafting. the plastic surgeon may be called upon years later to excise ulcerated, unstable scars down to normal tissue and to cover the new wound with grafts or even with pedicled flaps.

Another complication of the healing of some third-degree burns is development of contractures. Virtually all scars gradually decrease in length over a period of months or years. This may, in effect, lead to the limitation of motion of joints over which the skin must be able alternately to increase and decrease in length. The inelasticity of a short contracted scar over a joint may very well limit the range of motion of the joint and so interfere with normal usefulness. Seldom is simple excision of the scar sufficient for restoration of function; it is frequently necessary not only to remove the scar but also to add new skin.

Keloids—excessive overgrowths of scarlike tissue at the site of destruction of skin—may follow any deep skin injury, but are most prone to follow third-degree burns in those persons who have the inherent tendency to develop them. Little is known of the underlying reasons for the excessive overgrowth of scar, but the end results can be improved in some cases by plastic surgery combined with the therapeutic influence of X-rays or some other means for lessening the amount of new scar formation.

Psychologic Implications of Plastic Surgery.—In many instances, the deformity or abnormality which is being subjected to plastic surgical repair is gross and obvious to everyone, but in many others deviation from an accepted norm is so slight that an observer might wonder why the patient calls for correction. In addition to the patient's simple displeasure with his appearance, there may of course be economic or sociologic implications when the patient believes that an abnormality is preventing him from securing or holding a specific position or gaining the affection of a specially desirable mate. Many persons, for example, ask for such operations as "face-lifting" so that they may continue to hold jobs in which the appearance of old age is considered undesirable. Under such circumstances as these, recourse to plastic surgery may save the patient much unhappiness.

Although patients may occasionally request alteration of almost any part of the body, the majority of cosmetic surgical procedures are carried out for remodeling of the nose, ears and breasts, and for the removal of wrinkles from the aging face. Sometimes the amount of surgical alteration, as in cosmetic rhinoplasty, may involve the addition or removal of a very small amount of tissue, yet result in a striking change in the patient's appearance.

The Specialty of Plastic Surgery.—Although some of the techniques of plastic surgery are used by many different types of surgeons, surgeons who devote all their time to this type of surgery in the United States usually take the examination of the American Board of Plastic Surgery after a prolonged period of study and hospital training. For the dissemination of new information, the Society of Plastic and Reconstructive Surgery publishes a monthly journal. See also TRANSPLANTS, TISSUE AND ORGAN.

BIBLIOGRAPHY.—Ferris Smith, *Plastic and Reconstructive Surgery* (1950); Arturo Castiglioni, *A History of Medicine* (1947); John Staige Davis and William Bowdoin Davis, "Plastic Surgery," in Lewis' *Practice of Surgery,* vol. v (1955). (C. G. N.)

PLATA, RÍO DE LA (PLATE **RIVER**), has two meanings: in the most limited sense, it is a broad estuary, approximately 171 mi. long, located between Argentina and Uruguay and flowing southeast into the South Atlantic; in a more comprehensive sense, it is the mouth of an enormous drainage basin which includes the Paraguay, Paraná and Uruguay rivers and numerous smaller rivers and streams. This basin drains the southern portion of South America, as the Orinoco and Amazon drain the northern. The area covered, 1,679,535 sq.mi., includes the whole of Paraguay, southeastern Bolivia, most of Uruguay and large portions of Brazil and Argentina, thereby ranking this river system fourth in the world by size. The rate of discharge, however. estimated at 2,800,000 cu.ft. per second, makes this system second only to the Amazon in volume.

The Estuary.—At its upper extremity, where this estuary receives the waters from the great river systems of the Paraná and the Uruguay, the width is 19 mi. The Argentine island of Martin Garcia is located near this extremity and provides a control point for navigation. The estuary gradually widens to 63 mi. at Montevideo and then fans out to 140 mi. at its mouth. Despite the enormous amount of water discharged into the ocean, the Rio de la Plata is relatively shallow. The depth of the main channel above Montevideo is 36 ft. The average depth outside the main channel is 10 to 20 ft. Seasonal rates of flow, winds and tide have a considerable effect on the depth. Constant dredging is necessary to keep a 20 mi. side channel, 31 ft. deep, open to the port of Buenos Aires, and to clear other parts of the main channel. Consequently, ships, after entering the Rio de la Plata, are restricted to prescribed courses. The bottom is composed of sand and silt. The expanse of low plain or pampas on the southern or Argentine side, permits violent winds, known as *pamperos* to build up and whip the waters of the estuary into violent storms at certain times of the year.

Upper **Paraná and Affluents.**—The Paraná, meaning "mother of the sea" in the Guarani language. is the larger and'more important of the two river systems which flow into the Rio de la Plata estuary. About 1,400 mi of its estimated 2,347-mi. length is above its juncture with the Paraguay river and is known as the Upper Paraná (Alto Paraná). The Paraná is formed by the union of the Paranaiba and Grande rivers at 20° S.. these tno rivers having traced the western and southern borders of the state of Minas Gerais. Brazil, in their previous course. The Paranaiba originates a few miles from the headwaters of the Sho Francisco river, but flows in the opposite direction, at first west and then southwest. By the time it joins the Grande, it has already received eight sizable tributaries. The Grande originates in the Serra da Mantiqueira, almost within sight of Rio de Janeiro, Braz , and descends in many falls and rapids for about 845 mi. to its juncture with the Paranaiba.

A number of Brazilian rivers from the states of Mato Grosso, São Paulo and Paraná empty into the Paraná as it flows generally southwest Most of these tributaries, such as the Sucurih, Verde, Pardo, Ivinheima, Amambai and Iquatemi on the west and the Tieté, rising within 35 mi. of the city of São Paulo. the Peixe. Ivai, Pequiri on the east. are navigable only for short stretches by canoes or small launches and are broken by frequent waterfalls and rapids. The largest of the eastern tributaries is the Paranapanema, which descends 559 mi. from the Serra Paranapiacaba overlooking the Atlantic ocean.

Small river boats can navigate the upper reaches of the Paraná river in Brazil for 400 mi. between the falls of Urubu-Pungá and the falls of Guairá (or Sete Quedas). At this latter point, the river has torn a 2-mi. gorge through the red sandstone of the Serra de Maracaju (Serra do Mbaracayú.) The result is a stupendous although not well-known sight. The river. which widens to a 3-mi, lagoon, suddenly becomes constricted between canyon walls only 300 ft. apart. As a result the water boils in deafening crescendo, which can be heard for 20 mi. through several channels and some 18 cataracts in a total descent of approximately 300 ft. There the Paraná becomes an international boundary and serves to divide Brazil and Paraguay for a distance of 130 mi. until joined by the Iguaçú (Iguassu) river.

Iguaçu.—This river, the most spectacular of the Paraná's affluents, also rises in the Brazilian coastal range, the Serra do Mar, and flows nearly directly west for 430 mi. For its last 75 mi. it divides the Argentine province of Misiones from Brazil. About 15 mi, before it joins the Paraná, the river plunges over an escarpment, which is 23 mi. in width. The resultant cataracts are among the most famous falls in the world, often compared with the Niagara or the Victoria on the Zambezi. Although most of the escarpment is broken into two descents of approximately 100 ft. each, one mass of water roars 269 ft. down the Garganta del Diablo or Devil's Throat. As many as 275 separate waterfalls have been counted in the dry season, while at flood stage the volume exceeds that of Niagara. (See IGUAÇU.)

From the mouth of the Iguaçu to the juncture with the Paraguay, 420 mi. further on, the Paraná serves as the boundary between Paraguay and Argentina. There are no important tributaries which join the river in this stretch. Near the capital of the province of Misiones, Posadas. 27° 22' S., the Paranb turns westward. The relatively narrow river, 1.500 ft. in width. has cut several channels between high rocky banks, creating large islands in its course, such as Yaciretá, ApipC Grande and ApipC Chica, and Talavera. The current in these channels is strong and the passage is made difficult by rapids such as those of the ApipC. Shortly after these rapids. however, the Paranb escapes from its red sandstone bed, and its flow becomes more leisurely as the river widens. The banks of the river are lower and the bottom is sandy.

Paraguay.—This main affluent of the Paraná is 1,584 mi. long.

It rises in the Brazilian state of Mato Grosso, near the town of Diamantino, 14° 24′ S., not far from the headwaters of the Tapajós and the Xingu, tributaries of the Amazon. It flows first southwest and then south into the morass of Xarayes, which expands into still vaster swamps as the river grows in size. Few streams feed the Paraguay from the west with the exception of the Jaurú. There are, however, a number of large shallow lakes to the west of the Paraguay which receive overflow from the morass of Xarayes. Several important affluents swell the Paraguay from the east and drain a vast area of Mato Grosso. These Brazilian rivers, north to south, are the Cuiabá and São Lorenzo, the Taquari, Miranda and Apa. the last serving as a boundary between Mato Grosso and northern Paraguay. In this northern area, the Paraguay is a shallow, sluggish river. During the rainy season, it spreads out for hundreds of miles from each bank. turning the vast swampland between 17° and 20° S., into great lakes. In this Corumbá territory of Brazil, as much as 30,000 sq.mi. have been inundated.

South of the mouth of the Apa river, the Paraguay flows through Paraguayan territory. On the west, the vast Chaco jungle and morass is only imperfectly drained by the Pilcomayo and Bermejo rivers and by innumerable smaller streams. Much of the east bank of the Paraguay, in particular, the lowland between Concepción and Asuncion, is also subject to seasonal flooding. About 250 mi. south of Asunción, the Paraguay merges its slow moving mass (140 ft. above sea level) with the Parana river.

Pilcomayo, Bermejo and **Salado.**—These three rivers, north to south, rise in the Andes and flow southeast in parallel courses. The Pilcomayo, '(river of the birds" in Guarani language. descends from its source north of Potosi, Bolivia, 8,000 ft. in 350 mi. to the Chaco plains. The course of the river then loses itself in the Chaco morass and finally wanders in three separate branches to its juncture with the Paraguay opposite Asunción. The main channel, such as it is, marks the boundary between Argentina and Paraguay.

The Bermejo rises on the Bolivian-Argentine frontier. After a rapid plunge to the Chaco lowlands, the river flows in a sinuous course around islands and sandbars which make any estimate of depth meaningless. The current is stronger than that of the Pilcomayo. Much silt is carried in suspension thus originating its name to describe the reddish colour. It has been estimated that this river alone carries off 6,400,000 cu.yd. of soil from the Chaco each year.

The Salado is formed by several rivers which drain the Argentine province of Salta and emerge on the Chaco lowlands. Like the Pilcomayo and Bermejo. the Salado follows no prescribed channel but wanders in a braided pattern across the countryside, particularly at floodtime. The Indian use of such alluvial croplands has been imitated by settlers growing maize, wheat, flax and cotton, although permanent or continuous use of the land is, at best, difficult when irrigated only by such annual floods.

Lower **Paraná.**—After its juncture with the Paraguay, the Paraná flows slightly southwest until it reaches the city of Santa Fe and is joined by the Salado river. Then it curves in a gradual arc until at Rosario it is flowing southeast to join the Rio de la Plata. The Lower Paraná is entirely within Argentine territory, passing through some of the richest agricultural land in the world. On the east lie the pastoral provinces of Corrientes and Entre Rios. while on the west is the breadbasket of Santa Fe and northern Buenos Aires.

The Paraná becomes a truly imposing river after it joins forces with the Paraguay. Even at low water, its 800-mi. course to the Rio de la Plata is from 2 to 4 mi. wide. Unlike the clear waters of its Brazilian sources, however, it is now tremendously burdened with silt. The Paraguay brings soil from Mato Grosso, while the Pilcomayo, Bermejo and Salado, eating away at the Andes, add tons of alluvium. The western bank of the lower Paraná is a high bluff of red clay rising 25–75 ft. above the river level and is constantly undermined by the current.

The amounts of silt lend themselves to a building as well as a tearing away process. Unlike the high rocky islands of the Upper Paraná, the Lower Paraná is dotted with large, low, often forested islands. During flood season, however, the Paraná may widen to 10 mi. and, in places, even 30 mi. burying islands and overfloaing into marginal swamps. The periodic floods as well as the seasonal rise and fall of the water level naturally wreak havoc with islands and channels. Below Rosario, the islands and the main channel are more stable, because the total rise, even of flood waters, is distributed over a wider area and consequently is not as great. The mouth of the Paraná river or the head of the Rio de la Plata estuary, until a recent geological period, must have been located much further inland, perhaps as far as 32" S., near the present town of Diamante in Entre Rios. Subsequently, silt has built up island structures from the sandy bottom. The clustering of these islands form a huge delta, 40 mi. wide and 100 mi. long, at the mouth of the Paraná.

The lower Paraná finds its may through the Paraná delta in 11 outlets and several canals. The two principal channels which are used by ocean vessels are the Paraná Bravo with a depth of 36 ft. and the Paraná Guazú with a depth of 20 ft. The depths of the other channels and connecting canals used by coasting craft vary greatly but are announced periodically. Constant dredging is naturally required to keep these channels open for navigation.

Uruguay and Its Affluent%— Thisis the second major system, 1,000 mi. in length, which flows into the Rio de la Plata. Like the Upper Paraná and the Paraguay, the Uruguay originates in Brazil, formed by several small streams which rise on the western slopes of the Serra do Mar, at 27° 09' S. From the south it is joined by the Pelotas, the two rivers serving to divide the states of Rio Grande do Sul and Santa Catarina. After floning west, the Uruguay turns southwest at its juncture with the Pepiri Guaçu, the first sizable affluent to join it from the north. For most of its course, the fast flowing Pepiri Guaçu marks the boundary between the Argentine province of Misiones and Brazil. Now the Uruguay serves to divide Brazil and Argentina. A few miles beyond the juncture with the Pepiri Guaçu, the river is constricted between rocky walls in the Salto Grande de Misiones. a 2 mi. stretch of rapids with a total descent of 26 ft. in 8 mi. At the cataracts, the river narrows suddenly from 1,500 ft. to an extreme of 70 ft.

Several small rivers join the Uruguay from the west and are navigable in their lower reaches by canoes and small boats. The principal of these, from north to south, are the Xguaypey. Mirinay, Mocoretá, which divides Entre Rios and Corrientes, and Gualeguaychú. The important affluents of the Uruguay, however, come from the east. The Ijuí, Ibicui and the Quarai (Cuareim) are short rivers but of considerable volume; the last forms part of the boundary between Brazil and Uruguay. At the mouth of the Quarai, the Uruguay becomes the boundary line between Argentina and Uruguay, and the river flons almost directly south. The Negro river, 300 mi. long and the Uruguay's largest tributary, joins the latter only 60 mi. from the estuary of the Río de la Plata. The Negro rises on the Brazilian border in Rio Grande do Sul and flows westward through the middle of the Republic of Uruguay. Sizable river craft can reach Mercedes, 32 mi. from its mouth. Like the Upper Paraná, the Uruguay is generally clear and carries little silt except in the seasonal floods. After its juncture with the Negro, the Uruguay broadens sharply to a width of 4 to 6 mi., and becomes a virtual extension of the Rio de la Plata estuary.

Navigation and Economic Importance.— The economic usefulness of these river systems is not commensurate with the area which they drain. A principal problem is that of navigation. A large portion of the rivers cannot be used at all or only by very shallow draught vessels. Elsewhere navigation can only be maintained by constant dredging and renovation of port facilities. The other economic uses to which these rivers might lend themselves, such as irrigation or hydroelectric power, are equally difficult to achieve. The swamps of Xarayes and the Chaco make agriculture a virtual impossibility in these areas, while under present conditions the potential electric power represented by the falls of Guairá or Iguaçu is too remote from any centres to be harnessed.

Buenos Aires is one of the principal seaports of the world and the main port of Argentina. Vessels approach it from the main estuary channel by one of two side channels which are clearly marked and dredged to depths of 31 ft. Ocean vessels can travel up the Paraná river as far as Santa Fe or Paraná. The channel depth from the mouth of the Paraná to Rosario is dredged to 21 ft., from Rosario to Paranb to 19 ft. Ocean trade can also reach Concepción del Uruguay directly by the Uruguay river where the dredged depth of the channel is 19 ft.

Commerce further upstream on these river systems operate under conditions which fluctuate considerably. Passage of vessels depends to a large extent on seasonal variations in depth. A 6-ft. depth is assured from Paraná to Corrientes and usually to Posada, although vessels of deeper draught can often pass Long fleets of barges carry the bulk of the river freight. The current, narrowness, and curves above Corrientes on the Upper Paraná, however, rule out such barge transport. Several rapids on the Upper Paraná can only be passed with the use of winches to pull the vessels. Narrowness of the river, whirlpools and the increased speed of the current to 5 m.p.h. make navigation more dangerous as the mouth of the Iguaçu is approached. The absolute head of navigation is located at Pôrto Mendes below the Guairá falls in Brazil. A railroad, 38 mi. long, circumvents the falls to the town of Guairá, and opens up another 400 mi. of navigable river further up the Paraná. Beyond, stretches of the Paranb and of tributaries are navigable only by launches or canoes.

On the Paraguay river, vessels drawing 7 ft. and displacing 2,000 tons are able to reach Corumbá in Brazil at all seasons. The most traveled stretch of this river is the 250 mi. from Corrientes to Asunción which is accessible to vessels of 10 ft. draught. Although Corumbá is considered as the head of navigation on the Paraguay, the Bolivian town of Puerto Suárez, 10 mi. away, was built to provide this landlocked nation with a port. Vessels can reach it from Corumbk during the flood season, March to Sept., but its population of 1,154 (1950) indicates that it is hardly a major commercial centre.

Some ocean vessels with a draught of 15 ft. can go 25 mi. beyond Concepción del Uruguay on the Uruguay river to Fábrica Colón. A 9 ft. depth is assured as far as Concordia and 6 ft. as far as Salto. Ships of deeper draught reach these river ports in flood time. Above Salto, there are few ports and no measurement of depths is taken. A considerable commerce and movement, however, is carried on by small launches, rafts and canoes.

Navigation of the Pilcomayo, Bermejo and Salado is negligible, because of shifting channels, sandbars and shallowness. Vessels of 3 ft. draught can ascend the Pilcomayo for the first 120 mi. to Fontana, although in a straight line this means only 45 mi. Barges and motorboats on the Bermejo reach Presidencia Rosa, 160 mi. from the mouth, on a regular schedule, although the depth in the shallows is reduced to 2 ft. in the dry season. During high water, November to April, small vessels can ascend the Bermejo 400 mi. from its mouth. Only very shallow draught vessels can use stretches of the Salado.

The value of these river systems as a commercial artery is, therefore, concentrated on the lower reaches. A large volume of ocean shipping reaches Rosario and Concepción del Uruguay, although the major seaports are Buenos Aires and Montevideo. The great bulk of river transport is concentrated within the limits of Asunción on the Paraguay, Corrientes on the Paranb, and Salto on the Uruguay. The Argentine Flota Fluvial del Estado, the Lloyd Brasileiro and the Compañía Uruguaya de Navegación, however, provide regular passenger and freight service to all navigable parts of these river systems. Rafts, canoes and motorboats provide irregular although important service on the tributaries and upper reaches of these rivers.

A lack of population, remoteness of markets and difficulty of transport are partial reasons for the failure to develop other uses from these river systems. Seasonal rainfall with consequent flooding of large areas may provide a very crude basis for agriculture along the Salado, but it prevents agriculture in vast areas of the Chaco and Mato Grosso. The same remoteness has prevented any effective harnessing of the rivers' power. One exception is the headwaters of the Tieté which, pumped across an intervening range, provide water for a hydroelectric plant near São Paulo.

History. — The Rio de la Plata was discovered by Juan Díaz de Solís, chief navigator of Spain, in 1516, as a result of efforts to find a route to the Pacific. The estuary was temporarily named in his memory after his death on its shores at the hands of unfriendly Charrua Indians. Magellan touched at the estuary in 1520 during his circumnavigation of the globe. In 1526, Sebastian Cabot ascended the rivers as far as the present city of Asunción and obtained silver trinkets in barter with the Guarani Indians. Spanish dreams gave the estuary its permanent name, Rio de la Plata, in the hope that it might indeed become a river of silver. The major Spanish expedition which settled near the present location of Buenos Aires in 1536 under Pedro de Mendoza proved a fiasco. After much misfortune the survivors moved upstream to the surroundings of the more docile Guarani Indians at Asunción. Buenos Aires was not refounded until 1580, and throughout the Spanish colonial era, the Rio de la Plata remained a backwash of the empire. The estuary was virtually closed to legal commerce until the end of the 18th century. Spain only renewed its interest in the area when Portuguese and English ambitions threatened to expand into the Rio de la Plata in the 1760s.

Navigation of the river systems became a problem when the national states of Argentina, Uruguay, Paraguay, Brazil and Bolivia emerged on its courses. Territorial conflicts and restrictions on navigation caused several wars, culminating in the titanic struggle by Francisco Solano López's Paraguay against Brazil, Uruguay and Argentina from 1864 to 1870. In the 20th century, similar conflicts sharpened by rumoured oil wealth resulted in the Chaco war between Paraguay and Bolivia.

The development of agricultural wealth, particularly in Argentina, resulted in greater appreciation of the commercial value of these river systems after the mid-19th century. Wheat, beef, wool and hides entered the river and world trade in increasing quantities from Argentina and Uruguay, while from Brazil and Paraguay came forest and tropical products and yerba mate or Paraguayan tea. Port construction and dredging made Buenos Aires more valuable as a seaport, and by 1902 similar improvements had been completed at Rosario. Marking of channels, soundings, dredging and other aids to navigation became a responsibility of all the riparian states. See also SOUTH AMERICA; BRAZIL; ARGENTINA; PARAGUAY; URUGUAY. (Js. R. S.)

PLATAEA (PLATAEAE), an ancient Greek city of Boeotia, situated close under Mt. Cithaeron near the passes leading from Peloponnesus and Attica to Thebes and separated from the latter city's territory by the Asopus river. Though one of the smallest Boeotian towns, it stubbornly resisted the centralizing policy of Thebes. In 519 B.C. it invoked Sparta's help against its powerful neighbour, but was referred by King Cleomenes to Athens (for the date, see Grote's History of Greece, ed. 1907, p. 82, note 4). The Athenians secured Plataea's independence and thus secured its enduring friendship. In 490 the Plataeans sent their full levy to the assistance of the Athenians at Marathon, and during the invasion of Xerxes they joined eagerly in the national defense. At Artemisium they volunteered to man several Athenian ships, and subsequently abandoned their town to be burned by Xerxes. In 479 they fought against the Persians under Mardonius in the decisive battle which bears the name of the city. (For an account of the battle see GRAECO-PERSIAN WARS.) Their great victory was celebrated by annual sacrifices and a festival of liberation (Eleutheria) in every fourth year at Plataea, whose territory, moreover, was declared inviolate.

In spite of this guarantee Plataea was attacked by Thebes at the beginning of the Peloponnesian War (431) and formally besieged by the Peloponnesians (429–27). The garrison after capitulating was put to death. and the city razed by the Thebans. The remaining Plataeans received a qualified franchise in Athens, and in 421 were settled on the territory of Scione. Expelled by Lysander in 404 they returned to Athens, until in 387 Sparta restored them in their native town as a check upon Thebes. The city was again destroyed by Thebes in 373 and the inhabitants once more became citizens of Athens. Plataea was rebuilt by Philip and Alexander of Macedon, and during the rest of antiquity enjoyed a safe but obscure existence. It continued to flourish in Byzantine and Frankish times. The walls of the town, which at various periods occupied different portions of the triangular ledge on which it stood, remain partly visible. Modern excavations discovered the Heraeum, but the temple of Athena the Warlike. built from the Persian spoils and adorned by the most famous artists, was not identified.

BIBLIOGRAPHY.—Strabo, p. 411; Pausanias, ix, 1–4; Herodotus, vi, 108. viii, 1, ix, 25–85; Plutarch, *Aristides*, 11–21; Thucydides ii, 1–16, 71–78, iii, 20–24, jz–68; Isocrates, *Plataicus;* G. B. Grundy, *The Topography of the Battle of Plataea* (London, 1894), *Great Persian War*, ch. xi (London, 1901); W. Woodhouse in *Journal of Hellenic Stzrdies*, pp. 33–59 (1898); H. B. Wright, *The Campaign of Plataea* (New Haven, Conn., 1904); R. W. Macan, *Herodotus*, vii–ix, appendix (London, 1908); W. XI. Leake, *Travels in Northern Greece*, ch. xvi, pp. 323–367 (London. 1835); *Amer. Journ. of Archaeology*, pp. 445–475 (1890), pp. 390–405 (1891). (M. C.)

PLATE GLASS: *see* GLASS.

PLATEN-HALLERMÜNDE, AUGUST, GRAF VON (1796–1835), German poet and dramatist who opposed romanticism and in his own work aimed at classical purity of style, was born Oct. 24, 1796, at Ansbach. He entered the Bavarian life guards in 1814, and took part in the campaign in France in 1815. After a tour in Switzerland and the Bavarian Alps: he entered the University of Wurzburg in 1818 as a student of philosophy and philology. In 1819 he moved to Erlangen, where he studied under the philosopher of romanticism; F. W. von Schelling, and made the acquaintance of Jean Paul, Jacob Grimm. the oriental scholar and poet Friedrich Riickert, Goethe and Ludwig Chland. He became a first-rate scholar and as a result of his oriental studies he published a little volume of poems. *Ghnselen* (1821). in which he imitated the style of Ruckert. This was followed by *Lyrische Blatter* (1821), *Spiegel der Hafis* (1822), *Vermischte Schriften* (1822) and *Neue Ghaselen* (1823).

Though Platen was at first influenced as a dramatist by the romantics and particularly by Spanish models, the plays he wrote while at Erlangen (*Der glaserne Pantoffel, Der Schatz des Rhampsinit, Berengar, Treue um Treue, Der Turm mit sieben Pforten*) show a clearness of plot and expression foreign to the romantic style. His antagonism to romanticism became more pronounced. and he attacked its extravagances, particularly the *Schicksaldrama*, or fate drama, in the witty "Aristophanic" comedies *Die verhangnisvolle Gabel* (1826) and *Der romantische Oedipus* (1829). *Der romantische Oedipus* earned him the enmity of Karl Immermann, whose work was ridiculed in it, and of Heinrich Heine, a close friend of Immermann, but he had many admirers, who delighted in the classical purity of his plays and their polished form and diction. After 1826 he lived in Italy, and his last play, *Die Ligu von Cambrai* (1833), and the epic fairy tale *Die Abbassiden* (1834), were written at Naples. He died at Syracuse, Dec. 5, 183j. Platen's odes and sonnets, and his *Polenlieder* (1831) expressing sympathy for the Poles in their rising against the tsar's rule, are among the best classical poems of their time.

Platen's *Gesammelte Werke* were published in one volume in 1839. There is a critical edition in 12 vol. by M. Koch and E. Petzet (1910). His *Tagebücher* (1813–3j) were edited by G. von Laubmann and L. von Scheffler, 2 vol. (1896–1900); his correspondence by L. von Scheffler and P. Bornstein, 4 vol. (1911–31).

See R. Schlosser, *August Graf von Platen*, 2 vol. (1910–13); F. Redenbacher, *Platen-Bibliographie* (1926). (A. Gs.)

PLATERESQUE, the earliest of the styles of Spanish Renaissance, so called either because the Renaissance found its first popular Spanish expression in silverware (*platero*, "silversmith") or because its rich and delicate ornament resembled silversmith work. It is characterized by the application to structurally simple forms of extremely rich ornament, distantly based on Italian Renaissance forms, using pilasters, entablatures, carved rectangular panels, shallow niches, much heraldic ornament and richly pierced. scrolled cresting. Its courtyards, usually with two or more openings on the upper floor, above a single opening below, are famous for their decorated columns, sometimes simulating balusters, their bracketed capitals and their graceful delicacy. As a result of Moorish influence there is a common tendency to carry the decoration around the door over the full height of the wall above. Decorative ironwork. as in the church *rejerias* or open metal screens, was highly developed. The style embraces, generally, the first half of the 16th century, but its decorative ideals influenced not only the classic period which followed but the baroque as well. Characteristic examples are the hospital of Santa Cruz, Toledo, by Enrique de Egas (1504–16), the college at Alcalá de Henares, the university and Irish college at Salamanca. the Casa de las Conchas at Salamanca and the Infantada at Guadalajara. *See* RENAISSANCE ARCHITECTURE. (T. F. H.)

PLATE RIVER: *see* PLATA, RÍO DE LA.

PLATFORM TENNIS is a combination of tennis and squash invented in 1928 by Fessenden Blanchard and James Cogswell at Scarsdale. N.Y. The game is played on specially constructed 60 × 30 ft. wooden platforms. The platform is surrounded by back and side stops of tightly strung wire which are 12 ft. high. The actual court measures 44 × 20 ft. and the net is 2 ft. 10 in. at centre. The paddles or bats, which are used instead of racquets. are oval plywood, metal-bound and perforated, and have short handles. Balls are made of sponge rubber. The rules are the same as tennis with two principal exceptions: balls may be taken off wires. after first striking inside the proper court, and only one serve is allowed.

Since its inception it has gained considerable popularity in the United States. (F. S. BD.)

PLATINUM is a chemical element which is a very heavy precious silver-white metal. It is the best known and most widely used of the six platinum metals. (*See* PLATINUM METALS and the articles on individual elements, IRIDIUM, OSMIUM, PALLADIUM, RHODIUM and RUTHENIUM.) The chemical symbol for platinum is Pt, atomic number 78 and atomic weight 195.09. The usefulness of this metal is due to its resistance to corrosion or chemical attack and to its high melting point of 1,773° C. For example, when brought to a white heat in air, it retains its bright surface. It is scarcely attacked by simple acids but does dissolve readily in aqua regia ($HCl;HNO_3$). With such a high melting point platinum is not easily fused or cast. In the fabrication of metal a sponge is commonly prepared by decomposition of its compounds. The sponge can be hammered and welded at a white heat into massive sheets and various objects. The massive metal has the very high specific gravity of 21.46. However, it is soft and ductile, and thereby unsuited for many purposes. Small amounts of iridium are commonly added to give a harder, stronger alloy which retains the advantages of the platinum. The boiling point of platinum is estimated to be 4,500° C., but the loss of weight of the solid by volatilization above 1,000° C. is very gradual but detectable.

Platinum did not receive general recognition in ancient times. Large deposits as heavy river sands were uncovered in the 16th-century Spanish conquest of South America. The Spaniards called the new metal *Platina del Pinto* after the Rio Pinto, from which its present name was taken. Samples of the element received the general attention of European scientists in the latter 18th century. Platinum occurs in native alloys which frequently contain smaller amounts of other platinum metals. It is recovered as a by-product in a number of metallurgical operations for the production of copper, nickel, lead and other metals.

Uses.—Platinum and its alloys are indispensable in the chemical laboratory for crucibles and dishes in which materials can be heated to high temperatures. However, some caution must be used, for it is attacked and alloyed by carbon, phosphorus, silicon and some low-melting metals such as lead, arsenic and antimony. Besides these metals it alloys readily with other platinum metals and with copper, gold and silver. Caustic alkalis at high temperature must be avoided, although alkali carbonates may be fused in platinum ware.

Platinum is used in the preparation of electrical contacts and sparking points because it resists the high temperature and chemical attack of electric arcs. The manufacture of jewelry and dental alloys consumes large amounts of the metal. The prototype international standard metre of length and standard kilogram of mass together with several national copies have been made from the alloy, 90% platinum and 10% iridium. Fine laboratory weights are frequently electroplated with platinum. Platinum electrodes are used in the important electrolytic preparation of hydrogen peroxide, strongly oxidizing salts and acids which corrode other metals. Electrodes of platinum also serve for quantitative electroplating operations in chemical analyses.

The electrical resistance and its temperature coefficient for platinum are relatively high for a metal, and the resistance of coils of exceptionally pure platinum wire therefore gives a precise measure of temperature. The international temperature scale from − 190° C. to 660° C. is defined in terms of such a platinum resistance thermometer. At higher temperatures, from 660° C. to 1,063° C. (the melting point of gold), the international temperature scale is defined by the electromotive force of a thermocouple with a wire of pure platinum against another of the alloy, 90% platinum and 10% rhodium. The coefficient of thermal expansion of platinum is low for a metal and near to those of soft glasses, so that thin electrical leads of the metal can be conveniently sealed through glass walls.

Platinum metal surfaces are exceptionally good catalysts for many chemical reactions, especially for reactions which involve the gases hydrogen or oxygen. For this purpose thin deposits of the metal may be formed on an inert supporting material, or fine gauze may be utilized. Also, very finely divided platinum black can be prepared by the reduction of solutions of its compounds or may be deposited by electrolysis on platinum sheet. Large quantities of platinum, which were used to catalyze the oxidation of sulfur dioxide in the manufacture of sulfuric acid, have been mostly replaced by vanadium oxide and other materials; but platinum gauzes serve as catalyst when ammonia is burned in air to yield nitric oxide in the manufacture of nitric acid. Vapours of hydrocarbons or alcohols in air ignite spontaneously, sometimes explosively, on these surfaces. The platinum catalysts can be used in the laboratory for hydrogenation or reduction of organic compounds. The catalytic properties of a platinum-black electrode allows the reversible oxidation of hydrogen gas. and the resultant hydrogen electrode serves as the standard reference electrode for potentials in electrochemistry. Bright platinum wires in ionic solutions function as reversible electrodes for a number of oxidation-reduction systems.

Platinum Compounds.— Platinum forms important series of compounds with the oxidation states of + 2 and + 4. Many of these compounds contain co-ordination complexes in which chloride, ammonia or other groups are bonded covalently to a central platinum atom. There are bonds from a platinum atom to six groups arranged symmetrically around it toward the corners of an octahedron for the + 4 state. For compounds of + 2 platinum, four bonds are commonly directed toward the corners of a square, a geometrical arrangement which can occur in chemical systems only under special circumstances of electronic configuration. Complexes of both oxidation states are kinetically inert in that groups are replaced slowly. The preparation of numerous isomers (complex compounds with the same composition, for example, Peyrone's chloride, *cis*-$[Pt(NH_3)_2Cl_2]$, Reiset's second chloride, trans-$[Pt(NH_3)_2Cl_2]$, and Magnus' green salt, $[Pt(NH_3)_4]$-$[PtCl_4]$), provided an important stimulus to the evolution of theories concerning structural arrangements of atoms (stereochemistry). All the compounds of platinum are readily decomposed or reduced to the metal. Many of their aqueous solutions decompose with an appreciable rate below boiling temperature.

When platinum dissolves in aqua regia, hexachloroplatinic (IV) acid, H_2PtCl_6, is formed. The slightly soluble yellow potassium and ammonium hexachloroplatinate (IV) are readily precipitated and are useful in analysis. Pure sponge metal is usually prepared by ignition of $(NH_4)_2PtCl_6$. Heated with sodium hydroxide, hexachloroplatinic (IV) acid gives soluble $Na_2Pt(OH)_6$ which yields yellow hydrous hydroxide when neutralized with weak acid. The hydroxide can be dehydrated to give black PtO_2. Electrolysis of the alkaline solutions gives a hydrous oxide corresponding to a higher oxidation state. Hydrates of hexachloroplatinic (IV) acid can be crystallized; and if the crystals are heated to 300° C. in an atmosphere of chlorine, a reddish-brown $PtCl_4$ is formed,

$PtCl_4$, heated to above 360° C., yields a green-brown platinum (II) chloride, $PtCl_2$, which is insoluble in water but dissolves very slowly in HCl solutions to give the red solution of tetrachloroplatinic (II) acid, H_2PtCl_4. This acid is readily prepared by the reduction of H_2PtCl_6 with sulfur dioxide. When alkali is added to a solution of a tetrachloroplatinate (II), a hydrous black platinum (II) hydroxide is precipitated. It can be dehydrated to gray PtO with some decomposition to metal. Hydrogen sulfide precipitates a black sulfide, PtS. (D. S. MN.)

PLATINUM METALS are a group of six chemical elements, including platinum, which are generally found together in nature with varying proportions in the metallic form. The elements are listed in the accompanying table together with their important atomic and physical properties.

The group is naturally divided into light and heavy triads of three elements each. For each light element there is a heavy element whose atomic number is greater by 32. The two elements in each such pair belong to the same family of the periodic table of elements so that three families are represented. As is normally the case, elements of the same family have strikingly similar chemical and physical properties. Although some similarities are noted among the entire group, there are wide differences in the chemical behaviour between different families. The six platinum metals are included together with iron, cobalt and nickel as Group VIII of the periodic table of elements.

Each of the individual elements is a silver-white metal. Although none melt below a white heat, there is still a wide range in the melting points. With such high melting points they are difficult to fuse or cast. Their boiling points can only be estimated roughly from extrapolations of vapour pressure measurements. The specific gravities of the light triad fall in the narrow range of 12.0–12.5; the heavy triad are exceptionally dense.

Osmium and iridium, whose densities are equal within the experimental accuracy, are the densest terrestrial materials known. Platinum and palladium are soft, ductile and easily worked; the other members are hard and difficult to work in the cold. However iridium and rhodium can be worked at a white heat. An important common property of the group is the instability of their chemical compounds which are readily decomposed or reduced to yield the free elements in the form of a metal sponge or powder. Chemists accordingly classify all members of the group as noble metals.

History and Occurrence.— None of the platinum metals received widespread recognition in ancient times, although artifacts containing platinum have been uncovered occasionally by archaeologists. Large deposits of platinum were first recognized in South America during the 16th-century Spanish conquest. The Spanish government originally held a low regard for the metal because its high density permitted the preparation of counterfeits for gold which were difficult to detect. The new metal came to the general attention of European scientists in the late 18th century. Within the two-year period 1803–04 the discoveries of four new elements from crude platinum were announced in England—palladium and rhodium by William Wollaston and osmium and iridium by Smithson Tennant. Although other elements were thought to be contained in crude platinum at times, Carl Claus in Russia demonstrated the existence of the remaining rare metal of the platinum group in 1844. He chose for it the name ruthenium, which G. W. Osann had suggested earlier.

Since compounds of all the platinum elements are readily decomposed to give dense metals, it is not surprising that the six elements have been concentrated together as native alloys by geological processes. The earliest deposits to be worked were heavy river sands which had been concentrated by gravity. Primary deposits of the metals dispersed in basic and ulrrabasic igneous rocks have since been productive. They are normally accompanied by other elements such as gold, and compounds of iron and nickel. Platinum metals are sometimes included in sulfide deposits and are recovered as by-products in the metallurgical operations for copper, nickel and other metals. The earliest workings of platinum were in Colombia and Brazil. In 1819 platinum was discovered in the Ural mountains. and since about 1825 Russia has been a dominant producer of the metals. For a period, 1828–41, coins were minted from a platinum-iridium alloy in Russia. Limited occurrences have been found in many areas of the world. Ores

Atomic and Physical Properties of the Platinum Metals

Metal	Ruthenium	Rhodium	Palladium	Osmium	Iridium	Platinum
Symbol	Ru	Rh	Pd	Os	Ir	Pt
Atomic number	44	45	46	76	77	78
Atomic weight	101.1	102.91	106.7	190.2	192.2	195.09
Mass number of stable isotopes	96, 98, 99, 100, 101, 102, 104	103	102, 104, 105, 106, 108, 110	184, 186, 187, 188, 189, 190, 192	191, 193	190*, 192, 194, 195, 196, 198
Outer electron configuration	$4d^7 5s^1$	$4d^8 5s^1$	$4d^{10}$	$5d^6 6s^2$	$5d^9$	$5d^9 6s^1$
Ionization energy (electron volts)	7.5	7.7	8.33	8.7	[illegible]	8.96
Structure	hexagonal close-packed	cubic close-packed	cubic close-packed	hexagonal close-packed	cubic close-packed	cubic close-packed
Density (g./cm.^{3} at 20° C.)	12.38	12.42	12.03	22.56	22.56	21.46
Metallic radius (C.N. 12) (angstroms)	1.34	1.34	1.37	1.35	1.36	1.39
Melting point (° C.)	2,450	1,980	1,550	2,700	2,450	1,773
Boiling point (° C.)	>2,700	>2,500	>2,500	>5,300	>4,800	>[illegible]
Specific heat (cal/g.deg. C.)	0.0551	0.0589	0.05838	0.0310	0.0307	[illegible]

*Possibly radioactive.

from the Union of South Africa and the nickel ores of the Sudbury, Ont., area have given especially high continued yields. Because sources of the elements are limited, the metals command high prices which have fluctuated widely.

In atomic energy reactors isotopes of the light triad are formed together with more than 30 other elements as products of the nuclear fission of uranium, plutonium or thorium. It is necessary to eifect their removal from the fissionable materials and sometimes from other fission products under difficult conditions imposed by the radiation hazards for large-scale applications of atomic energy.

Uses; — Platinum is the most readily available and widely used of the metals in the group. Its utility depends mostly upon its high melting point and its resistance to chemical attack by the atmosphere and by many chemical agents. The metals are used in the electrical industry for resistors, contacts and sparking points. In the chemical industry and laboratory they are used for dishes, crucibles, electrodes, nozzles and other objects which must resist corrosion. Also large quantities are consumed for dental alloys and decorative purposes in jewelry. The surfaces of these metals are extremely active catalysts for a number of chemical reactions. Therefore they are widely used in the laboratory and in industry to accelerate chemical reactions despite their high cost. However, unless wastage is very small, cheaper materials, which may be less effective catalysts, are frequently used.

Chemical Properties. — Platinum can be heated to a white heat in air without losing its bright surface. It k not attacked by simple acids but does dissolve readily in aqua regia. None of the metals in the massive form is appreciably oxidized by the atmosphere at room temperature. However, when heated in air osmium is converted to the tetraoxide, OsO_4, a volatile poisonous compound (boiling point 131° C.) with an unpleasant odour; and ruthenium oxidizes to give RuO_2. The other elements oxidize only superficially in the air. Palladium slowly dissolves in concentrated nitric or sulfuric acid, and osmium forms OsO_4 with fuming nitric acid. Even aqua regia scarcely attacks ruthenium, rhodium or iridium. A fused mixture of sodium hydroxide and sodium nitrate is an effective agent which will oxidize all of the elements.

A few examples suffice to show the wide differences in chemical properties among the group. Osmium and ruthenium are alone among all known elements in forming a few well-characterized compounds with the +8 oxidation state, for example RuO_4, OsO_4, OsF_8 and $KOsO_3N$. The volatility of the tetraoxides permits convenient, efficient and rapid separation of these two elements.

All the platinum metals can form compounds with more than one oxidation state. For ruthenium there is evidence for compounds in every oxidation state from +1 through +8. However both ruthenium and osmium are normally encountered in the states +3, +4, +6 or +8. In contrast, rhodium is limited with a few exceptions to the +3 oxidation state, whereas iridium forms important compounds for the +3 and +4 states. Palladium and platinum compounds are largely confined to the +2 and +4 states, the latter being very unstable for palladium.

All the platinum elements are characterized by a tendency to form co-ordination complexes in which chloride, ammonia, water or other groups are bonded covalently to the central metal ion. Replacements of one group by another, especially in the complexes of the heavy triad, are frequently slow.

Separation.—Processes for the recovery of the metals from the ores remain somewhat as trade secrets of individual firms and depend partly upon the composition and nature of metallurgical concentrates which must be handled. Commonly, at one step a mixture of the metals is dissolved in aqua regia. However, the mineral osmiridium, an alloy rich in osmium and iridium, is not dissolved by aqua regia. If it is heated with zinc it yields an alloy which is acid-soluble. The osmium distils away from the aqua regia solution as OsO_4 upon boiling. NH_4Cl added to an HCl solution of the remaining elements precipitates $(NH_4)_2PtCl_6$ and $(NH_4)_2IrCl_6$. These two compounds can be separated by repeated fractional crystallizations of the less soluble platinum compound. After platinum and iridium are removed, a precipitate of $[Pd(NH_3)_2Cl_2]$ can be formed by the addition of aqueous ammonia followed by HCl. If the remaining material in solution is reduced to metal and treated with fused potassium hydrogen sulfate. the rhodium is recovered as a soluble complex sulfate. $K_3Rh(SO_4)_3$. A ruthenium concentrate which remains can best be dissolved by a potassium hydroxide-potassium nitrate fusion and purified by a distillation procedure.

BIBLIOGRAPHY.—R. F. Vines, *The Platinum Metals and Their Alloys* (1941); C. A. Hampel, *Rare Metals Handbook, ch.* 15 (1954).
(D. S. MN.)

PLATO (428/427–348/347 B.C.), Greek philosopher whose influence on thought has been continuous for more than 2,400 years. was the son of Ariston and Perictione. His family was, on both sides. one of the most distinguished of Athens. Ariston is said to have traced his descent through Codrus to the god Poseidon; on the mother's side. the family. that was related to Solon, goes back to Dropides, archon of the year 644 B C. Perictione apparently married as her second husband her uncle Pyrilampes (*Parmenides* 126 *b*) a prominent supporter of Pericles. and Plato was probably chiefly brought up in his house: Critias and Charmides, leading men among the extremists of the oligarchic terror of 404, were respectively cousin and brother of Perictione; both were old friends of Socrates, and through them Plato must have known the philosopher from boyhood

His own early ambitions as he tells us in the *Epistle* vii. 324 *b*–326 *b*, were political The reactionaries urged him to enter public life under their auspices—at the age of 24—but he wisely held back until their policy should declare itself. He was soon repelled by their violences, particularly by their attempt to implicate Socrates in the illegal execution of their victim Leon. He hoped better things from the restored democracy, but its condemnation of Socrates finally convinced him that there was no place for a man of conscience in active politics. Hermodorus, an immediate disciple. is the authority for the statement that, on the execution of Socrates in 399 B.C., Plato and other Socratic men took temporary refuge with Eucleides at hlegara. The later biographies represent the next few years as spent in extensive travels in Greece, in Egypt and in Italy. Plato's own statement is only that he visited Italy and Sicily at the age of 40 and was disgusted by the gross sensuality of life there, but found a kindred spirit in Dion, brother-in-law of Dionysius I of Syracuse.

The Academy and Sicily. — About or soon after 387, Plato founded the Academy as an institute for the systematic pursuit of philosophical and scientific research. He presided over it for the rest of his life, making it the recognized authority alike in mathematics and in jurisprudence. From the allusions of Aristotle we gather that Plato lectured without manuscript, and we know that "problems" were propounded for solution by the joint researches of students. On the political side there are traces of tension between the Academy and the rival school of Isocrates.

The one outstanding event in Plato's later life is his intervention in Syracusan politics. On the death of Dionysius I in 367, Dion conceived the idea of bringing Plato to Syracuse as tutor to his successor, whose education had been neglected. Plato himself was not sanguine of results, but as both Dion and the philosopher-statesman Archytas of Tarentum thought the prospect promising, he felt bound in honour to risk the adventure The project was by training Dionysius II in severe science to fit him for the position of a constitutional king who might hold Carthaginian encroachment in Sicily at bay. The scheme was crushed by his natural jealousy of the stronger Dion, whom he drove into virtual banishment. Plato paid a second and longer visit to Syracuse in 361–360, in the hope of still eifecting an accommodation, but failed, not without some personal danger. When Dion captured Syracuse by a *coup de main* in 357, Plato wrote him a short letter of congratulation and warning against his own lack of tact and graciousness. After the murder of Dion in 354 the philosopher drew up his important *Epistles* vii and viii. reviewing and justifying the policy of Dion and himself and making proposals, unsuccessfully, for a conciliation of Sicilian parties.

The prejudice which led students in the 19th century to discredit the *Epistles,* in spite of the favourable opinion of scholars such as Richard Bentley, C. G. Cobet, George Grote, F. Blass and E. Meyer, worked havoc with their accounts of Plato's life. It is safe to say that the two letters of chief biographical importance, vii and viii, have the best claim to authenticity, i and xii the weakest.

To us Plato naturally is important primarily as one of the greatest of philosophical writers, but to himself the foundation and organization of the Academy must have appeared his chief work. In *Epistle* vii, 341 *b–e,* 344 *c,* he utters on his own account the same comparatively unfavourable verdict on written works, in contrast with the contact of living minds, as a vehicle of "philosophy," which he ascribes to Socrates in the *Phaedrus.* It can hardly be doubted that he regarded his dialogues as intended in the main to interest an educated outside world in the more serious and arduous labours of his "school."

All the most important mathematical work of the 4th century was done by friends or pupils of Plato. Theaetetus, the founder of solid geometry, was a member of the Academy, as were also the first students of the conic sections. Eudoxus of Cnidus, author of the doctrine of proportion expounded in Euclid's *Elements,* inventor of the method of finding the areas and volumes of curvilinear figures by exhaustion and propounder of the astronomical scheme of concentric spheres adopted and altered by Aristotle, removed his school from Cyzicus to Athens for the purpose of cooperation with Plato. Archytas, the inventor of mechanical science. was a friend and correspondent. The Xcademy is thus the link between the mathematics of the 5th-century Pythagoreans and those of the geometers and arithmeticians of Alexandria.

Nor were other sciences neglected. Speusippus, Plato's nephew and successor, was a voluminous writer on natural history; Aristotle's biological works have been shown to belong largely to the early period in his career immediately after Piato's death, before the breach between the younger philosopher and the Xcademy. The comic poets found matter for mirth in the attention of the school to botanical classification. The Academy was particularly active in jurisprudence and practical legislation. "Plato sent Aristonymus to the Arcadians, Phormion to Elis, Menedemus to Pyrrha. Eudoxus and Aristotle wrote laws for Cnidus and Stageirus. Alexander asked Xenocrates for advice about kingship; the man who was sent to Alexander by the Asiatic Greeks and did most to incite him to his war on the barbarians was Delius of Ephesus, an associate of Plato." (Plutsrch. *Adversus Coloten,* i126 *c–d).* The creation of the Academy as a permanent society for the prosecution of both exact and humane sciences was, in fact, the first establishment of a university. *(See* ACADEMY, GREEK.)

Formative Influences.—The most important formative influence to which the young Plato's mind was exposed was that of Socrates. But it does not appear that Plato. whose first ambitions were political. belonged to the innermost circle of the old man's intimates. or regarded himself as a "disciple." In *Epistle* vii he is careful to speak of Socrates not as a "master" but as an older "friend" *(hetairos)* for whose character he had a profound respect; and he has recorded his own absence (through indisposition) from the death scene of the *Phaedo.* It would seem that his own vocation to philosophy dawned on him only afterward, as he reflected on the moral to be learned from the treatment of Socrates by the democratic leaders. Aristotle incidentally ascribes to him an early familiarity with the Heraclitean Cratylus, a younger man than Socrates and apparently an admirer of the philosopher. This may be only Aristotle's inference from the existence of the dialogue *Cratylus.* It is more important to remember Plato's connection with Pyrilampes and Critias. Pyrilampes was a Periclean politician, and Critias was known as a democrat until his moral balance was upset by the collapse of the Periclean system in 404. Early upbringing in a family of Periclean politics having connection with Solon may explain why Plato's own estimate of democracy in the *Politicus* and *Laws* is much less unfavourable than that which he ascribes to Socrates in the *Gorgias* and *Republic.*

Beyond this, we can say only that Plato in early life must have been exposed to the same influences as his contemporaries. His early experiences covered the disastrous years of the Deceleian War, the shattering of the Athenian empire and the fierce civil strife of oligarchs and democrats in the year of anarchy 404–403. He was too young to have known anything by experience of the imperial democracy of Pericles and Cleon, or of the full tide of the sophistic movement. It is not from memory that he depicts Protagoras, or even Alcibiades, as they were in their great days.

THE DIALOGUES

The fixing of the canon and text of Plato has often been attributed to two scholars, Dercylides and Thrasylus, either shortly before or shortly after the Christian era (but *see* ACADEMY, GREEK). Thrasylus is uncertainly identified with Thrasylus of Mende and generally assumed to have been astrologer to and friend of Tiberius. By reckoning the *Epistles* as one item, the list was made to consist of 36 works, arranged in nine tetralogies, or groups of four. (Aristophanes of Byzantium had already attempted an arrangement in trilogies, or groups of three, which, however, he did not carry through.)

No genuine work of Plato has been lost, but there is a general agreement of modern scholars to reject a number of small items from the text. Their verdict may be said to have gone definitely against the following: *Alcibiades* I, *Alcibiades II* (suspected by some even in ancient times), *Theages, Erastae, Clitophon, Hipparchus, Minos.* Most or all of these are probably early Academic work, and possibly not all later in date than Plato's death. Most, though not all, contemporary scholars also regard the *Epinomis*—in the present writer's opinion wrongly—as an appendix to the *Laws* added *de suo* by the mathematician Philippus of Opus, who is recorded by Diogenes Laertius (iii, 37) to have transcribed the work for circulation. The *Hippias Major* and the *Menexenus* are still regarded as doubtful by some, though Aristotle used both in a way which seems to prove that he regarded them as Platonic (he expressly quotes the *Menexenus*). Plato's will, preserved by the same Diogenes (iii. 41–43), is pretty certainly authentic. Some of the 32 epigrams ascribed to him in the *Anthology* may conceivably be genuine.

Order of **Composition.**—Plato's literary career extended over the greater part of a long life. The *Apology* must have been written while the memory of Socrates' appearance before his judges was still fresh; the *Laws* is confessedly the work of an old man with a long experience of life behind him, and the state of its text fully bears out the tradition, preserved by Proclus, that its aged author never lived to give it final revision. Half a century or more must have elapsed between Plato's last and his earliest composition.

This of itself would prove that F. Schleiermacher, with whom modern critical study of Plato begins, went astray in assuming that Plato started his career with a ready-made complete "system' to be disclosed. We must expect to find in his writings evidence of the development of his mind. But if we are to read the development aright we must have some trustworthy way of determining the order of the dialogues. Plato himself has given us only the scantiest indications of the order. He has linked the *Sophistes* and the *Politicus* externally with the *Theaetetus* as continuations of the conversation reported in that dialogue; he has also, as most students recognize, linked up the *Timaeus* in the same way with the *Republic*. Aristotle adds one other piece of information, that the *Laws* were written after the *Republic*.

Further investigation of the problem opens in 1867 with L. Campbell's edition of the *Sophistes* and the *Politicus*, and the work thus begun was continued by others, notably W. Dittenberger, M. Schanz, C. Ritter, H. Arnim and W. Lutoslawski.

By consideration of independent stylistic criteria, it has been definitely established that the dialogues *Sophistes, Politicus, Philebus, Timaeus* (with its fragmentary sequel *Critias)* and *Laws* form a distinct linguistic group, which must belong to the later years of Plato's life, as we might have presumed from the consideration that Socrates, the central figure of other dialogues, becomes, in those of this group (with a solitary exception for the *Philebus*, the one member of the group which is wholly preoccupied with ethics), a secondary personage, and disappears altogether from the *Laws*. The whole group must therefore be later than the *Sophistes*, which professes to be a sequel to the *Theaetetus*. Now the *Theaetetus* can be dated with some accuracy, since it commemorates the recent death of the eminent mathematician after whom it is named from disease and injury contracted in a campaign before Corinth, which, as elaborately proved by Eva Sachs *(De Theaeteto Atheniensi,* 1914), must be that of 369 B.C. The dialogue may thus be safely ascribed to 368–367, the eve of Plato's departure for Syracuse, and the marked change of style visible in the *Sophistes* is best explained by the supposition that there was a break in Plato's literary activity during the years 367–360 when he was specially occupied with Sicilian affairs. So much may be regarded as fairly certain.

It is not so easy to reach conclusions about the order of composition of the earlier group of dialogues. It is generally recognized, on linguistic and other grounds, that the series ends uith the *Theaetetzrs* and the closely related *Parmenides*. Ritter, Lutoslawski and others tried to determine the internal order of the group on linguistic evidence, but there are obvious reasons for doubting whether the methods which proved successful in establishing the distinction between the two great groups of earlier and of later dialogues can be applied with the same confidence to works belonging to the same general period of their author's life and composed probably at no great distance of time from one another.

In point of fact, there is no complete agreement between the arrangements proposed by different "stylometrists," and their advocates have usually eked out the strictly philological argument by more or less dubious assumptions about the development of Plato's thought, though it is very questionable whether any real development can be traced before the *Theaetetus* and the *Parmenides*. Perhaps all that can be said with certainty is that the great outstanding dialogues, *Symposium, Phaedo, Republic* (and perhaps also *Protagoras),* in which Plato's dramatic power is at its highest, mark the culmination of this first period of literary activity. The comparative decline of dramatic power, accompanied by compensating maturity of critical acumen, is the most striking contrast between the dialogues of the second and those of the first period. A good account of the work done by the "stylometrists" is to be found in H. Raeder, *Platons philosophische Entwickelung* (1905), another in an article by C. Ritter in *Bursians Jahresbericht,* vol. 187, i (1921).

The Persons of the Dialogues. — The great initial difficulty which besets the modern student of Platonic philosophy is that created by the dramatic form of Plato's writings. Since Plato never introduces himself into his own dialogues, he is not formally committed to anything which is taught in them. The speakers who are formally bound by the utterances of the dialogues are their protagonists, Socrates, Parmenides, the Pythagorean Timaeus, and all these are real historical persons. The question thus arises, with what right do we assume that Plato means us to accept as his own the doctrines put into the mouths of these characters? Is his purpose dogmatic and didactic, or may it be that it is mainly dramatic? Are we more at liberty to hold Plato responsible for what is said by his dramatis personae than we should be to treat a poet like Browning in the same fashion?

It is tempting to evade this formidable issue in one of two mays. One is that of Grote, who held that Plato allows himself freely to develop in a dialogue any view which interests him for the moment, uithout pledging himself to its truth or considering its compatibility with other positions assumed elsewhere in his writings. Thus, according to this theory, Plato can make Socrates tolerate hedonistic utilitarianism in the *Protagoras* and denounce it in the *Gorgias,* or can assert the so-called ideal theory through the mouth of Socrates in the *Phaedo* and refute it in the character of Parmenides in the dialogue of that name, with equal gusto and without pledging himself to any view. His championships are purely dramatic, or, at most, reflect his passing mood at the moment of composition.

The more common assumption of the 19th century was that some of Plato's characters. notably Socrates and Timaeus, are "mouthpieces" through whom he inculcates tenets of his own, without concern for dramatic or historical propriety. Thus it was and often still is held that the most famous philosophical doctrines of the *Phaedo* and *Republic,* the "ideal theory." the doctrine of "recollection" and of the tripartite soul, were actually originated by Plato after the death of Socrates (to whom these speculations were supposed to be entirely unknown) and consciously fathered on the older philosopher by a mystification too glaring to deceive any one seriously. Careful study of the dialogues should satisfy us that neither of these two extreme views is tenable.

The Thought of the Earlier and Later Dialogues. — There is undeniably a real difference between the thought of the dialogues which are later than the *Theaetetus* and those which are earlier, and this difference will have to be accounted for. But there are no serious discrepancies of doctrine between the individual dialogues of the same period.

Now Plato seems to announce his own personal conviction of certain doctrines of the second group of dialogues by a striking dramatic device. In the *Sophistes* and *Politicus* the leading part is taken by an Eleatic and in the *Laws* by an Athenian who are the only anonymous, indeed almost certainly the only imaginary, personages in the whole of Plato's writings (except the two minor personages of the *Laws*, a Spartan and a Cretan, who have really nothing to do except to say "Yes," "No," in the appropriate places). It can hardly be doubted that the reason why these two characters have been left anonymous is precisely that the writer may be free to use them as "mouthpieces" for his own teaching. Plato thus takes on himself the responsibility for the logic and epistemology of the *Sophistes* and of the *Politicnrs* and for the ethics and educational and political theory of the *Politicus* and of the *Laws* in a specially marked way, and by doing so compels us to face the question how far he means the utterances of Socrates in his earlier dialogues to be taken as expressions of a philosophy of his own.

Forms. — It may be regarded as an established result of the inquiries of Henry Jackson and others that there is a definite philosophical doctrine running through the earlier dialogues which has as its main features the theory of "Forms" (the ideal theory; *see* FORM), the theory that knowledge is "recollection" and the theory of the "tripartite soul." In the dialogues of the second period these tenets, as we have learned to know them from the earlier dialogues, appear only in the mouth of Timaeus, a 5th-century Pythagorean older than Socrates; and the most important of them all, the theory of "Forms" is actually made the object of what looks like a refutation in the *Parmenides*.

The problem is to find an explanation of this puzzling fact. Are we to distinguish two philosophies, both originated by Plato after the death of Socrates, an earlier and a later? Or are we to suppose that in the main the object of the first group of Plato's dialogues is to preserve the memory of Socrates and that the philosophy expounded is in the main what it professes to be, the thought of Socrates, coloured, no doubt, unconsciously but not consciously distorted, in its passage through the mind of Plato? On the second view we should have to say that, strictly speaking, Plato had no distinctive Platonic philosophy until a late period in his life, much as we can say that, though Kant mas all through his life a prolific writer on philosophy, there was no distinctive Kantian philosophy before the *Critique of Pure Reason.* Most Platonic scholars are still unwilling to accept this interpretation of the facts, though there are weighty considerations which plead strongly for it.

Socrates and **Plato.**—It is significant that the only dialogue not earlier than the *Theaetetus* in which Socrates takes a leading part is the *Philebus*, the one member of the second group which deals exclusively with those ethical problems on which the thought of the historical Socrates had been specially concentrated. This is most naturally explained by supposing that Plato, from regard to fact, was unwilling to make Socrates the exponent of doctrines which he knew to be his own property, though it is hard to understand his misgivings if he had already for years been employing him in 'that very capacity. (If, as is most probable, *Epistle* ii is authentic, the question would be definitely settled by the sentence of the latter [314 *c]* "there is not, and never will be, a work of Plato; the works which now go by that name belong to Socrates embellished and rejuvenated.")

It is notable, too, that Aristotle apparently knew nothing of an earlier and a later version of Platonism. He attributes a definite doctrine to Plato which is quite unlike anything to be found in the first great group of dialogues, and seems to be known to him from oral communications in the Academy, though something similar to it can, by looking hard, be read between the lines in the *Philebus*. It was also the view of Neoplatonic scholars such as Proclus that the ideal theory expounded in the great earlier dialogues really originated with Socrates and that something of the same kind was also held by contemporary Pythagoreans in Italy (Proclus, *Commentarii in Parmenidem,* edited by G. Stallbaum [1839], 562, 610), and the fact that Proclus does not find it necessary to argue the point seems to show that this had been the standing tradition of the Academy. Similarly Galen, early in the 3rd century A.D., cites the definite statement of the learned Stoic Poseidonius that the doctrine of the "tripartite soul," often said in modern times to be another invention of Plato's, is as old as Pythagoras *(De Placitis Hippocratis et Platorzis, 425, 478).*

Moreover, as J. Burnet argued, it is hard to believe that any writer would introduce a far-reaching novel speculation of his own to the world in the curious fashion which Plato is supposed to have adopted in the *Phaedo,* where Socrates is made to describe the ideal theory as something quite familiar which he has for years constantly canvassed with his intimates (nearly all, if not all, of whom, were certainly living when the *Phaedo* was circulated). It is not necessary here to determine the historical question. We may be content to turn to the Platonic dialogues, carefully distinguishing the successors of the *Theaetetus* from its predecessors, and attempt a summary of their contents. The general doctrine of the first period will be described without any more or less arbitrary attempt to say how much of it may be actually Socratic. We may then consider how far this doctrine is modified in later dialogues, or in the version of Platonism presupposed by Aristotle's criticisms.

No attempt will be made here to describe the personality or temperament of Plato which is, in fact, as elusive as that of Shakespeare and for the same reason. He is often credited with a strongly "mystical" and "erotic" temperament. He does ascribe such a temperament to Socrates, but it is puerile to treat his picture of Socrates as evidence about himself, though the mistake is constantly committed.

It should therefore be noted that the "mysticism" is confined to dialogues of the first period, in which Socrates is its exponent, and that the "erotic" language in which Plato's Socrates speaks of his devotion to his young friends was also used by the Socrates of Aeschines to describe his relations with Alcibiades (fragment 4, edited by H. Krauss, 1911). There is no evidence that Plato personally ever fired the imagination of gifted boys as Socrates did. Apart from the *Epistles*, the most valuable light we possess on Plato's personality is afforded by Aristotle's description of him as a man "whom it is blasphemy in the base even to praise."

The Earlier Dialogues

In the *Republic,* the greatest of all the dialogues which precede the *Theaetetus,* there may be said to be three main strands of argument deftly combined into a consummate artistic whole, the ethical and political, the aesthetic and mystical and the metaphysical. Other major dialogues belonging to this period give special prominence to some one of these three lines of thought; the *Phaedo* to the metaphysical theme, the *Pvotagoras* and the *Gorgias* to the ethical and political. the *Symposium* and the *Phaedrus* to the aesthetic and mystical, though in none does Plato make an artificially rigid separation of any one of the great ideal interests of human life from the rest.

The shorter dialogues deal with more special problems, usually of an ethical character, and mostly conform to a common type. A problem in moral science, often that of the right definition of a virtue, is propounded, a number of tentative solutions are considered and are all found to be vitiated by difficulties which we cannot dispel; we are thus left, at the end of the conversation, aware of our discreditable ignorance of the very things it is most imperative for man to know. We have formally learned nothing but have been made alive to the worthlessness of what we had hitherto been content to take for knowledge and the need of seeking further enlightenment.

The effect of these dialogues of search is thus to put us in tune with the spirit of Socrates, who had said that the one respect in which he was wiser than other men was just his keen appreciation of his own ignorance of the most important matters. We learn the meaning of his ruling principle that the supreme business of life is to "tend!' the soul (to make it as good as possible) and his conviction that "goodness of soul" means first and foremost, *knowledge* of good and evil. The three dialogues directly concerned with the trial of Socrates have manifestly a further purpose. They are intended to explain to a puzzled public why Socrates thought it stuff of the conscience neither to withdraw from danger before trial, nor to make a conciliatory defense, nor, finally, to avail himself of the opportunity of flight after conviction. Even well-wishers such as Xenophon, as we know, were puzzled by what had seemed his wilfully defiant attitude; it was therefore a debt of honour to his memory to put the matter in the true light. In the remarks which follow, we will consider these shorter dialogues in an order adopted simply for purposes of convenience.

Hippias I and 11.—In these dialogues Socrates has as respondent the well-known polymath Hippias of Elis, whose self-complacency is sharply satirized. In the *Hippias Major* the question propounded is "What is the fine" (*kalon*)? "Fine" is a predicate by which we are constantly expressing both aesthetic and moral approval; do we really know what we mean by it? We discover that we do not, though incidentally me also learn that "fine" or "beautiful" is certainly not a synonym for either "useful" or "pleasant." *Hippias Minor* deals directly with the famous Socratic paradox that "wrong-doing is involuntary." It is commonly held that it is much worse to tell a willful untruth than to blunder into an unintentional false statement. Yet the analogy of the arts and professions seems to show that the man who errs intentionally, if there is such a person, is a better man than he who errs unintentionally. (The suggested thought, of course, is that there is no such person. The man who knows what is good will always aim at this and at nothing else,—the familiar doctrine of Socrates.)

Ion, Menexenus.— Both these are occasional works. Socrates had said that he found the poets, who as a class are commonly reckoned "wise," quite unable to explain to him how they came to say their best things, or what they meant by them. *(Apology*

22 a–c.) The *Ion* develops this thought into the theory that neither the poet, nor his interpreter the rhapsode, produces his effects "by science," that is, as a result of conscious artistry; the effect in both cases is due to a nonrational inspiration, or, as we now say. native genius. (The importance of this is that it rules out appeal to the poets as specially competent authorities on the conduct of life.)

The *Menexenus,* which professes to repeat a funeral oration learned from the famous Aspasia, is apparently meant as a satire on patriotic distortion of history. Apparently the discourses satirized are those of Pericles in Thucydides, Lysias *(Oratio* ii) and Isocrates (the *Panegyricus*). The singular anachronism by which Socrates (and Aspasia) are represented as commenting on the events of the Corinthian War down to the year 387 must be intentional, whatever its object.

Charmides, Laches, **Lysis.**—These are typical dialogues of search. The question of the *Charrnides,* which contains a particularly delightful picture of the way of Socrates with a promising lad, is what is meant by *sophrosyne,* the virtue which is shown alike in graceful and easy command of one's appetites and passions, in dutiful behaviour to parents, elders, official "superiors." in balance and sanity amid the ups and downs of fortune. We seem to be in a fair way to identify this virtue with "knowledge of self"—the self-knowledge Socrates had valued so highly—when we are confronted with an ambiguity. Self-knowledge might be taken to mean a knowledge which has knowledge itself for its object, in fact for epistemology. But it is hard to be sure that there is any such science as the knowledge of knowledge and harder still to see how such knowledge could be directive of conduct.

In the *Laches* we are concerned with valour, the soldier's virtue. Here again we are on the point of defining the virtue as knowledge of what is and what is not really to be dreaded. But this is tantamount to saying the true knowledge of evil and good, and the resultant definition "valour is knowledge of good," would identify valour with the whole goodness of man. That is, the definition is only possible if we can meet the popular objections to the Socratic thesis of the unity of virtue.

The *Lysis* examines in the same tentative way, friendship, the relation in which self-forgetting devotion most conspicuously displays itself. The crux of the problem is that after many false starts, we seem to have reached a promising result in the vien that each friend is really "a part of" the other in "soul or temper or body," and yet it is hard to reconcile this position with the facts which seem to show that "unlikeness" is a potent source of attraction. Aristotle has taken up and discussed the issues raised in the dialogue in his own treatment of the same subject (*Nicomachean Ethics,* viii–ix).

Cratylus.—The question here, one much agitated in the age of Socrates, is whether names are significant by nature or convention. Is there some special appropriateness of the sounds of names to the objects called by them, or is there no bond between the thing and its name but that of the "usage of the community"? The absurdity of attempts to get metaphysics out of etymologies is humorously exposed by shoning that the method can be used at pleasure to prove either that the "giver of names" agreed with Heraclitus that motion is the sole reality or that he held, with Parmenides. that motion is an illusion. Yet there are real analogies between "vocal gestures" and the things signified by them, which are pointed out with a good deal of insight. The main purpose of Plato, however, is to dwell on the point that language is an instrument of thought; the test of its rightness is not mere social usage, but its capacity to express true thought accurately.

Euthydemus.—The dialogue is, in large part, broad satire on "eristics" nho misapply the logic of Zeno for the purpose of entangling anyone who commits himself to any assertion in fallacies because of the ambiguity of language. (Aristotle has drawn freely upon it in his essay on fallacies, the De *Sophisticis Elenchis.)* Its more serious purpose is to contrast this futile contradiction mongering with the "protreptic" of Socrates. The lad Clinias is simply bewildered by the questions of the two professors of "eristic"; those of Socrates have the purpose of convincing him that the happiness we all desire is not guaranteed by the *possession* of the things the world accounts good, but depends on our making the right *use* of them. If we would attain happiness we must "tend" our "souls." and that means that we must acquire the "royal" science which ensures that we shall make the right use of all the gifts of mind, body and fortune, in other words, the knowledge of true and absolute good.

Gorgias.—The *Gorgias* is a greater as well as a much longer work than any of those hitherto considered. Beginning ostensibly as an inquiry into the nature and worth of rhetoric, the art of advocacy professed by Gorgias, it develops into a plea of sustained eloquence and logical power for absolute right, as against expediency, as the sovereign rule of life private and public, and ends with an imaginative picture, on Orphic lines, of the eternal destinies of the righteous and of the unrighteous soul. Literature has no more impressive presentation of the claim of conscience to unqualified obedience and the impossibility of divorcing the politically from the morally right.

Gorgias holds that "rhetoric" is an "art." the application of knowledge to practice, and the queen of all "arts," since it gives its possessor the object of man's highest ambition, power to enforce his will on society. The statesman, who is the man of men, is just a consummate advocate speaking from a brief. If he is clever enough he will, though a layman, carry the day with an audience of laymen, even against the expert specialist. To his audience he will seem, though he is not, the superior of the real expert Socrates declares that "rhetoric" is not an "art," a matter of native principles, but a mere "empiric knack" of humouring the prejudices and pleasing the tastes of an audience. It is a subspecies of parasitism.

There are two genuine arts conducive to the health of the body, those of the trainer and of the physician; each has its parasitic counterfeit, the one in the profession of the beautifier, the other in that of the confectioner. So there are two arts conducive to health of soul, those of the legislator, who lays down the rule of morally sane life, and of the judge, who corrects moral disorders. The sophist counterfeits the first, as the rhetorician the second, by taking the pleasant instead of the good as his standard The rhetorician is thus not the wise physician of the body politic but its toady.

This severe judgment is disputed by Polus, the ardent admirer of Gorgias, on the ground that the successful rhetorician is virtually the autocrat of the community. every man's life and property are at his mercy. To be such an autocrat is the summit of human happiness; even if, like Archelaus of Macedonia, the aspirant only reaches the position by a series of shocking crimes, he is the most enviable of mankind. because he is above law and can do whatever he likes.

Socrates rejects this view. The autocrat always does "as he pleases," and for that reason never does "what he wishes"; as all mankind, he wishes for true happiness or good. but no act which is immoral ("unjust") ever leads to happiness. To suffer a wrong is an evil, but to inflict one is much worse. And if a man has committed a wrong, it is much worse for him to go unpunished than to be cured of his moral malady by the sharp but wholesome medicine of punishment. If rhetoric is of real service to men, it should be most of all serviceable to an offender. If he knew his own interest, he would employ all his powers of persuasion to move the authorities to inflict the penalties for which the state of his soul calls. Polus is unable to meet this reasoning. because he had at least conceded to current morality that it is more disgraceful, though not more evil. to inflict wrong than to suffer it.

This is denied by Callicles of Xcharnae, an otherwise unknown politician, who proceeds recklessly to develop the doctrine of the "will to power." It may be a convention of the herd that unscrupulous aggression is discreditable and wrong, but "nature's convention" (a phrase which appears here for the first time in literature) is that the strong are justified in using their strength as they please, while the weak "go to the wall." Callicles and Socrates thus appear as champions of two contrasted moralities of private and public life. Callicles stands for self-assertion in ethics and aggressive imperialism in politics. Socrates opposes both. In his judgment the creators of the imperialistic Athenian democracy were no true statesmen, because they were content to give Athens a navy and a commerce without creating a morally sound national character. They may have been capable domestic servants of the democracy for whose tastes they catered; they were not its physicians. The one true statesman of the past was the just Aristides; in the present, Socrates himself is the one man who shows a statesmanlike mind, though it is perfectly true that he might at any moment have to pay with his life for refusing to call that good which pleases the public fancy. It is not true, as Callicles supposes it to be, that the secret of happiness is to have strong and vehement passions and be able to gratify them to the full. That would be a condition like that of the fabled sinners who are punished in Hades by being set to spend eternity in filling leaking pitchers. The truly happy life is that of measure in which the gratification of desire is strictly regulated by regard for justice and *sophrosyne*. If we may believe the Orphic doctrine of judgment to come, the votary of passion and injustice has a heavy reckoning to await hereafter.

Meno.—The *Meno* is nominally concerned with the question of what virtue is and whether it can be taught, but it is further interesting for two reasons. It states clearly the doctrine, which me have not met so far, that knowledge is "recollection"; it also introduces as a character the democratic politician Anytus, the main author of the prosecution of Socrates. It seems plain that Plato wishes to indicate his opinion that it was Socrates' severe criticism of the great figures of the history of Athenian democracy which led to the prosecution.

Can virtue be taught or learned (as must be the case, if the professional sophists can really do what they profess)? That depends on what virtue is. We are on the way to define it as "ability to secure good things by honest means," when we reflect that honesty itself is a "good thing," and the definition consequently is circular. This reminds us of the current dilemma that all such inquiries are futile because it is idle to inquire into what you already know, useless to inquire into what you do not know (since you could not recognize the unknown, even if you found it). This difficulty would vanish if it were true that the soul is immortal and has long ago learned all truth, so that it needs now only to be reminded by sense-experiences of truths which it once knew and has forgotten. This (Orphic) doctrine seems to be supported by the experience that a lad who has never studied geometry can be brought to recognize mathematical truths by merely showing him a diagram and asking him appropriate questions about it. He produces the right answer "out of himself." (The point thus is the presence of an a priori element in mathematical truth.)

In any case, we may say that if "virtue" is knowledge, it can be taught; if it is not knowledge, it cannot. But is it knowledge? If it is, one would suppose that there must be professional teachers of it. But Anytus assures us vehemently that the sophists, who claim to be such professionals, are mischievous impostors, and we can be sure that the ordinary decent citizen cannot "teach virtue," as Anytus maintains, since the "best men" of the democracy, Themistocles and the rest. have been unable to teach it to their own sons. Perhaps, then, we must say that the "best men" of Athens have no genuine knowledge of good; their successes have been due not to knowledge, but to mere correct opinions. Still, for practical purposes a correct opinion will serve as well as knowledge. The trouble is that you cannot depend on its permanency unless you fasten it down by thinking out the reason why of it. Then it becomes knonledge. If a man should arise who could actually teach statesmanship to others, he would be one who really *knew* what good is; the virtue of such a scientific statesman would be to that of other men as substance is to shadow.

Protagoras. — This finely dramatic dialogue gives us the most complete presentation to be found in Plato of the main principles of the Socratic morality and is the direct source of Aristotle's statements about the teaching of Socrates in the *Nicomachean Ethics*.

Socrates meets, in the house of Callias, the eminent sophist Protagoras, who is attractively drawn and represented as a great admirer of the younger man's ability. Protagoras explains that his profession is the "teaching of goodness," and that by "goodness" he means the art of making a success of one's own life, of one's household and of one's city. (Thus he teaches the conduct of life. private and public. and has done so for years with success.) Socrates urges that there are two considerations which make it look doubtful whether this art can be taught. The Athenians have a high reputation for intelligence, but it is notorious that their assembly requires no evidence of expert knowledge in a speaker who discusses the morality of a proposed course of action.

Also the eminent democratic statesmen have never taught their own "goodness" to their sons. Public opinion and the practice of the eminent few alike suggest that the conduct of life is not teachable. Protagoras, to be sure, thinks that the absence of special teachers only proves that every citizen of a civilized city can, in his degree, act as teacher, exactly as he can teach his children his native language or his trade. Goodness depends on the sense of right and conscience, and the whole of life in a civilized society is a process of education in these. His exposition at once raises the problem of the unity of virtue. Are the various commonly recognized virtues really different, so that a man may be strong in one but weak in another? Protagoras is at first inclined to say that they are, but on reconsideration is ready to identify all of them but one with wisdom or sound judgment.

An exception must be made for courage, a virtue which is popularly regarded as having something conspicuously nonrational about it. The dialogue culminates in an argument by which Socrates attempts to show that there is no need to make this exception. The general public, the party which insists so much on the nonrational character of courage, mould be ready to accept the identification of the good and the pleasant and to grant that the goodness of courage means that by facing pain and danger one escapes worse pain or danger. On their own theory, then, courage and the rest of virtue can be reduced to prudent computation of pleasures and of pains. The humour of the situation is that Socrates and Protagoras have thus changed places. Socrates, who had raised a difficulty about the teachability of virtue, is left satisfied that virtue must be knowledge; Protagoras, who claimed to be able to teach it, ends by declaring that, whatever virtue may be. it cannot be knowledge. It is important to observe that the dialogue does not teach hedonism. The equation *good = pleasant* is advanced only as one which would be accepted by the mass of men, and should forbid them to find a paradox in the identification of virtue with knowledge; it is expressly repudiated by Protagoras as unworthy of a man of high character.

All that Socrates asserts is that virtue is knowledge and wrongdoing consequently involuntary. There is no disagreement in moral principle between the *Protagoras* and the *Phaedo* or the *Gorgias*. If the mass of men are ready to accept the hedonist formula, that is because they are votaries of the body-loving life; this is why we are told in the *Phaedo* that "popular" virtue is illusory. The true explanation of Socrates' doubts is that. though he holds that true virtue, being knowledge, is teachable, he does not believe that what Protagoras is trying to teach is true virtue. Success depends on personal tact and tact cannot be learned from an instructor.

Euthyphro, Apology, **Crito.**—The main purpose of these three works, which deal with the bearing of Socrates before, during and after his trial, is to obviate possible serious misunderstandings of his position and motives; the theme of all three may be said to be the true meaning and importance of care or tending of the soul.

The problem of the *Euthyphro* is what is religion. The respondent Euthyphron is certainly meant to be a kind of Orphic sectary, not, as has been fancied, a representative of ordinary Athenian belief and practice. Socrates had associated with such men and was known to hold unusual beliefs about the soul; hence it was important to make it plain that he was something different from a fanatic. The dialogue. interesting also from its well-developed logical terminology, enables Socrates to repudiate immoral mythology and to reject the conception of "religious duty" as fulfilment of purely arbitrary commands. Its central thought, which, honever, is not formally asserted as a conclusion, is that the service of God which in religion means co-operation with God and under God in the production of a noble work, the nature of which is not further defined, though it is sufficiently clear that the "work" meant is the "tending of the soul."

Consideration of the Apology and Crito in detail belongs rather to the study of Socrates (*q.v.*) than to that of Plato. Of the Apology we must be content to say here that the real defense of Socrates is contained in the pages which explain that the mainspring of his life has been his conviction that he has a mission from God to spend his life in "philosophy," the endeavour to "make his own soul as good as possible," and to incite mankind to do the same; to this mission it is his duty to be strictly faithful, even if faithfulness means condemnation as a traitor by the democracy. The Apology thus depicts Socrates as carrying out in his own practice the ethical program of the Gorgias. The actual accusation is treated with contempt and satirical humour. (See SOCRATES.)

The point of the Crito, though simple, is often missed. Was Socrates wantonly throwing away a valuable life by refusing to escape from prison? Why did he make this refusal? Because, though the conviction was materially iniquitous, it was the verdict of a legitimate court, which could not be disregarded without real disloyalty. Socrates has been wronged not by the law, but by politicians who have abused the law. If he disregarded the conviction, he would be directly doing a wrong against the whole social system.

Foundation of Plato's Doctrine.—In the works so far considered we have the foundation of a moral and political doctrine based on Socratic principles, from which Plato never departed. The main underlying thought is that the great concern of man, a concern not limited to this earthly life, is the development of a rational moral personality (the tending of the soul). Our felicity depends wholly on our success in this task (to use J. Butler's language, on "our conduct," not on "our condition"). And this success, again, depends on rational insight into the true scale of good. It is not because they do not desire it that men fail to attain felicity: on the contrary, no man ever really desires anything else. The reason why men forfeit felicity is that they mistake apparent good for real, the conditionally for the absolutely good. If a man ever knew with assurance what absolute good is, he would in practice never pursue anything else. It is in this sense that "all virtue is knowledge" and that "all wrong-doing is involuntary" (*i.e.,* consists in the pursuit of what is falsely supposed to be good).

"Popular morality" is confused in theory and unreliable in practice because it does not rest on any assured insight into absolute good; "philosophic morality," just because it does rest on such certain insight, is a morality of absolute and unconditional obedience to conscience, such as Socrates had shown. Since the task of the statesman is simply the task of tending the soul extended to the national soul as its object, the philosophical moralist is also the only true statesman. True statesmanship means the promotion of national character as the one thing which matters, and is therefore simply the application, on the grand scale, of the principles of absolute morality; what falls short of this is opportunism masquerading as statesmanship.

These convictions clearly imply a far-reaching metaphysic as their foundation and justification. The principles of this metaphysic, though they are frequently hinted at in passages of dialogues already reviewed, are put before us more explicitly in those which we have now to consider; in connection with them we shall also observe an explicit theory of knowledge and scientific method.

Phaedo.—The Phaedo is often treated as though its object were to provide a demonstration of the immortality of the soul. It does not really profess to do this. The object is to justify faith in immortality as a rational faith by showing that it follows naturally from a fundamental metaphysical doctrine (the ideal theory or doctrine of forms), which seems to afford a rational clue to the structure of the universe, though it is expressly said at the end of the whole discussion that this doctrine itself still requires further examination. At the same time, it is made fully clear that the writer accepts this metaphysical doctrine, with the reservation just mentioned, and is passionately sincere in the faith in "personal immortality" which he brings into connection with it. To be strictly accurate, indeed, we ought to say that the faith to be defended goes beyond belief in immortality. What is being maintained is the divinity of the soul; its survival of death is a consequence of this inherent divinity.

The argument is briefly as follows: A true philosopher may naturally look forward to death without dismay. For death is the separation of soul from body, and the philosopher's whole life has been spent in trying to liberate the soul from dependence on her body. In life, the body is always interfering with the soul's activity. Its appetites and passion interrupt our pursuit of wisdom and goodness; its infirmities are perpetually hindering our thinking. Even in our scientific work, we only attain exact and certain truth in proportion as we detach ourselves from reliance on sense-perception and learn to depend on pure thinking.

Death, then, only completes a liberation which the philosopher has been "rehearsing" all through life—if, that is, the soul continues to exist after death, as there are reasons for thinking. For:

1. There is a belief that the soul has a succession of many lives and that, when it is born into this world, it has come back from another; and there are two considerations to be urged on behalf of this belief. In the first place, the processes of nature in general are cyclical: the hot becomes cold, the cold hot; the waking go to sleep, the sleeping wake. It is reasonable to suppose that this applies to the case of dying and coming to life, so that the dead return to life, just as the living die. If this were not so, if the process of dying were not reversible, life would ultimately vanish from the universe. Secondly, we may appeal to the doctrine that what we call "learning" is really "recollection," being reminded of something. This certainly seems to be the case, for in all our science we are perpetually being put in mind of precise ideal standards, mathematical or moral, with mhich sense or experience never presents us. We must therefore have become acquainted with them before we were confined to our bodies. and therefore must have existed before our birth. These two considerations together would prove what we want to prove, the soul's survival of death, though our dread of the dark makes us demand a more convincing argument.

2. We may consider the antithesis between the divine and eternal and the temporal and mutable, which runs through the universe. The body is certainly temporal and mutable. The soul is relatively immutable, like the fixed ideal standards or norms which she contemplates in her scientific thinking, Her thought is concerned with eternal objects and she herself has the likeness of that which she contemplates. If, then, some constituents of the body are nearly indestructible how much more should one expect the divine element in us, the soul. to resist destruction, as the traditions about rebirth assert that it does.

There are two grave "scientific" difficulties still to face. It may be argued: (1) that the soul is an epiphenomenon, the tune (*harmonia*) given out by the body, and if so, its superior divinity will not protect it from vanishing when the instrument which makes the music is broken; (2) that though the soul actually makes its own body, and perhaps can make a long succession of bodies, it cannot do so without expending energy, so that a time will come when it can no longer make a fresh body, and then it will itself disappear. We must not be driven into misology, antipathy to science, by this apparent clash betneen science and a faith to which we are attached.

The answer to (1) is that there are good souls and bad ones, and the good soul is more in tune than the bad one. But that which can be more or less in tune is clearly not itself a tune. And if the soul were the tune resulting from the functioning of the body, its character at any moment mould be a resultant of the condition of the body. How then could we have the experience, characteristic of the moral life, of the conflict betneen the soul with its aspirations and the body with its carnalities? The answer to (2) can only be given as part of a whole theory of the causes of "coming into being and passing out of being." Socrates had been led, early in life, to frame a tentative theory of the matter in consequence of his dissatisfaction with the chaotic state of physical speculation and in particular with the failure of Anaxagoras to make any satisfactory use of his apparently teleological principle that "mind is the cause of all order and structure." He fell back on the method of "hypothesis."

What distinguishes this method from all others is that it begins by making an undemonstrated postulate *(hypothesis)*. It then proceeds from this point to consider the truth or falsehood of the consequences which follow logically, from the initial postulate; the question of the truth of the postulate is, for the present, left unasked. Socrates' own fundamental unproved postulate has always been that usually, but loosely, called the theory of ideas. The postulate is that there really is a single determinate and immutable something answering to every significant general term and apprehended only by pure thought. The sensible things of which we predicate general terms temporarily partake in or communicate with the idea or form *(idea, eidos)*. When we say that a thing becomes beautiful, what we mean is that the form "beauty" begins to be present to that thing, the thing begins to partake of the form. When we say that a thing ceases to be beautiful, we mean that this relation of presence, participation, communication is dissolved. This is the true account of the cause of "coming into and passing out of being," and if we accept it, we may proceed to our final argument for immortality.

3. There are forms which are mutually incompatible, such as warmth and cold. Heat is never cool, and cold is never warm. But there are also certain sensible things of which it is an essential character to partake of a given form. Such things will never admit an incompatible form. Thus it is an essential character of snow to partake of cold. It mill never, therefore, partake of the form heat. Similarly it is an essential character of a soul to be alive, to partake of the form life It refuses to partake of the form death. At the approach of death. the soul must either retire or be annihilated (the metaphors are military). What we have said of its divinity forbids us to think that it is annihilated; we must therefore assume that it retires to some other region. The proof of immortality is thus hypothetical; it is shown to be involved as a consequence by the doctrine of forms. This doctrine has been stated as a fundamental unproved postulate and it is admitted that it demands fuller consideration.

But our inquiry has at least satisfied us that the hope of immortality is a reasonable one. (To distrust it would be to call the foundation of our whole philosophy into question.) The discourse ends with an imaginative cosmological myth depicting the future of the just and the unjust, respectively.

In this statement of the theory of forms we may note the following points: (1) The doctrine is a piece of realist metaphysics in so far as it is assumed that a universally predicated general term denotes or stands for an individual reality, apprehensible by thought, though not by sense; (2) there are a plurality of such forms, standing in various logical relations with one another (whether they constitute a system with a definite structure the *Phaedo* does not tell us); (3) they are at once the objects known in all genuine science and the formal causes of all the temporal processes of the sensible world; (4) the sensible things which have the same names as forms are said to owe their character to their participation of the forms, or, equivalently, to the presence or communication of the forms to them. though the precise character of this relation of participation is admitted to need further explanation (so far as the language of the *Phaedo* goes, a sensible thing would seem to be thought of as a temporary complex or meeting place of universal characters and as nothing more).

Symposium, **Phaedrus.**—It is by no means clear that these two dialogues are closely connected in point of date, but they may be considered together as both presenting the forms in a special light, as objects of mystical contemplation and excitant of mystical emotion.

The argument of the *Symposium* cannot be reproduced here as a a-hole. The immediate object of the dialogue, which professes to record the discourses made in eulogy of Eros by a group of eminent speakers at a banquet in honour of the tragic poet Agathon, in the year 416–415, is to find the highest manifestation of the love which controls the world in the mystic aspiration after union with the eternal and supercosmic beauty; to depict Socrates as the type of the aspirant who has reached the goal of union; and to set in sharp opposition to him the figure of Alcibiades, who has sold his spiritual birthright for the pleasures and ambitions of the world. The centre of philosophical interest lies in the discourse of Socrates, which he professes to have learned a quarter of a century ago from the priestess Diotima of Mantinea.

The mairi argument may be summarized thus: Eros, desirous love, in all its forms. is a reaching out of the soul to a good to which it aspires but has not yet in possession. The desirous soul is not yet in fruition of good. It is on the way to fruition, just as the "philosopher" is not yet in possession of wisdom but is reaching out after it. The object which awakens this desirous love in all its forms is beauty, and beauty is eternal. In its crudest form, love for a beautiful person is really a passion to beget offspring by that person and so to attain, by the perpetuation of one's stock, the *succedaneum* for immortality which is all the body can achieve. A more spiritual form of the same craving for eternity is the aspiration to win immortal fame by combining with a kindred soul to give birth to sound institutions and rules of life. Still more spiritual is the endeavour, in association with chosen minds, to enrich philosophy and science with noble discourses and thoughts.

But the goal still lies far ahead. When a man has followed the pilgrimage so far, he suddenly descries a supreme beauty that is the cause and source of all the beauties discerned by him so far. The true achievement of immortality is finally effected only by union with this. The philosopher's path thus culminates in a supreme beatific vision. It is clear that the object of this vision, the beauty sole and eternal of the dialogue, means what the *Republic* calls "the good" or "form of good" which by its presence actually causes the goodness of everything else to which the name of good can be given. The forms are thus thought of as a hierarchy with a supreme form at their head, though no attempt is made at a rational theory of the way in which the supreme form unites the rest into the system.

The immediate subject of the *Phaedrus* is the principles of rhetoric or, as we should say, prose composition. The *Gorgias* had told us that rhetoric as commonly practised is not a matter of rational principles at all, but a mere empirical trick of adapting one's tone to the prejudices of an audience. The *Phaedrus* aims at showing hon a really scientific rhetoric might be built on the double foundation of logical method and scientific study of human passions. Plato contrives, however, by making a real or supposed "erotic" composition of Lysias the starting point of his criticisms, to unite nith this topic a discussion of the psychology of love. and this, as in the *Symposium,* leads him to speak of the forms as the objects of transcendental emotion. The soul is immortal, because it has within itself a native source of spontaneous movement. (This is the argument for immortality to which Plato trusts in the *Laws* It is not specially mentioned in the *Phaedo,* but this can hardly mean that Plato had not yet discovered it, since it is, in fact, taken from Alcmaeon of Crotona. a medical man of the beginning of the 5th century) In its disembodied state it shared the life of the gods and could enjoy the direct contemplation of unbodied reality — that is. of the forms. It has suffered an antenatal fall into an embodied condition in which it is blind to everything nhich does not come in at the avenues of sense.

Now our senses only suggest few and faint images of such forms as justice and temperance, but they can suggest beauty in a much more impressive and startling way. To fall in love is to come under the influence of such sudden and arresting suggestions of beauty; the unreason and madness of the lover mean that he is being awakened to realities which other men ignore. The wings of his soul are beginning to grow again, and his experience, rightly used, will be the first step in the soul's return to its high estate. This section of the *Phaedrus* is the *locus classicus* in Plato for the forms as objects of mystical contemplation.

Republic. — The philosophy presupposed in all these dialogues receives its fullest exposition in the *Republic.* Here the immediate problem is strictly ethical. What is justice? Can it be shown that justice is always a boon, injustice a curse. to its possessor, apart from all consideration of consequences in this life or another? That is, is there a rational principle at the root of moral distinctions, and does the principle carry with itself its own intrinsic and indefeasible authority?

Plato's answer is that there is such a principle; each of us, in virtue of his special endowments and aptitudes, has a specific work or vocation; there is some special contribution which he, and no other, can make most effectively to the life of a rational society. Morality, justice, is to discharge that vocation to the height and with a single mind. To live thus is to be in spiritual health; to live otherwise is to be spiritually diseased. The obligation is thus intrinsic and absolute. This position has to be made good against the incoherencies of a morality of uncriticized traditional maxims, as well as against the inmoralism of advanced thought (represented by Thrasymachus in book i, expounded more intelligently by Glaucon in book ii).

This leads us to consider what would be the general type of life in a society where the principle of justice had power as well as manifest authority, and how it might acquire that power. Hence the need for a sketch (books ii–iii) of the institutions of the reformed society, and particularly of its moral and religious education. We have next to satisfy ourselves that the principles which regulate the public life of the morally healthy society are also recognizably the principles of the great virtues of private life. For this purpose, we need a psychology of voluntary action which is provided (book iv) by the doctrine of the tripartite soul. This is not, indeed, a scientific psychology, but proves adequate to describe the moral life of the ordinary good citizen of such a society as we have conceived. The foundation of all this moral excellence is thus laid in absolute loyalty to a sound moral tradition enforced by education.

To ensure that the tradition shall be thoroughly sound, we must stipulate that the authorities who create it do not themselves depend on tradition for their convictions about good and evil; they must not opine, but know, by personal insight. The statesmen at the head of the community must be "philosophers" as well as kings (book vi).

But the vision of "the good" will only dawn on them if they have been prepared for it by an intellectual discipline in hard thinking which leads them through the curriculum of the exact sciences to the critical study of the metaphysical principles involved in science (book vii). The central books of the Republic thus present us with an outline of metaphysics and a philosophy of the sciences. We now turn back to consider the various stages of degeneration through which national and personal character pass when the true moral ideal is allowed to fall more and more completely out of view. As we pass them in review, we are increasingly confirmed in our conviction that, in respect of happiness, the life of regard for right is immeasurably superior to that of sating one's cupidities or gratifying one's personal ambitions (books viii and ix), and this conclusion is finally clinched (book x) by reaffirmation of the immortality of the soul. Since the soul is immortal, the issue which hangs upon our choice to live well or ill is one of infinite moment.

The ethical scheme of the Republic, like that of the Gorgias and Phaedo, is dominated by the conception of the "three lives," ascribed by Heraclides Ponticus to Pythagoras. The "lives" are those of the philosopher, of the man of action and of the votary of enjoyment. The end of the first is wisdom, of the second, distinction, of the third, the gratification of appetite. Distinction is a worthier end than mere satisfaction of appetite; the supremely worthy end is wisdom. In a well-lived life, then, the attainment of wisdom will be the paramount end, and ambition and appetite will be allowed only such gratification as is compatible with loyalty to the pursuit of that paramount end. The psychological foundation of this doctrine is the theory of the tripartite soul, expounded fully in book iv. Analysis of familiar experience reveals three elements or active principles within us: (1) considered rational judgment of good; (2) a multitude of clamant appetites for particular gratifications, which may be in violent conflict with our own considered judgment of good; (3) a factor of spirit higher ideal emotion, which manifests itself as resentment against both the infringement of our just rights by others and the rebellion of our own appetites against our judgment.

The same distinctions reappear in the structure of society. A society naturally falls into three divisions: the statesmen, who direct the public life; the general civilian population, who carry on the business of providing for material needs; and the executive force (army and police), whose function is, in a rightly ordered society, to give effect to the counsels of the statesmen by repressing attacks from without and rebellion from within.

These three orders are thus respectively, the judgment, the appetitive element and the spirited element in the national soul. On this basis, we can proceed to work out an ethical and political theory. In ethics we can define the great types of goodness, the quadrilateral, later known as the cardinal virtues. Wisdom is the excellence of the thinking part, clear and assured knowledge of the good; courage, the fighting man's virtue, is the excellence of the spirited part, unswerving loyalty, unshaken by pain, by danger, by the seductions of pleasure, to the rule of life laid down by judgment; temperance, the special excellence of the appetitive part, is the contented acquiescence of the nonrational elements in the soul in the plan of life prescribed by judgment; justice is just the state in which each of the elements is vigorously executing its own function and confining itself within the limits of that function. In the rightly ordered society, the national wisdom has the statesmen as its organ, the national courage the executive force; the national temperance is shown in the loyal contentment of each class in the community with its prescribed place and its duties.

Such a society is a true aristocracy, or rule of the best. Timocracy, the military state, in the better sense of that phrase, arises when the mere man of action, only competent to fill the part of a good soldier, takes the place which rightly belongs to the thinker as directing statesman. Oligarchy (*e.g.*, the dominance of merchant princes, plutocracy) is a further deviation from the ideal, which arises when political power is bestowed on property as such. A still worse system is democracy, in which no attempt is made to connect political power with any special qualifications. Worst of all is tyranny, exercise of irresponsible po er by the positively disqualified, the man of criminal will. The psychological scheme on which this construction is based is not given by Plato as a piece of strict science. We are carefully warned that exact truth is not to be reached by such an analysis of prima facie facts of social life (435 d) and reminded later on that this apparent triplicity of the soul may prove to be only a temporary consequence of its conjunction with the body (611 b). The tripartite psychology, it is meant, enables us to give an account of the moral life, as it actually appears in a good citizen, which will fairly describe the facts. It is good popular psychology, useful for the moralist, but it is no more.

Hence it is improbable that the analysis originated with Plato himself. More probably it was, as the Stoic Poseidonius asserted, a piece of earlier Pythagorean doctrine, as is also suggested by the constant recurrence, throughout the section of the Republic in which the analysis is offered, of analogies from the specially Pythagorean science of harmonics; and by the fact that the same doctrine is taught by the Pythagorean speaker in the *Timaeus*. Plato has, however, worked the theory into his ethics so completely that through him it has actually become a part of the psychology of Thomism, where it has to be squared, not quite satisfactorily, with the radically divergent psychological scheme of Aristotle.

In point of fact, the tripartite schema proves inadequate in the Republic itself when we advance in book vi to the consideration of the moral life of the philosopher-king, whose virtue is founded on a personal knowledge of good. A higher level of moral goodness is demanded of him than of other citizens even of the ideal state; his courage, for example, is declared to be no mere loyalty to right opinions inculcated by early education, but a high serenity arising from the knowledge of the relative insignificance of a brief individual life in the great universe which lies open to his contemplation. This has an important bearing on the teaching of the Republic about the unity of virtue.

In the ideal state itself, virtue does not appear as a complete unity. The leading types of moral excellence receive their several definitions. It is recognized that a special demand may be made on a particular section of the society in respect of a particular virtue of which it is, so to say, the public organ, as the fighting force is of the valour of the whole society. This is because, even in the ideal state, the moral convictions of citizens, other than the men of superlative intelligence and character who become kings, are not supposed to arise from personal insight. They rest on opinions implanted by education and are thus taken on trust. The good civilian or soldier, after all, is not living by a knowledge which is his own. But the rulers, by whose knowledge the rest of the community lives, must not. of course, themselves take their convictions on trust. They must know with a personal knowledge. The foundation of their virtue must be insight into a system of absolute values embodied in the very structure of the universe. In virtue of this deeper foundation the virtues in them are. so to say, transubstantiated and can no longer be distinguished from one another. They will fuse in knowledge of the good, as, in the Christian saints, they are fused in knowledge and love of God. It is in this form that the Socratic doctrine, "all virtue is one thing, knowledge" reappears in the *Republic* as the foundation of a society in which mankind has at last "escaped from its wretchedness," because knowledge rules.

In the *Republic,* as in the *Phaedo,* the forms appear in the double character of objects of all genuine science and formal causes of the world of events and processes. It is expressly denied that there can be knowledge, in the proper sense of the word, of the temporal and mutable. In the scheme laid down for the intellectual training of the philosophic rulers, ten years, from the age of 20 to that of 30, are assigned for systematic study of the exact sciences in the order: arithmetic, plane geometry, solid geometry, astronomy and harmonics. Special stress is laid on the points that the object of these studies is not practical applications but the familiarizing of the mind with relations between terms which can only be apprehended by thought. and that diagrams and models are to be treated merely as incidental aids to imagination. Five years are then further to be given to the still severer study which Plato calls dialectic, a study which avails itself of no sensible aids to imagination. It proceeds "by means of forms, through forms, to forms" (511 b). It is, in fact, what we should call a critical metaphysic of the sciences. It examines the *hypotheses* or unproved postulates, of the various sciences, and its object is to destroy their character as unproved ultimate postulates (533 *c*) by discovering some still more ultimate really self-evident principle (511 *b*) from which they follow as consequences.

There can be no doubt that this most ultimate principle which is more than a postulate means the good or form of good which is said to be the source at once of the reality and the knowability of all that is real and knowable. though it is itself neither knowledge nor being, but transcendent of both (509 *b*). On the methodological side the *Republic* thus completes the teaching of the *Phaedo* by providing the answer to the question then left open. when a postulate may be regarded as finally established. It may be so regarded when it is seen to follow itself from the good, which is the principle at once of existence and of value.

Socrates is made to confess (506 *d-e)* that he can give no positive account of this supreme metaphysical principle; he can only indicate its nature by an analogy. It is to the whole system of forms what the sun is to the system of visible things, the source at once of their existence and of the light by which they are apprehended. The good is thus thought of, to use scholastic terminology, as a transcendent reality which can be apprehended but never fully comprehended. The comparison with the sun and the free employment of the metaphor of vision indicate that the thought of the *Republic* is here the same as that of the *Symposium:* the good is no other than the supreme beauty which was there said to dawn suddenly upon the pilgrim of love as he draws near to the goal of the journey. R. L. Nettleship rightly says that it holds the place taken in later philosophies by God, when God is thought of as the "Light of the world." But it would be deforming Plato's thought to call the good of the *Republic* God. The *Republic* is permeated by religious faith, but theism as a principle of metaphysical explanation only makes its appearance in Plato's latest dialogues, and there as the solution of a problem which can hardly be said to have been adequately faced in the dialogues so far considered.

How the good gives systematic structure to the plurality of forms. the *Republic* does not tell us.

Development of the Doctrine of Forms.—So far we have been presented with a body of thought nhich has remained recognizably the same without serious modification throughout its various expositions. When me come to the two works which there is reason to regard as directly preluding to the dialogues of Plato's old age, the *Parmenides* and *Tkeaetetus,* we are struck by a remarkable difference of tone. With Plato, as with Kant, the middle years of life were clearly a period of fruitful critical reconstruction. There is an obvious motive for each reconstruction suggested by the *Phardo* and *Republic* themselves.

The theory there expounded does not allow enough reality to the sensible world. It is quite false to say that even the *Phaedo* teaches an absolute dualism of two disconnected worlds, a realm of genuine being which never appears and a realm of sensible appearances which are merely unreal. What is true is that both *Phaedo* and *Republic* leave us with an unsolved problem. They tell us that a sensible thing is a complex or meeting place of a plurality of forms. What else, or what more, it is they do not tell us. And yet it is clear that a thing is not simply a bundle of universal predicates.

Or, to put the point rather differently, according to the *Phaedo* a thing becomes for a while beautiful because beauty "becomes present to it." But why does beauty become present to this particular thing at just this particular moment? Clearly the relation between a thing and a form which has been called participation needs further elucidation. Again the simple epistemological formula that knowledge is confined to forms and their relations, while me can only have shifting opinions about temporal facts does less than justice to our scientific knowledge of the natural world; truths of fact have not yet come by their rights. Finally, if the forms constitute a rationally ordered system, there must be definite principles of interrelation between forms themselves as well as between forms and sensible things and these principles demand investigation. (If the good is what the *Republic* says it is, not only will things "participate" in forms; forms also will "participate" in it.) Here are internal motives for active re-examination of the whole system.

It is clear that there was also an external motive. The *Parmenides,* the *Theaetetus* and the *Sophistes* all reveal a special interest in the Eleatic philosophy, and the first and third show an anxiety on Plato's part to maintain that, in spite of important divergences, he, and not the professed Eleatics, is the true spiritual heir of Parmenides. This is easily explained when we remember that Plato was personally a friend of the chief representative of Eleaticism among the Socratic circle. Eucleides of Megara. while Polyxenus of Megara, an associate of Eucleides, was a hostile critic of the doctrine of participation. The doctrine of Eucleides, like that of Parmenides was that sensible appearances are illusions with no reality at all. Against criticism from this quarter, it mould be necessary for Plato to show that the *Phaedo* itself does not allow too much reality to the sensible; the attempt to prove this point would inevitably show that it had conceded too little. Continued reflection on the same problem of the worth of propositions about sensible fact leads straight to the discussion of the meaning of the copula. and the significance of denial, which is the subject of the *Sophistes.*

Parmenides.—Formally the dialogue conducts to an impasse. In its first half the youthful Socrates expounds the doctrine of the participation of things in forms to the Eleatic philosophers Parmenides and Zeno as the solution of the problem of the one and the many. Parmenides raises what appear to be insoluble objections to the conception of participation, though he admits that dialectic would be impossible if the existence of forms were denied: he hints that the helplessness of Socrates under his criticism arises from insufficient training in logic.

In the second and longer half, Parmenides gives an example of the logical training he recommends. He takes for examination his onn thesis, the one is. and constructs an elaborate set of antinomies after the fashion of Zeno, apparently proving that whether this thesis be affirmed or denied, in either case we are compelled either to affirm simultaneously or to deny simultaneously a series of contradictory predicates. alike of the one and of the many. The conclusion is patently ironical, and we are left to divine the author's purpose, if we can.

The objections to participation, which is formulated precisely as in the Pizaedo, are directed not against the existence of forms, but against the possibility that sensible things should participate in them. From the point of view of this criticism Socrates' error is that he attributes some sort of secondary reality to the sensible. The main arguments are two. First, the doctrine does not really reconcile unity with plurality, since it leads to a perpetual regress. It says that the many things which have a common predicate participate in or imitate a single form. But the form itself also admits of the common predicate, and there must therefore be a second form. participated or imitated alike by the sensible things and the first form, and so on endlessly. We could not escape by the suggestion that the form exists only in our minds, since that would mean that a form is a thought, and it would follow that things are made of thoughts. But if so, either everything thinks, or there are thoughts which do not think, and both alternatives are absurd. Secondly, a graver difficulty is that if there are two realms, a realm of forms artd a realm of sensible things, the relations between forms must belong to the realm of forms, those between sensible things to the realm of things. We ourselves belong to the second. and therefore all our knowledge belongs to it too; we know nothing of the true realities, the forms: if anyone knows them, it is God, but God's knowledge, being knowledge of realities, will not extend to our world, the sensible. The purpose of the objections is thus to suggest that the manifold of sense has not even a derivative reality; it is mere illusion.

This is precisely the position of the Eleatics and their Megarian continuators. The inference is that Plato is reproducing Megarian criticisms of the doctrine ascribed by himself to Socrates, an inference confirmed by the notice preserved by Alexander of Aphrodisias (on *Metaphysics* 990 b 15) of the "third man" argument of the Megarian Polyxenus against participation. Plato does not indicate his own opinion of the cogency of the reasoning, which is, in fact. fallacious, as was properly pointed out by Proclus. (For a detailed discussion of it, see A. E. Taylor, "Parmenides, Zeno and Socrates." in *Proceedings* of the Aristotelian Society for *the Systematic Study of Philosophy,* vol. xvi, pp. 234 ff.)

The purpose of the antinomies which follow has been differently understood. It seems possible that they may be deliberate parody, the object being to show that the methods of the Megarian logicians are even more damaging to their own fundamental metaphysical tenet than they are to the doctrine of participation. Megarian logic is a double-edged weapon, and Plato, if he chooses, can apply it even more dexterously than its inventors.

Theaetetus.—Except for a magnificent interlude in praise of the contemplative life. the dialogue is a straightforward discussion of the question how knowledge should be defined. It naturally ends negatively. None of the proposed definitions will stand examination (the reason is that we are really trying to define truth and truth is an ultimate). But the incidental results of the discussion are of the first importance. We learn (1) that knowledge cannot be identified with sensation nor with any formless simple apprehension; (2) that pure relativism is as impossible in epistemology as in metaphysics. We have the beginning of a doctrine of the categories which is further developed in the *Sophistes.*

The increasing value which Plato is coming to put upon natural knowledge is marked by the use of the word doxa (which in earlier dialogues had commonly meant mere uncertain opinion) in the new sense of "judgment" which it retains in Plato's subsequent work. The most striking negative feature of the *Theaetetus* is that it discusses knowledge at length without making any reference to the forms or to the mythology of recollection. It remains to this day the best of introductions to the problem of knowledge. The main argument may be briefly summarized as follows:

1. It seems plausibie at first to say that knowledge (*episteme*) is sensation (aisthesis). This sounds like the proposition of Protagoras. "what seems to me is so to me; what seems to you is so to you." We might base such a thoroughgoing doctrine of the relativity of all knowledge on a still more ultimate metaphysical theory, if we said—it is implied that Protagoras himself said nothing of the kind—that. within us and without us, the only reality is motion. Organ and environment are both motions; when these motions impinge on one another, they give rise to the twin product. felt sensation–sensible quality.

Both the sensation and the quality sensed will therefore be affected by any difference in the pair of slower motions which cause them (the organ and its environment), and each percipient, therefore, is confined to his strictly private world, which exists only for him. There is no common perceived world, and therefore no standard of truth or reality other than the individual percipient. A teacher does not aim, any more than a physician, at convincing his pupil of the falsity of his judgments, but at giving him useful or healthy convictions in place of harmful or diseased convictions.

The full discussion of such a theory would demand a thorough study both of the Heraclitean philosophy, which says that there is nothing but motion, and the Eleatic philosophy which says that motion is an illusion. But for our immediate purpose, a more summary argument is sufficient. It is certain that even the relativists, who hold that each man is the one infallible measure of his present perceptions, do not hold that he is the only and inerrant measure of his future sensations. A physician can often judge better than his patient whether the patient is going to have, say, the sensations of an ague. A man's own opinion whether a certain course will be expedient or good for him is often far from being the soundest. We must distinguish carefully between what the soul perceives through bodily organs—the data of sense—and what she apprehends by herself without organs. The latter class includes number, sameness. difference, likeness, unlikeness, being, good, bad, right, wrong; *i.e.*, the great universal categories of fact and value. These are apprehended not by sense, but by thinking, and as they are the formal element in all knowledge, knowledge must be found not in our sensations, but in the judgment (syllogismos) of the mind upon them.

2. Is knowledge, then, true judgment? The statement implies that me know nhat we mean by false judgment, error. But is this the case? Error must not be confused with mere false recognition, misinterpretation of present sensation, since there are purely intellectual errors, and we find ourselves unable to explain the nature of this kind of error. And, in fact, it is clear that persuasive rhetoric may produce in the hearer judgments which are true, but have no claim to be called knowledge.

3. Finally, is knowledge "true judgment accompanied by discourse true judgment for which we can give grounds"? This would distinguish knowledge from simple apprehension and would harmonize with the theory of those who hold that knowledge is always of complexes, never of their simple constituents. But this doctrine has difficulties of its own, and, in any case, if we say that knowledge is true judgment + discourse, the discourse meant must be a statement of the logical differentia of the object of which I have knowledge. The proposed definition therefore amounts to saying that knowledge is true judgment about an object + knowledge of the *differentia* of that object and so is circular.

Later Dialogues

Sophistes **and** Politicus.—Formally these two important dialogues are closely connected. They are made to appear as a sequel to the *Theaetetus,* and a further connection is afforded between them by the fact that both are ostensibly concerned with a problem of definition. which is treated by the characteristic Platonic method of repeatedly subdividing a *genus* until we obtain the *definiendum* as a subspecies. The real purpose of the *Sophistes* is logical or metaphysical; it aims at explaining the true nature of negative predication and so as to dispose of the Eleatic thesis that the temporal and sensible realm, containing, as it does, a negative moment, must be mere unreal illusion. The object of the Politicus is to consider the respective merits of two contrasted forms of government, personal rule and constitutionalism, and to recommend the second, particularly in the form of limited monarchy, as most suitable to the actual condition of mankind. The Sophistes lays the foundations of all subsequent logic, the Politicus those of all constitutionalism.

A more temporary purpose in both dialogues is to illustrate the value of careful classification as a basis for scientific definition. In both dialogues Socrates is almost silent; his place as chief speaker is taken by an unnamed and very unorthodox Eleatic, who seems to be a purely fictitious character. Plato is, in fact, claiming that he, and not the formal logicians of Megara, is the continuator of Parmenides, much as Aristotle in his polemic against Xenocrates claims to be the true successor of Plato.

In the Sophistes the main discussion is led up to through a definition of the "sophist" as an "illusionist," a person who, by abuse of logic. produces the illusion, or false appearance, that nature and human life are alike riddled by insoluble contradictions. (This shows that the persons aimed at under the name sophist are the Megarian controversialists who make an illegitimate use of the dialectic of Zeno and Socrates). Now the sophist himself would retort that this definition is senseless, for there can be no such thing as a false statement or a false impression. For the false means "what is not," and "what is not" is nothing at all and can neither be uttered nor thought. To refute him we need to correct the fundamental thesis of so venerable a thinker as Parmenides. Either we must admit that there can be no false statements, or we must be prepared to maintain that "what is not, in some sense also is," and "what is, in some sense is not" (*i.e.*, me must explain what is the meaning of a significant negative proposition). In our theory of being we have to meet at once Parmenides and two different types of pluralist opponents of Parmenides, (1) the corporealists who say that the real. "what is." is just visible and tangible body and (2) certain friends of forms who maintain that the real is a multitude of incorporeal forms, denying that sense-perception gives us any apprehension of it. The corporealist is sufficiently refuted by the consideration that he himself cannot deny the reality of force (*dynamis*) and that force is not a body. The incorporealist friends of forms cannot be met in this way. They regard force, or activity itself as belonging to the unreal realm of becoming. We meet them by urging that knowing is itself an activity and that we cannot deny intelligence and knowledge to the supreme reality. This means that it has a "soul" and is alive. But if life is real, movement and repose from movement must be real too.[1]

This leaves us free to attack the Parmenidean monism itself. That is refuted by drawing the distinction between absolute and relative nonbeing. A significant denial, A is ***not*** B, does not mean that A is nothing, but that ***A*** is other than B. Every one of the great categorical features of reality is other than every other, and the true business of dialectic is to study the various possible combinations of these universal categories. The dialogue mentions five of them, being, identity, difference, motion and rest. (Though it is not said that this is a complete list of categories, it was treated as such by the Neoplatonists.)

The important result is thus that we have learned to think of forms themselves as an interrelated system, with relations of compatibility and incompatibility among themselves. Negation is a moment in the system of intelligible reality, and therefore its presence in the sensible realm does not stamp that realm as illusion. This is the ontological position which interests Plato; the recognition of the function of the logical copula is a consequence.

The Politicus has as its main result the conclusion that government by the personal direction of a benevolent dictator is not suitable to the conditions of human life, where the direction is necessarily that of a fallible man, not of a god. In an actual human society, the surrogate for personal direction by a god is the impersonal supremacy of inviolable law. Where there is such a recognized sovereign law, monarchy is the most satisfactory type of constitution, democracy the least satisfactory. but where there is no fundamental law, this situation is inverted. A sovereign democracy is preferable to an irresponsible autocrat. The dialogue is rich in thoughts which have passed into the substance of Aristotle's ethics and politics. Aristotle took directly from it the conception of politics as the architectonic practical science to which all others are subordinate; the formula of the right mean comes from it together with the Philebus.

Philebus.—The subject of the dialogue is a strictly ethical one. and this, no doubt, explains why it is the only dialogue after the *Theaetetus* in which Socrates is the principal speaker. The issue propounded is the question whether the good is pleasurable feeling or whether it is thought, the exercise of intelligence.

Comparison with the notices of Aristotle in the Nicomachean Ethics shows that this was the subject of a sharp division in the Academy. the hedonist party being led by the mathematician and astronomer Eudoxus, the antihedonists by Speusippus. Under the guidance of Socrates the question is narrowed down to a consideration of the good for man in particular, and a mediating conclusion is reached. The best life for man contains both elements but intelligence is the predominant partner.

All forms of knowledge find a place in it, but only those pleasures which are compatible with wisdom and virtue; *i.e.*, those which are "unmixed" (not preceded by a sense of want or craving) and those of the "mixed" pleasures (the satisfactions of appetite) which are innocent and moderate. The *Philebus* contains Plato's ripest moral psychology; it is the immediate source of the famous doctrine of the mean.

Philosophically the most important feature of the dialogue is a classification adopted with a view to determining the formal character of the two claimants to recognition as the good. All components of the actual belong to one of four classes, (1) the infinite or unbounded (*apeiron*), (2) the limit (*peras*), (3) the mixture or combination of infinite and limit, (4) the cause of the mixture. (Infinite and limit are just the two fundamental opposites of Pythagoreanism.) All the good things of life belong to the third class, that is. they are produced by the introduction of definite limit or ratio into an indeterminate continuum. (This is precisely the doctrine of the mean.) The establishment of such a ratio is a genesis into being, a process resulting in a stable being, and it is indicated that the cause or agent in such a process is always intelligence. human or divine.

There has been much discussion of the question in which of these classes the forms should be placed. The only tenable alternatives would be to put them into the class of limit or into that of the mixture (a view suggested both by the teaching of the *Sophistes* and by Aristotle's express statement that Plato distinguished two constituents within the form and advocated ably by H. Jackson). The truth seems to be that the particular classification in the *Philebus* is devised for a special purpose and that it is not intended to apply to anything but the things and processes of the sensible realm. In that case, though there is a close correspondence between what the *Philebus* teaches about stable being in the sensible realm and what. as we know from Aristotle; Plato taught about the forms, it will be a mistake to look for any actual exposition of the metaphysic of the forms in the Philebus.

Timaem. — The *Timaeus* is an exposition of cosmology, physics and biology put into the mouth of the astronomer Timaeus of Locri. Though Plato avoids expressly describing the speaker as, a Pythagorean. his doctrine is revealed by attentive analysis as an attempt to combine the mathematics and astronomy of the Pythagorean~with the biology of Empedocles, the real founder of Sicilian medicine. The discussion is introduced by the famous narrative of the gallantry of the prehistoric Athenians who defeated the kings of the imaginary Atlantis in their ambitious attempt to become masters of the world. The story was to have been told more in detail in the unfinished *Critias*.

Timaeus opens his discussion by drawing a distinction between

[1]It is still a much agitated question who are the logical atomists described in the *Sophistes* as the friends of forms. The view that they are adherents of the philosophy of the *Phaedo* and *Republic* is deservedly dead. They are still often supposed to be Megarians, but this seems inconsistent with the way in which they are carefully distinguished from the followers of Parmenides as belonging to the other side at 245 *e* Proclus (*Commentarii in Parmenidem*, 562) says positively, as though it u-ere the only view known to him, that they are Italian Pgthagoreans, and this is probably correct, since, the Eleatic of the dialogue refers to them as persons with whom he is familiar. It is Important to remark that the identification of being with force is given merely as a consequence which would follow from, and contradict, the corporealist hypothesis. The implication of the passage is rather that the identification is false than that it is true.

eternal being and temporal becoming and by insisting on the point that it is only of the former that we can have exact and final knowledge. All accounts of the temporal can be only tentative and liable to repeated revision. Cosmology, then, at best, is not exact science. The visible world, being mutable and temporal, is a copy of a model which is eternal, and the copy is the work of God. The reason why there is a copy at all is the unceasingly active and generous goodness of God. (In the sequel Timaeus speaks of the forms which God had before Him as His model in much the same language as the *Phaedo,* except that he uses the Pythagorean word imitation, not participation, to describe the relation of sensible things to forms.)

The world, then, had a beginning. (The Academic tradition from the first was that this is not to be understood literally; Aristotle insists on taking it literally.) God first formed its soul out of three constituents, identity. difference, being. Its body was made later from the four Empedoclean elements. The world soul was placed in the circles of the sidereal equator and ecliptic the latter being split into seven lesser circles, those of the planets, and the two were animated with movements in opposite senses. Subsequently were formed the various subordinate gods and the souls of human beings, that is the immortal and rational element in the human soul, which come straight from the hands of God Himself. The formation of the human body and of the two lower mortal components of the human soul was effected through the intermediacy of the "created gods" (i e., the stars). The most important question of detail arising from this part of the dialogue is that debated between A. Boeckh and G. Grote. Does Timaeus ascribe a motion to the earth? The restoration of the correct text at 40 c ("going up and down on the path about the axis of the universe") proves definitely that he does, but it is not a diurnal revolution, as Grote supposed; it must be rectilinear displacement of unknown period.

The contact is made between Pythagorean geometry and the Empedoclean biology which mill be needed for the physiology and medicine of the dialogue by a mathematical construction of the elements. Starting with two primitive triangles, the isosceles right-angled, and .the right-angled scalene in which the hypotenuse is double the shortest side, Timaeus constructs four of the regular solids, cube, tetrahedron, octahedron, icosahedron, and these are assumed to be the shapes of the corpuscles of earth, fire, air, water. These four in their turn are the immediate constituents of all organic and inorganic compounds.

The important features of the dialogue are not the particular tentative scientific hypotheses but its leading methodological principles. We should note the introduction of God as the intelligent efficient cause of all order and structure in the world of becoming, which preludes to the natural theology of the *Laws,* and the emphatic recognition of the essentially tentative and therefore progressive, character of natural science. It is also noticeable that though Plato's scientific ideal is a mathematical corpuscular physics — his influence in creating this ideal has been much more important than that of the ancient atomists — he constructs his physical world without matter as a metaphysical substrate. The place of matter is taken in his analysis, as Aristotle complained, by *chora,* space, as in the *Principia* of Descartes, a point of view to which physical speculation seems to be returning. He analyzes the passage of nature into three factors: being (a form). space and happening (genesis) much as A. N. Whitehead analyzes it into objects, events and the ingredients of object into event.

It is a fundamental point that the presence of space as a factor makes it necessary to recognize over and above God or mind a subordinate element of ananke, "necessity," in events. Since necessity is also called the errant cause, *planomene* aitia (with an allusion to the name of the planets or tramp-stars) the word clearly does not mean conformity to law. It is rather a name for the fact that there is always in the actual an irreducible remainder of brute datum, "conjunctions" in Hume's phrase, which we cannot rationalize completely into intelligible connections. Thus ananke is not a rebel or evil principle in the constitution of things; its function is everywhere to be instrumental to the intelligent and beneficent purpose of mind or God. There are many facts which we have to be content to accept simply as facts without seeing their reason why. We do not know and may never know, why it is "best" that they should be as they are (*e.g.,* why it is "best" that we should live on a moving earth) but we may be sure that, since it is the fact, it is in some way best that it should be so. This seems to be what is meant by the statement that God or mind (*nous*) persuades ananke. It is the expression of a rational faith in Providence and the supremacy of the moral order. The details of the cosmology, physiology and psychophysics of the dialogue are of great importance for the history of science, but metaphysically of secondary interest.

Laws and Epinomis.—The Laws, Plato's longest, is also his most intensely practical work and contains his ripest utterances on ethics, education and jurisprudence, as well as his one entirely nonmythical exposition of theology. The immediate object is to meet a practical need by providing a model of constitution making and legislation for members of the Academy who may be called on to assist his advisers in the actual founding or refounding of cities.

Plato's attempt to do work of this kind himself at Syracuse had borne no immediate fruit but had given the Academy a recognized standing as a school of scientific politics and jurisprudence. The work of constitution making and legislation was going on in many quarters at the end of his life, and his experience might be made fruitful in sage counsels to younger men. The practical character of the subject explains some novelties in the outward form of the work. As the dialogue is assumed to be dealing with the actual present, Socrates has disappeared and his place is taken by an unnamed Athenian who is, to all intents, Plato himself.

The scene is laid in Crete; the imagined situation is that the Cretans are about to found a settlement on the site of a long deserted city. The chief commissioner for the project is walking out to inspect the proposed site with a Spartan friend. when they meet the Athenian and, being favourably impressed by his conversation invite him to join them as an expert adviser.

The problem thus differs from that of the Republic; the question is not the construction of an ideal state, but the framing of a constitution and code which might be successfully adopted by a society of average Greeks in the middle of the 4th century. Hence the demands made on average human nature, though exacting, are not pitched too high; the communism of the *Republic* is dropped. And for the same reason it is assumed all through that the regulations are carefully adapted to the particular economic and geographical conditions, though it is said that these conditions will not really suit any actual Cretan locality. If so, we must suppose that Plato. under a transparent disguise, is contemplating the actual conditions in quarters from which the Academy was more likely to receive appeals for help.

The special purpose of the work also explains why purely speculative philosophy and science are excluded from its purview. The metaphysical interest is introduced only so far as to provide a basis for a moral theology; the one matter of first-rate scientific importance touched on is the diurnal motion of the earth, and this is only hinted in connection with the practical problem of the construction of the calendar. In compensation. the *Laws* is exceptionally rich in political and juristic wisdom and appears, indirectly, through its influence on the law of the Hellenistic age, to have left its mark on the great system of Roman jurisprudence.

It is impossible to do more than to call attention to a few of the striking features of this great work. The ethical ideal is still that familiar from earlier dialogues. It is interesting that the demand is expressly made that all unnatural vices shall be completely suppressed and that the rule of sexual life is to be monogamous marriage with strict chastity, outside the limits of marriage, for both sexes. In politics, Plato declares himself definitely in favour of a mixed constitution; a good government demands a balance betneen two principles, *eleutheria,* "popular control," and *monarchia,* "personal authority." Persia is an illustration of the mischief of unqualified autocracy, Athens of the evils which come from elimination of the authoritarian principle, and considerable care is taken in the suggested system of magistracies to secure both genuine popular representation and the proper regard for personal qualifications. The basis of society is to be agriculture, not commerce, the citizens are to be peasant proprietors — communism is regretfully abandoned as impracticable in a society of ordinary human beings. But the patrimony of each household is to be strictly inalienable, and differences in personal property are to be kept within strict bounds by what amounts to a supertax of 100% on incomes beyond the statutory limits. Education, as in the Republic, is regarded as the most important of all the functions of government; it is placed under the control of a minister who is the premier. As far as possible, the distinction between the sexes is, as in the *Republic,* to be treated as irrelevant to the educational program.

The most striking features of the scheme are the careful attention paid to the problems of the physical training of children in their earliest infancy and to the right utilization of the child's instinct for play and the demand, made now for the first time, that in adolescence, the young shall be taught in institutions where expert instruction in all the various subjects is co-ordinated. It is from this proposal that the grammar school, or secondary school, has taken its origin. Though we hear no more of philosopher-kings the demand is still made that the members of the "nocturnal council," the supreme council of the state, which is always in permanent session, and exercises a general control over administration, shall be thoroughly trained, not only in the exact sciences, but in the supreme science, which "sees the one in the many and the many in the one"; that is, they are to be dialecticians.

The work is full of suggestions for the practical application of science, such, for example, as that of the necessity of strictly standardizing all weights and measures, or that of basing the calendar on a solar year (of 363' days). The object of the apparently arbitrary selection of the number of patrimonies and the scheme of subdivision of the whole society into smaller groups appears to be the practical one of making it easy to determine exactly what quotum each subdivision may justly be called on to contribute to the revenue or the defenses.

At least two fundamental improvements are made on the Attic jurisprudence which Plato has adopted as the foundation of his own code. One great blot on the heliastic system is removed by the regulations which ensure that trials for serious offenses shall take place before a court which contains highly qualified magistrates, and shall proceed with due deliberation and that there shall be provision for appeals from the primary tribunal to a court of cassation. It is even more important, perhaps, that Laws ix by drawing a clear distinction between blabe, "detriment," and adikia, "infringement," of rights, lays the foundation for the discrimination between civil and criminal actions at law.

An incidental passage in the Laws (822 a-b) and another in the *Epinomis* (987 b) definitely show that Theophrastus was right in crediting Plato with belief in the earth's motion. In the Laws it is said that the real orbit of each planet is a single closed curve, in the *Epinomis* the view that the circle of the stars communicates its motion to those of the planets is called that of men "who know but little of the subject." The allusion is to the famous theory of the celestial motions put forward by Plato's friend and associate, the great mathematician Eudoxus.

According to this, the first great geocentric theory in scientific astronomy, the movements of each planet can be analyzed into a combination of circular revolutions, the unmoved earth being taken as the common centre of all. What Plato asserts is that each planet has only one proper revolution, the remaining revolutions are apparent, not real. The implication is that these apparent revolutions of the planet must be real motions of the earth from which we make our observations. The earth is thus a planet, though not a satellite of the sun. The language of the *Epinomis*—which may be safely regarded as at least true to Plato's thought — definitely makes the sun, itself, one of the planets. We have, therefore, to think of the earth as also a planet revolving with the rest round an unseen centre. We may infer from the words of Theophrastus that Plato, like some of the Pythagoreans, held that there is a luminary, the "central fire," at this centre. The period of the earth's revolution would certainly be taken to be the natural day, so that the motion ascribed to the earth is equivalent to the diurnal rotation, though from Plato's point of view it is not a rotation on an axis, but a revolution round a centre. It follows that the alternation of day and night is no longer accounted for by a rotation of the heaven of the fixed stars. This outermost circle is still credited in the *Epinomis* with a revolution in the sense east to west, but its period is not specified. We need not suppose either that Plato could have specified the period or that he used it to explain any special appearances. It has nothing to do with precession of the equinoxes. being in the wrong sense for that purpose.

What is to Plato's credit is that he has the insight to see that, with all its attractions, the scheme of Eudoxus starts from a wrong presupposition, a stationary earth.

In Laws x Plato. for a practical purpose, creates natural theology. There are three false beliefs which are fatal to moral character, atheism, denial of the moral government of the world, the belief that divine judgment can be bought off by offerings. Plato holds that he can disprove them all. The refutation of atheism turns on the identification of the soul with the "movement which can move itself," already used in the *Phaedrus.* All motion is either communicated from without or self-initiated, and the ultimate source of all communicated motion must be self-initiated motion. The only thing which can move itself is a soul. It follows that all motion throughout the universe is ultimately initiated by souls. It is then inferred from the regular character of the great cosmic motions and their systematic unity, that the souls which originate them form a hierarchy with a best soul, God, at their head. Disorderly and irregular motions are equally due to souls, but to bad and disordered souls, and from the fact that there are disorderly motions, it is inferred that the best soul cannot be the only soul.

There is no suggestion that there is a worst soul, a devil or evil world-soul; all that is said is that there must be one soul which is not the best, and may be more. This is Plato's way of excluding pantheism, as incompatible with the reality of evil. The argument thus establishes at once the immortality of the soul and the existence of God. The other two heresies can now be disposed of. It is inconsistent with the goodness of the best soul to be indifferent to our conduct, and still more so to be venal. The moral government of the world is, in fact, assured by the establishment of the single principle that every soul gravitates into the society of its desires and consequently does and has done to it what it befits such a soul to do and have done to it. Plato thus becomes the originator of the view that there are certain theological truths which can be strictly demonstrated by reason.

It is these demonstrable truths which are subsequently named by M. Terentius Varro natural or philosophical theology in contradistinction to the poetical theology, the myths related by the poets, and the civil theology. the ritual cultus instituted by politicians. From Varro the distinction of three theologies passed to St. Augustine and thus in the end became the foundation of the scholastic distinction between natural theology, those truths about God which can be ascertained independently of any specific revelation, and revealed theology, the further truths which are only made accessible by the Christian revelation. Since Plato's object in demonstrating his three propositions is an ethical one, he goes on to enact that the denial of any of them shall be a grave crime to be visited by the state with penalties ranging from a minimum of five years' solitary confinement, and with death on a second conviction. Plato is thus the inventor, so far as European society is concerned, of the proposal to make an official creed for the state and to treat dissent from it as criminal, an innovation foreign to the spirit of the Hellenic cities, in which religion was a matter not of beliefs but of cultures. Plato's last word, then, on the problem how the sensible comes to partake of form is that it does so through the agency of divine goodness and wisdom. God molds the sensible upon the pattern of the intelligible. The obvious question, how God, who is a soul not a form, is related to the good which is the supreme form never receives discussion or solution. To answer that question was to be the main business of Plotinus.

PLATONISM AFTER PLATO

Aristotle's Account of Platonism. — Since Plato refused to write any formal exposition of his own metaphysic. our knowledge of its final shape has to be derived from the statements of Aristotle. nhich are confirmed by scanty remains of the earliest Platonists preserved in the Neoplatonist commentaries on Aristotle. These statements can, unfortunately, only be interpreted conjecturally. According to Aristotle (*Metaphysics* i, 987 *b* 18–25) Plato's doctrine of forms was, in its general character, not different from Pythagoreanism. the forms being actually called numbers. The two points on which Aristotle regards Plato as disagreeing with the Pythagoreans are (1) that whereas the Pythagoreans said that numbers have as their constituents, the unlimited and the limit, Plato taught that the forms have as constituents the one and the great and small; and (2) that whereas the Pythagoreans had said that things are numbers. Plato intercalated between his forms (or numbers) and sensible things an intermediate class of mathematicals. It is curious, that in connection with the former difference Aristotle dwells mainly on the substitution of the "duality of the great and small" for the "unlimited." not on the much more significant point that the one, which the Pythagoreans regarded as the simplest complex of unlimited and limit, is treated by Plato as itself the element of limit. He further adds that the "great and small" is, in his own technical terminology, the matter, the one, the formal constituent, in a number.

If we could be sure how much of the polemic against number-forms in *Metaphysics* xiii–xiv is aimed directly at Plato. we might add considerably to this bald statement of his doctrine, but unluckily it is certain that much of the polemic is concerned nith the teaching of Speusippus and Xenocrates. It is not safe. therefore, to ascribe to Plato statements other than those with which Aristotle explicitly credits him. We have then to interpret, if we can, two main statements: (1) the statement that the forms are numbers; (2) the statement that the constituents of a number are the great and small and the one.

Light is thrown on the first statement if me recall the corpuscular physics of the *Timaeus* and the mixture of the *Philebus.* In the *Timaeus,* in particular, the behaviour of bodies is explained by the geometrical structure of their corpuscles. and the corpuscles themselves are analyzed into complexes built up out of two types of elementary triangle, which are the simplest elements of the narrative of Timaeus. Now a triangle, being determined in everything but absolute magnitude by the numbers nhich express the ratio of its sides, may be regarded as a triplet of numbers. If we remember then, that the triangles determine the character of bodies and are, themselves, determined by numbers, we may see why the ultimate forms on which the character of nature depends should be said to be numbers, and also what is meant by the mathematicals intermediate between the forms and sensible things. According to Aristotle, these mathematicals differ from forms because they are many, whereas the form is one, from sensible things in being unchanging. This is exactly how the geometer's figure differs at once from the type it embodies and from a visible thing. There is, for example, only one type of triangle whose sides have the ratios 3:4:5, but there may be as many pure instances of the type as there are triplets of numbers exhibiting these ratios; and again. the geometrical triangles which are such pure instances of the type, unlike sensible three sided figures, embody the type exactly and unchangingly. A mathematical physicist may thus readily be led to what seems to be Plato's view that the relations of numbers are the key to the whole mystery of nature, as is actually said in the *Epinomis* (990 *e*).

We can now, perhaps, see the motive for the further departure from Pythagoreanism. It is clear that the Pythagorean parallelism between geometry and arithmetic rested upon the thought that the point is to spatial magnitude what the number 1 is to number. Numbers were thought of as collections of units, and volumes, in like fashion, as collections of points; that is, the point was conceived as a minimum volume. As the criticisms of Zeno showed, this conception was fatal to the specially Pythagorean science of geometry itself, since it makes it impossible to assert the continuity of spatial magnitude. (This, no doubt, is why Plato, as Aristotle tells us, rejected the notion of a point as a fiction.)

There is also a difficulty about the notion of a number as a collection of units, nhich must have been forced on Plato's attention by the interest in irrationals which is shown by repeated allusions in the dialogues, as well as by the later anecdotes which represent him as busied with the problem of doubling the cube or finding two mean proportionals. Irrational square and cube roots cannot possibly be reached by any process of forming collections of units, and yet it is a problem in mathematics to determine them, and their determination is required for physics (*Epinomis* 990 *c*–991 *b*).

This is sufficient to explain why it is necessary to regard the numbers which are the physicist's determinants as themselves determinations of a continuum (a great and small), by a limit and why, at the same time the one can no longer be regarded as a blend of unlimited and limit but must be, itself, the factor of limit. (If it were the first result of the blending, it would reappear in all the further blends; all numbers would be collections of one and there would be no place for the irrationals.) There is no doubt that Plato's thought proceeded on these general lines. Aristotle tells us that he said that numbers are not really addible (*Metaphysics* xiii. 1083 *a* 34). that is, that the integer series is not really made by successive additions of 1; and the *Epinomis* is emphatic on the point that contrary to the accepted opinion. surds are just as much numbers as integers. The underlying thought is that numbers are to be thought of as generated in a way which will permit the inclusion of rationals and irrationals in the same series. In point of fact there are logical difficulties which make it impossible to solve the problem precisely on these lines. It is true that mathematics requires a sound logical theory of irrational numbers and. again, that an integer is not a collection of units; it is not true that rational integers and real numbers form a single series.

The Platonic number theory was inspired by thoughts which have since borne fruit abundantly but was itself premature. We learn partly from Aristotle, partly from notices preserved by his commentators, that in the derivation of the integer series, the even numbers were supposed to be generated by the dyad which doubles nhatever it lays hold of, the odd numbers in some way by the one which limits or equalizes, but the interpretation of these statements is, at best, conjectural. In the statement about the dyad there seems to be some confusion between the number 2 and the indeterminate dyad, another name for the continuum also called the great and small, and it is not clear whether this confusion was inherent in the theory itself, or has been caused by Aristotle's misapprehension.

Nor, again, is it at all certain exactly what is meant by the operation of equalizing ascribed to the one. It would be improper here to propound conjectures which our space will not allow us to discuss. A collection and examination of the available evidence is given by L. Robin in his *Thdovie platonicienne des idées et des nombres d'après Aristote* (1908), and an admirable exposition of the significance of the problem of the irrational for Plato's philosophy by G. Milhaud in *Les Philosophes-géomètres de la Grèce, Platon et ses prédécesseurs,* new ed. (1934). For a conjectural interpretation *see* A. E. Taylor, "Forms and Numbers." in *Mind,* new series, 140, 141.

The Academy After **Plato.**—Plato's Academy continued to exist as a corporate body down to A.D. 529 when the emperor Justinian, in his zeal for Christian orthodoxy, closed the schools of Athens and appropriated their emoluments (*see* ACADEMY, GREEK). Plato's greatest scholar. Aristotle, had finally gone his own way and organized a school of his own in the Lyceum, claiming that he was preserving the essential spirit of Platonism, while rejecting the difficult doctrine of the forms. The place of official head of the Academy was filled first by Speusippus, Plato's nephew (*c.* 347–339 B.C.), then by Xenocrates (*c.* 339–314 B.C.). Under Arcesilaus (c. 276–241 B.C.) the Academy began its long-continued polemic against the sensationalist dogmatism of the Stoics, which accounts both for the tradition of later antiquity which dates the rise of a New (some said Middle) and purely skeptical Academy from Arcesilaus and for the 18th-century associations of the phrase "academic philosophy."

In the 1st century B.C. the most interesting episode in the history of the school is the quarrel between its president Philo of Larissa and his scholar Antiochus of Ascalon, of which Cicero's *Academica* is the literary record. Antiochus, who had embraced Stoic tenets, alleged that Plato had really held views indistinguishable from those of Zeno of Citium and that Arcesilaus had corrupted the doctrine of the Academy in a skeptical sense. Philo denied this. The gradual *rapprochement* between Stoicism and the Academy is illustrated from the other side by the work of Stoic scholars such as Panaetius of Rhodes and Poseidonius of Apamea, who commented on Platonic dialogues and modified the doctrines of their school in a Platonic sense.

The history of the Academy after Philo is obscure, but since the late 1st century A.D. we meet with a popular literary Platonism of which the writings of Plutarch are the best example. This popular Platonism insists on the value of religion, in opposition to Epicureanism, and on the freedom of the will and the reality of human initiative, in opposition to the Stoic determinism; a further characteristic feature, wholly incompatible with the genuine doctrine of Plato, is the notion that matter is inherently evil and the source of moral evil.

Genuine Platonism was revived in the 3rd century A.D., in Rome, and independently of the Academy, by Plotinus. His Neoplatonism (*q.v.*) represents a real effort to do justice to the whole thought of Plato. Two aspects of Plato's thought, however, in the changed conditions inevitably fell into the background, the mathematical physics and the politics. The 3rd century A.D. had no understanding for the former, and the Roman empire under a succession of military chiefs no place for the latter. The doctrine of Plotinus is Platonism seen through the personal temperament of a saintly mystic, and with the *Symposium* and the teaching of the *Republic* about the form of good always in the foreground. Plotinus lived in an atmosphere too pure for sectarian polemic, but in the hands of his successors, Neoplatonism was developed in conscious opposition to Christianity. Porphyry, his disciple and biographer, was the most formidable of the anti-Christian controversialists; in the next century, "Platonists" were among the allies and counsellors of the emperor Julian in his attempts to invent an Hellenic counterpart to Christianity.

Early in the 5th century. Neoplatonism flourished for a short time in Alexandria (which disgraced itself by the murder of Hypatia in 415) and captured the Athenian Academy itself, where its last great representative was the acute Proclus (A.D. 410–485). The latest members of the Academy, under Justinian, occupied themselves chiefly with learned commentaries on Aristotle, of which, those of Simplicius are the most valuable. The doctrine of the school itself ends in Damascius with mystical agnosticism.

Influence on Christian Thought.— Traces of Plato are probably to be detected in the Alexandrian *Wisdom of Solomon;* the thought of the Alexandrian Jewish philosopher and theologian Philo, in the 1st century A.D., is at least as much Platonic as Stoic. There are, perhaps, no certain marks of Platonic influence in the New Testament, but the earliest apologists (Justin, Athenagoras) appealed to the witness of Plato against the puerilities and indecencies of mythology. In the 3rd century Clement of Alexandria and after him, Origen made Platonism the metaphysical foundation of what aas intended to be a definitely Christian philosophy. The church could not, in the end, conciliate Platonist eschatology with the dogmas of the resurrection of the flesh and the final judgment, but in a less extreme form the platonizing tendency was continued in the next century by the Cappadocians, notably St. Gregory Nyssa and passed from them to St. Ambrose of Milan. The main sources of the Platonism which dominated the philosophy of western Christian theologians through the earlier middle ages, were, however, Augustine, the greatest thinker among the western fathers, who had been profoundly influenced by Plotinus read in a Latin version, before his conversion to Christianity; and Boethius, whose wholly Platonist vindication of the ways of Providence in his *De Consolatione Philosophiae* was the favourite serious book of the middle ages.

A further powerful influence was exerted by the writings of the so-called Dionysius the Areopagite (*q.v.*), which laid down the main lines of medieval mystical theology and angelology. These works are, in fact, an imperfectly Christianized version of the speculations of Proclus and cannot date before the end of the 5th century A.D. at the earliest, but they enjoyed an immense authority based on their attribution to an immediate convert of St. Paul. After their translation into Latin in the 9th century by Johannes Scotus Erigena, they became popular in the west.

Apart from this theological influence, Plato dominated the thought of the earlier Renaissance which dates from the time of Charlemagne in another way. Since the west possessed the philosophical writings of Cicero, with the Neoplatonic comment of Macrobius on the *Somnium Scipionis,* as well as the Latin translation of the first two-thirds of the *Timaeus* by Chalcidius, with his commentary on the text, and versions, also, at least of the *Phaedo* and of the *Meno,* whereas nothing was known of the works of Aristotle except Latin versions of some of the logical treatises, the middle age, between Charlemagne and the beginning of the 13th century, when the recovery of Aristotle's physics and metaphysics from Moors, Persians and Jews began, was much better informed about Plato than about Aristotle; in particular, in the various encyclopaedias of this period, it is the *Timaeus* which forms the regular background.

The 13th century saw a change. Aristotle came to displace Plato as the philosopher, partly in consequence of the immediately perceived value of his strictly scientific works as a storehouse of well-digested natural facts, partly from the brilliant success of the enterprise carried through by St. Thomas Aquinas, the reconstruction of philosophical theology on an Aristotelian basis. Plato is, however, by no means supplanted in the Thomist system; the impress of Augustine on western thought has been far too deep for that. Augustine's "exemplarism," that is, the doctrine of forms in the version, ultimately derived from Philo of Alexandria, which makes the forms creative thoughts of God, is an integral part of the Thomist metaphysics, though it is now denied that the'exemplars are themselves cognizable by the human intellect, which has to collect its forms, as best it can, from the data of sense.

Directly or through Augustine, the influence of Plato, not only on strictly philosophic thought but on popular ethics and religion, has repeatedly come to the front in ages of general spiritual requickening and shows no signs of being on the wane.

Two revivals in particular are famous. The first is that of the 16th century, marked by the Latin translation of Marsilio Ficino and the foundation of Lorenzo dei Medici's fantastic Florentine Academy. What was revived then was not so much the spirit of Plato as that of the least sober of the Neoplatonists; the influence of the revival was felt more in literature than in philosophy or morals, but in literature its importance may be measured by the mere mention of such names as Michelangelo, Sir Philip Sidney and Edmund Spenser.

In the 17th century, Plato, seen chiefly through the medium of Plotinus, supplied the inspiration of a group of noble thinkers who were vindicating a more inward morality and religion against the unspiritual secularism and Erastianism of Hobbes: namely the so-called Cambridge Platonists, Benjamin Whichcote, Henry More, Ralph Cudworth and John Smith. In the 20th century, on the one hand A. N. Whitehead tried to work out a philosophy of the sciences which confessedly connected itself with the ideas of the *Timaeus;* and on the other the rise of totalitarian governments produced a number of publications confronting Plato with the theories (Communist, Fascist, etc.) inherent in their policies.

See also Index references under "Plato" in the Index volume.

BIBLIOGRAPHY.—The works of Plato are conveniently arranged in nine tetralogies as follows: (1) *Euthyphro, Apology, Crito, Phaedo;* (2) *Cratylus, Theaetetus, Sophistes, Politicus;* (3) *Parmenides, Philebus, Symposium, Phaedrus;* (4) *Alcibiades I, Alcibiades 11, Hipparchus, Erastae;* (5) *Theages, Charmides, Laches, Lysis;* (6) *Euthydemus, Protagoras, Gorgias, Meno;* (7) *Hippias I (major), Hippias II (minor), Ion, Menexenus;* (8) *Clitophon, Republic, Timaeus, Critias;* and (9)

Minos, Laws, Epinomis, Epistles. Of the manuscript codices, none of which are earlier than the 9th century A.D., the most important are the Bodleianus-Clarkianus (containing the first six tetralogies), the Parisinus 1807 A (containing the eighth and the ninth) and the Venetus (containing the first seven and part of the eighth). Since the end of the 19th century papyrus fragments have been found; on these, *see* H. Leisegang, "Platon" (1950), in Pauly-Wissowa, *Real-Encyclopädie der Classischen Altertumswissenschaft.* On the text and the canon *see:* H. Alline, *Histoire du texte de Platon* (1915); L. A. Post, *The Vatican Plato and Its Relations* (1935); G. Jachmann, "Der Platontext" in *Nachrichten der Akademie der Wissenschaften in Göttingen, Phil.-hist. Klasse 1941* (1942); E. Bickel, "Das Platonische Schriftenkorpus . . ." and "Geschichte und Recensio des Platontextes," in *Rheinisches Museum,* 92 (1943).

Modern editions of Plato refer to the pagination of the edition by (J. Serranus and) H. Stephanus, 3 vol., with Lat. trans. (1578), which is used also in the foregoing text of this article. The standard edition is that by J. Burnet, 5 vol. (1899–1907), containing not only all the 36 works of the nine tetralogies but also the *spuria* (*Definitions, On Justice, On Virtue, Demodocus, Sisyphus, Halcyon, Eryxias* and *Axiochus*). Earlier editions deserving mention are those of G. Stallbaum, 12 vol. (1827–42), improved edition with extensive commentary in Latin; and of K. F. Hermann, 6 vol. (1851–53), rev. by M. Wohlrab (1884–87), containing not only Plato's works and the *spuria* but also the Pseudo-Timaeus Locrus *On the World Soul,* two writings by Albinus, the biography by Olympiodorus, the scholia, an index of names, etc. There is a collected edition in Greek and English by W. R. M. Lamb, H. N. Fowler *et al.* (1914 *et seq.*); and another in Greek and French by A. Croiset *et al.* (1920 *et seq.*). The Eng. trans. by B. Jowett, 4th ed., rev. by D. J. Allan and H. E. Dale (1953), omits *Alcibiades II, Hipparchus, Erastae, Theages, Clitophon, Minos, Epinomis* and *Epistles.* Among translations into other languages are those into German by H. Müller, 8 vol. (1850–66) and by O. Apelt, 25 vol. (1912–22; with rich bibliographies and index); into French by L. Robin and J. Moreau, 2 vol. (1940 *et seq.*); and into Italian by E. Turolla, 3 vol. (1953).

For individual works, the following editions, annotated translations and commentaries may be recommended: *Hippias I,* ed. by D. Tarrant (1928); *Ion,* ed. by St. G. Stock (1909); *Menexenus,* ed. by J. A. Shawyer (1906); *Laches,* ed. by G. Ammendola (1933); *Euthydemus,* ed. by E. H. Gifford (1905); *Gorgias,* ed. by W. H. Thompson (1894); *Meno,* 3rd ed. by St. G. Stock, 2 parts (1955); *Protagoras,* ed. by J. Adam (1893; reissue 1940) and 7th ed. by W. Nestle (1931); *Euthyphro, Apology and Crito* (1924) and *Phaedo* (1911), both ed. by J. Burnet, as well as *Apology,* ed. by J. Riddell (1867) and *Phaedo,* trans. by R. S. Bluck (1955) and by R. Hackforth (1955); *Symposium,* 2nd ed. by R. G. Bury (1932); *Phaedrus,* trans. by R. Hackforth (1952) and by J. B. Skemp (1952); *Republic,* ed. by J. Adam, vol. i, 4th ed. (1926), vol. ii, 3rd ed. (1921) and trans. by F. M. Cornford (1941); *Parmenides,* trans. by F. M. Cornford, *Plato and Parmenides* (1939; reprinted, 1950); *Theaetetus* and *Sophistes,* trans. by F. M. Cornford, *Plato's Theory of Knowledge* (1935; 1957); *Theaetetus,* 2nd ed. by L. Campbell (1883); *Politicus,* trans. by J. B. Skemp, *Plato's Statesman* (1952; new ed., 1957); *Philebus,* ed. by R. B. Bury (1897) and trans. by R. Hackforth, *Plato's Examination of Pleasure* (1945); *Timaeus,* ed. and trans. by R. Archer-Hind (1888) and trans. by F. M. Cornford, *Plato's Cosmology* (1937; reprinted 1957), commentary by A. E. Taylor (1928); *Laws,* commentary by C. Ritter (1896) and ed. by E. B. England, 2 vol. (1921); *Epinomis,* trans. by J. Harward (1928); with *Philebus,* trans. by A. E. Taylor (1956); *Epistles,* ed. by G. Pasquali (1938) and by A. Maddalena (1948) and trans. by L. A. Post (1925), by J. Harward (1932) and by G. R. Morrow (1935). The standard edition of the *Scholia Platonica* is ed. by W. C. Greene *et al.* (1939). *See* also A. Diès, *Autour de Platon: essais de critique et d'histoire,* 2 vol. (1927); R. Schaerer, *La Question platonicienne* (1938); M. Pohlenz, *Aus Platos Werdezeit* (1913); H. Arnim, *Platons Jugenddialogue und die Entstehungszeit des Phaidros* (1914); and R. Hackforth, *The Composition of Plato's Apology* (1933).

Comprehensive presentations are to be found in J. Burnet, *Greek Philosophy,* part 1 (1914); in E. Zeller, *Die Philosophie der Griechen,* vol. ii, part 2, 4th ed. (1921); in T. Gomperz, *Griechische Denker,* vol. ii, 4th ed. (1925); in F. Ueberweg, 12th ed. by K. Praechter, *Die Philosophie des Altertums* (1926); and in J. Geffcken, *Griechische Literaturgeschichte,* vol. ii (1934). Separate studies are: C. Ritter, *Platon,* 2 vol. (1910–23); U. von Wilamowitz-Moellendorff, *Platon,* 2 vol., 3rd ed. rev. by B. Snell (1948); P. Friedlander, *Plato,* Eng. trans., 3rd ed. (1958–); J. Burnet, *Platonism* (1928); P. Shorey, *What Plato Said* (1933; reprinted 1957); L. Robin, *Platon* (1935); G. M. A. Grube, *Plato's Thought* (1935; reprinted 1958); W. F. R. Hardie, *A Study in Plato* (1936); R. Demos, *The Philosophy of Plato* (1939); E. Hoffmann, *Platon* (1950); A. E. Taylor, *Plato: the Man and His Work,* 5th ed. (1948); L. Stefanini, *Platone,* 2nd ed. (1949); P. M. Schuhl, *L'Oeuvre de Platon* (1954); R. E. Cushman, *Therapeia: Plato's Conception of Philosophy* (1958). *See* also O. Apelt, *Platonische Aufsätze* (1912); V. Brochard, *Études de philosophie ancienne et de philosophie moderne,* new ed. (1926); R. Simeterre, *Introduction à l'étude de Platon* (1949); and H. Leisegang, *Die Platondeutung der Gegenwart* (1929); O. Gigon, *Platon,* with a bibliography (1950).

On Plato in relation to his forerunners and contemporaries *see* P. M. Schuhl, *Essai sur la formation de la pensée grecque,* 2nd ed. (1949); G. C. Field, *Plato and His Contemporaries,* 2nd ed. (1953); E. Howald, *Platons Leben* (1923); V. de Magalhães-Vilhena, *Le Problème de Socrate* (1952) and *Socrate et la légende platonicienne* (1952); E. Frank, *Plato und die sogenannten Pythagoreer* (1923); G. R. Levy, *Plato in Sicily* (1957); H. Cherniss, *Aristotle's Criticism of Plato and the Academy* (1944); P. Wilpert, *Zwei aristotelische Frühschriften über die Ideenlehre* (1949); W. Jaeger, *Aristoteles,* 2nd ed. (1955); J. Bidez, *Eos . . .* (1945); and W. J. W. Koster, *Le Mythe de Platon, de Zarathoustra et des Chaldéens: étude critique des relations intellectuelles entre Platon et l'orient* (1951). For his influence on posterity *see* ACADEMY, GREEK; NEOPLATONISM; K. Singer, *Plato der Gründer* (1927); P. Shorey, *Platonism, Ancient and Modern* (1938); G. Méautis, *Platon vivant* (1950); R. Klibansky, *The Continuity of the Platonic Tradition During the Middle Ages,* 2nd ed. (1950); A. Fox, *Plato and the Christians* (1957). On the 20th-century question whether Plato could be called a Fascist or not, *see* K. R. Popper, *The Open Society and Its Enemies,* 2nd ed., rev. (1952); R. B. Levinson, *In Defense of Plato* (1953).

On special aspects of Plato's thought *see* P. Natorp, *Platons Ideenlehre,* 2nd ed. (1921); G. Capone Braga, *Il Mondo delle idee* (1928); J. Stenzel, *Zahl und Gestalt bei Platon und Aristoteles,* 2nd ed. (1933), *Plato's Method of Dialectic,* Eng. trans. (1940), *Platon der Erzieher* (1928); N. Hartmann, *Zur Lehre vom Eidos bei Platon und Aristoteles* (1944), *Platos Logik des Seins* (1909); W. D. (Sir David) Ross, *Plato's Theory of Ideas* (1951); Joseph Moreau, *Réalisme et idéalisme chez Platon* (1951); W. Lutoslawski, *The Origin and Growth of Plato's Logic* (1897); R. Robinson, *Plato's Earlier Dialectic,* 2nd ed. (1953); A. Rivaud, *Le Problème du devenir et la notion de la matière dans la philosophie grecque* (1906); J. Wahl, *Étude sur le Parménide de Platon* (1926); E. Grassi, *Il Problema della metafisica platonica* (1932); W. F. Lynch, *Approach to the Metaphysics of Plato Through the Parmenides* (1959); M. Heidegger, *Platons Lehre von der Wahrheit* (1947); A. Levi, *Sulle interpretazioni immanentistiche della filosofia di Platone* (1921); P. E. More, *The Religion of Plato,* 3rd ed. (1928); F. Solmsen, *Plato's Theology* (1942); O. Reverdin, *La Religion dans la Cité platonicienne* (1945); V. Goldschmidt, *La Religion de Platon* (1949); A. J. Festugière, *Contemplation et vie contemplative selon Platon,* 2nd ed. (1951); P. Lachièze-Rey, *Les Idées morales, sociales et politiques de Platon,* 2nd ed. (1951); H. G. Gadamer, *Platos dialektische Ethik* (1931); R. C. Lodge, *Plato's Theory of Ethics* (1928; 1953), *Plato's Theory of Education* (1947), *Plato's Theory of Art* (1953); J. Gould, *The Development of Plato's Ethics* (1955); E. Barker, *Greek Political Theory: Plato and His Predecessors,* 4th ed. (1951) and *Political Thought of Plato and Aristotle* (1959); R. L. Nettleship, *The Theory of Education in Plato's Republic* (1935); N. R. Murphy, *The Interpretation of Plato's Republic* (1951); W. Jaeger, *Paideia: the Ideals of Greek Culture, Eng. trans.* (1939 *et seq.*); K. F. Reinhardt, *Platons Mythen* (1927); P. Frutiger, *Les Mythes de Platon* (1930); L. Robin, "Études sur la signification et la place de la physique dans la philosophie de Platon" (1919; reprinted in *La Pensée* grecque, 1923); S. Demel, *Platons Verhältnis zur Mathematik* (1929); C. Mugler, *Platon et la recherche mathématique de son époque* (1948); R. S. Brumbaugh, *Plato's Mathematical Imagination* (1954); A. Wedberg, *Plato's Philosophy of Mathematics* (1955); P. M. Schuhl, *Platon et l'art de son temps,* 2nd ed. (1952). (A. E. TA.; PP. M.)

PLATO (fl. *c.* 400 B.C.), Greek poet, was a writer of Old Comedy. His earliest play was probably produced in 427 B.C., his last in 387. Of his 28 comedies most were on political themes. He attacked Hyperbolus in his *Perialges* ("The Sufferer"; 420?), Dieitrephes in the *Heortai* ("The Festivals"; 414?) and Peisander and Cleophon in the so-named plays. Mythological burlesques are represented by such plays as the *Adonis,* the *Daidalos,* the *Phaon,* etc., and social (= Middle) comedy by the *Sophistai,* for example.

Antiquity admired the elegance of his style.

BIBLIOGRAPHY.—T. Kock, *Comicorum Atticorum fragmenta* (1880–88); G. Norwood, *Greek Comedy* (1931); J. M. Edmonds, *Fragments of Attic Comedy* (1957). (M. PR.)

PLATONIC LOVE, a locution used in two senses, with allusion in both cases to Plato's account of love in his *Symposium* (*see* PLATO: *The Earlier Dialogues*).

1. In common speech, platonic love means a supremely affectionate relationship between human beings in which sexual intercourse is neither desired nor practised. In this sense, it most often refers to a heterosexual relationship. By extension, it may be used to cover that stage of chivalrous or courtly love in which sexual intercourse is indefinitely postponed.

2. From the Renaissance to the end of the 19th century platonic love was used as an occasional euphemism for homosexual love, in view of the comparatively tolerant attitude to such love discernible in Plato as well as in other Greek authors.

PLATOON, a tactical subdivision of a military company. It is customarily a lieutenant's command and consists of from 25 to 50 men.

In the 17th century the term referred to a small body of musketeers who fired together in a volley, alternately with another platoon. In the 18th century battalions were often organized for tactical purposes into 16 platoons of about 24 men each, plus two or four platoons of grenadiers or light infantry. Since then the term has been applied to various tactical subdivisions of a company of infantry, cavalry or artillery.

The term "platoon" has been used in American manuals since 1779, and throughout the 19th century meant half a company. It has always retained some sense of systematic alternate employment. Hence "platoon fire" meant a regulated fire of alternating platoon volleys, and "platoon" sometimes meant the volley itself. The "platoon system" in municipal police and U.S football organizations signifies teams or shifts of comparable strength that alternate on duty.

The platoon was reintroduced into the British service in 1913 and became the name of the tactical subdivision of a company in most modern armies, being in turn subdivided into sections or squads.

See also COMPANY, MILITARY. (F. P. T.)

PLATT, CHARLES ADAMS (1861–1933), U.S. architect and landscape gardener, whose work showed the marked influence of Italian form, was born in New Tork, N.Y., on Oct. 16, 1861, and educated in the National Academy of Design and in Paris under Gustave Boulanger and Jules J. Lefebre. After a visit to Italy he nrote a book. *Italian Gardens* (1892). He designed many private houses and gardens in addition to public buildings, among the latter being the Maxwell Memorial library, Rockville, Conn. (1917); the Freer Gallery of Art, Washington, D.C. (1918); the library. Connecticut College for Women, New London (1922); the agricultural building, University of Illinois, Urbana (1923); and the Lowell Memorial fountain, New York, N.Y.

See *Monograph of the Work of Charles A. Platt,* with an introduction by Royal Cortissoz (1913).

PLATT, THOMAS COLLIER (1833–1910), U.S. politician, born in On-ego, N.Y., July 15, 1833, studied at Yale university, New Haven, Conn., 1849–52. He became a banker and speculated in lumber. In the 1860s Platt was chairman of the Tioga county (N.Y.) Republican committee, and in 1877, after having been elected for two terms to the U.S. house of representatives, he became chairman of the state Republican convention. Elected to the U.S. senate in Jan. 1881, Platt soon resigned, and within ten years he became the Republican boss of the state. Although he again served in the U.S. senate, his political power waned steadily after about 1903. He died in New York city, March 6, 1910.

PLATT AMENDMENT, an amendment to the U.S. army appropriation bill of March 1901, offered by Sen. Orville H. Platt of Connecticut and adopted by congress, which defined the conditions on which the United States was willing to end the military occupation of Cuba that had followed the Spanish-American War of 1898. Elihu Root, secretary of war, had previously formulated the terms on which the United States would withdraw and leave the government of Cuba to the Cubans. It was the Root formulation that Platt offered in the senate, with the proviso that the conditions must be embodied in the new Cuban constitution and also in a permanent treaty with the United States. The Cuban Constitutional convention reluctantly accepted the amendment. In so doing, it agreed that Cuba would validate the acts, and carry out the sanitary program, of the U.S. military government; that it would not impair Cuban independence by treaty with, or cession of territory to, any "foreign" power, or contract any debt beyond the capacity of the ordinary revenues to pay. It conceded to the United States the right to a naval base in Cuban territory and waters (later fixed at Guantbnamo bay) and gave the United States the right to intervene in Cuba for the preservation of orderly government or of Cuban independence — a right the Cnited States exercised repeatedly during the next 30 years. The Cubans never liked the Platt amendment, for they regarded it as an infringement of their sovereignty. In 1934 the United States negotiated a new treaty with Cuba that abrogated all provisions of the Platt amendment except the right to the naval base at Guantánamo bay.

BIBLIOGRAPHY.—P. C. Jessup, *Elihu Root,* 2 vol. (1938); Dexter Perkins, *The Monroe Doctrine, 1867–1907* (1937); J. W. Pratt, *America's Colonial Experiment* (1950). (J. W. PR.)

PLATTE, a river system of the western United States, tributary to the Missouri river. The Platte river, 310 mi. long, is formed at Korth Platte, Neb., where the North Platte, 618 mi. long, and the South Platte, 424 mi. long, flow together. The North Platte river rises in the Medicine Bow and Park ranges and the Rabbit Ears mountains of north-central Colorado. It flows north into Wyoming and bends east-southeast at Casper, Wyo., flowing into western Nebraska. In eastern Wyoming the North Platte valley is one to ten miles wide and from 100 to 300 ft. below the surrounding uplands. On the Wyoming-Nebraska boundary the North Platte flows through the Goshen Hole'where the valley has widened to 50 mi. in places and the bordering bluffs are 400 ft. high. Torrington, Wyo., and Scottsbluff, Neb., mark the western and eastern extremities of the Goshen Hole. On the North Platte there are three large reservoirs used for irrigation and power: Pathfinder reservoir near Alcova, Wyo., completed in April 1909, with storage capacity of 1,016,000 ac.ft.; Seminoe reservoir near Leo, Wyo., completed in March 1939, capacity 1,012,000 ac.ft. and Alcova reservoir at Alcova completed in Jan. 1938, capacity 190,400 ac.ft.

The South Platte river rises in Park county on the Mosquito range of central Colorado and flows southeast across South Park. West of Divide, Colo., the river turns sharply northeast, flows through the Front range via the Platte River canyon and emerges on the flat land of the Colorado piedmont southeast of Denver. Continuing its northeast course, it flows through Denver to Greeley, Colo., where it bends eastward to North Platte. From Greeley east the valley of the South Platte is from two to ten miles wide. The river bed is filled with sandbars and the stream channel is often braided. Cheesman, Eleven Mile Canyon, and Antero reservoirs on the upper South Platte are storage units for Denver's water supply.

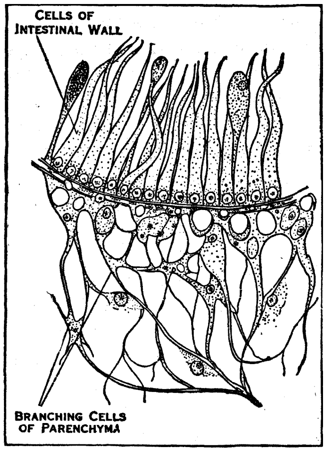
From North Platte the Platte river flows southeast into a big bend at Kearney, Neb., turns northeast and empties into the Missouri at Plattsmouth, Neb. During the spring runoff the Platte river is a mile wide in many places and almost dry the remainder of the year. Important tributaries of the North Platte are the Sweetwater and Laramie rivers and Medicine Bow creek. South Platte tributaries are Clear creek and Boulder creek and the Big Thompson, St. Vrain and Cache La Poudre rivers. The Loup river is the largest tributary of the Platte. The vast quantities of water diverted for irrigation agriculture and for municipal use are the most significant aspects of the Platte river system.

(M. J. L.)

PLATTSBURGH, a city of Clinton county, N.Y., U.S., on the west shore of Lake Champlain. Plattsburgh is surrounded by beautiful scenery: the broad island-studded lake in front, the Green mountains beyond, and on the southern horizon the distant Adirondacks. South of the city is Plattsburgh air base, a unit of the U.S. Strategic Air Command. Part of the base occupies the site of an army post established in 1815 where reserve officers were trained during World War I. After World War II the first university for U.S. veterans was established there; it later became a unit of the State University of New York and was eventually disbanded. Lccated in the centre of Plattsburgh is a college of education which originated in 1889 as a normal and training school and which became a unit of the State University of New Tork in 1949. Plattsburgh is a recreational area and marketing and manufacturing centre of pulp, paper and allied products. The city was founded by Zephaniah Platt (1740–1807), who brought a colony from Long Island. Recognized as a town April 4, 1785, it was incorporated as a city in 1902. The opening naval engagement of the American Revolution (a victory for the British) took place at Valcour Island 5 mi. S.E. of Plattsburgh on Oct. 11, 1776. In the War of 1812 the city was the headquarters of the U.S. army on the northern frontier. In Sept. 1814, the village was besieged in what was planned to be a joint attack by sea and by land; on Sept. 11, Commodore Thomas Macdonough and the U.S. forces defeated the invading British fleet and the British army, deprived of naval support, retreated. See WAR OF 1812. For comparative population figures *see* table in *NEW* YORK: *Population.* (*G. L. F.*)

PLATYHELMINTHES or PLATODARIA, a phylum of invertebrate animals, containing soft-bodied creatures which are bilaterally symmetrical and usually somewhat flattened in shape, and in which there is no true "coelom" or perivisceral cavity and no true (metameric) segmentation. The animals contained in this group (flatworms) are the simplest and probably the most primitive of those in which the tissues and organs of the body are developed from three, instead of two, original embryonic layers.

The external covering of the body is typically a cellular or syncytial epidermis providedwith vibratile cilia. These serve partly for locomotion and partly for creating currents to be tested by the sense organs. In the adults of certain parasitic groups, the epidermis is replaced by a smooth or spiny cuticle. Pigment is commonly present beneath the epidermis in free-living forms, but is usually absent in those which are parasitic. The spaces between the internal organs are for the most part filled up with a kind of loose connective tissue called the parenchyma. A coelom is absent. The musculature of the body is mainly peripheral, consisting of layers of transverse, longitudinal and often also oblique muscle-fibres running beneath the epidermis.

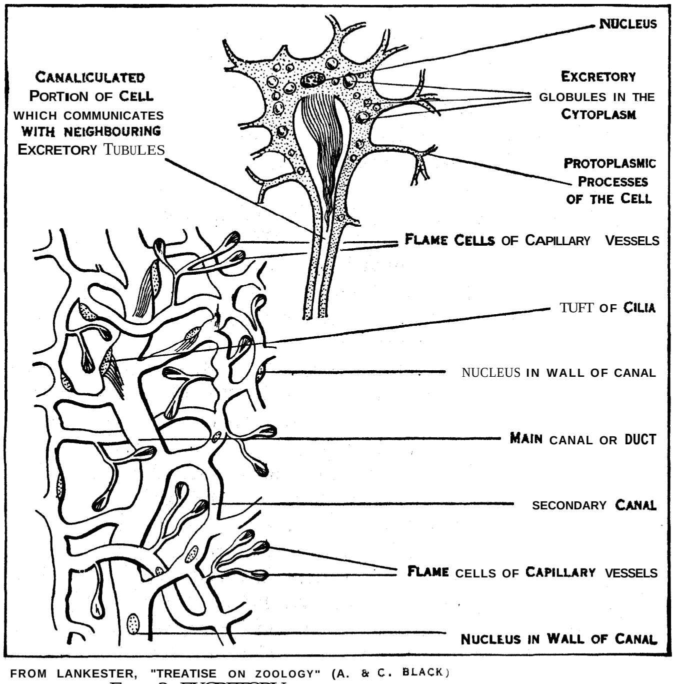


AFTER KERBERT, IN "ARCHIV FUR MIKROSKOPISCHEN ANATOMIE" (FRIEDRICH COHEN)

FIG. 1.—SECTIONAL PORTION THROUGH THE BODY OF A TREMATODE (PARAGONIMUS), SHOWING STRUCTURE OF TISSUES

These muscles render the body capable of extreme elongation and contraction, and often of surprising variability in shape.

Anterior and posterior ends of the body can usually be distinguished, the animals having a definite direction of locomotion, accompanied by a greater degree of specialization of the anterior extremity. Dorsal and ventral surfaces are also generally distinguishable, the latter being that on which the animal creeps, and on which the oral and genital apertures are commonly situated. In the parasitic flatworms special clinging organs are generally developed, in the form of muscular suckers, often supplemented by cuticularized hooks or spines.



FROM LANKESTER, "TREATISE ON ZOOLOGY" (A. & C. BLACK)

FIG. 2—EXCRETORY SYSTEM OF A PLATYHELMINTH

Below, diagram of a portion of the excretory system showing branching ducts ending in flame cells. Above, a single flame cell more highly magnified

An alimentary canal may or may not be differentiated. When present, it may either be a simple saclike organ or may be variously branched. With very few exceptions, its only aperture is the mouth, which may be situated subterminally, near the anterior end, or much further back, sometimes even behind the middle of the body. The mouth may be surrounded by an oral sucker, and usually a highly muscular, often protrusible pharynx intervenes between mouth and intestine.

The main ganglia of the nervous system (the "brain") and the chief sense organs are generally concentrated towards the anterior end. In addition to tactile papillae or special sensory cilia, "eye-spots" or ocelli are frequently present in free-living forms, and sometimes in the free-living larval stages of parasitic forms. In certain free-living flatworms *statocysts* (saclike organs containing minute calcareous nodules or *statoliths*) and ciliated pits, probably sensory in function, also occur.

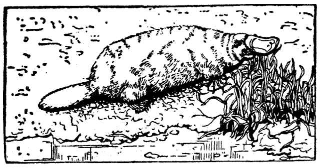
There is no blood-vascular system or haemocoele. The excretory organs consist of a branching system of canals ending internally in "flame-cells." These are minute pyriform structures containing cilia which keep up a constant flickering movement. The main collecting vessels of the system open to the exterior by one, two or many pores.

The Platyhelminthes are, with rare exceptions, hermaphroditic animals, each individual being functionally both male and female. The reproductive system is usually very complex. The male organs consist essentially of one or more (often very numerous) testes, whose ducts are usually connected with a protrusible intromittent organ (penis or cirrus). The essential organs of the female apparatus are an ovary (sometimes multiple ovaries) and a tubular duct communicating with the exterior. The arrangement of the parts of the female system is subject to great variation in different groups. In some cases (most cestodes) the only communication with the exterior is a vagina, which is connected internally with an oviduct leading from the ovary to a saclike uterus! but does not serve for the expulsion of eggs. In such forms the eggs are either shed only by the dehiscence of the wall of the uterus and of the body wall, or by a special (temporary or permanent) birth-pore. In almost all flatworms there is a yolk gland or vitellarium (often multiple vitellaria), producing yolk cells which form nutritive material for the developing embryos. There is also usually a "shell gland," which usually secretes adhesive material for iastening eggs together or to a substratum. The ducts of these glands open into the oviduct or into a specialized portion of it called the ootype. The external apertures of the male and female ducts are sometimes separate, but frequently both ducts open into a common "genital atrium," which is often muscular. Not infrequently a special duct and pore for copulatory purposes are present.

The Platyhelminthes are extremely widely distributed, free-living forms occurring in almost every kind of environment—in shallow or deep water, both fresh and marine, and on land—while parasitic forms occur on or in animals of almost every class. The free-living forms usually feed actively on small animals or plants. The parasitic forms show various degrees of modification in habits, some being external parasites and feeding on mucus or other matter derived from the skin of their hosts, while others are internal parasites and feed on partly digested food or on body fluids. Among the latter class some are without special digestive organs and can only feed by the absorption of liquid nourishment.

The phylum is usually considered to include three main divisions or classes: (1) Turbcllaria (including Temnocephalidea), the majority of which are free-living, but some parasitic. This group is probably nearest to the primitive ancestral form. (2) Trematoda (flukes), all of which are wholly or partly parasitic either upon or within other animals. (3) Cestoda (tapeworms), all of which are wholly endoparasitic. *See* TAPEWORMS, TREMATODES, TURBELLARIA. (H. A. B.; X.)

PLATYPUS, a remarkable Australian aquatic mammal belonging to the primitive subclass Monotremata (*q.v.*). The duckbilled platypus (*Ornithorhynchus anatinus*), the only species, is oviparous; two eggs, $\frac{3}{4}$ in. long and $\frac{1}{2}$ in. wide, each enclosed in a strong, flexible, white shell, are produced at a time. The animal shows many primitive features; there are no true teats in the female, the milk glands being probably modified sweat glands; the body temperature is relatively low. The platypus inhabits the streams and rivers of southeast Australia and Tasmania. About 20 in. long, it is clad in short, dense fur of a deep brown above, paler below. There are no teeth in the adult, their purpose being served by horny prominences, two on each side of each jaw. The broad horny muzzle is very beaklike. In the cheek are capacious pouches. The limbs are short and strong, each with five claw-bearing toes. In the forefeet, the web extends far beyond the ends of the claws, but it can be folded back on the palm when the animal comes out on to the land. On the heel of the male is a movable horny spur, perforated by a canal which communicates with a poison-gland. The platypus forms deep burrows in the banks, in which it sleeps and brings up its young, the entrance being under water. The food consists of aquatic insects, Crustacea and worms. The animal is nocturnal.


PLATYPUS (ORNITHORHYNCHUS ANATINUS), AN EGG-LAYING MAMMAL

See H. Burrell, *Platypus* (1927); D. Fleay, *Animal Kingdom (1944)*.

PLATYRRHINA, the name applied, in contradistinction to Catarrhine (*q.v.*), to the new world monkeys. The name (New Lat. platys, "wide'!; Gr. rhinos, "nose") refers to the broad septum between the nostrils.

See PRIMATES.

PLAUEN, a town of Germany, in the district of Karl-Marx-Stadt. Pop. (1950) 84,438. Plauen, probably founded by the Slavs, is first mentioned in 1122. It passed under the authority of Bohemia in 132i and came to Saxony in 1466, remaining united with the electorate after 1569. The manufacture of white goods was introduced by Swabian, or Swiss, immigrants about 1570.

It was formerly the capital of Vogtland, or Voigtland. a territory governed by the imperial vogt, or bailiff, and this name clings to the district. The fine Gothic church of St. John, with twin spires, was restored in 1886. The town hall dates from about 1550; and the old castle, Hradschin, is now a law court. Plauen manufactures embroidered white goods and makes lace. It manufactures much of the machinery used in the town and it has a trade in coal, yarn and cattle.

PLAUTUS (fl. late 3rd and probably early 2nd century B.C.) was the great comic dramatist of ancient Rome. Twenty-one plays (Amphitruo, Asinaria, Aulularia, Baechides, *Captivi*, Casinu, Cistellaria, Curculio, Epidicus, Menaechmi, Mercator, Miles Gloriosus, Mostellaria, Persa, Poenulus, Pseudolus, Rudens, Stichus, Trinummus, *Truculentus* and the fragmentary Vidularia) ascribed to Plautus have survived in the manuscripts (*i.e.,* the 4th-century Ambrosian palimpsest, known as "A," and various manuscripts of the 10th century and later, known as the "Palatine" family). According to Festus and Jerome he was born at Sarsina, in Umbria: his death occurred in 184 B.C. according to Cicero; in 200, according to Jerome. The two *didascaliae* (notes in the form of a preface) preserved in "A' are usually regarded as firm evidence that the *Stichus* was produced in 200 and the *Pseudolus* in 191; but see H. B. Mattingly, "The Plautine 'Didascaliae,"' Athenaeum (nuova serie), xxxv, pp. 78–88 (1957). According to Cicero, Plautus in his old age took great pleasure in his Pseudolus and Truculentus. This may be invention, indicating merely that these were popular plays in Cicero's day; but on it is founded the usual view that Plautus was born about 250 B.C. The only extant record as to his life is that of Aulus Gellius (based on Varro), the historical character of which is questioned by Friedrich Leo in his Plautinische *Forschungen* (2nd ed.; 1912). It is probably invention or mistaken inference, but the record may be near the truth in stating that from an early age Plautus was connected with the theatre (perhaps as an actor). The prologue to the *Asinaria* gives the author's name as Maccus; the prologue to the Mercator gives it (in the genitive) as mactici (Macci *Titi*?); at the end of the Casinu in "A" it is given (in the genitive) as T. Macci *Plauti.* The poet Accius, however, seems to have distinguished between Plautus and Titus Maccus. It will be remembered that Maccus was the clown in the Atellanue *fabulae* (*q.v.*) and that Plautus is said by Festus to mean *planis pedibus* (cf. *planipes,* "mime"). The other prologues which give the name give it as "Plautus."

There is no certain evidence as to the dates of the plays. *Cistellaria* (201 ff.) refers to approaching victory over the Carthaginians. The supposed reference in Miles Gloriosus (211 ff.) to the imprisonment of the poet Naevius is perhaps itself the source of that story. Evidently Plautus' plays were popular and were revived after his death (see the post-Plautine prologue to the Casinu). The works of other dramatists came to be attributed to him; by Varro's day the number of his plays had risen to 130. Varro made out a list of 21 (evidently those now known) which he said were universally agreed to be genuine (perhaps on grounds of style); others he himself accepted on grounds of style but did not include in the 21; still others he rejected. He can scarcely have been right in excluding the Commorientes (attested as Plautine by Terence and Accius) and, perhaps, the *Colax,* mentioned by Terence as either partly or doubtfully Plautine.

Attempts to arrange the plays in chronological order, on the evidence of topical allusions, metrical development, etc., must be regarded as speculative. What one scholar thinks a topical allusion by Plautus another will ascribe to the Greek original and yet another to a post-Plautine hand. Metrical variety is indeed characteristic of Plautus; but the prominence of the so-called "lyrical" metres might just as plausibly be attributed to the poet's youth as to his age. (*See,* however, W. B. Sedgwick, "The Origin and Development of Roman Comic Metres," *Classica* et *Mediaevalia*, 10, pp. 171–181, 1949).

Indebtedness and Originality. — The plays of Plautus are based on Greek originals of the New Comedy, of which original examples are to be found in the fragments of Menander (including the Dyscolus, discovered in 1956). But Plautus was not a mere translator. This was shown by K. M. Westaway (The Original Element in Plautus, 1917) and Eduard Fraenkel (Plautinisches *im* Plautus, 1922); later, Italian scholars pointed to the vitality and verve which pervade all his work. On the other hand, there are passages in which he does not hesitate to take over allusions which can hardly have been intelligible to a Roman audience; *e.g.,* the reference in the Rudens to Stratonicus, a musician of the time of Alexander the Great. Terence refers twice to Plautus' "carelessness" as a translator, says that he omitted a scene from Diphilus' *Synapothnescontes* in his Commorientes and implies that he himself is following Plautus' example in his own practice of borrowing from a second original. Of large-scale remodeling there is no evidence; Aulus Gellius speaks rather of difference for the worse in style. Are the prologues mainly Greek, or Plautine, or post-Plautine? The romanization of the plays by way of allusions to towns in Italy, to the streets, gates and markets of Rome, to Roman magistrates and their duties and to Roman laws and the business of Roman law courts, banks, comitia and senate. etc., still leaves the structure Greek. Frank inconsistency is shown by his use, side by side, of the contemptuous expressions *barbarus* (applied to the Romans) and pergraecari, "to play the Greek" (applied to the Greeks). Frequently, as in passages in the *Aulularia,* the Poenulus and the Pseudolus, he seems to take delight in casting dramatic illusion to the winds.

But as an adapter for the Roman stage Plautus is nothing less than masterly. His command of Latin is such that his plays read like original works. Some of his characters stand out so vividly from his canvas that they have ever since served as representatives of certain types of humanity; *e.g.,* Euclio in the Aulularia, the model of Molière's miser. Alliteration, assonance, deft use of metre for dramatic effect, plays upon words and happy coinages of new terms give his plays a charm of their own. "To read Plautus is to be once for all disabused of the impression that Latin is a dry and uninteresting language," wrote Franz Skutsch in *Die Cultur der Gegenwart* (1905). It is a mistake to regard the Latin of Plautus as "vulgar" Latin. It is essentially a literary idiom. based upon the language of Roman society in his day.

Characters and Plots.—The characters in his plays are the stock characters of New Comedy (though there may well be a suspicion that he has heightened the farcical element, perhaps under the influence of native Italian farce). The finer insight into human nature and the delicate touch in character drawing which 'Terence presents in his reproductions of Menander may be missing. but there is wonderful life and vigour and considerable variety in Plautus' characters. Their language is often downright and sometimes obscene, but, as has been well said, "the coarseness of Plautus' plays is not as great as is sometimes supposed" (John N. Hough, "Miscellanea Plautina," *Transactions of the American Philological Association,"* 71, p. 186, 1940). The careful reader will take note of occasional touches of serious thought, examples of which are to be found in the *Pseudolus* (683 ff.); the *Stichus* (124); the *Rudens* (1235–1248), etc. The *Captivi* is the story of the heroic self-sacrifice of a slave; the *Amphitruo* is a mythological burlesque; the *Rudens* tells of shipwreck and treasure trove. But most of his plays depend for their main interest on intrigue. In the *Menaechmi* and *Amphitruo* and as a subordinate element in the *Bacchides* the theme of mistaken identity is to be found.

Metres.—In the metrical structure of his plays Plautus (no doubt following the earlier Latin dramatists) made an important change from the Greek model. The New Comedy had confined itself for the most part to the metre of dialogue (the six-foot iambic trimeter), occasionally relieved in moments of excitement by the trochaic tetrameter catalectic (seven and a half feet), which latter was accompanied by the pipe. Plautus greatly developed this trochaic metre in its Latin form (trochaic septenarius); it is actually more common than the iambic senarius (six-foot line), the only metre not accompanied by the pipe. But he used many other metres as well, all accompanied by the pipe; in fact the senarius or metre of unaccompanied speech (*diuerbium*) is only about half as common as the metre (whatever its form) of *canticum*, or declamation supported by the pipe. The *cantica* are not mere inserts or accessories, like the songs introduced in the Shakespearean drama; they comprise two-thirds of the text. The effect was probably not that of full song but rather that of the recitative "patter" of W. S. Gilbert, in which the words and rhythm are important and the music simply supports the rhythm. In *Stichus* (758 ff.) the piper (*tibicen*) is given a drink, and while he is drinking the metre changes for seven lines to iambic senarius. The *tibicen* was on the stage throughout the play; in *Pseudolus* (573a) he is asked to supply a solo.

The origin of the *cantica* has been much debated. Leo put forward the view that Plautus derived their metrical structure from contemporary Hellenistic music-hall songs; Fraenkel suggested that some earlier Latin dramatist had endeavoured to enliven comedy by introducing the metrical variety which he found in Creek tragedy; A. M. G. Little and others have sought the origin in Italian popular comedy (see *Harvard Studies in Classical Philology*, 49, p. 226, 1938). The individual metres employed were not indeed invented by Plautus; they are adapted from Greek and are common to Roman tragedy and Roman comedy, however, Plautus handled them with peculiar literary and dramatic skill.

Reputation.—Plautus held the stage until the end of the republic. Aelius Stilo, Cicero's teacher, praised his Latinity. Cicero. though in the *Orator* he found fault with the iambics of the Latin comedians generally as *abiecti* ("slovenly"), admired Plautus' type of wit as *elegans, urbanum, ingeniosum, facetum.* Varro ranked him above all other Latin comic dramatists for dialogue. Horace in the *Ars Poetica* is a more severe critic: he is impatient with the taste of an earlier age which had admired Plautus' command of rhythm and jest, and in *Epistles* ii he accuses Plautus of carelessness in character drawing and indifference to everything except box-ofice success. The mime seetns to have driven Plautus off the stage during the empire (though a ticket has been found at Pompeii giving admission to a performance of the *Casina*, and Arnobius says that the *Amphitruo* was performed in the reign of Diocletian). But he was still read; Aulus Gellius praises his style; Sidonius Apollinaris ranked him above the Greeks in wit; Jerome, after a night of weeping over his own sins, would console himself by reading Plautus; Eusebius praised him. In the middle ages he seems to have been best known as the supposed author of the *Querolus* (5th century A.D.?). Only the first eight of his plays were known to Petrarch and other scholars at the beginning of the Renaissance: but in 1429 Nicolaus Cusanus brought to Rome a manuscript containing the 12 later plays; this event gave a strong impulse to the study of Plautus, who took rank as one of the great dramatists of antiquity.

Influence on Modern Literature.—Carl von Reinhardstoettner in his *Spätere Bearbeitzrngen plautinischer Lustspiele* (1886) deals at length with the influence of Plautus on modern literatures. In the 15th century Italian scholars were producing Plautus' plays, new Latin plays and new Italian comedies (the *commedia erudita*) based on Plautus and Terence. In 1484 the *Aulularia* was presented on the Quirinal. An important play on the theme of the *Menaechmi* was *Gl'Ingannati*, by the members of the Sienese Academy; this was translated into Spanish as *Los Enganados* by Lope de Rueda. In the 16th century Plautine influence was strong in Germany. Holland and France. In England the *Menaechmi* was performed by the boys of St. Paul's school in 1527. Nicholas Udall's *Ralph Roister Doister*, the first English comedy. was written about 1552; it is based on the *Miles Gloriosus*. Shakespeare's *Comedy of Errors* (about 1591), based upon the *Menaechmi*, with additional material from the *Amphitruo*, is thought to reflect the poet's Latin studies at school; his Falstaff and Parolles and Ben Jonson's Captain Bobadil owe much to the Plautine braggart warrior; the *Taming of the Shrew* has been influenced by the *Mostellaria*. In *Hamlet* II, ii. 377–382, Polonius says "The best actors in the world . . . Seneca cannot be too heavy nor Plautus too light." Ben Jonson's *The Case is Alterd* (1609) is adapted from the *Captivi* and the *Aulularia*. Thomas Heywood adapted the *Amphitruo* in his *Silver Age* (1613), the *Rudens* in his *Captives* (1624) and the *Mostellaria* in his *English Traveller* (1633) John Dryden's *Amphitryon* (1690) is based partly on the Latin *Amphitruo* but chiefly on Molière's adaptation. Henry Fielding's *Miser* (acted 1732) rests on Moliere's *L'Avare* rather than on the *Aulularia*. In 1929 Jean Giraudoux scored a resounding success with his *Amphitryon 38*, based on the *Amphitruo*.

BIBLIOGRAPHY.—*Standard texts:* G. Goetz and F. Schoell (1893–95); F. Leo, 2 vol. (1895–96; 2nd ed., 1958); W. M. Lindsay, 2nd ed. (1910); A. Ernout, with French trans. (1932–40). Paul Nixon's Loeb text, with Eng. trans. (1916–38), is based on Leo's text. *Editions with notes: Captivi* by W. *M*. Lindsay (1900); *Epidicus* by *G. E.* Duckworth (1940); *Mercator*, 2 vol. (1932) and *Truculentus*, 2 vol. (1953) by P. J. Enk; *Mostellaria*, 2nd ed. (1907) and *Rudens* (ed. min., 1901) by E. A. Sonnenschein; *Rudens* by F. Marx (1928); other plays in Macmillan's "Classical Series" and the "Pitt Press Series." or the annotated Teubner series by Brix-Niemever and others. *Lexicon:* Gonzalez Lodge, *Lexicon Plautinum*, 2 vol. (1924 and 1933). *Syntax:* W. M. Lindsay, *Syntax of Plautus* (1936). *Metre and Prosody:* W. M. Lindsay, *Early Latin Verse* (1922); *E*. A. Sonnenschein, *What is Rhythm?*, ch. vi (1925); W. Beare, *Latin Verse and European Song* (1957). *General:* G. E. Duckworth, *The Nature of Roman Comedy* (1952); W. Beare, *The Roman Stage*, 2nd ed. (1955); E. Paratore, *Storia del teatro latino* (1957). (WM. BE.)

PLAY: *see* DRAMA; *THEATRE*.

PLAY, ANIMAL. At the beginning of any discussion of play in animals it is necessary to emphasize the fact that understanding " the subject is extremely limited. The factual evidence consists exclusively of descriptions of a wide variety of responses that have been lumped arbitrarily together in the category of play. The explanations and interpretations are speculative, deductively derived and untested. Some of the theories purporting to elucidate the causes and results of play are emotionally appealing but scientifically unsound; others appear plausible and may be valid, but none has been subjected to objective verification.

Characteristics of Play.—The general characteristics of playful behaviour in animals as set forth by most students of the subject can be stated briefly: (1) It is almost universally agreed that in animals, as in men, playful responses carry an emotional element of pleasure. (2) Play is characteristic of the immature animal rather than of the adult; mature individuals sometimes play, but it is generally believed that they do so less frequently than juvenile members of their species. (3) The majority of students concur in the belief that play differs from nonplayful activities in having no immediate, utilitarian result affecting the continued existence of the individual. (4) The type of play is characteristic of the species; furthermore, the nature and amount of play exhibited by members of a particular species vary according to evolutionary position. (5) Play is more common, occurs during a greater portion of the life span and appears in more diversified form in the higher animals than in the lower.

These generalizations refer to the commonly accepted characteristics of play. They are descriptive rather than analytical; and they cannot be used as explanations or interpretations.

Types of Behaviour Regarded as Play.—General Bodily Activity.——Young children take delight in racing about a room at top speed, stamping violently upon the floor, shouting loudly in utter abandon. Many young animals display similar behaviour. Colts, calves, kids, puppies and kittens expend vast amounts of energy in vigorous locomotor activity to no apparent biologically useful end. They gallop, run, bound and gambol to the point of apparent exhaustion. Many observers regard this behaviour as a form of play. It is assumed to constitute an outlet for surplus energy, to bring pleasure to the performer and to lack any practical purpose.

Youthful Practice of Adult Activities.—The African lion cub lies in hiding and creeps forth, belly close to the ground, to stalk and leap upon an unsuspecting brother or sister. Two puppies wrestle and roll in mock combat, sinking tiny teeth into thick fur and uttering infantile growls. Twin lambs face each other with heads lowered and forefeet pawing the earth; charging forward, they meet head-on and tumble awkwardly on the grass. The common element in such activities lies in their resemblance to similar behaviour patterns the animal will display in somewhat different form later in life.

There are, however, several significant differences between the behaviour of the young and the adult individual. These responses, when they appear during infancy, do not terminate in the same result they will achieve in the adult stage. The kitten's chase of a ball or a blowing leaf mirrors the cat's pursuit of a mouse; but in one instance food is obtained and in the other it is not. The puppy's battle with his brother reflects the adult dog's combat with other grown animals; but in the infant's struggle no damage is inflicted. The young animal's performance is often imperfect and incomplete; whereas that of the adult is relatively polished and well integrated. From such observations it was deduced by Karl Groos arid others that this type of play serves to prepare the animal for a more efficient adult life. It is thought that incomplete and imperfect instincts are modified, strengthened or suppressed during the practice period of youthful play. C. Lloyd Morgan suggested that the play period of infancy permits the practice of vital responses under conditions in which error and incompleteness are not fatal. The perfection of essential reactions is thus held to take place before the animal is subjected to the exigencies of an independent existence, wherein the forces of natural selection are constantly operating to weed out inefficiency and the penalty for error may be sudden death.

It seems probable that this theory may hold good for the play of certain higher mammals. The chimpanzee, for example, passes through a lengthy period of infancy and childhood during which a number of highly imporrant reactions are exercised and possibly organized into biologically effective form. There is, however, no proof that the generalization may correctly be extended to include all examples of this type of behaviour. The kitten's play with small, moving objects may indeed improve its abilities as a mouser, but there is no factual evidence to prove or disprove the assumption. In some cases youthful practice is demonstrably unnecessary. It is certain, for example, that the common sex play of some animals, such as the immature rat, has no demonstrable effect upon the efficiency of adult mating performance. The existence of a preparatory function of play can be established only by direct test of each activity in each species.

Exploration and Experimentation.—Young animals often peck, scratch, claw, pull and bite at objects in their environment, and such activities are sometimes classified as experimental play. The puppy's destructive attentions to a book or pillow are interpreted as play that serves to acquaint the animal with the properties and potentialities of the object thus investigated. Similarly, certain reactions of the young animal to its companions can be listed under the heading of exploratory or experimental play. An eventually practical outcome of such behaviour is held to lie in its tendencies to promote the development of new modes of conduct and to inhibit biologically dangerous reactions. Although this assumed function of exploratory play is based chiefly upon a priori reasoning, there are some instances in which it can be shown to exist. Wolfgang Kohler reported that captive chimpanzees given stout sticks or poles soon devised a crude form of vaulting or jumping, using the pole as a sort of crutch. Originally this response was apparently indulged in as a form of amusement and nas not used as a means of achieving any secondary objective. Although further test and observation would be necessary to establish the point, it seems probable that the pole vaulting response was a form of play and the outgrowth of experimentation with the stick. Later, however, when the chimpanzees were confronted with the problem of obtaining a banana suspended above their reach, they quickly turned the vaulting technique to good use, employing it as a means of getting the fruit.

Social Play.—Young British warblers are describec! as engaging in "tilting matches," during which each bird commands a perch and attempts to dislodge other birds from theirs. African lion cubs play "king of the mountain." When one assumes possession of a high spot of ground or climbs on top some low object, all others try to force him off and take his place. "Follow the leader" games occur in the repertory of several mammalian species. Otters have been observed sliding down muddy banks into the water, one after the other in quick succession, and then climbing out to repeat the performance time and again.

Young monkeys in the jungle often swing single file through the branches, each copying roughly the actions of the animal ahead of him.

The group play of chimpanzees is highly diversified, anti often resembles certain human activities. Kohler's description of "dancing" is illustrative. Several chimpanzees start to march in single file around a box or post. Gradually their pace quickens, and they trot, often with emphasis upon one foot, so that a primitive kind of rhythm emerges; and as they trot and stamp the animals wag their heads in time with the rhythm. Other kinds of social play occur in this species; and 0. L. Tinklepaugh suggested that this type of behaviour early in life enhances the individual's adaptability and co-operativeness, both of which are essential characteristics of the chimpanzee.

Play Between Species.—Although young animals of one species may investigate those of a foreign species, they do not often play together. Exceptions to this generalization sometimes occur when two domesticated animals are reared together.

Thus a dog and a goat may engage in mock battles if they have been associated long enough to establish friendly relations, so tc speak.

The outstanding type of interspecies play is that which occurs between man and his pets. If any of the criteria of play that have been accorded common use are to be accepted, it must be agreed that the dog frequently plays with his master. The dog may enter into mock chases or battles with a man much as he would mith another dog. On the other hand, he will with equal willingness participate in a learned game such as fetching the ball or performing tricks without any material reward. It is significant that the animal may initiate the play and in many different ways signalize his desire to stimulate playful relations with the human partner.

Explanations of Play.—Several theories have been formulated in an attempt to elucidate the causes of playful behaviour. None is completely satisfactory although several are partially serviceable.

Surplus Energy Theory.—This holds that play is a safety valve, providing an outlet for unused vigour. This interpretation has little to recommend it. Energy is not stored up in the organism like water in a reservoir. Animals are either completely rested and ready to react quickly to stimuli from the environment, or they are tired and sluggish in their responses. All types of behaviour occur more promptly and persist longer in the rested individual.

The energy expended in play differs in no way from that used in nonplayful pursuits.

Joie-de-Vivre Theory.—A second attempt to explain play is found in the *joie-de-vivre* theory, which interprets play as the expression of a general exuberance, an overflowing enthusiasm for life itself. A serious objection to explanations of this type is that they add nothing to basic understanding of natural phenomena; they explain nothing. They involve merely the substitution of one word or phrase for another, although the meaning or significance of the new term is no more precise nor illuminating than the old.

Instinctive Theory.—The instinctive theory of play in animals was championed by Karl Groos, who interpreted all play as responses based upon inherited tendencies or predispositions. However, to label an act as "instinctive" is not to explain it; and although the form that play takes in various animal species is unquestionably influenced by hereditary constitution, the serious student of behaviour is still faced with the responsibility for determining the stimuli that evoke playful responses, identifying the physiological and psychological processes that mediate the behaviour, and describing in objective terms the eventual effects and results.

Future Theories.—Although no completely satisfactory explanation for the occurrence of play in animals is available, it is possible to predict with reasonable certainty the form which such a theory must assume.

1. In the first place it is obvious that no single hypothesis can be formulated to explain all forms of play in every animal species The types of activity that have been labeled "play" are so variable in form and complexity that a different interpretation is indicated for each major category.

2. It must be recognized that playful behaviour differs from nonplayful pursuits in subtle and often elusive fashion. There is no sharp border line between play and work for animals or for man. The two types of activity merge insensibly one into the other, and some complex responses may be partly play and partly work. Therefore, any acceptable definition of play must be based upon a list of predominating characteristics that combine to set it off from nonplayful behaviour, and cannot be derived from adherence to a single, rigid criterion such as nonutilitarianism or imperfect, juvenile performance. It is, for example, permissible to state that playful reactions as a class tend to lack the immediate. biologically practical results that normally accompany nonplayful responses, but it is not permissible to set up as an inflexible rule the dictum that no activity is play if it achieves a useful end.

3. Play must be explained in purely objective terms. A small start in this direction was made by workers such as J. B. Cooper, who suggested that the playful execution of certain behaviour patterns is characterized by the absence of the consummatory phase and by the rapid shift from one element of the pattern to another. Cooper noted that the play of lions is more prevalent on cool days, and tends to occur most frequently following a major change in the environmental situation (such as release of the animals from an indoor cage, the introduction of new lions into the pride, or the sudden appearance of the keeper). Much more extended analysis along lines such as these will provide the basis for an interpretation of play that is biologically significant and subject to direct test and verification.

The play of human beings is no more clearly understood than is that of lower forms, and the careful study of animal play offers potentially important results in the increased understanding of similar behaviour in man See also ANIMAL BEHAVIOUR; PSYCHOLOGY, COMPARATIVE.

BIBLIOGRAPHY.—J. B. Cooper, An Exploratory Study on African Lions, Comparative Psychology Monographs (1942); W. Kohler, The Mentality of Apes (1931); C. L. Morgan, Animal *Behaviour* (1900); Karl Groos, Play of Animals (1898). (F. A. BH.)

PLAYER-PIANO, a piano equipped with a mechanical device for automatically playing written music or for reproducing the playing of a pianist. All types of player-piano mechanism are operated by utilizing the difference between external and internal air pressures. In fig. 1, the tracker-bar, T, with its 88 holes, is represented as being closed by the paper roll, R, which lies closely against it. Some of the air has been extracted from the duct, D, and from the chamber, C, by means of an air-exhaust to which they are connected. These is a very tiny vent, V, which allows air from the tracker duct to leak into the chamber. A disk, K, closes the chamber from the outer air, being held down because the air in C, is at a lower pressure than normal. The pneumatic, B, is full of air at normal atmospheric pressure and is open to the external air by means of the port, A.

Should a hole in the paper come into line with any hole in the tracker-bar, the external air rushes into the duct and lifts the pouch, P, which is simply a circular piece of soft kid about $\frac{3}{4}$in. in diameter, and bigger than K. Hence it lifts K, connecting the pneumatic with the partial vacuum, C, and disconnecting it from the external air by closing the port A. The air in B spreads to C and, the external pressure on the surface, S, being greater than the reduced pressure inside, the pneumatic collapses suddenly, the movable leaf rising and lifting with it the pilot, L, which operates the piano action.

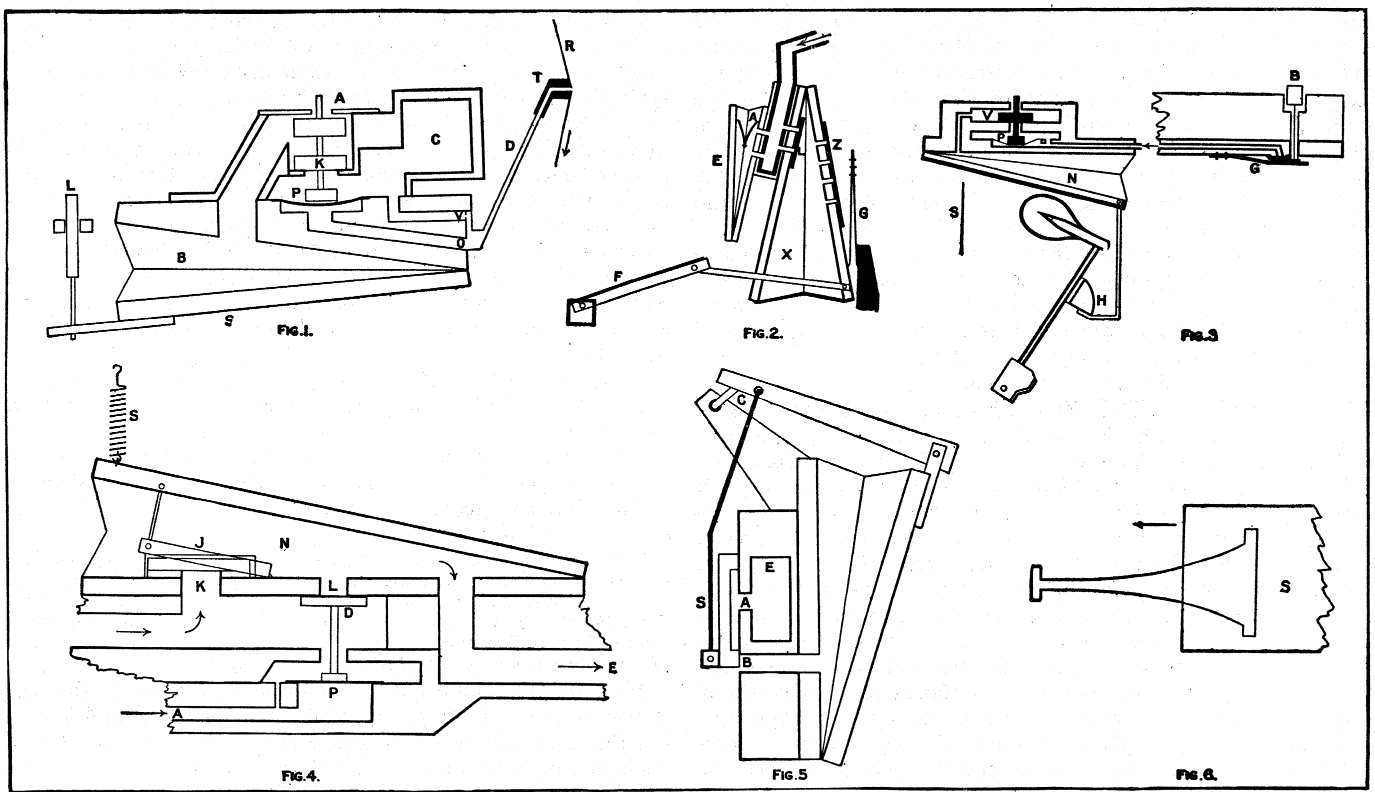
The pneumatic remains collapsed until paper again blocks the hole in the tracker-bar. The air in D then leaks through into C and can no longer hold up the pouch, which falls back into position and allows K to close the chamber C again, at the same time opening the pneumatic to the external air at A. The external and internal pressure on S now being the same, the pneumatic reinflates and allows the pilot to drop back into position.

In the days of heavy and clumsy valves it was difficult to provide the necessary power to lift them rapidly without hard pedalling and consequent loud tone. To overcome this defect the more expensive player action was provided with an additional (or primary) valve of light construction, easily lifted by the inrush of air when a hole was opened on the tracker-bar. Its lifting admitted air to the other and heavier valve, through the port O, operating the striking pneumatic as previously described. Both single and double valve systems are still in use.

The interior of the player action is maintained. in a steady state of reduced pressure by forcing the pedal, F, to open the exhaust, X (fig. 2). This allows all the interior air to spread itself into X past L, a flat strip of well-tanned leather, lying over holes. A fan spring, G (about 12lb. in strength), then closes the exhaust, expelling the air via another flap valve, Z. A strong spring, A, is always trying to open the equalizer, E, but is prevented from so doing when the external air pressure is much greater than the reduced pressure inside. When, however, there is not much difference between the external and internal pressures, the spring can open and in so doing allows air to spread into it from the interior. The effect is to reduce the internal pressure once more to such an extent that the equalizer begins to collapse. Its constant to-and-fro motion enables a steady amount of reduced pressure to be mairtained in the interior channels, despite unsteady working of the pedals.

Controls.—The simplest method of operating the "soft" and "sustaining" pedals is to connect the ordinary mechanism of the piano, by suitable levers, to finger controls in front of the keyboard. Many manufacturers prefer to control the distance from the hammers from the strings as shown in fig. 3. A button, B, opens a gate, G, when pressed down. This admits air to a pouch, P, which lifts the valve lying above it, and puts the pneumatic, N, into communication with a partial vacuum, V, thus collapsing it and causing it to lift the hammer rail, H, which softens the tone by giving the hammerhead less distance to travel towards the string, S.

A similar device withdraws all the dampers from the strings. This being a heavier task than shifting the hammers, a larger



MECHANISM OF THE PLAYER-PIANO. THE FIGURES AND LETTERS ARE EXPLAINED IN THE TEXT

pneumatic has to be employed, and two valves instead of one. Music rolls are provided with an additional hole at the left-hand edge, which works the lifting of the dampers, if desired.

Change of power, in addition to the means above described, is provided by varying the strength of the blow given to the hammer. Fig. 4 shows how the normal amount of reduced air is altered by interposing a pneumatic, N, between the main exhaust, E, and the small playing pneumatics. Pressing a button (as in fig. 3), air is allowed to enter at A, the pressure from which lifts the pouch, P, and with it the valve, D. This closes the large hole, L, and leaves only the aperture, K, over which lies a knife-cutter valve, J, so called because it closes like the blade of a pen-knife. The spring, S, is of such strength that it governs the amount of air passing through to the bellows, hard pumping closing N and therefore closing the aperture K and preventing loud playing.

A slight alteration of fig. 4 would give a fair representation of the automatic Accenting Device, which is worked from marginal perforations in the music roll. The valve disk, D, is moved to the other side of the hole, L, keeping it normally closed and softening the tone until a marginal perforation allows air to rush towards P. The pouch lifts the valve, opens L and accents the note.

The pedals also provide sufficient power to work the spool which draws the music roll over the tracker-bar. Five pneumatics of the type shown in fig. 5 are fixed at equal angular distances upon a crank-shaft, C, each one collapsing in turn and so driving the shaft round steadily. Collapse is effected when the hollow slide, S, is covering both of the ports A and B, for the pneumatic is then in direct communication with the main exhaust, through E. As the crank-shaft is thus moved round, the slide is raised, and no longer covers both ports. External air is admitted to the pneumatic, and the collapse of one of its neighbours provides the power to lower its slide and again get into communication with the main exhaust.

All communication between motor and exhaust is by way of a governor pneumatic; powerful pedalling tends to collapse it, but directly this happens a knife-valve partly closes the passage-way (as in fig. 4), and thus prevents the motor from "racing." Variation in tempo is secured by deliberately altering the size of the passage-way within an enclosure known as the Tempo Box. The shape of the slot is usually as shown in fig. 6, over which passes a slide, S. When half the area of the slot is covered, the speed of the motor is half its maximum, and so on, the slide being worked mechanically from the control board.

The holes in the paper roll being so close together, it is essential that they should track correctly, despite the effects of wear and weather. Correct tracking is controlled in ways which vary in detail, but usually depends upon the action of two pneumatics, kept under exhaust. Holes in the tracker-bar are so placed as to be uncovered when (and only when) the roll goes to one side, letting air into one of the pneumatics and causing it to open slightly, taking with it either tracker-bar or spool.

Reproducing Pianos.—The "reproducing" instruments are in a separate class, designed to reproduce faithfully all the shades of tempo and expression made by well-known pianists. All control is rightly withdrawn from the operator when using the specially cut rolls, but the same instrument may be used for ordinary rolls by putting the reproducing mechanism out of action. Additions to the normal player mechanism are mostly for the purpose of controlling more completely the comparative loudness or softness of individual notes. To do this effectively it is necessary to have as many grades of power as possible, to include smooth crescendo as well as sforzando effects.

The Ampico mechanism alters the size of the main passage-way (and hence the power) by means of a regulator valve, which is attached to a lever, controlled by a set of pneumatics under vacuum (three small "intensity" pneumatics above, balanced by a large "spring" pneumatic beneath). When marginal perforations connect up to the valves of the "intensity" pneumatics, these lift and allow the pneumatics to fill with air, thus exerting an up-push on the lever, raising the regulator valve and increasing the size of the passage-way. As these pneumatics lie along the lever, their lifting power depends upon position, those furthest from the fulcrum end being the most effective. When it is necessary for an intensity pneumatic to collapse again, another marginal perforation, connecting up to a "cancel" valve, admits air and allows this to happen. Further marginal perforations are provided, one for slow crescendo, and the other for fast crescendo, each connecting up to the same crescendo pneumatic, but in the latter case two ways are open for the air to escape, making the pneumatic collapse quickly. For "brilliant" or extra powerful performance, the Ampico can be switched over so as to close the slight "in-leak" provided on one of the three pumpers of the power mechanism. The whole system then works at maximum power. For subdued performance the main passage-way is blocked by a disk, operated pneumatically from a switch in the spool-box.

The Duo-Art (Aeolian Company) is essentially a theme and accompaniment expression arrangement, the former being at a higher dynamic power than the other. Each has a knife-valve control of the passage-way, operated by a set of four pneumatics, varying in their amount of possible collapse. In this way sixteen variants of power are obtained. There is also an "in-leak," closed by another knife-valve so as to get maximum power when the passage-way is already nearly full open. (S. A. H.)

PLAYFAIR, LYON PLAYFAIR, 1ST BARON (1818–1898), was born at Chunar, Bengal province, on May 21, 1818, and educated at St. Andrews, Glasgow, Edinburgh, University College, London, and under Liebig at Giessen, where he took his doctor's degree. Playfair translated into English Liebig's *Chemistry of Agriculture.* From 1841–42, he was chemical manager of the Primrose print-works at Clitheroe, and in 1843 was elected honorary professor of chemistry to the Royal Institution of Manchester. Soon after he was appointed a member of the Royal Commission on the Health of Towns, a body whose investigations may be said to have laid the foundations of modern sanitation. In 1845 he was appointed professor in the new School of Mines, and chemist to the geological survey, and thenceforward was constantly employed by the public departments in matters of sanitary and chemical inspection. For his services as special commissioner of the 1851 Exhibition, he was made C.B. From 1856 to 1869 he was proiessor of chemistry at Edinburgh University. In 1868 he was elected to represent the universities of Edinburgh and St. Andrews in parliament, and retained his seat till 1885, from which date until 1892 he sat as member for Leeds. In 1873 he was made postmaster-general, and in the following year, after the dissolution of parliament, was made president of a commission to inquire into the working of the civil service. Its report established a completely new system, known as the "Playfair scheme." From 1880, when Gladstone returned to power, till 1883, Playfair acted as chairman of committees. In 1892 he received a peerage, and in 1895 the G.C.B. He died in London, on May 29, 1898, and was buried at St. Andrews.

PLAYFORD, JOHN (1623–*c.* 1686), English musical publisher, was born at Norwich. From 1653 he was clerk to the Temple church, and from his shop in the Inner Temple issued most of the English music of his day. Of his own compositions the chief are numerous psalm tunes, the popular *Introduction to the Skill of Musick* (1654, 19 ed. 1730) and *The English Dancing-Master* (1651), a collection of airs for the violin used for country dances. which constitute a treasury of English national tunes.

See F. Kidson, *British Music Publishers.*

PLAYGROUNDS: *see* PARK AND PLAYGROUND.

PLEADING, that branch of the law which governs the successive formal papers in which litigants in the opening stages of a lawsuit set forth the facts upon which they claim legal relief or challenge the claims of their opponents to such relief. *See* PRACTICE AND PROCEDURE. (C. E. CL.)

PLEASURE: *see* FEELING, PSYCHOLOGY OF; HEDONISM; ETHICS.

PLEBISCITE, a term borrowed from the French for a vote of all the electors in a country or given area, taken on some specific question. The most familiar example for the use of the plebiscite in French history was in 1852, when the *coup d'état* of 1851 was confirmed and the title of emperor was given to Napoleon III. Its essential characteristic, as distinguished from the referendum (*q.v.*), is this: a plebiscitary vote decides a specific question, *ad hoc* and *pro hac vice.* It is not, as in the case of the referendum, a normal method or procedure of voting applied on a general system to certain classes of legislation. In Europe its use has been almost wholly political and national.

As a means of settling the destination of populations and territories, this method was first used in the French Revolution to defend the wholesale annexations of territory made by the conquering French republic, and subsequently by Napoleon I. It was revived by Napoleon III and applied (successfully for him) in the case of Nice and Savoy, and (successfully for Victor Emmanuel) in the duchies of north Italy during the years 1859–60. The peace conference of 1919 proposed the taking of 17 plebiscites to settle difficult national questions, of which 8 were actually held. Of these the Turkish plebiscite in Transcaucasia was a farce, Others, which decided the fate of Allenstein Marienwerder, of the Burgenland, the attribution of the northern and southern zones of Schleswig, the partition of Upper Silesia, the fate of Klagenfurt and the economic destiny of Luxembourg had substantial and important results.

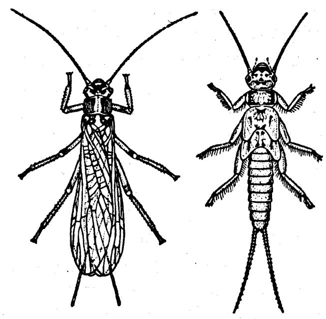
By a plebiscite of Jan. 14, 1935, the Saar, which had been administered by the League of Nations since 1920, voted to return to Germany.

Another plebiscite in 1947 favoured France but on Oct. 23, 1955, a third plebiscite rejected a Europeanization proposal leading to a Franco-German agreement on July 4, 1956, to reunite the Saar with Germany on Jan. 1, 1957.

BIBLIOGRAPHY.—H. W. V. Temperley (ed.), *A History of the Peace Conference oj Paris,* references in subject index to vol. vi, 703 (1920–24); Sarah Wambaugh, A *Monograph on Plebiscites* (1920), *Plebiscites Since the World War,* 2 vol. (1933); F. Llewellyn Jones, *Plebiscites,* Grotius Society Transactions (1927); C. R. M. F. Cruttwell, *A History of Peaceful Change in the Modern World* (1937).

PLEBS, the "multitude." or unprivileged class, in the early Roman state (cf. Latin *plenus,* "full"; Gr. *plethos,* "multitude"). For the origin and history of this order *see* PATRICIANS. Its disqualifications were originally based on descent, but after the political equalization of the two orders these ceased.

PLECOPTERA (Gr. *plekos,* "plaited"; *pteron,* "wing") is the order of insects known as stone flies. The immature stages are aquatic, living in streams and rocky lake margins. The female lays several thousand eggs, discharging them in masses into the water. The nymphs are active and elongate, have long antennae and a pair of long "tails." Some forms have gills, but most do not. They feed on microorganisms, decaying organic matter or other insects. Nymphs may be found in clumps of rotted leaves, masses of debris or beneath submerged logs and stones. When mature, the nymph crawls out of the water and attaches itself firmly by its claws to a rock or tree trunk. The nymphal skin then bursts along the back and the adult emerges.



BY COURTESY OF THE ILLINOIS STATE NATURAL HISTORY SURVEY

STONE FLY (ISOPERLA CLIO)

(Left) adult, length about 0.8 in.; (right) nymph, length about 0.6 in.

The adults are soft-bodied and range in length from $\frac{1}{8}$ to $1\frac{1}{2}$ in., plus the tails. They have long, many-segmented antennae; a pair of "tails" (minute in some forms); and usually two pairs of membranous wings folded flat over the back. In a few species the wings are mere stubs. Most species are black or dark brown, but some are bright yellow or leaf green and others may be marked with orange or red. Stone flies fly rather slowly, but run actively. They are found on stones. foliage or tree trunks along the edge of a stream, or hiding in crevices of bridges or bark. Most species emerge from the water in spring, but there is a fairly large group of winter species, and a few in summer and autumn. Most adults do not feed, but some species eat algae, pollen and bud exudates. All forms are important as fish food and in general stream ecology. Both adults and nymphs are best collected in 80% alcohol.

The order Plecoptera contains about 1,200 species classified in nine families, distributed throughout the world. There are about 450 species in North America, 34 in the British Isles. Australia and New Zealand contain many primitive forms.

Fossil stone flies appear first in the Permian period, but are reasonably common only in the middle Tertiary amber of the Baltic region of Europe.

See also INSECT.

BIBLIOGRAPHY.—J. G. Needham and P. W. Claassen, *The Plecoptera of North America,* Entomological Society of America (1925); T. H. Frison, "Stoneflies, or Plecoptera of Illinois," *Illinois Natural History Survey Bulletin*, 20:281–471 (1935); W. E. Ricker, *Systematic Studies in Plecoptera,* "Indiana University Publications, Science Series," 18 (1952); H. B. N. Hynes, *A Key of the Adults and Nymphs of British Stone-flies (Plecoptera),* Freshwater Bioiogical Association, Scientific Publication, 17 (1958). (W. E. R.)

PLEDGE or **PAWN,** in law, a "bailment of goods by a debtor to his creditor to be kept till the debt is discharged" (Jones on Bailments). The term is also used to denote the property which constitutes the security. Pledge is the *pignus* of Roman law from which most of the modern law on the subject is derived. It differs from hypothecation and from the more usual kind of mortgage in being confined to personal property, and also in that the pledge is in the possession of the pledgee. A mortgage of personal property, in the majority of instances, takes the name and form of a bill of sale (*q.v.*). In the case of a pledge, it is held that a special property passes to the pledgee, sufficient to enable him to maintain an action against a wrongdoer, but the general property, *i.e.*, the property subject to the pledge, remains in the pledgor. As the pledge is for the benefit of both parties, the pledgee is bound to exercise only ordinary care over the pledge. He must, however, insure against loss by fire (3 5/36 Vict. ch. 93, s.36). The pledgee has the right of selling the pledge if the pledgor makes default in payment at the stipulated time.

The law of Scotland as to pledge generally agrees with that of England, as does also that of the United States. The main difference is that in Scotland and in Louisiana a pledge cannot be sold unless with judicial authority. Chattel mortgages, which differ from pledges in that the owner retains possession of the article, are uniformly required to be recorded in order to be valid against third parties, but except for a few States and aside from the Factors acts, a pledge, for the validity of which possession must be transferred to the pledgee, will be enforcible against third parties without being recorded. (See also FACTOR and PAWNBROKING.)

PLEDGE OF ALLEGIANCE TO THE U.S. FLAG. This pledge was first published in the juvenile periodical *The Youth's Companion* on Sept. 8, 1892, in the following form: "I pledge allegiance to my Flag and the Republic for which it stands: one nation indivisible, with liberty and Justice for all." The words "the Flag of the United States of America" were substituted for "my Flag" in 1924, and the pledge was officially recognized by the C.S. in 1942. In 1954 "under God" was added, making it read: "I pledge allegiance to the fag of the United States of America and to the Republic for which it stands, one Nation under God, indivisible, with liberty and justice for all." A controversy arose concerning the authorship of the pledge of 1892. Claims were made on behalf of both James B. Cpham, one of the editors of The *Youth's* Companion, and Francis Bellamy, an assistant editor. In 1939 a committee of the U.S. Flag association ruled in favour of Bellamy, however, and a detailed report issued by the Library of Congress on July 18, 1957, concluded that "the Bellamy claim to authorship rests upon the more solid ground."

See also LOYALTY.

PLEHVE, VIATSCHESLAF KONSTANTINOVICH (1846–1904), Russian statesman, was born of Lithuanian stock in 1846. He was educated at Warsaw and at the university of St. Petersburg (Leningrad) before he entered the department of justice, in which he rose rapidly to be assistant solicitor-general in Warsaw, then solicitor-general in St. Petersburg, and in 1881 director of the state police. As assistant to the minister of the interior he attracted the attention of Alexander III. by the skill he showed in investigating the circumstances of the assassination of Alexander II. He received the title of secretary of state in 1894, became a member of the council of the empire, and in 1902 succeeded Sipiaguine as minister bf the interior. Plehve carried out the "russification" of the alien provinces within the Russian Empire, and earned bitter hatred in Poland, in Lithuania and especially in Finland. He despoiled the Armenian Church, and oppressed the Armenians of the Caucasus. He certainly did nothing to discourage pogroms against the Jews, and he was credited with being accessory to the Kishinev massacres. His logical mind and determined support of the autocratic principle gained the tsar's entire confidence. He opposed commercial development on ordinary European lines on the ground that it involved the existence both of a dangerous proletariat and of a prosperous middle class equally inimical to autocracy. He was a determined and successful opponent of Witte's policy. An attempt was made on his life early in 1904, and he was assassinated on July 28 of the same year by a bomb thrown under his carriage as he was on his way to Peterhof to make his report to the tsar; the assassin, Sasonov, was a member of the socialist revolutionary party.

PLEIAD, in Greek literature, the name given (by analogy from PLEIADES) by the Alexandrian critics to seven tragic poets who flourished during the reign of Ptolemy Philadelphus (285–247 B c.). In French literature, in addition to the Pleiad of Charlemagne, there were two famous groups of the kind. The first, during the reign of Henri III. (1574–89), the chief member of which was Pierre de Ronsard, sought to improve the French language and literature by enthusiastic imitation of the classics; the second, under Louis XIII. (1610–43), consisted of authors who excelled in the composition of Latin verse.

PLEIADES, an asterism, or star cluster; in mythology the seven daughters of Atlas and Pleione, and sisters of the Hyades (*q v.*). Because of their grief at the death of their sisters or at the sufferings of their father, they were changed into stars. In another account, the Pleiades and their mother met the amorous hunter Orion (*q.v.*) in Boeotia; for five years he pursued them through the noods. until Zeus translated them all—Pleione and her daughters, Orion and his dog—to the sky. This is one of the few myths really astronomical in origin, for it is based on the relative positions of the constellations in the sky. The names of the sisters are Xlcyone, Asterope, Electra. Celaeno. Maia, Merope and Taygeta; one is always dim or invisible, because she is Electra mourning for Troy, or Merope, who is ashamed of having wedded a mortal. Sisyphus. All the Pleiades became the ancestresses of divine or heroic families. The early winter rising and spring setting of the Pleiades (Lat. Vergiliae) are important dates to the farmer.

See H. J. Rose, *Handbook of Greek Mythology,* 5th ed rev. (1953).

The stars are situated in the constellation Taurus (*q.v.*). They are referred to in the Old Testament (Job ix, 9; xxxviii. 31). The brightest star is Alcyone (η Tauri), of the third magnitude. This group is physically connected, being distinguished from the background stars by community of proper motion. Photographs show a faint nebulosity filling the whole region; there is little doubt that this is rarefied matter made luminous by stimulation of the radiation of the hot stars comprised in it. The distance of the Pleiades from the solar system is estimated at 100 parsecs (300 light-years), but is not very certainly known.

Alcyone and the other bright stars are of the hottest type of spectrum (Type B) and give out several hundred times as much light as the sun.

PLEISTOCENE EPOCH. This is the sixth of the seven epochs that constitute the Cenozoic era (*q.v.*) of geological history (if, as is indicated on the accompanying geologic time chart, the Recent is taken as the seventh and the Pleistocene is not separated as the Quaternary era). By recommendation of the commission, 18th International Geological congress, the nonglacial Pleistocene (Greek *pleistos,* most, and *kainos,* recent) is defined on the basis of its fauna and separated from the preceding Pliocene by this means. Broadly speaking, however, it is thought to coincide with a period when glacial and interglacial conditions alternated over a large part of the earth's surface and because of this it is often known as the Glacial epoch or the Great Ice Age. During the glacial ages, widespread continental ice sheets repeatedly covered large areas in the northern hemisphere and alpine glaciers were more numerous and extensive in both the northern and southern hemispheres. During the interglacial ages, the climate seems to have been as warm or warmer than the present. The glaciated areas were reclothed with vegetation and repopulated with animal life and soils were formed. This epoch, the major part of the Quaternary period, is believed to have lasted several hundreds of thousands of years. It is generally regarded as having been terminated by the melting away of the latest of the great ice sheets, but at the same time it is also recognized that the Recent epoch of warm climate is not dissimilar to the interglacial ages, though shorter, and therefore the conditions of the Pleistocene glacial epoch have continued uninterruptedly to the present day.

This article is divided into sections and subsections dealing with various aspects of the epoch. The general geology of the period is considered under QUATERNARY. In addition to the cross references to related articles given under the several headings in this article *see* also ARCHAEOLOGY: *Prehistory;* GLACIER; MAN, EVOLUTION OF; PALAEOBOTANY; PALAEONTOLOGY.

Following are the main divisions of this article:

- I. The Glacial Concept
- II. Extent of Glaciation
  - 1. Areas of Continental Glaciation
  - 2. Source-Areas of Glacial Radiation
- III. Revolutionary Effects of Glaciation
  - 1. Effect of the Continental Glaciers
  - 2. Effects Beyond the Glaciated Area
  - 3. Warping of the Earth's Crust
  - 4. Fluctuations of Sea Level
- IV. The Glacial and Interglacial Ages
  - 1. Subdivisions of the Latest Glacial **Age**
  - 2. Nonglaciated Regions
  - 3. Duration of the Glacial Epoch
- V. Life of the Pleistocene Epoch
  - 1. North America
  - 2. Europe
  - 3. Early Man
- VI. The Glacial Climates
  - 1. Character
  - 2. Causes

I. THE GLACIAL CONCEPT

The concept of an ice age, when climates were colder and glaciers were far more extensive than they are at present, was first advanced by A. Bernhardi (1832) and Louis Agassiz (1837). Agassiz conceived the idea in Switzerland as the outgrowth of examining evidence earlier pointed out by scientific colleagues that certain glaciers in the Alps had formerly extended far down their valleys. He confirmed his views after a field study in Scotland in 1840. and extended them still further after he went to the United States in 1846 to spend the rest of his life.

Prior to the announcement of this glacial hypothesis naturalists commonly viewed the extensive glacial deposits and the widespread evidence of glacial erosion in the lowlands of both Europe and North America as the work of a cataclysmic flood (many believed it to have been the biblical deluge), or of a temporary submergence of the lands beneath the sea, with or without icebergs to help carry the large quantity of stones and boulders visible in the deposits. Not until about three decades after Agassiz' first announcement were the majority of scientific men on either side of the Atlantic convinced that glaciers rather than water had been responsible for these features. The term "drift," still applied to glacial deposits in general, dates from the time when the submergence hypothesis was widely accepted.

Geologic **Time** *Chart*

System and Period	Series and Epoch	Distinctive Records of Life	1,000 Years
CENOZOIC ERA			
Quaternary	Recent	Modern man	11
	Pleistocene	Early man	1,000
Tertiary	Pliocene	Large carnivores	
	Miocene	Whales, apes, grazing forms	
	Oligocene	Large browsing mammals	
	Eocene	Rise of flowering plants	
	Paleocene	First placental mammals	70,000
MESOZOIC ERA			
Cretaceous		Extinction of dinosaurs	130,000
Jurassic		Dinosaurs' zenith, primitive birds, first small mammals	160,000
Triassic		Appearance of dinosaurs	200,000
PALEOZOIC ERA			
Permian		Reptiles developed, conifers abundant	235,000
Carboniferous			
Upper (Pennsylvanian)		First reptiles, coal forests	260,000
Lower (Mississippian)		Sharks abundant	285,000
Devonian		Amphibians appeared, fishes abundant	320,000
Silurian		Earliest land plants and animals	350,000
Ordovician		First primitive fishes	400,000
Cambrian		Marine invertebrates	500,000
PRE-CAMBRIAN TIME			
		Few fossils	3,500,000–4,000,000

II. EXTENT OF GLACIATION

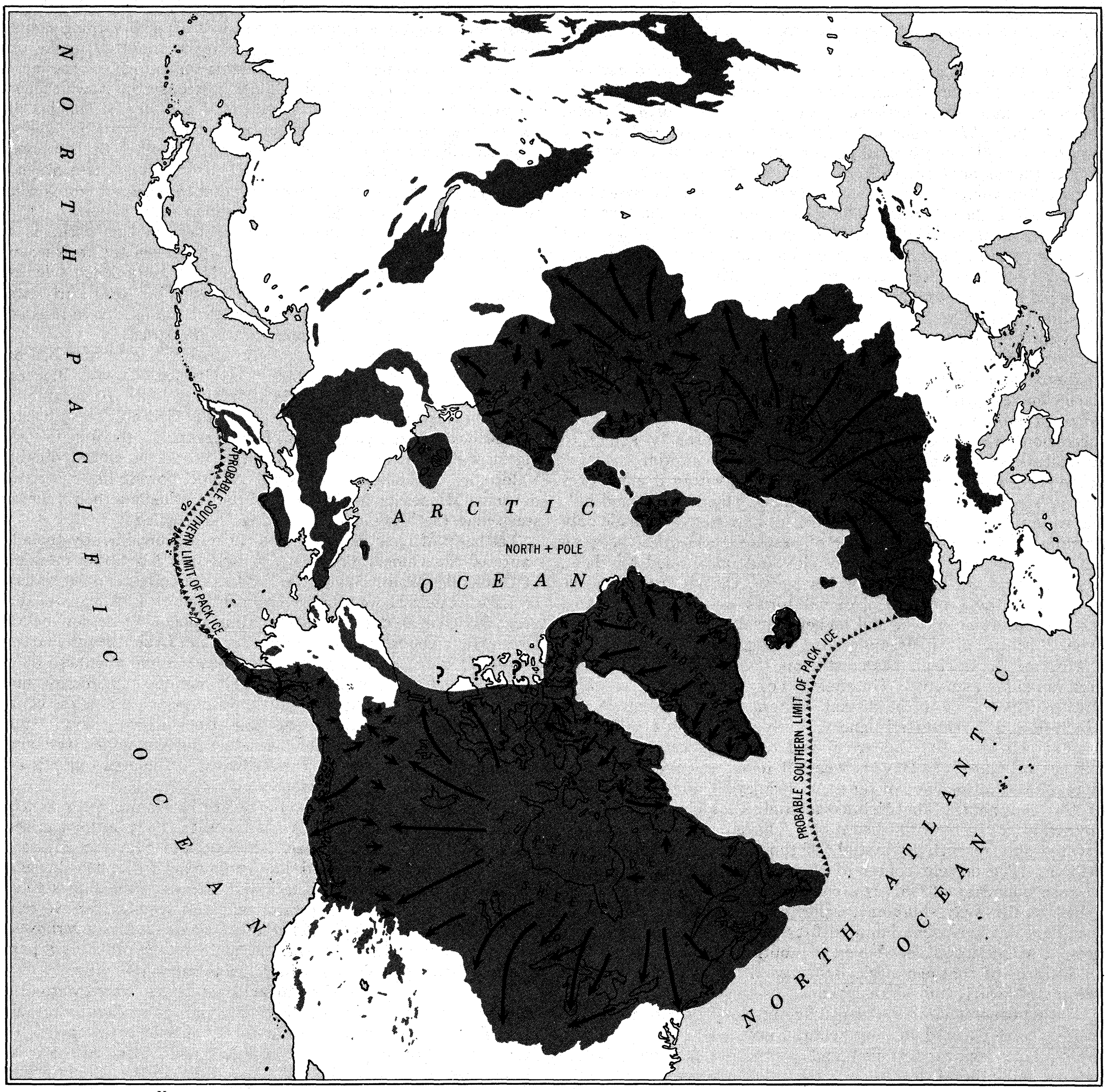
1. Areas of Continental Glaciation.— The convincing evidence of the former. much greater extent of glaciers is so generally accepted that it need not be presented here. The areas within the northern hemisphere that were formerly ice-covered are shown in the accompanying maps (the less extensive glaciers in the southern hemisphere are not illustrated). The mountainous western part of North America was occupied by a vast complex of glaciers which throughout most of the Canadian sector formed a nearly continuous covering of ice. The vast area from the Atlantic to the Rocky mountains. Canada and the northern part of the United States (as far south as New York city. Cincinnati. O., Carbondale, Ill., St. Louis, Mo., Kansas City. Mo., and Pierre, S.D.) were buried beneath an ice sheet (the Laurentide ice sheet) that had its source in Canada and also reached north to the Arctic ocean. The Laurentide ice sheet overtopped the White mountains in New Hampshire and so was at least 5.000 ft. thick in that region. This is the greatest minimum thickness that is shown by direct evidence, but it is considered probable that this ice sheet was 5,000 to 10,000 ft. thick throughout the greater part of its extent.

Greenland and Iceland were almost entirely ice-covered. Nearly half of Europe—from the North Cape off the north coast of Norway south to Kiev on the banks of the Dnieper—was covered by a single vast ice sheet (the Scandinavian ice sheet) which is believed to have attained a maximum thickness of 10.000 ft. Much of Siberia was overspread by mountain glaciers and by a great ice sheet (the Siberian ice sheet) on its northwestern plain. The Alps, the Caucasus and the Pyrenees in Europe and most of the high mountains on other continents carried glaciers of varying dimensions. The antarctic continent was even more nearly completely ice-covered than now. and the glaciers of the southern Andes spread westward to tidewater in Chile and eastward onto the pampas of Argentina. The highest mountains of Hawaii, Japan and New Guinea were marked by glaciers.

At present about 5,800,000 sq.mi (about 10.4% of the land area of the globe) are covered by glacier ice. but 98% of this ice is in the distant higher latitudes of Antarctica and Greenland. In contrast, when glaciers were at their maximum they extended into temperate latitudes now the sites of highly organized civilizations and abundant agricultural and manufacturing production.

2. Source-Areas of Glacial Radiation.— During the early part of the last glacial age, the Wisconsin, the great Laurentide ice sheet over Canada had two primary areas of glacial radiation, one known as the Labradorean area located over the highlands of Labrador and eastern Quebec, and the other known as the Keewatin area located on the plains of Manitoba and adjacent territory of Ontario and Hudson bay. Later there was another area of almost equal importance, the Patrician. which developed south of Hudson bay and sent ice lobes southward through the Lake Michigan basin to form the moraines around the southern end of that basin and westward and southwestward through the Lake Superior basin into northern Wisconsin and northeastern Minnesota. The Keewatin ice lobe was crowded westward by it but even so the Keewatin ice received sufficient snowfall and possessed the energy to advance nearly as far south as Des Moines. Ia. Over the Cordilleras of western Canada the excessive snowfall, though much greater than today's, failed to form a continuous ice cap because of the rapid movement of the valley glaciers. especially on the west side, and the calving of icebergs into the sea.

The Scandinavian ice sheet had its origin on the high divide between Norway and Sweden. The Siberian ice sheet possibly began as small glaciers on three separate highlands: the Putorana mountains. the Byrranga ridge on the Taimyr peninsula and the



NORTHERN PART OF THE NORTHERN HEMISPHERE SHOWING AREAS GLACIATED DURING THE PLEISTOCENE EPOCH

Arrows show principal directions of flow (much generalized) of former glaciers, where information is available. Base from Hydrographic and Map service, Can. Polar Equidistant projection. Glacial data from many sources, notably Glacial Map of North America published by the Geological Society of America; Great Soviet atlas; E. Antevs, Gerasimov and Markov

Severnaya Zemlya archipelago.

A consideration of these ice fields makes it appear that they were all in response to a changing glacial atmospheric organization measurably different from the present; some ice fields began on plains, some on highlands, all necessarily being in the paths of maritime air masses charged with moisture. These ice fields varied in relative importance from age to age. During the Nebraskan age the Keewatin was the dominant field. During the following Kansan both fields were important. During the Illinoian, the third glacial age, the Labradorean area of radiation was preponderant and the Keewatin played a minor role.

This history emphasizes the fact that the nature of the atmospheric organization is unpredictable. The facts lie in the stratigraphic record.

(See also *The Glacial Climates,* below.)

III. REVOLUTIONARY EFFECTS OF GLACIATION

1. Effect **of** the Continental Glaciers.—The northern part of North America and of Eurasia as well suffered profound changes from continental glaciation. The features of the latest glacier are indeed climactic. In North America the Great Lakes—the greatest fresh-water bodies on earth—are due more to glacial scour on a grand scale of former lowlands than to glacial deposition and later crustal deformation that followed the unloading of the earth's crust by the melting of the continental ice sheet. The moraines of glacial drift that lie beyond the basins are in large part the debris resulting from the glacial scour. The lake floors have irregular contours due to both glacial scour and deposition. However, the present outlines of the Great Lakes were assumed when crustal deformation tipped the land southward and helped to fix the present outlets. Northern Lake Michigan is more than

100 ft. shallower than when the glacier scoured it, and the northern part of Lake Huron and Georgian bay is something like 600 ft. shallower.

The lakes, muskegs, embossed and striated rock and other features of the irregular topography of Canada, the 10,000 lakes of Minnesota and large portions of the terrain of North Dakota, South Dakota, Wisconsin and Michigan are mainly such as only the processes of a continental glacier can bring about. New England and areas adjacent to it show the beautiful flowing lines of glaciated hills once buried deeply beneath the great ice sheet that terminated in the Atlantic. The lake basins among the hills, the anomalous sources of streams, the setting of the lakes and the strewing of the countryside with boulders and stony deposits are also features that result from glaciation. Maine has its eskers (rounded ridges of sand and gravel) crossing hill and dale, marking for mile after mile the courses of subglacial streams.

To the south and southwest of Lake Michigan, westerly and southward from Lake Erie, southwest from Saginaw bay, and in northern Iowa and the eastern Dakotas, the spreading continental glacier made a plains country and left upon its retreat a successive series of moraines that fashioned the country into a rhythmic succession of ridge-and-plain topography remarkably suited to agriculture and transportation. This central interior lowland, however, is not all glacial. The glaciers left within it a driftless area of some 10,000 sq.mi., a topographic "island" of rugged hills and valleys branching treelike (dendritic) in pattern and made only by running-water erosion, a relic of preglacial times left between the Keewatin and Patrician ice fields and unmodified by them. Regardless of the direction of his travel, the motorist can see in contrast these pristine erosional forms of the driftless area and the bordering, newer and higher glacial landscape which has beneath it the older stream-eroded topography.

Most of the ancient master streams that preceded the glacial invasion did not survive. The ancient Teays-Mahomet river which once had its source in the distant western fringe of Virginia and which flowed northwesterly and westerly, eventually crossing the present course of the Ohio river and traversing central Indiana and central Iliinois to Havana where it joined the ancient Mississippi, indeed formed one of the master valleys of the great interior of the continent. The Nebraskan and Kansan glaciers which crossed it transversely finished it off. This ancient valley was discovered only recently by a study of thousands of records of well drilling. The present course of the Ohio river along the southwestern boundary of Ohio is a consequence of this geological accident to the Teays-Mahomet valley, as is the upper portion of the Wabash river. One hundred fifty miles of the course of the present Mississippi river above the mouth of Illinois river is also an accident of continental glaciation, as is the Missouri river for 500 mi. in North and South Dakota.

These phenomena of the glacial age in North America are in a real sense duplicated in continental Europe — the glacial topography, lake regions. terminal and recessional moraines, buried valleys and other features — but there is no counterpart of the Great Lakes. A vast river flowed across northern Germany, along the southern part of the North sea floor and through the English channel because the normal drainage to the north was blocked by the Scandinavian ice sheet. (The English channel and much of the North sea floor were then dry land.) Capacious abandoned valleys excavated by the previous drainage are present in the north German plain. Where the land surface sloped toward the ice sheet, there were formed large temporary lakes, one shore of which was against the glacier ice. Lakes of great extent, now drained, also originated in this way in Ontario, Manitoba and the Great Plains region of Canada.

The people of many other parts of the North American continent marvel at the fertile soils of the north central states. It is common to refer to them as glacial. In the main, however, they are not derived from glacial drift but from loess, a silt picked up, carried and deposited by terrific glacial winds. The greatest thickness of loess in the middle west is along the east or southeasterly side of wide valleys containing silty glacial outwash and along the margin of the Iowan drift sheet, where the loess mantle averages 50 ft. or more and extends over the adjacent uplands in decreasing thickness, fineness and lime content. The shells of air-breathing snails, forms whose habitat is commonly the open woodland, make up the chief fossil fauna. In central Illinois some 10 ft. of the loess occurs under the Tazewell or Middle Wisconsin drift which has protected it from oxidation. Here peaty and woody remains of the original vegetation still occur in the loess, some in layers, thus recording pauses in the deposition. Beyond the terminal moraine and the protective cover of the Tazewell there are no plant remains, merely thin layers of orange-coloured iron oxide representing the iron residue of the former plant layers.

Niagara falls, one of the natural wonders of the world, is a product of the glacial age. It was initiated when the melting of the ice uncovered the cliff at Lewiston. N.Y., and opened a lower outlet for the waters of Lake Erie. That this occurred fairly late in geological times is shown by the fact that the falls have receded only about seven miles at a rate that is measurable.

The fertile Red river valley of the north is the former bed of Lake Agassiz whose natural outlet to Hudson bay was blocked until the Laurentide ice sheet was virtually melted. Its maximum area far exceeded the combined area of the Great Lakes. It had two histories, Lake Agassiz I and Lake Agassiz II. the first following the melting of the Mankato ice, the second the melting of the Valders ice. Its outlet was of great volume, flowing like a torrent down the Minnesota and Mississippi rivers, widening their valleys, steepening the bluffs and truncating the headlands.

The basin of Lake Agassiz 1 was entirely overridden by the advance of the Valders glacier which built the Big Stone moraine at Ortonville, Minn. When the Valders ice retreated, the waters of Lake Agassiz II were obliged to cut a new outlet, narrow and gorgelike compared to the wide Minnesota river valley below Ortonville. Though of shorter duration than Lake Agassiz I, Lake Agassiz II lasted long enough to form beaches and a smooth floor out of a moderately undulating ground moraine topography, but the gravel of the beaches show little water wear. Upon the complete melting of the glacier the lake, from its very south end, drained into Hudson bay, thus beheading the Minnesota river and forming a new river system, the Red river. The area today is an important wheat-growing region.

Lake Winnipeg and other water bodies in Manitoba are relicts of ancient Lake Agassiz II. A similar water body formed in the Baltic sea basin of northwestern Europe and over the adjacent coasts of Sweden and Finland, its overflow being through the submerged channel between Denmark and Sweden. A lake of similar origin is reported in the headwater region of Irtysh river, western Siberia. Obstructed by the Siberian ice sheet the lake overflowed southward into the ancient Aral sea, at that time probably a part of the Caspian sea-Black sea-Mediterranean water body.

The various outlets of the glacial Great Lakes, which were also held back by the ice sheet, hold interest too because of their great size. Among these overflow routes may be mentioned: (1) from Chicago to the Illinois river valley and thence to the Mississippi river; (2) from Fort Wayne, Ind., via the Maumee and Wabash river valleys to the Ohio river; (3) from Lake Erie via the Mohawk river valley to the Hudson river; (4) from North Bay, Ont., via the Ottawa river valley to the St. Lawrence river. The old lake shores are variously marked by distinct cliffs, beaches and bars, many of which later served the early Indian as travel routes and still later were adopted in part for highways.

In the course of early geological investigations the students of glacial geology were amazed to find that some of the later beaches, which have a northward trend, rise higher and higher to the north, the oldest one reaching 600 ft. higher at North Bay than farther south. Thus was born the concept that the ice load had depressed the earth's crust and that removal of the ice permitted it to rise. The response was tardy but still continues, as accurate and refined measurements prove. Similar and equally striking phenomena occur in northeastern North America and northwestern Europe. The first-formed beach in the Baltic, following the shrinkage of the Scandinavian ice sheet, is now found in places as much as 700 ft. above sea level (see also Warping of the Earth's Crust, below).

The valley glaciers of the Cordilleras, the Alps, Carpathians and other high mountains in both the northern and southern hemispheres deepened and widened the pre-existing valleys, steepened the valley sides and excavated basins in the bedrock of the valley floors.

Farther down the valleys glaciers built up side ridges with the rock debris that they had acquired, in many cases hundreds of feet high (lateral moraines), and made ridges across the valleys from side to side (end moraines). Some lateral moraines consist partly of debris washed and avalanched onto the sides of valley glaciers from the steep slopes above. Melt-water streams coursing away from the glaciers spread boulders, gravel and sand over the valley floors. in some cases scores of miles beyond the farthest positions reached by the glaciers themselves. Far up in the mountains, ridge crests were sharpened to serrate forms by intense frostwork at those altitudes.

The world-famous, deep, steep-sided fiords of the coasts of Norway, Greenland, Alaska, Chile and parts of New Zealand were glacially carved from pre-existing valleys, and deepened far below sea level.

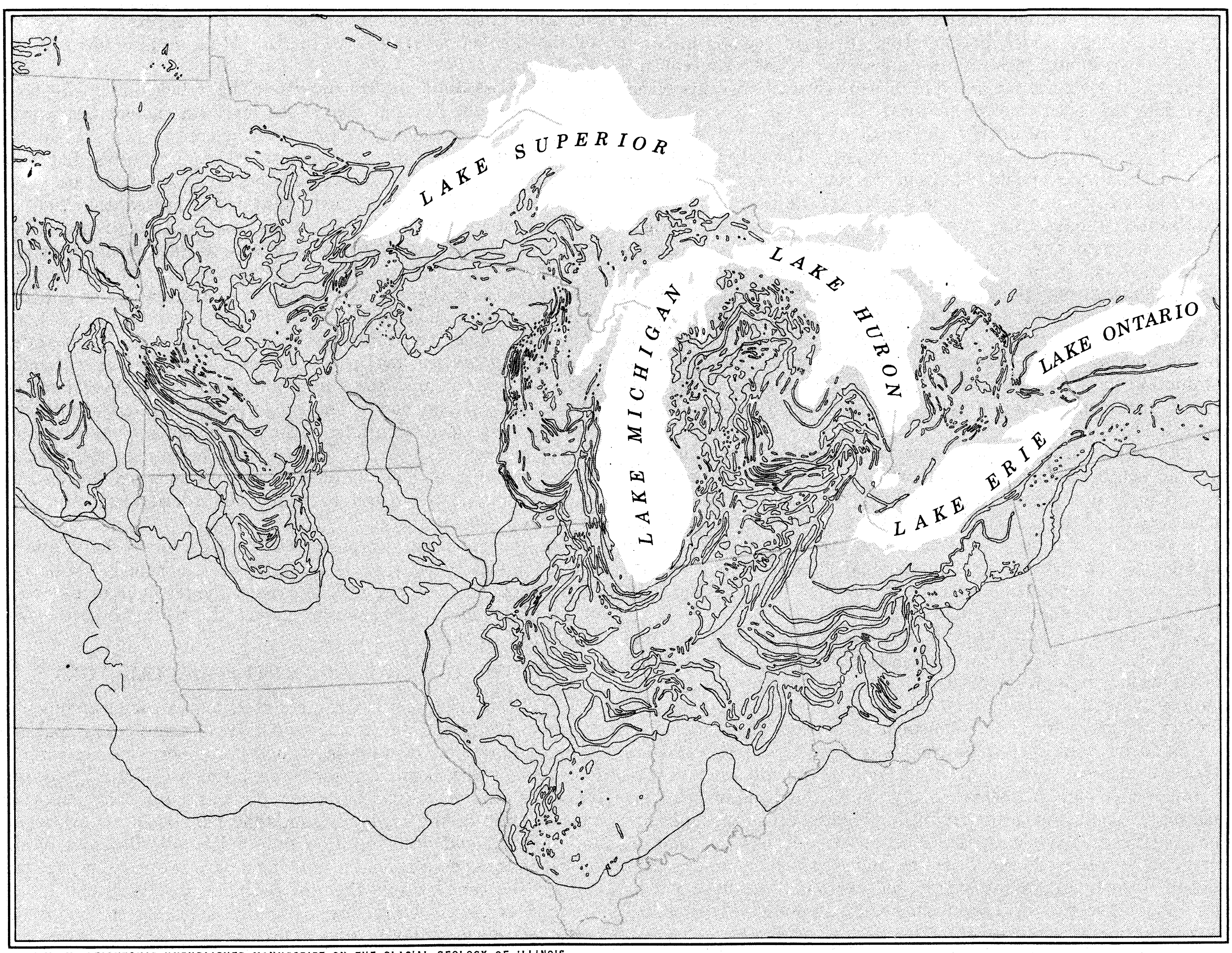
2. Effects Beyond the Glaciated Area.—The effects of the glacial climate and continental ice sheets extended far beyond the limits of glaciation. Rivers like the Mississippi and its strikingly spaced tributaries, the Ohio and the Missouri, and the Susquehanna and Columbia were greatly augmented by glacial melt water and overloaded with glacial sediment which they deposited as valley-train outwash all of the way to their receiving embayments. Sea levels were lower than they are at present and the extension of the Mississippi delta was controlled by such levels, only to become platforms upon which the later delta deposits were laid. Other river systems of the earth were affected similarly, the Volga, Don and Dnieper of eastern Europe being among those that are better known.

Mixed with some of the glacial sediment were ice-rafted boulders that reached the sea.

The valley trains that came from the glaciers of the Rocky mountains down the Missouri. the Platte and other rivers were sources of silt for winds to whip up and deposit as loess on the adjacent uplands. These valley-train sediments joined those from the upper Mississippi, so that loess in great thicknesses is found on the eastern bluffs of that valley as far south as Natchez, Miss., and beyond.

In the dry regions in low and middle latitudes on all continents there is impressive evidence both of former lakes where none now exist and of the former much larger size of existing lakes These phenomena show that in these regions there were repeated times of greater precipitation and smaller evaporation than now occur. In at least two cases (Lake Bonneville in Utah and Mono lake in California) a close time relationship has been established between the shore lines of the expanded lakes and glacial moraines. It is widely believed that the times of greater precipitation and less evaporation coincided nith the glacial ages, and that the times of low water or even desiccation coincided with the interglacial periods.

The most widely studied of these dry regions is in the western United States, where no fewer than 68 former lakes have been



FROM M. M. LEIGHTON'S UNPUBLISHED MANUSCRIPT ON THE GLACIAL GEOLOGY OF ILLINOIS

OUTLINES OF GLACIAL MORAINES AROUND THE DISTAL ENDS OF THE GREAT LAKES SHOWING THE LOBATE ORGANIZATION OF THE LAST ICE SHEET identified by their abandoned shore lines and sediments. The largest of these lakes was Lake Bonneville which filled a number of coalescent intermontane basins in Utah, Nevada and Idaho and had a maximum area of more than 20,000 sq.mi. and a maximum depth of more than 1,000 ft. Since the last glacial age this enormous fresh-water body has been shrunken by evaporation to Great Salt lake, Provo lake and Sevier lake. Second only to Bonneville in size was Lake Lahontan, which had a maximum area of **8,422** sq.mi. in Nevada, Oregon and California. Pyramid lake, Winnemucca lake, the Carson lakes and Walker lake are its reduced successors. Some of the **68** basins, studied in detail, have yielded evidence of two and even three high-water stages separated by stages of partial or complete desiccation.

In Eurasia a similar record has been recognized. The Caspian sea and the Aral sea east of it had at least three expansions separated by drier times. Both basins filled and overflowed. Similar though less fully determined records have been reported from the larger undrained basins of central Asia. According to Max Blanckenhorn the Dead sea of biblical fame filled, at least once, to four times its present length and to a height nearly 1,400 ft. above its present surface.

In northern, eastern and southern Africa the record of former lakes is closely similar. This repeated expansion and desiccation form the basis for a Pleistocene sequence for that continent.

The low temperatures responsible for the formation of glaciers in higher latitudes are believed to have been the basic cause of the lake expansions. Decreased evaporation directly resulted. As the ice sheets formed, they became the sites of high atmospheric pressure, which in turn pushed the principal middle-latitude belts of moving cyclones south of where they presently lie. These cyclones brought added precipitation to broad regions in lower latitudes that in nonglacial times were semiarid. As a consequence of increased precipitation and diminished evaporation, lakes either came into existence or were enlarged.

Because they were in part the result of increased rainfall, the high-lake stages are termed pluvial stages. The lakes appear to have reached their maxima at about the times when the ice sheets were at their maxima. Thus the glacial ages and the pluvial ages are thought to have been coincident and closely related in origin.

A conspicuous effect of the glacial climates in regions that lay a short distance beyond the ice sheets is the effect of frost heaving and solifluction. Solifluction is the slow creeping of superficial soil, even on very gentle slopes, as a result of freezing and thawing of the ground. It takes place today in arctic and antarctic regions and on high mountain summits in lower latitudes. The effects of solifluction in producing contortion of stratification and the patterned arrangements of stones resulting from frost-heaving of the soil are distinctive.

These effects also have been observed in regions never glaciated, such as southern England and northern France, and where the ground does not freeze today. They have been found also in various parts of the United States, even on the older drift sheets that extend beyond the younger. The inference is that during the glacial ages the temperatures in the regions surrounding the ice sheets were reduced enough to cause the ground to freeze and thaw vigorously, with resulting solifluction.

3. Warping of the Earth's Crust.—The building of large glaciers on the earth's surface during the glacial ages had two direct effects which in some places conditioned and resulted in greater changes than those attributable to erosion and deposition by the glaciers. These effects were conspicuous fluctuations of sea level and extensive warping of the earth's crust. The crust yields to excessive loading such as that induced by the great ice sheets. In the substratum below the rocky crust plastic flow transfers rock material outward away from the weighted area causing basin-like subsidence. When the ice sheet begins to melt the load on the crust is reduced, the direction of plastic flow in the substratum is reversed, the rocky crust bulges up very slowly in dome-like fashion and not until some time after the ice has disappeared are conditions restored to normal.

Along the seacoast and in regions of large glacial lakes extensive areas were submerged as they were uncovered by the melting ice. Waves and currents fashioned cliffs and beaches along the shores. The delayed updoming of the crust gradually caused the water to recede and at the same time warped the shore lines out of their original horizontal positions. Where there are several successive shore lines it has been possible to reconstruct the general form and progress of updoming. Doming movements related to the latest glacial age began so recently that they are still in progress, at least in eastern North America and in northwestern Europe. In the latter region the warping is concentric to an area in east-central Sweden. From this fact it is inferred that the Scandinavian ice sheet was thickest over that area. It is estimated that when the warping movement has been completed, thousands of years in the future, most of the floor of the Gulf of Bothnia will have become dry land.

In North America updoming is evident throughout the northern part of the vast region uncovered by melting of the Laurentide ice sheet. The great system of temporary glacial lakes, now extinct, that extended from Montana and the Great Plains of Canada on the west to northern New York and northern Ontario on the east left an array of shore lines whose measurements have yielded much information about the progress of updoming of the crust as the ice sheet disappeared. The thickest part of this ice sheet—at least during its later history—is inferred to have stood over the Hudson bay region because the warped shore lines are generally concentric to that region. Farther east along the St. Lawrence. in the maritime provinces of Canada and in Newfoundland, well-developed marine strand lines record submergence beneath the sea as the ice melted, followed by slow upwarping toward the northwest. This movement is still continuing throughout much of the region. It is predicted that the future completion of the doming movement will cause Hudson bay virtually to disappear.

4. Fluctuations of Sea Level.—The other direct effect of glaciation is the fall and rise of sea level throughout the world. As was correctly deduced by Charles Maclaren in **1842,** the building of large glaciers when none existed before requires that vast quantities of atmospheric moisture be precipitated in the form of snow. As this moisture must come from the sea, the result is lowering of the sea level. Under warming climates the existing glaciers melt and large volumes of melt water are returned to the sea, thereby raising its level. The alternation of glacial and interglacial ages therefore has resulted in fluctuation of the sea level through a range of hundreds of feet, including levels both somewhat higher and much lower than today. It is generally thought that the sea level has stood, during glacial ages, perhaps 400 ft. lower than now, and during interglacial age's several scores of feet higher than now. These figures are arrived at by two methods: (1) calculation from estimated volumes of present and former glaciers; (2) measurement of the heights of interglacial marine deposits and shore lines above present sea level; and (3) ascertaining the depth to which shoreward sediments and submerged channels occur.

Measurements made throughout the past century have established the fact that the sea level is rising at a rate of about 2.5 in. per century. This rise may be largely the result in many areas of the shrinkage of glaciers throughout the world, in others of subsidence of the earth's crust.

IV. THE GLACIAL AND INTERGLACIAL AGES

The U.S. middle west is the great classic area for clear records of successive glacial and interglacial ages of many thousands of years of duration. A mere layer of humus between deposits is looked upon with skepticism for representing a long time because humus can accumulate within a few decades. But when the soil zone includes deep leaching of limestone pebbles, deep oxidation and staining, and decomposition of granites, diorites and other silicate rocks as deep and intense as in modem soils on the younger drifts in the same latitude, then the record of an interglacial age is regarded as clear. Drift sheets of adjacent areas may also be compared in age by the relative degree of erosion which they exhibit under comparable conditions—the older the drift sheet the better developed the drainage pattern and the greater the erosion.

A weathered drift beneath an unweathered drift is a reliable basis for recognizing the lower drift as much older than the upper. Along the sea coast if two drift sheets exposed in a sea cliff are separated by marine sediments containing warm-water fossils, the difference in age is apparent. Other means of differ'entiating drift sheets and the problems involved will not be discussed in this brief article. It should be noted. however. that the wood of buried soils is commonly coniferous even in such latitudes as central Illinois. The soil zone may be interglacial but it is questionable if the wood is. It is probably from the new forest that migrated southward in response to the oncoming glacial climate.

In North America the following sequence of glacial and interglacial stages (and ages) is recognized, the oldest at the bottom:

Wisconsin glacial
Sangamon interglacial
Illinois glacial
Yarmouth interglacial
Kansan glacial
Aftonian interglacial
Kebraskan glacial

All of these names originated in the upper Mississippi valley states where the type areas or sections occur. Certain correlations have been made with the Atlantic coast and with the Cordilleras. The Kansan is the surface drift over a large part of southern, western and eastern Iowa, northern Missouri, northeastern Kansas and eastern Nebraska. It also extends north into Minnesota and South Dakota. The Nebraskan is exposed beneath the Kansan at a great many places, rather commonly with a deep weathered zone preserved. For many years northeastern Iowa as far south as Dubuque was regarded as driftless, but patches of Kebraskan have been found on the upland ridges, making it quite certain that the Nebraskan ice sheet covered all of Iowa. A deposit of old weathered drift which some believe to be Nebraskan occurs on a high rock terrace in the mouth of the Wisconsin river valley. The Illinoian drift covers a large portion of Illinois and parts of southern Indiana and southwestern and eastern Ohio. and in places a fringe extends eastward beyond the Wisconsin. The Kansan seems to extend almost as far south in Indiana and Ohio as the Illinoian. Naturally the Wisconsin drift, being the youngest, is the surface drift over a much greater territory than the older drift sheets.

In the western mountains glacial deposits of at least three different ages have been found. The youngest is probably of Wisconsin age; the older ones have not been confidently correlated. Deposits as old as the Kansan, which in the middle states has been greatly eroded with only small ground moraine remnants remaining, are probably the oldest that can be positively identified in the mountains.

For many years the following classification of glacial deposits in the Alps by A. Penck and E. Bruckner has been recognized:

Würm glacial
Riss-Wdrm interglacial
Riss glacial
Mindel-Riss interglacial
Mindel glacial
Günz-Mindel interglacial
Gunz glacial

Though some would add to this a suggested older deposit, the Donau. this classification seems to stand. In the area of continental drift in northern Germany and Denmark three stages are recognized. They are:

Weichsel glacial (includes Brandenburg)
Eem interglacial (marine)
Saale glacial (Warthe, an upper member)
Holstein interglacial (marine)
Elster glacial

As in the case of North American geological literature the European literature is replete with suggested revisions, concerning the merit of which only the test of further investigations will tell. The fact. ho ever, is patent that the effects of the glacial period were world-wide and it comprised a series of glacial and interglacial equivalents. Much research remains to be done to perfect the record. See also QUATERNARY.

1. Subdivisions of the Latest Glacial Age.—Because there is much hidden history of the older glaciations the Wisconsin offers the best opportunity to learn the nature of a glacial stage and from some standpoints the substages of the Wisconsin glacial stage hold greater interest than the older glacial stages. In North America the substages of the Wisconsin deposits are recognized from youngest to oldest as follows:

Valders
Mankato
Cary
Tazewell
Iowan
Farmdale

The Farmdale and the Iowan lobes are somewhat similar in that both ice sheets had their axial directions of movement diagonal to the succeeding stages; they were of short duration; and, like the fall season, they preceded the greater and more intense glaciation of the Tazewell. The Tazewell marks the "winter" of the glacial age. The ice sheet was bulkier, more persistent and extended farther than any other substage of the Wisconsin. It was inferred that the temperature reached its lowest point and snowfall was heaviest. The Cary marks a late resurge of low temperature and heavy precipitation but it did not last long. The Mankato and Valders have the earmarks of late pulsations that were brief and portended another interglacial summer.

Some geologists are inclined to regard the Recent epoch as beginning when the Valders ice began to melt back. Others regard the Cochrane minor advance which terminated at Cochrane, Ont.—less than 200 mi. south of James bay—as the last substage. The former group of geologists thinks of the Cochrane as minor in degree and insignificant in the role of geologic processes that characterized the Recent.

In Europe as in North America, the last glacier did not steadily wane after the maximum advance, but there were climatic pulsations, each less severe and shorter than the preceding, resulting in glacial and intraglacial substages. International correlations of some of the interstadial intraglacial deposits have received much attention.

2. Nonglaciated Regions.—Southeastern California, now a very arid region, had a chain of large lakes, hundreds of feet in depth, of which the dry floor of Searle's lake is a successor. Radiocarbon dates of the upper part of the sediments agree closely with dates of the Wisconsin drift in Illinois. The overlying beds of salts and carbonates, which are 65 ft. to 100 ft. thick, are the result of evaporation in postglacial time. It does not seem too much to anticipate that an alternating series of salts and clays and silts will be found to match the older interglacial and glacial climates.

3. Duration of the Glacial Epoch.—The method of carbon dating back to the beginning of the Wisconsin (Wiirm) rapidly came into use after 1949. W. F. Libby and J. R. Arnold developed the radiocarbon method by which discretely selected samples of wood, charcoal and certain other organic remains from deposits younger than 20,000 years could be dated. Radiocarbon C^{14}, a radioisotope of carbon with the mass number of 14 produced in the upper atmosphere by the bombardrnent of nitrogen by cosmic-ray neutrons, reacts with oxygen to form carbon dioxide. In that form it enters into all organic matter and all material exchangeable with atmospheric carbon dioxide, including carbonate in sea water. Upon death of any organism the radiocarbon diminishes by its own radioactive disintegration at a known rate. Therefore, by determining accurately the loss that has taken place from wood, for example, since its burial. the age of the wood, *i.e.*, the time since burial, can be computed. The method of determination has been improved to include specimens somewhat older than 30,000 years. (See GEOCHRONOLOGY.) According to this method wood from the Farmdale loess, the oldest known Wisconsin deposit. is from 25 000 to 29,000 years old. This does not take into account the time required for the development of the Laurentide ice sheet, for its movement into the drainage basin of the upper reaches of the Mississippi and for development of the valley train from which the loess was blown. The date of wood in the Iowan loess is 21,000 to 23,000 years; in Tazewell sediments, 15,000 to 19,000 *years; Cary, 13,000 to 14,000 years; Mankato about 12,200 years; and Valders advance, 11,400 years, all before the present time. E. Antevs, on the basis of varves and other geological evidence, disagrees. He calculates the date for the Mankato substage at about 19,000 years. In the early 1940s G. F. Kay estimated the retreat of the Mankato to have been about 25,000 years ago.*

It is seen that radiocarbon dating allows only about one-half of the time permitted by the older estimates. In the second half of the 20th century research was being conducted to determine whether microorganisms of decay and other factors affect dating. Minute shells associated with low temperatures have been recovered from deep sea cores taken from the Caribbean and mid-Atlantic. Some C^{14} measurements have been made of them which show an age range from 10,000 to about 55,000 years. Those that record the lowest temperatures are about 15,000 years old, which is the latter part of the Tazewell. The feeling of conservative glacial geologists is that research should be pursued to acquire further and broader information. In the meantime respect is held for carefully documented stratigraphic work and sampling.

The extensive erosion of the Kansan drift and the prolonged exposure recorded by its zone of weathering are so impressive that it seems quite clear that the Kansan glacial stage was several hundred thousand years ago. The deep weathering of the Nebraskan before that drift sheet mas superseded by the Kansan ice sheet, together with the apparent extensive erosion of the Nebraskan in northeastern Iowa, make the Nebraskan antedate the Kansan by an interval many times the duration of the Recent epoch. Hence. the over-all age of the Glacial epoch is at least several hundreds of thousands of years.

Another method of age determination, which has been applied to the older stages, is the "per cent of equilibrium method for uranium, ionium and radium," worked out by W. D. Urry. This method, which relies on the analysis of radioactive disintegration products, has been applied to ocean-bottom sediments in areas where they indicate alternating warm and cold periods, as for example alternating layers of globigerina ooze (see FORAMINIFERA*) and red clay in the southeastern Pacific ocean. The dates obtained, according to Jack L. Hough, seem to correlate well with Pleistocene events on the North American continent, including six substages of the Wisconsin glacial stage (11,000, 15,000, 26,000, 37,000, 51,000 and 64,000 years ago), three substages of the Illinoian glacial stage (274,000, 310,000 and 330,000 years ago) and, by extrapolation, with the end of the Kansan glacial stage, about 700.000 years ago. The above data corroborate the former conclusions drawn from geologic study of the drift sheets that the Yarmouth interglacial, between Kansan and Illinoian times, was longer than the Sangamon interglacial between Illinoian and Wisconsin times, and that the interglacial ages were much longer than the glacial ages.*

One of the intriguing methods for studying the glacial history of the earth, also based on marine deposition but employing radiocarbon dating instead of the per cent of equilibrium method, is that of taking deep-sea cores some 60 ft. or more long where the rate of sea-floor sedimentation is slow. These cores bring up alternating layers of oozes of microorganisms and red clay. The fossil microorganisms include those that are sensitive to temperature changes (Foraminifera, diatoms) and thus they afford opportunity to study the ocean temperatures of the Pleistocene. These temperatures, based on carbon-isotope ratios and the C^{14} datings of the shells, provide comparison for this information from the ocean depth with the C^{14} datings of wood and other carbon remains from soils and peat beds of known geological positions on the land. This is a frontier of scientific investigation in glacial geology.

V. LIFE OF THE PLEISTOCENE EPOCH

The extent to which the plants and animals of the earth have become adapted to the new environment since the end of the glacial age is an indication of what can transpire in something like 10,000 years. The older glaciations, Illinoian, Kansan and Nebraskan, had similar effects on the life of those of the last ice age. Since the interglacial ages that followed are estimated to have had a duration of something like 100,000, 300,000 and 200,000 years respectively, it is to be inferred that the land surface from which the ice had retreated became completely reclothed with vegetation, and repopulated several times during the glacial period.

Mammalian life changed greatly both through extinctions and through the appearance of new forms. Among the new ones were zebrine horses, cattle, camels, certain elephants, rhinoceroses and a woolly mammoth, a distinctly cold climated form not known to have lived before the first glaciation. Horses and moose were immigrants near or at the close of the Kansan glaciation. The greatest number of the extinctions came in the period roughly from 5,000 to 10,000 years ago, and included all the camels, horses and ground sloths; two genera of musk oxen; peccaries; antelope-like ruminants; all but one species of bison; a giant beaver-like animal; a stag moose; and several kinds of cats, some of which were of lion size. The huge mammoths, larger than living elephants, which had become common throughout the United States also disappeared as did the forest dwellers, the mastodon and the woolly mammoth of tundra and level stretches. Their extinction in North America, as well as Europe, is credited to early man. Man's appearance in North America was rather sudden, probably taking place when there was a land bridge across the Bering strait.

1. North America.— There were forms that lived on the tundra close to the ice front— the woolly mammoth (Mammuthus primigenius) and the caribou; in the subarctic forest the mastodon, moose, stag moose, giant beaver (Castoroides), deer and bears; farther removed, the other elephants of the mammoth line, tapirs, peccaries and a variety of deer and carnivores; in the central Great Plains elephants, horses, bison, elk, antelope, ground sloths from South America and many small mammals. The late glacial forms that lived in Florida included the mastodon, elephant, camels, a huge bison, peccaries, deer, tapirs, horses, ground sloths, armadillos, several carnivores including a sabre-toothed cat (Smilodon), wolves and bears. In central Alaska the frozen ground of alluvial silt contains fossils of bears, wolves, foxes, badgers, wolverines, sabre-toothed cat, jaguar, lynx, woolly mammoth, mastodon, horses, camel, saiga antelope, four bisons, caribou, moose, stag moose, elk, sheep, musk ox, ground sloth and various rodents. It is suggested that this fauna may be interglacial.

Today the Bering strait separates Alaska from Siberia. The fossil record indicates that this was a land connection one or more times during the Pleistocene. The Japanese current probably gave it a mild climate and permitted the growth of long thick grass like that on the Alaska peninsula. The immigrants and emigrants appear to have been entirely cold-temperate or boreal forms. Not only may crustal warping have produced the bridge, but lowered sea level prevailed during the early and late parts of the different glacial ages when much sea water was still locked up in the ice sheets.

Immigration from South America is recorded in the ground sloths which came to live as far north as central Alaska. The North American horse and deer traversed the Isthmus of Panama to live in South America. (*R. F.* FT.; *M. M. L.*)

2. *Europe.— The Pleistocene mammal fauna went through a series of striking changes in Europe as it did in North America. Basically there was a steady change as certain species like the elephants, rhinoceroses and horses evolved, while at the same time other forms became extinct against the competition of immigrants from the east. Superimposed on this progression, however, was an oscillation due to a north-south shift of animal population as the glaciers waxed and waned, so that faunas which were very similar appeared at two or more different times, separated by a fauna of quite different character.*

The very earliest part of the Pleistocene (Villafranchian) produced some strange inhabitants of western Europe— lynx, several species of bear, a macaque monkey and the great sabre-toothed cat, Machairodus. The elephants included Mastodon arvernensis, but also the first of the true elephants, Elephas meridionalis. This fact, and the appearance of the true horses (in the form of Equus stenonis), is regarded by many as the criterion of the Pleistocene.

In the later part of the Lower Pleistocene (the Günz-Mindel interglacial stage, the Aftonian in North America, identified in *The Glacial and Interglacial Ages,* above), though the macaque monkey, sabre-toothed cat and *Elephas meridionalis* persisted, the latter was accompanied by a more advanced type, *trogontheri.* Two species of rhinoceros *(mercki* and *etruscus)* were present, *a* giant extinct beaver *(Trogontlzerium)* was found, and the red deer and hippopotamus made their appearance.

The Middle Pleistocene started with the Mindel-Riss, or Great Interglacial, with the macaque monkey and Merck's rhinoceros still lingering on. A deer, *Dama clactonianus,* was distinctive. For the first time the straight-tusked elephant (*antiquus*) appeared, with the great ox (the aurochs, *Bos primigenius*) and the bison and the modern species of horse; and most interesting of all, *Homo sapiens.* (Fossil specimens from Steinheim. Ger.. and Swanscombe, Kent. Eng., are discussed in MAN, EVOLUTION OF: *Antiquity of Homo Sapiens.)* As the climate changed to the Riss glaciation. a characteristic cold-climate fauna replaced that of the preceding interglacial. For the first time appeared the woolly mammoth (*Mammuthus primigenius*) and woolly rhinoceros *(Tichorhinus antiquitatus),* both extinct, the bison and animals like the reindeer and musk ox which are associated with the arctic tundra.

The Upper Pleistocene started with the Riss-Wurm, or Last Interglacial, and the fauna was once more "warm." with the hippopotamus, straight-tusked elephant, brown bear, beaver, lion. leopard. marmot, red deer and the giant elk (*Megaceros giganteus*). As the Würm glaciation developed, so a "cold" fauna very like that of the Riss glacial period once more migrated in—the woolly rhinoceros and mammoth, cave bear, lynx, arctic fox, bison, aurochs. musk ox. horse and arctic lemmings. After the vicissitudes of this last glaciation, the progress to the present-day climate included the extinction of the mammoth and woolly rhinoceros (whose frozen remains have been found in the Russian tundra), the elimination of the beaver and the driving to the far north of the reindeer and the musk ox. *See* F. E. Zeuner. *The Pleistocene Period* (1959). (F. W. SN.)

3. Early Man.—In the examination of the past for the physical and cultural records of man. the written record gives way to the archeological record of pottery, drawings and carvings on the walls of caves and pieces of ivory, and artifacts of stone and bone, the basic materials of the science of archeology. The physical anthropology of man—the family of Hominidae—goes back to near the beginning of the Ice Age in Europe. Heidelberg man, the first recognized species of the genus *Homo,* lived at approximately the close of the Mindel glacial stage (Kansan in North America). Nonhomo manlike species. Archanthropic, prophetic of man. appeared first during the Günz-Mindel interglacial stage (Aftonian). The last of these are not known to have lived after the Mindel-Riss interglacial stage (Yarmouth). Their genera in successive order have been identified as *Gigantopithecus, Meganthropus, Pithecanthropus* and *Sinanthropus.* However. the time span from the beginning of the first interglacial to near the end of the Mindel-Riss interglacial is much longer than all subsequent time. Extinct fossil species of the genus *Homo* (paleoanthropic man)—Heidelberg, Neanderthal, Rhodesian and Solo—cover the period from the close of the Mindel glacial to the early part of the Würm glacial (Wisconsin). *Homo sapiens,* the present world-wide species, has lived since the close of the Mindel-Riss interglacial. Cro-Magnon man. the modern erect man. was found in fossilized condition in the Cro-Magnon cave in Dordogne, France. His appearance is dated as in the fourth glacial.

The skeletal parts show that marked evolution took place during the 1,000,000-year stretch of Pleistocene time, particularly in the brain. which increased greatly in size. The artifacts show a general progressive increase in perfection and adaptability, which in turn record an increase in intelligence and skill among the people who made them. These increases. however, apparently took place at different rates in different regions; very different degrees of culture flourished at the same time in different parts of the world. This has been learned in part through dating the various groups of artifacts and skeletal remains, both by means of fossil mammals that have been preserved with them and by identification of the deposits in which some of the remains occur with deposits of known glacial or interglacial age. Radiocarbon C^{14} datings have made significant contributions.

The record in America does not extend as far back in time as that in the old world. No skeletons or artifacts dating from early in the Pleistocene have been found, but discoveries indicate that man may have come to America at about the close of the Sangamon interglacial or the beginning of the Wisconsin glacial.

VI. THE GLACIAL CLIMATES

1. Character.—At the height of the glacial ages at least 28% of the land area of the world was covered by glacial ice. At present more than 10% is so covered, but significantly this is in the higher latitudes. The same was probably true for the interglacial ages. Some differences between the present and one of the interglacial ages are apparent, however, from comparison of fossil faunas with the living forms.

Glacial cirques (theatrelike valley heads fashioned by the action of snow fields at the heads of individual glaciers in mountainous terrain) bear a rough general relation to the snow line or lower limit of perennial snow. Through measurements of the altitudes of cirques in many parts of the world the approximate position of the snow line at the height of the latest glacial age has been determined. Wherever measured, this former snow line is lower than the snow line of today—at the equator as well as in polar latitudes.

In order to determine the glacial-age climate of a coastal point **A,** a point B on the same coast is located by finding the place where the present snow line has the same altitude as the glacial-age snow line of A. The present climate of B is then taken as representative of the former climate of A. The method is rough. but over a wide region it gives consistent results. Coastal points such as A are seen to have received much greater precipitation than they do at present, and to have had mean annual temperatures of the order of 7° C. to 8° C lower than now, nhereas in interior regions the increase in precipitation and decrease in temperature, compared with present conditions mere less pronounced. In other words. the subpolar climate belts were shifted toward the equator during the glacial ages. This shift may have amounted to as much as 15° of latitude for the boreal, or northern. belt, less for the warmer belts.

The pluvial conditions of the dry regions of middle and low latitudes support this conclusion in that they appear to show equatoruard shifting of the middle-latitude belts of rain-bringing cyclonic storms. The evidence of fossil animals in the northern hemisphere likewise indicates southnard shifting of the cold northern climatic zone through many degrees of latitude.

On the other hand the evidence of fossil plants and animals indicates that during the interglacial ages the climatic zones uere shifted toward the poles, and that at least once these zones. in the northern hemisphere have been pushed north of the positions they occupy at present. It is generally believed though it has not been conclusively proved. that these climatic shifts were synchronous throughout the world In summary. the climatic changes were world-wide and apparently contemporaneous; the climatic belts were shifted alternately. equatornard and poleward; and changes in mean annual temperatures amounted to several degrees centigrade.

2. Causes.—The causes of these remarkable climatic changes have received the attention of geologists, astroncmers. physicists and meteorologists for a century Of the many hypotheses put forward, a fen may be mentioned only to be dismissed: (1) Changes in the amount of volcanic or cosmic dust in the earth's atmosphere, thereby varying the thermal insulating effect of the atmosphere. This hypothesis encounters many objections and is wholly inadequate to meet the facts (2) Displacement of all or part of the earth's crust relative to the earth's axis thus bringing different regions into the positions of the poles at various times. This hypothesis is negated by the consistent relative positions of the climatic zones throughout long periods of time and by the lack of independent geophysical evidence of crustal displacement. (3) Broad uplifts of continents and localized uplifts of mountain masses, thus reducing temperatures and creating conditions favourable for the formation of glaciers. This hypothesis, which usually also applies to shifts in ocean currents, was proposed before the fact of the interglacial ages was fully established, and fails because it demands frequently repeated crustal uplifts and subsidences of which there is no independent evidence.

The basis of a theory that has received wide adherence was suggested by J. Adhémar in 1832. It was extended by J. Croll in 1875, and much later was elaborated, with variations, by M. Milankovitch, R. Spitaler, W. Koppen and A. Wegener, W. Soergel and others. This theory, sometimes termed "the astronomical theory," is based on the periodic changes that affect the earth's motion in three different respects: (1) eccentricity of the orbit (period 91,800 years); (2) inclination of the axis to the ecliptic plane (period 40,000 years); (3) shifting of the perihelion (period 21,000 years). These changes affect the distribution of solar heat received by the earth's surface, though they do not affect its total amount. The results of these changes can be plotted as a curve showing variations in the amount of heat received during the summer at any selected latitude. Because the three periods differ, such curves are nonperiodic. They show irregularly spaced maxima and minima of heat, which are taken by the advocates of the theory to represent the interglacial and glacial ages respectively. Four pairs or groups of temperature minima (nine in all), held to indicate four principal glacial ages, are represented as having occurred within the past 600,000 years.

Four objections to this theory may be mentioned: (1) it demands that the cold times alternate between the two polar hemispheres, yet there is no geologic evidence that such was the case; (2) it requires that at the equator there be little or no heat fluctuation, yet there is clear evidence in the east African mountains, directly on the equator, that the snow line there fluctuated throughout more than 3,000 ft. between glacial and interglacial ages; (3) the heat-fluctuation curves deduced from the theory show nine minima; these do not agree with the geologic evidence, which records only four glacial ages.

Another group of theories is based on the premise that there is a considerable variation in the absolute quantity of radiant energy emitted by the sun, and holds that terrestrial climatic fluctuations take place in accordance with such variations. E. Huntington's version of this idea laid emphasis on a supposed connection between solar energy and the incidence of cyclonic storms on the earth. Sir G. Simpson's version deduced an elaborate and ingenious scheme in which glacial ages are offset in time with respect to the maxima and minima of solar radiation. It applies best to the antarctic region. A. Penck's version deduces a direct connection between reduced solar radiation, world-wide temperature reduction and glaciation. Although there is no proof whatever that large fluctuations in solar energy have occurred, the assumption that they have occurred appears to meet all the requirements for the causes of the glacial climates. *See* also GEOLOGY.

BIBLIOGRAPHY.—Albrecht Penck and E. Briickner. *Die Alpen im Eiszeitalter* (1912); Ernst Antevs, *The Last Glaciation* (1928); C. E. P. Brooks, *Climate Through the Ages* (1949); R. A. Daly, *The Changing World of the Ice Age* (1934); Friedrich E. Zeuner, *Datzng the Past*, 4th rev. ed. (1958); A. L. Kroeber (ed.), *Anthropology Today* (1953); Von Paul Woldstedt, *Das Eiszeitalter* (1954); Willard F. Libby, *Radiocarbon Dating* (1955); Leland Horberg and Richard C. Anderson, "Bedrock Topography and Pleistocene Glacial Lobes in Central United States," *Journal of Geology* (1956); Thor N. V. Karlstron, "The Problem of the Cochrane in Late Pleistocene Chronology," *Bulletin*, U.S. Geological Society (1956); J. K. Charlesworth, *The Quaternary Era*, 2 vol. (1957); R. F. Flint, *Glacial and Pleistocene Geology* (1957).

(R. F. FT.; M. M. L.)

PLEKHANOV, GEORGY VALENTINOVITCH (N. BELTMAN) (1857–1918), the founder and for many years the chief exponent of Russian philosophic Marxism, was born on Nov. 26. 1857, in the province of Tambov, of an old noble family. His father wished him to enter the army, but while a student he joined the Narodnist (populist) revolutionary movement. In 1876 he led the first great popular demonstration at St. Petersburg (Leningrad) in the Kazansky square. When the majority section of the Narodnists adopted terrorist methods in 1879, Plekhanov seceded, and with Deutsch, Axelrod, Vera Sassulitch and Ignatov, formed the Marxist "Liberation of Labour" group in Geneva (1883). He spent 40 years in exile, chiefly at Geneva, from which town he became the intellectual leader of the Russian Social-Democratic movement, in particular playing a large part in Lenin's early mental development. In the '90s and the early years of the 20th century the two men were closely associated. In Dec. 1900 was founded the S.D. journal *Iskra* ("The Spark") of which Plekhanov was joint editor with Lenin, Martov and others. In the first split of the Russian S.D. party in 1903 Plekhanov was largely on the side of the Bolsheviks, holding views closely akin to those of Lenin.

After the resignation of the Mensheviks from editorship of the *Iskra* Plekhanov and Lenin were joint editors, but some months later differences arose between them on the question of collaboration with the Mensheviks, and Lenin resigned. Thenceforth for several years Plekhanov worked with the Menshevik section of the party, but after 1907, while remaining a Menshevik, he took up an attitude on many issues, particularly on the question of participation in the state Duma and also on illegal activities, in agreement with that of the Bolsheviks. At the end of 1910 he again co-operated with the latter in contributing to the Bolshevik *Zviezda* ("The Star") but the alliance did not last long, and when the war broke out in 1914 Plekhanov was foremost in advocacy of the principle of "revolutionary defence" of the country against the Bolshevik policy of working for the defeat of the government. After the March revolution he returned to Russia and was invited to join the Provisional government. He refused, but actively supported the government against the Bolsheviks, and remained an opponent of the Bolshevik revolution until his death in Finland on May 30, 1918.

Plekhanov had an enormous influence on the development of the Socialist movement in Russia. The Moscow Marx-Engels institute published a complete edition of his works in 26 volumes. His biggest work is available in German: *Beitriige zur Geschichte des Materialismus.*

PLESIOSAURUS, technically the name of a genus of extinct reptiles of the group Sauropterygia; it is commonly used to apply to all the later members of that group. The typical plesiosaurs are completely adapted for a marine existence in the open sea. They first appear in the Rhaetic and are last seen in the Upper Cretaceous.

A typical plesiosaur has a small head with a large mouth and slender pointed teeth adapted to the catching of fish. The neck is long, often four times as long as the head. The body is relatively short, as is the tail. All four limbs are converted into paddles, no external trace of the fingers being visible.

From these forms two main evolutionary lines appeared. In one, the animals adopted the habit of living on large prey which they captured by their superior speed; in this line the head grew bigger and the neck shorter until it became no longer than the head. The body is comparatively long, the tail little more than the pointed hinder extremity of the body. The paddles become very large indeed, the hinder pair being bigger than the front ones. There are large members of this line in the European Jurassic, with skulls 5 or 6 ft. long and a body length of 16 ft. or more. The giant of the tribe was *Kronosaurus* of the Cretaceous of Australia, with dimensions nearly twice as great.

The other line consists of animals which fed on small quick-moving prey which they seem to have captured by sudden lateral movements of the head and neck. Its most recent member, *Elasmosaurus*, is found in the Upper Cretaceous of Kansas, England, Queensland and New Zealand. In it the head is about 18 in. in length, the neck with as many as 76 vertebrae may reach a length of 19 ft., and the total length of the animal about 30 ft. The paddles of such an animal were about 3 ft. in length. Some plesiosaurs had the habit of eating pebbles which were kept in the stomach to assist in grinding up food. Although the majority of plesiosaurs were marine, some few are always found in estuaries or fresh-water deposits. *See* REPTILES. (D. M. S. W.; X.)

PLEURA, DISEASES OF. The pleura is a continuous thin sheet which lines the interior of the thoracic cavity (parietal pleura) and is reflected at the root of each lung to cover the entire surface of the lung (visceral pleura).

Pleurisy. — Inflammation of the pleura, which may occur as an accompaniment to almost any major lung disease, is often called pleurisy or pleuritis. The word is sometimes used in a loose and inaccurate manner to indicate any type of thoracic pain. The pain of pleural inflammation is usually sharp in character, well localized and clearly related to breathing.

Pleural Effusion. — Accumulation of excess amounts of fluid between the visceral pleura and the parietal pleura (pleural effusion) frequently results from pleurai inflammation or circulatory congestion. The amount of fluid may be very great, even several pints, sufficient to prevent expansion of the lung and, hence, result in respiratory insufficiency. Small amounts are often difficult to detect except by X-ray examination. The fluid is usually clear and straw coloured but may be cloudy and occasionally tinged with blood.

Infection of the pleural space with tuberculosis, secondary to a tuberculous lesion in the lung, is a common cause of pleural effusion. The fluid is usually clear and straw coloured and contains moderate numbers of lymphocytes. It may contain tubercle bacilli, but often biopsy of a small portion of the pleura is necessary to establish the diagnosis. Often, but not always, it is possible to diagnose the associated tuberculosis of the lung by the usual methods.

Treatment of tuberculous pleural effusion is usually effective when the specific antituberculosis chemotherapeutic drugs are administered as for pulmonary tuberculosis. Cntreated tuberculous pleural effusions are often followed by manifestations of lung tuberculosis after an interval of several months or several years of good health, during which latent period there may be no X-ray evidence or other indication of the infection.

Acute inflammatory diseases of the lung, including pneumonia (*q.v.*), are sometimes associated with pleural pain and occasionally by accumulations of pleural fluid. The amount of such fluid is usually small. and it usually disappears promptly when the lung inflammation subsides.

Impaired circulation of blood in the lungs due to ineffectual heart action often leads to a seeping of fluid from the swollen and congested lungs into the pleural space. Treatment of the heart failure may relieve the congestion and permit resorption of the fluid. Often this requires the administration of diuretic drugs; limitation of sodium intake; rest; and administration of digitalis. Occasionally needle aspiration of the pleural fluid may accelerate improvement.

Empyema of the Thorax. — A collection of pus in the pleural space, known as empyema, is the result of severe and prolonged infection. Treatment is difficult and requires removal of the pus. either by repeated needle aspirations or by surgical drainage. Antibacterial drugs are selected which are active against the causative organism, hence bacteriologic examination of the pus is important. Surgical treatment sometimes requires the removal of large portions of the infected pleural membrane (decortication).

Tumours of the Pleura. — Most tumours which originate from the pleura can be classified as mesotheliomas. They may be either malignant or benign and may be either localized or extended over a large area of pleural surface. Diagnosis is rarely possible without microscopic examination, and that necessitates surgical biopsy in most circumstances.

Cancer of the lung (bronchogenic carcinoma) often extends peripherally to involve the pleura producing symptoms and findings similar to those of infection. Malignant implants on the pleura of tumours originating elsewhere in the body are rather common in the latter stages of widespread metastatic cancer. Such implants often lead to marked pleural effusion, and the fluid is often bloody. Diagnosis is established by X-ray examinations and sometimes by biopsy. Treatment is difficult, but radiation, using either X-ray or radioactive isotopes, and chemotherapy with tumour-inhibiting drugs may provide some temporary symptomatic relief. *(See* also CANCER; TUMOUR.)

Chylothorax.—Rupture of the thoracic duct, a channel which transmits lymph (chyle) from the abdominal cavity to the large veins of the upper thorax. may lead to accumulation of chyle within the pleural space. This material is recognized by its milky appearance and its high fat content. The t o commonest causes of chylolhorax are injury and metastatic malignancy.

Hemothorax. — Accumulation of blood in the pleural space may be a serious result of injury, especially when there has been damage to the larger blood vessels of the chest wall. Sometimes the rupture of adhesions between visceral and parietal pleura, occurring in association with pneumothorax, will lead to occult bleeding which may become serious before it can be recognized. It is possible for a patient to lose very large amounts of blood by this type of internal hemorrhage. Diagnosis often requires needle aspiration as well as X-ray examination, and treatment may or may not require open operation for repair.

Fibrothorax.—Pleural fluid may contain large amounts of fibrin, which may be deposited on the pleural surfaces eventually to be organized by formation of scar tissue. Sometimes this is sufficient to envelop all or a portion of the lung in a thick inelastic coating ahich limits lung expansion and impairs breathing ability. Surgical removal (decortication) may improve respiratory function in selected cases. Small localized collections of fibrin are frequent and of little or no significance.

For other diseases of the chest, *see* LUNG, DISEASES OF AND RESPIRATORY SYSTEM. DISEASES OF. (H. C. H.; H. C. Hw.)

PLEURONECTIDAE, one of the families of fishes to which the name "flatfish" is popularly applied. It includes the halibut, flounder, plaice and sole (*qq.v.*). *See* also FISHES.

PLEUROPNEUMONIA (LUNG PLAGUE) is a specific contagious disease of bovine animals usually terminating in a characteristic inflammation of the lungs and pleura (lining of the chest cavity). It is caused by a minute organism so small that it will pass through bacteriological filters. By magnifying at least 1,500 diameters. the organisms can be seen as small dots or coccoid bodies, spiral forms, branching and star-shaped figures, from which the name *Asterococcus mycoides* was given to the organism by Pierre Borrel. Although extremely small. it probably should not be classed as a truly ultramicroscopic virus.

The disease was once prevalent over much of Europe, having been recognized by Claude Bourgelat in 1769 in France and being known even earlier in Switzerland and Germany. It spread rapidly because of the traffic in breeding cattle, especially from the Netherlands and Switzerland, and caused such great losses that energetic steps of eradication had to be developed, including slaughter of diseased animals, quarantine and veterinary sanitation measures. It is reported that in Great Britain alone 187,000 cattle died of the disease in one year, 1860.

In the United States. contagious pleuropneumonia first appeared in Brooklyn in 1843, in New Jersey in 1847 and in Massachusetts in 1850, and then spread over most of the important cattle-raising states east of the Mississippi, causing the deaths of thousands of animals, particularly in Illinois. The disease was such a serious problem that the federal government finally intervened to set up an eradication program to supplement the efforts of the several states; this was a major factor in the establishment of the U.S. bureau of animal industry. The ultimate eradication of contagious pleuropneumonia in 1892 was the bureau's first great accomplishment; it did not appear afterward in the United States.

The disease was also eradicated or greatly reduced in most countries, but still occurred after the mid-20th century in parts of Asia. Africa. Australia and the U.S.S.R.

Natural infection usually takes place by contact of diseased animals with susceptible cattle. probably by inhalation of infective material. The incubation period is about two weeks, and the symptoms manifested are fever, loss of appetite, dry painful cough, accelerated pulse and respiration and the usual signs of acute pneumonia. Depending on the extent and severity of the infection, the disease may terminate fatally in a few days or run a more chronic course with apparent recovery. The disease may become active again because of focuses remaining in the affected lung tissues, however, and death often follows.

No effective treatment had been discovered by the 1960s, although immunization methods had had some success. Materials used for vaccination by inoculation in the tip of the tail include pleural exudate from naturally occurring cases and culture preparations made from the causative organism. Neither is entirely satisfactory, however, because a small percentage of vaccinates may die and many more lose their tails. The only effective method of dealing with the disease is by eradication. quarantine and other veterinary sanitation measures. Institution of such measures is preceded by a veterinarian's diagnosis through use of the complement-fixation test. A simple slide flocculation test also has been used with success by British workers, particularly in areas where it is not practical to employ the complement-fixation technique

A sidelight of possible public health interest is the expressed view of certain workers that bovine pleuropneumonialike organisms may be responsible for some of the obscure human illnesses of respiratory origin seen in the United States. (J. G. HH)

PLEVNA (Bulgarian PLEVEN), a city in Bulgaria on the Sofia-Varna railway (opened in 1899). Pop. (19j6) 57,758 A branch line, 25 mi. long, connects Plevna with Samovit on the Danube, where a port has been formed. After the events of 1877, it was almost entirely forsaken by the Turks, and most of the mosques have gone to ruin; but, peopled now mainly by Bulgarians, it has quite recovered its prosperity, and has a large commerce in cattle and wine (see RUSSO-TURKISH WARS).

Plevna, a small and unknown town uithout fortifications. became celebrated as the scene of Osman Pasha's exploits. He left Widin on July 13 with a column consisting of some 12.000 men and 54 guns. Hearing that he was too late to relieve Nikopol, he pushed on to Plevna, where there was a small garrison, and on July 19 he took up a position on the bare hills to the north and east. He was none too soon. General Schilder-Schuldner, commanding the 5th division of the 9th corps. uhich had just captured Nikopol, had been ordered to occupy Plevna, and his guns were already in action. On July 20, having made no preliminary reconnaissance, the Russian commander advanced his infantry in four separate columns. On the north flank they pressed into Bukova, and also succeeded in driving back the Turkish right wing; but in both cases Turkish counterattacks pressed back the Russians, with the result that by noon they were in full retreat.

Second Battle of **Plevna.**—In accordance with orders from the Russian headquarters at Tirnova, a fresh attack was made by Krudener on July 30. After a preliminary cannonade the infantry advanced at 3 P.M., as before, in widely spread columns The columns attacking from the north and northeast were repulsed with heavy loss. Shakovskoi temporarily occupied two redoubts, but a counterstroke by the Turkish reserves forced him back. The Russians retreated.

The Russians now concentrated all their available forces against Plevna and called in the aid of the Rumanians. By the end of August they had assembled a force of 74,000 infantry, 10,000 cavalry and 440 guns. On August 30 Osman moved out of Plevna, and on the 31st attacked the Russians about Pelishat. He returned to Plevna the same evening. The Turks lost 1,300 and the Russians 1,000 men. The Russians determined to occupy Lovcha, and so cut Osman's communications before again attacking Plevna. After three days' fighting this was accomplished by Skobelev, acting under Imeretinski, with a force of 20,000 men, on September 3. Osman moved out to the relief of the garrison that day with a strong column, but, finding he was too late, returned to Plevna on the 6th. The survivors from Lovcha were re-formed into 3 battalions, including which Osman had been reinforced to a strength of over 30,000, with 72 guns.

Third Battle of **Plevna.**—The Russians moved to their preliminary positions on the night of September 6–7. Their plan was to attack the north-east, south-east and south fronts simultaneously. An artillery bombardment began at 6 A.M. on September 7, and was carried on till 3 P.M. on the 11th, when the infantry advanced. The Rumanians took one Grivitza redoubt; Skobelev occupied two redoubts on the south front, but the centre attack on the Radischevo front failed. On the 12th the Turks recaptured the southern redoubts, the Rumanians remained in possession of the Grivitza redoubt, but the Russian losses already amounted to 18,000 and they withdrew, and entrenched themselves on a line Verbitza-Radischevo, with cavalry on either flank to the Vid. The Turkish losses totalled 5,000, of which only a few hundred were caused by the artillery fire of the first few days. There was no question of pursuit. The Russians were greatly superior in numbers and the Turks were completely exhausted.

Investment and Fall of **Plevna.**—This was the last open-force attack on Osman's lines. General Todleben, the defender of Sevastopol, was now entrusted with the conduct of the siege, and he determined to complete the investment, which was accomplished by October 24, Osman's request to retire from Plevna having been refused by Constantinople. Supplies eventually gave out and a sortie on the night of Dec. 9–10 failed, with the result that he and his army capitulated.

Plevna is a striking example of the futility of the purely passive defence, which is doomed to failure however tenaciously carried out. (J. H. V. C.; X.)

PLEYEL, IGNAZ (JOSEPH) (1757–1831), Austrian composer, conductor and publisher, and founder of one of the principal French firms of piano manufacturers. The 24th son of a schoolmaster, he was born at Ruppersthal, near Vienna, on June 1. 1757. He studied the piano in Vienna under J. B. Wanhal and, from 1774 to 1779, composition under Haydn. In 1776 he produced his puppet opera Die Fee Urgele on a libretto derived from Voltaire and Chaucer, at Esterhaz, and in 1780 his opera *Ifigenia* in *Aulide* was produced in Naples. He mas made deputy chapelmaster at Strasbourg cathedral in 1783 and principal chapelmaster in 1789. In 1792 he conducted symphonies by Haydn, Mozart and himself at the Professional concerts in London. In 1795 he opened a music shop in Paris where he sold his compositions. most of which were published between 1783 and 1793. In 1802 he published the first collected edition of Haydn's quartets. Having founded the Pleyel piano factory in Paris in 1807, developed b~ his son Camille Pleyel (1788–1855), he retired to his estate near Paris, where he died on Nov. 14, 1831. His instrumental works, written under the influence of Haydn, include 29 symphonies, eight concertos and numerous chamber works.

PLIMER, ANDREW (*c.* 1763–1837), English miniature painter, was the son of a clockmaker at Wellington. With his brother Nathaniel (1757–*c.* 1822), who also became a miniature painter, he joined a party of gypsies and wandered about with them, eventually reaching London, where in 1781 he was engaged by the miniaturist Maria Cosway as studio boy. Her husband. Richard Cosway, the leading miniature painter of the time, then received him into his own studio. In 1785 he set up for himself in Great Maddox street. He exhibited many times in the Royal Academy. His miniatures are of great brilliance and are in considerable demand among collectors. They are distinguished by the peculiar wiry treatment of the hair and by the large, expressive eyes that Plimer invariably gave to his female sitters. He died at Brighton in 1837 and was buried at Hove.

See G. C. Williamson, *Andrew and Nathaniel Plimer* (1903). (G. C. W.; X.)

PLIMSOLL, SAMUEL (1824–1898), British politician and social reformer, was born at Bristol on Feb. 10, 1824. His efforts for reform were directed more especially against "coffinships"—unseaworthy and overloaded vessels, often heavily insured, in which unscrupulous owners risked the lives of their crews. Plimsoll entered parliament as Liberal member for Derby in 1868, and failing to pass a bill dealing with the subject, he published a work entitled Our Seamen (1872), which made a great impression throughout the country. On Plimsoll's motion in 1873, a royal commission was appointed, and in 1875 a government bill was introduced, which Plimsoll, though regarding it as inadequate, resolved to accept. On July 22, when Disraeli, announced that the bill would be dropped, Plimsoll lost his self-control, applied the term "villains" to members of the house, and shook his fist in the Speaker's face.

Eventually Plimsoll apologised, but the country shared his view that the bill had been stifled by the pressure of the shipowners, and the popular agitation forced the government to pass a bill, which in the following year was amended into the Merchant Shipping Act. This gave stringent powers of inspection to the Board of Trade. The mark that indicates the limit to which a ship may be loaded is generally known as Plimsoll's mark. Plimsoll was re-elected for Derby at the general election of 1880, but gave up his seat to Sir W. Harcourt, in the belief that the latter, as home secretary, could advance the sailors' interests more effectively than any private member. Later on Plimsoll was estranged from the Liberal leaders by what he regarded as their breach of faith in neglecting the question of shipping reform. He became president of the Sailors' and Firemen's Union, and raised a further agitation about the horrors of the cattle-ships. Later he visited the United States with the object, in which he did good service, of securing the adoption of a less bitter tone towards England in the historical textbooks used in American schools. He died at Folkestone on June 3, 1898.

PLINY THE ELDER (GAIUS PLINIUS SECUNDUS) (A.D. 23 or 24–79), Roman savant and author of the celebrated *Natural History,* was born at Novum Comum (Como), in Transpadane Gaul. On this ground he claimed Catullus, a native of Verona in the same region, as a fellow countryman. His own writings and those of his nephew Pliny the Younger show that the date of his birth was in A.D. 23 or 24, that he must have come to Rome at an early age and that he practised for some time as an advocate. He saw military service in Germany. Under Vespasian, with whom he was on the most intimate terms, he served as procurator in Hispania Tarraconensis and elsewhere. He was in Africa, Gallia Narbonensis and Gallia Belgica and perhaps also in Judaea and Syria.

Finally Vespasian appointed him prefect of the Roman fleet at Misenum, in Campania, which Augustus had made one of the principal Roman naval stations. He was stationed at Misenum when, on Aug. 24, 79, there occurred the great eruption of Vesuvius which overwhelmed Herculaneum and Pompeii and cost Pliny his life. The circumstances are vividly told in a letter of the younger Pliny to the historian Tacitus. Pliny, wishing to assist those persons who were in danger, sailed from Misenum to his friend Pomponianus at Stabiae (Castellamare) on the southern shore of the Bay of Naples. There, in order to allay the fears of his friends, he dined, as his nephew says, "cheerfully, or what was equally splendid, with a pretence of cheerfulness!" and then retired to rest. In the middle of the night, when stones and ashes were already falling about the house and the house itself was rocking alarmingly, he was roused and he and his party determined to seek safety in the open, binding pillows about their heads as a protection against falling debris. "Now it was day elsewhere," runs his nephew's account. "but there night darker and denser than any night: alleviated a little by numerous torches and lights of various sorts. It was decided to go out upon the shore and see at close quarters whether the sea now offered any prospect of safety; it still continued wild and adverse. There Pliny lay down upon a cast-off linen cloth, and once and again he asked for cold water, which he drank. Then flames and a smell of sulfur announcing the approach of flames caused the others to take to flight and roused him. Supported by two slaves he got upon his feet, but immediately collapsed, his breathing, I gather, being obstructed by the thickening vapour which closed up his windpipe—naturally weak and narrow and frequently painful. When day returned—the third (in English reckoning the second, *i.e.,* Aug. 26) after the last day (Aug. 24) that he had seen—his body was found intact and uninjured: covered as he had been dressed. The appearance of the body suggested one sleeping rather than dead."

A list of Pliny's books in chronological order is given in a letter by his nephew: (1) *De iaculatione equestri unus* ("On Throwing the Javelin From Horseback, in One Book"), "written while he was serving as commander of a cavalry regiment with equal ability and care." (2) *De vita Pomponi Secundi duo* ("Life of Pomponius Secundus, in Two Books"), "the discharge, as it were, of a debt due to the memory of a friend who had entertained a singular affection for him." Pomponius, described by Tacitus as a man "of refined character and conspicuous ability" was a tragic poet who had also a military career of some distinction. (3) *Bellorurn Germaniae viginti* ("German Wars, in Twenty Books"), "in which he brought together all the wars waged between us and Germany. He began the work while he was serving in Germany, being admonished by a dream. The ghost of Drusus (stepson of Augustus and brother of Tiberius) who, having carried his conquest of Germany to the widest extent, died there, stood by him as he slept and commended to him his memory and entreated him to vindicate him from the injustice of oblivion." This work is cited by Tacitus, who probably used it in his *Germania.* (4) *Studiosi tres* ("The Student, in Three Books") "in which he instructs and perfects the orator from the cradle up." (5) *Dubii sermonis octo* ("Dubious Language, in Eight Books") "written in the last years of the reign of Nero when slavery had rendered dangerous every study of a free and elevated character." Fragments of the treatise were edited by J. W. Beck (1894). (6) *A fine Aufidi Bassi triginta unus* ("Continuation of the History of Aufidius Bassus, in Thirty-One Books"). The history of Bassus of which the terminal point is not known, Pliny continued down to his own day. (7) *Historiae Naturalis XXXVII* ("Natural History in Thirty-Seven Books"). This work alone is extant.

Pliny the Younger has given a description of his uncle's studious habits. He would call upon the emperor Vespasian before daybreak and then after performing his official duties return home and devote what time remained to study. After a light meal, if it were summer and he had leisure, he would often lie in the sun while a book was read and notes and extracts were made: he never read a book without making extracts, holding that no book was so bad as not to contain something good. Next he frequently had a cold bath, a snack and a short siesta, after which, "as if it were another day," he studied until dinnertime. During dinner a book was read and notes were made. He rose from the dinner table in summer before nightfall, in winter within the first hour of night. Thus at Rome; but in vacations no time was exempt from study, save bathtime, and even then he had something read to him or dictated something. while he was rubbed and dried. When traveling he was accompanied by a shorthand writer armed with book and notebook and in winter provided with gloves. To procure' time for study he was carried even in Rome and his nephew tells how he was once reproved by him for wasting valuable time in walking. R'hen he died Pliny bequeathed to his nephew 160 volumes of extracts *(electorurn cornmentarios)* "written on both sides and in the minutest hand." for which, uhen he was procurator in Spain and when the number of volumes was rather less, he had declined an offer from Larcius Licinus of 400,000 sesterces (c. £3,100).

The *Natural History,* which appeared with a dedication to Titus, son of Vespasian and his successor as emperor, two years before Pliny's death, is, as stated above, in 37 books. Book i has a general preface and contains a table of contents of the other books, to each being appended a list of the authors consulted. These lists contain the names of 146 Latin and 327 foreign authors. Book ii is devoted to a mathematico-physical description of the world and deals with the heavenly bodies—sun, moon, planets, fixed stars; various meteorological phenomena; the succession of the seasons; the earth's shape and surface phenomena—seas, rivers, springs and the like. The subject matter of this book affords Pliny an opportunity. of which he readily avails himself, to expound his own philosophic creed. which is a modified Stoicism. His view of nature is pantheistic. Books iii–vi are devoted to geography and ethnography. This is unscientific and uncritical but extremely valuable for the incidental facts which it presents. There is an interesting mention of maps of Armenia in book vi. 40.

Books vii–xi are occupied with zoology and are the most generally interesting section. The seventh book deals with man and is occupied less with the normal than with the marvelous and portentous, which the scientific creed of the author and his belief in the infinite power of *ingeniosa natura* enabled him to accept or at least not to reject outright. Thus there are tales such as would have charmed the ear of Desdemona--of men whose feet were turned the wrong way; of the Mouthless Men (Astomi) who subsisted upon the mere fragrance of flower and fruit; of the Umbrella-feet (Sciapodes) who used their extensive feet as parasols to protect them from the sun; of monstrous births; of precocity or exceptional development of physical strength or speed, sight or hearing, and mental powers; of men who were unconscionably long in dying. Incidentally, Pliny here declares his disbelief in immortality. Book viii treats of terrestrial animals other than man. Here again, amid much that is interesting in detail, there is an unfortunate absence of scientific arrangement and an excessive proneness to accept the marvelous, of which he was so unconscious that he expresses surprise at the credulity of the Greeks (*mirum est quo procedat Graeca credulitas*). Hence side by side with sound science, which comes mostly from Aristotle and, so far as concerns Africa, from Juba, there is a host of imaginary animals — winged horses, unicorns and like monstrosities. Book ix deals with aquatic animals and scientifically is the soundest of all the zoological books, which is no doubt due to the fact that Pliny's information is mainly derived, at least ultimately, from the *History of Animals* of Aristotle, who treats of aquatic animals with unusual fullness. The marvelous in this book is chiefly represented by Pliny's belief in Nereids and Tritons and the usual stories of the human sympathies of the dolphin. Book x treats of birds, commencing, according to Pliny's practice of beginning with the largest, with the ostrich. Such classifications as he makes of birds are of an empirical kind and based on very superficial observations. The first part of book xi is occupied with insects — the bee being treated with some fullness — and the latter part with what may be called comparative anatomy. Books xii–xix deal, generally speaking, with botany, including forestry and agriculture, the subject of book xviii, which is one of the most interesting in this section. Books xx–xxvii treat of medical botany or the medicines derived from plants. Books xxviii–xxxii deal with other than botanical *materia medica, i.e.*, with medicines derived from the bodies of man and other animals. The remaining books are occupied with mineralogy and with metals and metallic products, the precious metals, gold and silver, being discussed in book xxxiii; bronze, bronze statuary, iron and lead in book xxxiv; chiefly painting in book xxxv; stone, including its use in building and sculpture, in book xxxvi, gems and precious stones in book xxxvii.

Pliny's *Natural History* is a storehouse of ancient errors, but there are many branches of ancient manners and culture, such as sculpture and painting, concerning which he gives valuable information which can be found in no other extant writer. His style is sometimes dry and abrupt and sometimes slovenly, but at other times strongly rhetorical, pointed or mannered. The influence of his work on later times was great. Some three-quarters of the *Collectanea rerum memorabilium* of C. Julius Solinus (3rd century A.D.) were based on it, and on books xx–xxxii was based the *Medicina Plinii*, a compilation of the 4th century.

BIBLIOGRAPHY.—*Editions by:* J. Sillig (1851–58); L. von Jan, Teubner series, 6 vol. (1854–65); D. Detlefsen, 6 vol. (1866–82); C. Mayhoff, Teubner series (1892–1909).

Editions with translation, etc., by: A. Ernout *et al.*, with French trans. and notes (1947–); in Loeb series, with Eng. trans. by H. Rackham and W. H. S. Jones (1938–); K. C. Bailey, *The Elder Pliny's Chapters on Chemical Subjects*, with Eng. trans. and notes, 2 parts (1929–1932); E. Sellers (ed.), *The Elder Pliny's Chapters on the History of Art*, with Eng. trans. by K. Jex-Blake (1896).

English translations by: Philemon Holland (1601); J. Bostock and H. T. Riley (1855–57).

General: W. Kroll, *Die Kosmologie des Plinius* (1930); A. Klotz, *Quaestiones Plinianae geographicae* (1906); D. Detlefsen, *Die Anordnung der geographischen Bücher des Plinius und ihre Quellen* (1909); A. Nies, *Die Mineralogie des Plinius* (1884); H. Le Bonniec, *Bibliographie de l'histoire naturelle de Pline l'ancien* (1946); A Önnerfors, *Pliniana: in Plinii maioris naturalem historiam studia grammatica, semantica, critica* (1956); H. N. Wethered, *The Mind oj the Ancient World: a Consideration of Pliny's Natural History* (1937); J. W. Duff, *A Literary History of Rome in the Silver Age, From Tiberius to Hadrian*, pp. 347–385 (1927); Pauly-Wissowa, *Real-Encyclopädie der classischen Altertumswissenschaft*, vol. xxi, col. 271–439 (1951).

(*A. W. MA.*; G. B. A. F.)

PLINY THE YOUNGER (GAIUS PLINIUS CAECILIUS SECUNDUS) (A.D. *61* or *62–c.* 113), Roman author and administrator, nephew and adopted son of the elder Pliny, who left a collection of private letters of great literary charm which intimately illustrate public and private life in the heyday of the Roman empire. His official correspondence as a provincial governor is a unique set of documents, and his career is characteristic of those concerned with the management of the peaceful areas of the Roman empire.

Born *c.* A.D. 61–62 of a wealthy family at Comum in north Italy, he was educated at Rome and began to practise law when aged 18. He made a reputation in the courts of civil law, and later was in demand in the political court that tried provincial officials on charges of extortion. His most notable success was in A.D. 100, when he secured the condemnation of the proconsular governor of Africa: and of a group of officials from southern Spain. Meanwhile he had reached the highest grades of the administration by securing the titular posts of praetor in 93 and of consul in 100, despite the fact that he was the first member of his family to become a Roman senator. In this he owed much to the influence of friends of his uncle. Pliny had financial ability, and was head successively of the military treasury (*aerarium militare*) and of the senatorial treasury (*aerarium Saturni*), (A.D. 94–100). After administering the drainage board of the city of Rome—*cura alvei Tiberis*— (*c.* A.D. 104–106) he was sent (c. A.D. 110) by the emperor Trajan on a special mission to investigate corruption in the municipal administration of Bithynia. He apparently died there in office about two years later. His military experience mas limited to a short commission on the staff of the governor of Syria at the beginning of his career, where his duties were financial. The details of his life are known from his letters: and from inscriptions set up in his honour at Comum.

Pliny, like his contemporary Tacitus was a conventional man who accepted the Roman empire, serving under "good" and "bad" emperors alike, and making in his writings the conventional complaints against the latter. He concealed the preferment which he secured from the hated Domitian, and even claimed, later, that he had been in political danger through his tenuous connection with the faction that had criticized Domitian and had suffered accordingly in a famous state trial in the year of Pliny's praetorship.

The Letters.— Publication and Chronology.— He published selections of his private letters in nine books, issued apparently in three or four groups at irregular intervals between 100—109. After essaying the state of the market with the first two volumes, possibly issued separately, since they contain no interconnecting links, he issued a series of five or six, in which the letters are arranged to a certain extent in interconnected series. The ninth volume contained a miscellany of mostly very short letters of uneven interest and uncertain date, which may well represent the residue of publishable material in his files before he left Italy for the governorship of Bithynia. The tenth book is a posthumous publication. The chronology of the letters has been much discussed. The material in the first eight books is chronologically coherent. Books i and ii overlap, covering events from after the death of Domitian in Oct. 97 to the early part of 100. Book iii touches events of the next three years. Thereafter books iv to vii inclusive (%-ith the exception of iv, 9, for a special reason) are confined each to the events of about a 12-monthly period from 104-105, to 107-108. The last two books cover much the same period as vii, but contain a few letters from earlier periods of the correspondence. This chronology depends not only upon a number of dated or datable historical references, and of obviously continuous groups of letters, but also on a series of subsidiary cross-references and interrelations in the subject matter which have not yet received sufficient attention.

Style and Content.— The letters are neither imaginary epistles in the style of Seneca nor unimproved copies of daily correspondence like those of Cicero. They are carefully written occasional letters. The topics are very diverse. Each letter contains an item of recent social, literary, political or domestic news or sometimes an account of an earlier but contemporary historical event, or else initiates moral discussion of a particular problem. Each has a single subject, and is written with considerable artifice in a style which mixes, in Pliny's terminology, the historical, the poetical and the oratorical manner, to fit the theme. Length depends on theme, but brevity is preferred. Pliny apologizes for the unusual length of certain letters. Whether they were all written as genuine letters is much discussed, but is the wrong question. Several are obvious literary revises of more practical originals, as nhen he discusses a new building with his agent, but omits its dimensions. Touches of revision can be detected in some of the longest historical letters that most resemble formal essays (*e* g., i, 5). The composition of these *litterae curiosius scriptae* ("letters written with special care") was a contemporary fashion which Pliny developed into a miniature art form. to uhich the closest parallel lies in the similar occasional verses of Martial. Pliny is a prose Martial. without the indecency. The form arose naturally in a wealthy and cultured class of interrelated families, lacking rapid communications.

There are letters of advice to young men, often illustrated by anecdotes short notes of greeting and inquiry to absent friends, descriptions of newly discovered scenes of natural beauty or of natural curiosities. There are compressed accounts of the lives and habits of famous men. Estate business is a frequent theme—crises in farming, famines, sales and floods. Forensic scenes play a large role; the longest letters describe the triumphs of Pliny in the political courts. Roman society is there in all its diversity—an aged and decrepit roué cheating his toadies in his last testament, or an octogenarian relict of the court of Nero maintaining bygone depravities in a more strait-laced age.

Pliny reveals himself as a successful and complacent, kindly man, patronizingly generous towards his juniors and inferiors. and smoothly tolerant of all but the most objectionable of his peers. His character is often unfavourably judged, but the model of the magnanimous man, mhich he consciously imitates, was honoured in antiquity as the highest pattern of human virtue.

Pliny was a shrewd man. who kept a careful eye on his landed estates, now discussing the pros and cons of a new purchase. now advising a friend how to prevent a municipality from wasting its endowments, now offering his wholesale buyer a price reduction when the grape market broke, with an eye to future deals, now modifying his system of rentals in order to keep the tenantry on his estates. Such letters reveal the abilities for which Trajan chose him to reorganize the municipal finances and local government of Bithynia. The tenth book of letters contains the minutes which he addressed to Trajan on sundry problems, and the emperor's replies. He consulted Trajan 42 times in a period of some 18 months. The topics include municipal expenditure on public works, the qualification of municipal councilors, the treatment of criminals and the prosecution of Christians.

Pliny has been criticized for lack of independent judgment and responsibility by those with little experience of modern bureaucracy, but it must be remembered that his province nas lacking in archives and permanent administrative staff. Official documents were known only from copies held by plaintiffs and petitioners. Many problems required an alteration of the basic law of the province, or the amendment of an imperial edict. Others involved the rights of Roman citizens, or the privileges of independent imperial officials. Pliny was also anxious that his decisions should be based on general rules approved by the central government instead of on *ad hoc* decisions. Hence he had good reasons for the submission of most of his inquiries to the emperor at Rome. who only once reproves him for writing needlessly.

On eight occasions Pliny seeks Trajan's approval for large public building operations — theatres. aqueducts. baths. sports stadium, and a canal; it seems that Trajan initiated a rule that required central sanction for new municipal expenditure of this sort. Pliny was also anxious to secure Roman engineers and architects to supervise these works for a reason which Trajan failed to understand — that he did not trust the local experts, who had been responsible for extensive jerry-building. Pliny's humanity was in several instances notably greater than that of the emperor. In the affair of the Christians his examination of prisoners led him to query the assumption that the new cult was associated with vicious practices. Though ready to execute Christians as members of a proscribed sect, he sought confirmation that this was the policy of the central government.

Pliny's letters introduce many of the leading figures of Roman society in the 12 years after the death of Domitian — men of letters, politicians, administrators, generals and rising young men of rank. They make possible the social reconstruction of an age for which there is otherwise no serious historical record. He was an adept at brief character sketches, less satirical, more kindly and possibly more complete than those of Tacitus. His portrait of the learned lawyer Titius Aristo is typical (i, 22, 1–3). He was also a devotee of literature. He has left a detailed picture of the amateur literary world of his time, and of the salons in which it was the custom to recite one's work and to seek critical revision from one's friends.

Pliny published his forensic and literary speeches with loving care, and late in life took to the contemporary fashion for light verse in the style of Martial, at which his samples show that he was no adept. Though fulsome in the praise' of contemporary writers, his judgment of the dead Statius was fair: "he was ever writing poems with greater pains than ability." His letters addressed to his fellow advocate Tacitus (*q.v.*), then occupied with his first major work. tell the little that is known about the date and circumstances of the composition of the *Historiae,* to which. Pliny contributed his famous account of the eruption of Vesuvius. The biographer Suetonius was among his *protégés.*

A seldom noticed aspect of Pliny's mentality is his semiscientific interest in natural phenomena, which he shared with his uncle, author of the *Naturalis Historia.* Four long letters describe with careful accuracy the peculiar behaviour of subterranean springs, the course of the Vesuvian eruption and the floating islets of the Vadimonian lake (iv, 30; vi, 16. 20; viii, 20). His speculations about their causes are rational. His discussion of dreams and visions has the same quality (vii, 27). His description of external scenery, whether natural or artificial, is remarkably precise, with an exact sense of detail, despite an elaborate literary style.

Style as an Orator.—Pliny's grand oratorical style is known from his panegyric. delivered in the senate when he entered office as consul. This is elaborately antithetical, colourful in ornament, inflated in substance, passionate and violent in tone, and contrasts with the deiicacy and balance of the letters. In it he contrasts the merits of the new emperor Trajan with the vices of Domitian, in a most partial manner. but still provides a valuable historical account of Trajan's succession and the first phase of his reign. Pliny's normal forensic manner was probably a great deal quieter and more argumentative, as in viii, 14. He debates the "battle of styles" in several letters.

BIBLIOGRAPHY.—The best modern editions of the letters and of the panegyric of Trajan are those in the "Teubner Series," by M. Schuster, 2nd ed. (1952) and in the "Budé Series," vol. i–iii, by A.-M. Guillemin (1927–43), vol. iv by M. Durry (1947). *See* the Eng. trans. by W. Melmoth, *The Letters of Pliny the Consul* (1746), rev. by W. M. Hutchinson, "Loeb Series," 2 vol. (1915). There are no modern general commentaries except E. G. Hardy, *Plinii epistulae ad Traianum* (1889); M. Durry, *Panégyrique de Trajan* (1938). *See* also (for Pliny's life and chronology) T. Mommsen, *Gesammelte Schriften,* vol. iv (1906), pp. 366 ff.; A. N. Sherwin-White, "Pliny's Praetorship Again," in *Journal of the Royal Society,* pp. 126 ff. (1937); R. Syme, *Tacitus,* ch. vii–viii (1938); (for Pliny and literature) **h.-M.** Guillemin, *Pline et la vie littéraire de son temps* (1929). (A. N. S.-W.)

PLIOCENE (from Gr. *pleion,* "more," and *kainos,* "recent"), the geological epoch immediately preceding the Glacial (Pleistocene) epoch as indicated on the accompanying geologic time chart. Many modern genera appeared before the epoch was over.

The name Pliocene was introduced by Sir Charles Lyell (1830, published 1833) for the youngest of his three divisions of the Tertiary (q *v.*) period of time. Lyell initially recognized a "Newer" and an "Older Pliocene." In 1839 he substituted the name "Pleistocene" for "Newer Pliocene." restricting the "Pliocene" to "the formations of Tuscany. and of the Subapennine hills in the north of Italy. as also the English Crag." In 1846 Edward Forbes redefined the Pleistocene, making it equivalent to the time interval of continental glaciation in Europe. This was considered to have begun somewhat later than was originally envisaged by Lyell and resulted in controversy as to the age of strata falling between the Pliocene as defined by Lyell and the Pleistocene as described by Forbes. During the 18th International Geological congress. in 1938, discussion of criteria for definition of the Pliocene-Pleistocene boundary indicated that the beginning of the

Geologic Time Chart

System and Period	Series and Epoch	Distinctive Records of Life	1,000 Years
CENOZOIC ERA			
Quaternary	Recent	Modern man	11
	Pleistocene	Early man	1,000
Tertiary	Pliocene	Large carnivores	
	Miocene	Whales, apes, grazing forms	
	Oligocene	Large browsing mammals	
	Eocene	Rise of flowering plants	
	Paleocene	First placental mammals	70,000
MESOZOIC ERA			
Cretaceous		Extinction of dinosaurs	130,000
Jurassic		Dinosaurs' zenith, primitive birds, first small mammals	160,000
Triassic		Appearance of dinosaurs	200,000
PALEOZOIC ERA			
Permian		Reptiles developed, conifers abundant	235,000
Carboniferous			
Upper (Pennsylvanian)		First reptiles, coal forests	260,000
Lower (Mississippian)		Sharks abundant	285,000
Devonian		Amphibians appeared, fishes abundant	320,000
Silurian		Earliest land plants and animals	350,000
Ordovician		First primitive fishes	400,000
Cambrian		Marine invertebrates	500,000
PRE-CAMBRIAN TIME			
		Few fossils	3,500,000–4,000,000

glacial epoch occurred earlier than previously recognized. The boundary has been placed at the original Lyell horizon.

Miocene-Pliocene Boundary.— Type sections of the Lyellian epochs do not occur in the same region. Deposits in many areas of the world cannot exactly be correlated with the Lyell units but are intermediate in position. The problem of the Miocene-Pliocene boundary, for example, has become complex. Vertebrate-bearing Sarmatian and Pontian strata of eastern Europe are not represented in the type sections of either epoch. Vertebrate paleontologists consider the advent of Hipparion, a primitive horse found in North America, Europe. Asia and Africa. as marking the beginning of the Pliocene. This genus first occurs in Pontian faunas; hence they are recognized as basal Pliocene. Correlative marine faunas are of distinctive Miocene aspect; invertebrate paleontologists assign the containing strata to the Upper Miocene (*q.v.*), which is the classification used in this article.

PHYSICAL HISTORY

The Miocene epoch closed with a widespread marine regression and consequent development of continental deposits. The expanded Black Sea and Caspian basins, cut off from the Tethyan (ancestral Mediterranean) sea, became brackish water bodies that persisted through the Pliocene. The marine life trapped in these basins underwent striking evolutionary changes.

The Pliocene began with a marine transgression and closed with a regression. In the Sub-Apennine area of Italy, considered as the type area of the epoch, the transgressive phase is represented by blue marls with offshore faunas. These pass upward into yellow sands with littoral faunas regarded as regressive deposits. Above are intertonguing marine (Calabrian) and nonmarine (Villafranchian) strata that, prior to 1948. were assigned to the Upper Pliocene. Much of Italy was flooded by Pliocene seas but small gulfs in the mouths of the larger river valleys characterize most of the Mediterranean Pliocene.

Embayments from the North sea covered Belgium and eastern England. Lower strata have a fauna of warm water affinities indicating a seaway opening toward the south. The deposits in England include the Coralline Crag (crag = shell sand) remarkable for the abundance of bryozoans. formerly identified as coral. The overlying Red Crag of Sussex has a cold water fauna suggesting that the southerly connection had closed.

In eastern Europe large fresh-water lakes formed. Most important were: (1) the Pannonian lake covering the Hungarian plains; (2) the Dacian lake. separated from the Pannonian by the Carpathian mountains. covering the lower Danubian plains; (3) the Aegean lake occupying the area of the Sea of Marmora, most of the Aegean sea, and parts of Greece and Thrace.

Marine Pliocene deposits in eastern North America are confined to peninsular Florida (Caloosahatchie formation) and coastal South Carolina and southern North Carolina (R'accama formation). The thickest known marine Pliocene, however: occurs in southern California where more than 13,000 ft. of sediments are found in the Ventura basin. Local embayments occurred from Lower California to Alaska.

Occasional mammalian teeth in the shallow water marine formations aid in correlating the marine and nonmarine strata of California. The Thousand Creek formation of Nevada and the Rattlesnake beds of Oregon are of Pliocene age, as is the upper part of the Ogallala group of the high plains; the lower part is correlated with the Pontian stage. These sandy deposits contain seeds of grasses and herbs, bones and teeth of grazing mammals, and leaves of poplar, willow, hackberry, elm and other trees that grew along stream valleys.

In Texas the first appearance of large ground sloths (*Megalonyx*), migrants from South America, testifies to the re-establishment of the connection between the two continents.

Pliocene deposits are not extensive in South America. In Argentina continental Hermoso beds of the Pampas, and the Tunuyan and Araucanian deposits of the Andean foothills yield mammalian remains. Marine faunas occur in the Mancora and Sechura formations of northwestern Peru.

In Japan, marine deposits are widespread but thin and discontinuous due to deposition in small gulfs. An exception occurs in the Vezo-Karafuto geosyncline bordering the Japan sea in northern Honshu island. Here a thick sequence of Miocene-Pliocene strata has no evidence of stratigraphic break between the two epochs. Elsewhere a major hiatus is evident.

Many Pacific islands show raised reefs and reef limestones that are believed to be of Pliocene age. There are also areas of local embayment, as in the Cagayan valley of northern Luzon and the Iloilo basin of Panay, in the Philippines, where clastic sediments represent marine transgressions. In New Zealand Pliocene sediments occur only along the coast of South Island, but an embayment or strait transected North Island in the Napier Bay-Wanganui area. Noteworthy is the fact that whereas the Lower Pliocene faunas are of colder water facies than those of the Miocene, the Upper Pliocene (Castlecliffian) Mollusca indicate warmer waters. This trend which continued into the Pleistocene is interpreted as resulting from the shifting of oceanic currents caused by Late Pliocene diastrophism in the Pacific basin.

Continental deposits of Pontian age are widely distributed in Asia; true Pliocene deposits, however, occur only in the Nagri and Dhok Pathan formations of the Siwalik series of northern India, and at a few poorly known localities in China.

Volcanism.—The volcanic Massif Central of France was initiated as early as Oligocene time, but the first well-dated flows are of Upper Miocene (Pontian) age. During the Pliocene, however, the great volcanoes of Cantal and Mont-Dore grew to elevations comparable to Mt. Etna. Ash and lava flows, 1,000 m. in thickness entomb Lower Pliocene plants and insects. Activity continuing into Villafranchian time culminated in basalt flows that form the present Massif surface.

Tertiary volcanism in North America occurred mainly during the Miocene epoch, but in many areas eruptions continued throughout Pliocene time.

PLIOCENE LIFE

Marine Life.—Marine mollusks show a predominance of recent species. Notable is the trend toward cooler water conditions than are evidenced by Miocene life. The only major exception is in New Zealand. Marine mammals reached their maximum development in the Miocene seas. Many genera became extinct at the end of that epoch, but nearly all families persisted, in reduced numbers. into the recent. Pliocene additions are the rorqual (Balaenopteridae) and the right whales (Balaenidae).

Continental Life.—The Pliocene mammalian fauna of the northern hemisphere is of modern aspect with the majority of the families represented still being extant. A limited amount of faunal exchange took place between Eurasia and North America during Pontian time at the end of the Miocene, but there is little to suggest a connection during the Pliocene itself. No representatives of the Bovidae (cattle, bison. antelope, etc.) or of the Cervidae (deer), families of Eurasian origin, were in the North American fauna. Their place was taken by antilocaprids, related to the pronghorn. Hypohippus, a long-necked. long-bodied. short-limbed. forest horse, and *Hipparion*, a three-toed horse, reached Europe during the Upper Miocene and are present in Eurasia and North America during the Pliocene; typical North American Pliocene horses including *Pliohippus*, ancestor of Equus, did not reach the old world. (See also EQUIDAE.)

Characteristic North American Pliocene mammals include camels (Pliauchenia, *Procamelus*); hornless rhinoceroses (*Aphelops*, Peraceras); short-legged, hip'popotamuslike rhinoceros. *Teleoceras;* beavers (Castor, *Dipoides*); large cats (Felis) and sabretooths (*Machairodus*); proboscideans, including *Tetralophodon*, shovel-tusked *Amebelodon*, and mastodons; and many others.

Eurasian faunas are strikingly like those of modern Africa. Bovids include cattle, bison, sheep and goatlike forms and many genera of antelopes. Deer, including Cervus, flourished, along with abundant suids and, in Asia, varied giraffids. Proboscideans include the peculiar *Dinotherium* with recurved lower jaw tusks, Stegodon, an ancestral elephant, and Mastodon. Among the Primates are the monkeys *Macacus* and Cercopithecus, and the apes Dryopithecus and Pliopithecus in Europe, and a larger number of genera in Asia.

Floras. — Pliocene floras are, generically, almost identical with those of today. Distributional differences reflect differing climatic conditions that obtained during the epoch. Unusual is the flora of England, dominated by a mixture of Japanese and North American forms with some Himalayan and Indo-Malayan types. See also PALAEOBOTANY; PALAEONTOLOGY.

BIBLIOGRAPHY.—C. W. Cooke *et al.*, *Bull. Geol. Soc. America*, vol. 54, p. 1713 (1943); C. W. Durham *et al.*, *Calif. Div. Mines, Bull. 170*, ch. 3, p. 59 (1953); M. Gignoux, *Stratigraphic Geology*, trans. *by* G. G. Woodford, p. 554 (1955); R. C. Moore et *al.*, *Bull. Amer. Assoc. Petrol. Geol.*, vol. *33*, p. 1276 (1949); R. A. Stirton, *Rep. 18th Intern. Geol. Congress*, pt. 11, p. 74 (1951); A. S. Romer, *Vertebrate Paleontology* (1945); C. E. Weaver *et al.*, *Bull. Geol. Soc. America*, vol. 55, p. 659 (1944). (H. E. V.)

PLOCK (PLOTSK), a town of Poland in the province of Warszawa. on the Vistula, 67 mi. by the Vistula W.N.W. of Warszawa. Pop. (1931) 32,777; (1950) 33,100. It has a cathedral dating from the 12th century, but restored in 1903, which contains tombs of Polish dukes and of Kings Wladyslaw and Boleslav (of the 11th and 12th centuries). There is considerable navigation at this point on the Vistula. Germany occupied Plock during World War II. It was returned to Poland in 1945.

PLOEȘTI, a city of Rumania, in the region of the same name, at the southern entrance of a valley among the Carpathian foothills. through which flows the Prahova river; it is at the junction of railways to Buzau, Bucharest and the Transylvanian system. Pop. (1956) 114,544. As the name Ploești (*pluviena*, "rainy") implies, the climate is moist. The surrounding hills are rich in petroleum, salt and lignite. Ploegti is the greatest centre of the Rumanian oil industry, and was severely bombed by the allies in World War II. There are cardboard factories, roperies and tanneries. Ploești possesses various schools. several banks and many churches, including the Orthodox church of St. Mary, built in 1640 by Matthew Bassarab.

PLOTINUS (A.D. 205–270) was the founder and incomparably the greatest philosopher of the Neoplatonist school. There is a good deal oi reliable information about his life, as his pupil and editor Porphyry wrote his master's biography as an introduction to his edition of the works of Plotinus, the Enneads (it appears at the beginning of all complete manuscripts of the Enneads and is printed in the same place in all editions). But Plotinus himself would never say anything about his family or birthplace, and it is not known for certain to what race or country he belonged, though it is generally assumed. on the strength of a statement of rather doubtful reliability in Eunapius, that he came from upper Egypt. He was certainly Greek by education and cultural background. He studied philosophy at Alexandria, where he could find no teacher to satisfy him till someone introduced him to the mysterious Ammonius Saccas (*q.v.*), with whom he remained for 11 years. He went east in 243 with the emperor Gordian III's expedition, in the hope of studying Persian and Indian philosophy. But Gordian was murdered in Mesopotamia in 244, and Plotinus escaped to Antioch without having made any contact with eastern thinkers. In the same year he went to Rome. where he spent the rest of his life teaching philosophy and, after ten years, began to write. This is the period when he is known best from Porphyry's biography, where he appears not only as a great teacher and spiritual director but also as a man of great charm and of far-reaching and efficient practical kindness. He died in his 66th year, after a long and painful illness (probably a form of leprosy) which he bore most bravely. His writings were collected and published by Porphyry in the rather artificial arrangement known as the Enneads; but Porphyry also kept and published in his biography a record of the chronological order in which they were written, which is followed in some modern editions.

The importance of Plotinus in the history of European thought is very great indeed. For more than two centuries before his time a revived Platonism, much influenced by Aristotelianism and by the Stoics, had been developing. But it was Plotinus, a philosophical genius of the first order and at the same time a man of deep contemplative religion and one of the world's greatest mystical writers, who made this new Platonism into one of the great religious philosophies. The success of Neoplatonism was rapid. Soon after Plotinus' death it came to dominate the Greek philosophical world completely. It deeply influenced, too. the new intellectual world of the great Christian thinkers. It is true that the beginnings of Christian Platonism go back behind Plotinus and that the great Christian Platonists were more original and independent — and indeed more thoroughly Christian — thinkers than has sometimes been supposed and so must not be represented as merely passive recipients of the influence of Plotinus and his school. Nevertheless that influence did go very deep with many of the Christian Fathers. notably with St. Augustine in the west and with the great Cappadocians, St. Basil and St. Gregory of Nyssa, in the east; and. later, the enigmatic but extremely influential Dionysius Xreopagiticus (*q.v.*) was much influenced by Neoplatonism. Plotinus, through these and other intermediaries, had a great indirect influence on the thought of the middle ages and both a direct (after the publication of Marsilio Ficino's Latin translation in 1492) and an indirect influence on the Renaissance; and his philosophy, still living and actual in the 20th century, seems likely to continue to be so, for his writings have in them an unusual power to inspire a new outlook on the world. to raise men's minds to the eternal and to encourage a moral virility very valuable in precarious times.

Philosophy. — Like other philosophers of the Hellenistic and Roman periods, Plotinus is a religious and moral teacher as well as a professional philosopher engaged in the critical interpretation of a long and complicated school tradition. He is an acute critic and a formidable arguer, with the intellectual honesty of a true philosopher; but philosophy for him is not primarily a matter of abstract speculation, or critical discussion of language or concepts, but a way of life in which, through an exacting intellectual and moral self-discipline and purification, those who are capable of the ascent can return to the source from which they came out. His philosophy is an account of how from the eternal creative act, at once spontaneous and necessary, of that transcendent source. the One or the Good, proceeds a world of living reality constituted by repeated double movements of outgoing and return in contemplation; and this account. showing the way for the human self, which can experience and be active on every level of being, to return to the One, is itself an exhortation to follow that way.

Plotinus always insists that the One or the Good is beyond the reach of thought or language; what he says about this supreme principle is only intended to point the mind along the way to it, not to describe or to define it. But though no adequate concept or positive definition of the Good is possible, it is certainly not for Plotinus a mere negation or ultimate void in attaining to which the human personality disintegrates into unconscious nothingness.

It is a positive reality of infinite richness and superabundant excellence. Plotinus often speaks of it in extremely negative language—largely inherited from the Platonic school tradition. But his object in doing so is to stress the inadequacy of all our ways of thinking and speaking to express this supreme reality, or to make clear the implications of saying that the Good is absolutely one and infinite and the source of all defined and limited realities.

The original creative act of the One produces the first great derived reality, *nous,* intellect or spirit; from this again comes soul, which forms, orders and maintains in being the material universe. It should be remembered that the generation of this ordered universe is timeless; *nous* is eternal, and time is the life of soul, and there was never a time when the material universe did not exist. Also we must remember that the "levels of being" are not spatially separate or cut off from each other. They are really distinct, but all intimately present in every part of the universe and in each one of us. To ascend through soul to intellect and from intellect to the One we do not have to travel in space to another world, but must wake to a new kind of awareness.

Intellect for Plotinus is both thought and object of thought; it is a mind which is perfectly one with its object. As object, it is the world of forms or ideas, the totality of real being in the Platonic sense. These forms are produced by intellect's apprehension in multiplicity of the rich unity of its principle, the One; and, being one with intellect, they are not merely static objects but living, thinking subjects, each not only itself but capable in contemplation of becoming the whole. They are archetypes and causes of the necessarily imperfect realities on lower levels, souls and the forms in body. We, at our highest, are intellects, or souls perfectly conformed to intellect; we become aware of our intellectual nature when, passing beyond not only sense perception but also the discursive reasoning characteristic of the life of soul. we attain to an intuitive contact and immediate possession of eternal realities.

Soul in Plotinus is very much what it is in Plato, the intermediary between the uorlds of intellect and sense and the representative of the former in the latter. It is produced by intellect, as intellect is by the One, by a double movement of outgoing and return in contemplation, but the relationship between the two is more intimate and the frontier less clearly defined. For Plotinus, as for Plato, the characteristic of the life of the soul is movement, and this soul movement is the cause of all other movements. Soul, unlike intellect. does not possess being as a whole, one with itself in immediate awareness; it is on the level, as already mentioned, of discursive thought which does not grasp its object immediately but has to seek it by a process of reasoning. The life of the soul in this movement is time, and on it all physical movement depends. Soul in relation to the material universe exists on two levels, a higher and a lower. The higher, in close and unbroken touch with intellect, forms and rules the material universe from above; the lower, which Plotinus often calls nature, acts as an immanent principle of life and growth and in its dreamlike contemplation, the last and lowest of contemplations, produces the immanent forms in body, which are noncontemplative and so sterile. Below these lies the darkness of matter, the absolute limit, the final absence of being at which the expansion of the universe from the One through diminishing degrees of reality and increasing degrees of multiplicity comes to an end. Because of its utter negativity, matter (at least the matter of the lower regions of the sense world) is for Plotinus the principle of evil; and his language about it has a strongly dualistic flavour. His real thought, however, does not seem to be genuinely dualistic, and he strongly maintained against the Gnostic dualists of his time the goodness and nobility of the physical universe as the best possible work of soul; in this he was faithful to the teaching of Plato in his later dialogues, as expressed most impressively and influentially in the Timaeus.

We, as souls in bodies, can exist on any level of the soul's experience and activity. (Our descent into bodies is for Plotinus, who has some difficulty in reconciling Plato's various statements on this point, both a fall and a necessary compliance with universal law.) We can ascend in spirit to the level of universal soul, become that whole which we already are potentially and, in soul, attain to intellect; or we can isolate ourselves on the lower level, shutting ourselves up in the experiences, desires and concerns of the lower nature to which we are attached and remaining ignorant of any higher kind of awareness than that of the senses. Philosophical conversion, the beginning of the ascent to the One, consists precisely in turning away from the life of the body, dominating and rising above its desires and "waking to another way of seeing. which everyone has but few use." This, Plotinus insists, is possible while we are still in an earthly body and without neglecting the duties of our embodied state. But the body and bodily life is something which weighs us down and hampers us in our ascent; Plotinus' language when speaking of it in this connection is strongly dualistic and other-worldly. In this he follows Plato in the *Phaedo,* but it is not impossible that he was unconsciously influenced by the Gnosticism that he consciously opposed.

The material universe for Plotinus is a living organic whole. Its organic wholeness is the best possible reflection on the material level of the living unity-in-diversity of the world of forms in intellect. It is held together in every part by a universal sympathy and harmony (a belief in which, deriving both from Stoic philosophy and from some very primitive conceptions, Plotinus shared with contemporary magicians and occultists). In this harmony external evil and suffering take their place as necessary elements in the great pattern, the great dance of the universe. Evil and suffering can affect our lower selves but cannot touch our true, higher selves and so cannot interfere with the real well-being of the philosopher who chooses to live on that higher level.

From what has been said so far something of the nature of Plotinus' religion should have become clear. It is essentially the effort to actualize in ourselves the great impulse of return to the Good which constitutes reality on all its levels. By a rigorous moral and intellectual self-discipline we awake from the alienation of our lower state and rediscover our true selves. We become intellect and then, when the One manifests to us his continual presence, we rise to the mystical union, carried on the surge of the current of the impulse of return in its strongest and final flow, the pure love of intellect for its source. There is no consciousness of duality in that union; we are not aware of ourselves; but we are not destroyed or dissolved into the One because even in the union we are still intellect, though intellect "out of itself," transcending its normal nature and activity. The mystical union was for Plotinus, in this life at any rate, a rare and transitory experience. He attained to it, Porphyry tells us, four times while Porphyry himself was a member of the school. But it was the goal of all his effort and the source of the continuing power of his teaching. Philosophy for him was the way to union with the Good through moral purification and intellectual enlightenment.

BIBLIOGRAPHY.—The Greek text of the Enneads was first printed by P. Perna (Basle, 1580), together with the Latin trans. by Marsilio Ficino, which had already appeared (Florence, 1492). The best 19th-century edition is by R. Creuzer and G. H. Moser (Oxford, 1835; text reprinted in the Didot ed., Paris, 1855); others are by A. Kirchhoff (Leipzig, 1856). by H. F. Miiller (Berlin, 1878–80) and by R. Volkmann (Leipzig, 1883–84). The edition of E. Bréhier (Paris, 1924–38), though the text is poor, is valuable for its admirable notes and introductions to the several treatises. A great critical edition, to supersede all others, was undertaken by P. Henry and H. R. Schwyzer (Paris and Brussels, 1951 ff.).

Plotinus has been translated into most modern European languages. In English there is a complete translation by S. MacKenna and B. S. Page, 2nd ed., rev. (London, 1957); also selections trans. with introduction and notes by A. H. Armstrong (London, 1953). The French translation by M. N. Bouillet (Paris. 1857–61) is still valuable for its vast and learned commentary; and there is a version by E. Bréhier (in his edition). The German translation by R. Harder (Leipzig, 1930–37; reissue, with text and commentary, Hamburg, 1956 ff.) and the Italian by V. Cilento (Bari, 1947–49) are accurate and scholarly.

For a complete bibliography of the vast literature on Plotinus, up to 1949, see B. Marien, *Bibliografia critica* degli studi plotiniani (Bari, 1949), published with the last volume of Cilento's trans. Only a few works can be mentioned individually here: W. R. Inge, ***The Philosophy***

of Plotinus (1918; reprint 1948); E. Bréhier, *La Philosophie de Plotin* (1928); A. H. Armstrong, *The Architecture of the Intelligible Universe in the Philosophy of Plotinus* (1940); J. Katz, *Plotinus' Search for the Good* (1950); H. R. Schwyzer, "Plotinos," in Pauly-Wissowa, *Real-Encyclopädie*, vol. xxi (1951); M. de Gandillac, *La Sagesse de Plotin* (1952); J. Trouillard, *La Procession plotinienne* and *La Purification plotinienne* (1955); H. Fischer, *Die Aktualitat Plotins* (1956).
(A. H. Ag.)

PLOVER, the name given to an indefinite group of birds which, with the snipes and sandpipers, form the group *Limicolae* or "waders," although the plovers themselves rarely enter water. Perhaps the best entitled to the name are the golden plover (*Charadrius pluvialis*) and the gray plover (*Squatarola helvetica*). The latter is the larger and lacks the hind toe; otherwise the two forms are similar. The gray plover breeds in the far north of America, Asia and Europe, migrating south in the winter, when it reaches the Cape, Australia and Ceylon. The golden plover is more local but ranges from Iceland to Siberia, including the British Isles, as a breeding species. It also migrates south in winter. Both forms are exceedingly wary. In America occur two further golden plovers, breeding in the far north, where, in Alaska, their ranges are scarcely 100 mi. apart. But whereas the eastern form winters in Patagonia, which it reaches via Labrador. Newfoundland and the Antilles, returning by way of Panama. the Pacific bird widters in the Low Archipelago. Plovers are gregarious but monogamous birds, partial to mud flats and marshes and eating worms and small arthropods and mollusks. The legs are long, the bill shorter than in most waders.

The ringed plovers include the shore-haunting British bird of that name; killdeer (*q.v.*); and zick-zack (*Hoplopterus spinosus*). *Pluvianus aegyptius* (crocodile bird; *q.v.*), is celebrated for its connection with the crocodile, from the mouth of which it picks parasites. besides, from its wariness, acting as a sentinel to the reptile. The coursers, Cursorius and allied genera, to which the last belongs, are mainly desert forms from Africa and India. Other allies of the plovers are the stone curlews (*see* CURLEW), lapwings (*q.v.*), oyster catchers (*q.v.*), turnstones (*q.v.*) and avocets (*q.v.*). For "plovers' eggs" see LAPWING.

PLOW (PLOCGH): see TILLAGE MACHINERY.

PLUCKER, JULIUS (1801–1868), German mathematician and physicist, best known as an analytic geometer, but also carried out important research in magnetism and spectroscopy. He was born at Elberfeld on June 16, 1801. After studying at the universities of Bonn, Heidelberg and Berlin he went in 1823 to study in Paris, where he came under the influence of the great school of French geometers whose founder, Gaspard Monge, had only recently died. In 1825 he was received as Privatdozent (official but unpaid lecturer) at Bonn, and after three years he was made professor extraordinary. He then held the following posts: professor of mathematics at Friedrich Wilhelm's *Gymnasium,* Berlin (1833–34), professor of mathematics at Halle (1834–36), professor of mathematics (1836–47) and finally professor of physics (1847) at Bonn. He died at Bonn on May 22, 1868.

From his lectures at Bonn sprang his first great work, *Analytisch-geometrische* Entwickelungen, 2 vol. (1828–31), in which he introduced the abridged notation in analytical geometry. (See ANALYTIC GEOMETRY.) He applied this notation to the straight line, circle and conic sections, and he used it in his theory of cubic curves. Also he established the great principle of duality. He discovered the six equations known as "Plucker's equations" connecting the numbers of singularities in algebraical curves. (See CURVE.) Plucker communicated his formulas in the first place to *Crelle's* Journal, vol. xii (1834) and gave a further extension and complete account of his theory in his Theorie der algebraischen Curven (1839). In his System der analytischen Geometrie (1835) he introduced the use of linear functions in place of the ordinary co-ordinates; he also made the fullest use of the principles. of collineation and reciprocity. He discussed curves of the third order and gave a complete enumeration of them, including 219 species. In 1846 Plucker published his System der Geometrie des Raumes in *neuer* analytischer Behandlungsweise, but this contains merely a more systematic and polished rendering of his earlier results.

After his appointment as professor of physics at Bonn, Plücker began a series of researches in physics. His first physical memoir, published in J. C. Poggendorff's *Annalen der Physik und Chemie* (1847), deals with the behaviour of crystals in a magnetic field. Then followed a long series of researches, mostly published in the same journal, on the properties of magnetic and diamagnetic bodies, establishing results which are now part and parcel of our magnetic knowledge. This was followed by researches on the discharge tube; he investigated the deflection of the discharge by a magnet and the behaviour of the negative glow in a magnetic field. Plücker, first by himself and afterward in conjunction with J. W. Hittorf, made many important discoveries in the spectroscopy of gases. He anticipated R. Bunsen and G. R. Kirchhoff in announcing that the lines of the spectrum were characteristic of the chemical substance which emitted them and in indicating the value of this discovery in chemical analysis. According to Hittorf he was the first who saw the three lines of the hydrogen spectrum, which a few months after his death were recognized in the spectrum of the solar protuberances, and thus solved one of the mysteries of modern astronomy. Induced by his mathematical friends in England, Plücker in 1865 returned to "line geometry." His first memoir on the subject was published in the *Philosophical Transactions* of the Royal society in 1865. Plücker worked out the theory of complexes of the first and second order, introducing in his investigation of the latter the famous complex surfaces of which he caused those models to be constructed which are now well known to the student of higher mathematics. He left an uncompleted work on the subject which was so far advanced that his pupil and assistant, Felix Klein, was able to complete and publish it.

PLUM, the name of a fruit tree which belongs to the genus *Prunus* in the Rosaceae family. Like the peach and cherry, also members of the same genus and family, it is called a stone or drupe fruit. The fruit of the plum develops from a single ovary. As the fruit grows to maturity, the outer part of the ovary ripens into a fleshy, juicy exterior making up the edible part of the fruit and a hard interior called the stone or pit. The seed is enclosed within the stone. The fruits show a wide range of size, flavour, colour and texture.

The trees of some plum species are vigorous in growth with upright branches reaching a height of 20–30 ft., while others are much smaller; some are small shrubs with drooping branches, and some have great beauty as ornamental plants. The flower buds on most varieties and species are borne on short spurs or along the terminal shoots of the main branches. Each bud may contain from one to five flowers: two or three being most common; and where the buds are close together, they give an appearance of densely packed, showy flower clusters when the trees are in full bloom. Characteristic of the genus Prunus, the individual flower is made up of a receptacle forming a hollow cup bearing sepals, petals and stamens on the outer rim surrounding a single pistil attached at the bottom of the cup. After fertilization of the flower, the receptacle and attachments fall off and the style withers and drops off, leaving the enlarged basal portion of the pistil, the ovary, which develops into the fruit.

Native Habitat of Plum Species.—The common European plum, known botanically as Prunus domestica, appears to have originated somewhere in southeastern Europe or western Asia, probably in the region around the Caucasus and the Caspian sea. Although it is called the European plum, some botanists who have summarized the history of these stone fruits are doubtful that P. domestica is indigenous to Europe. According to the earliest writings in which this plum is mentioned, the species dates back about 2,000 years.

Another old world plum species, probably of European or Asiatic origin, is the damson plum (P. *insititia*). This species seems to antedate P. domestica, as is suggested by the finding of damson plum pits in ancient ruins. The ancient writings connect the early cultivation of these plums with the region around Damascus.

An important species native to China is the plum (P. *salicina*), which was domesticated in Japan and was introduced into the

United States about 1870.

Two less important species are the myrobalan plum *(P. cerasifera)*, a native of Europe, and the Simon or apricot plum *(P. simoni)*, a native of China. The myrobalan plum has been used a great deal in the United States as a rootstock. Varieties of *P. cerasifera* and *P. simoni* are noted for their ornamental foliage.

ROCHE

PLUM BLOSSOMS

Botanists have divided the native American plums into a number of species and subspecies. Many of them have numerous characteristics in common, so that they overlap somewhat in horticultural groups and classifications. *P. americana*, the most important of the native species, has a wide range of adaptation in the United States, extending from Maine to Florida. westward to Utah, and northwestward into Manitoba. The tree is small. not so vigorous as the European, and it has rough, shaggy, grayish bark. The fruit is red. reddish-yellow. or reddish-orange, possesses a pleasant flavour and is of good quality, but it has a thick. tough skin and the flesh clings to the pit. Desoto and Weaver are among the typical cultivated varieties of americanas.

Other American species of minor importance from a commercial standpoint but of interest to the fruit breeder are the native varieties of *P. hortulana*, the chickasaw plum *(P. angustifolia)*. and the wildgoose plum *(P. munsoniana)* of the southeastern and south central United States, of which Wildgoose and Robinson are important varieties.

Still other species of plums growing in North America are the Canada plum *(P. nigra)*, which is adapted to the north central United States and Canada; the small beach plum *(P. maritima)*, which grows along the eastern seacoast; and the western or Pacific plum *(P. subcordata)*, which grows east of the Coast range in southern Oregon and northern California.

Plum Culture in the United States.— Cultivated varieties of at least 12 species of plums are to be found in U.S. orchards or growing in the wild, but most of the important commercial varieties are confined to four of the species already mentioned, namely, *dornestica, insititia, salicina* and *americana.*

It is not known just when European plums were introduced into North America, but probably pits were brought over by the first colonists. It is reported that plums were planted by the Pilgrims in Massachusetts and importations were made by the French into Canada. These European plums have done remarkably well in the new world. and they constitute the most important group grown commercially for canning and drying.

The best known and most important of these groups are varieties of *Prunus domestica*, the European plums and prunes. These are vigorous-growing trees. upright spreading in habit. Unfortunately, they are not well adapted to regions with hot, dry summers or dry. cold winters. They are at home in the northeastern United States and in sheltered sections along the Great Lakes; but they are at their best in the irrigated regions of the intermountain and Pacific coast states, as is evidenced by the extensive production of fresh fruit and dried prunes in this region. The trees do well on medium heavy soils that are well drained. They blossom later than peaches and thus escape spring frosts. The European plums have been under domestication longest, and the fruits are notable for large size and attractive appearance. They vary in colour from the green and golden yellow of the Reine Claude (greengage) and Yellow Egg groups to the red and dark purple of the Lombard and Italian prune.

The damsons (P. *insititia)* of the old world are quite different from the domesticas. The trees are more upright, compact and dwarfish; the leaves and flowers are smaller; and the fruits are small, round and quite tart, so that they are especially suitable for preserves and jams. Varieties of this group are hardy, vigorous and productive, and the trees make good stocks for other species, being adapted to a wide range of conditions and thriving even when they are neglected. The Shropshire and the French are important blue damsons in the United States. while the yellow Mirabelles are popular in France. The demand for varieties of plums of this type is limited, and they are not planted as extensively as those varieties that can be consumed fresh, dried or canned.

The oriental plums *(P. salicina)* are relatively new to North America, but they were widely planted and became second to the domesticas in commercial production. The trees are more spreading in habit than the domesticas or damsons. and in leaf and fruit characters they are very different, resembling the native American plums. The fruits are very attractive and are characterized by a yellow ground colour overlaid by various shades of red. In some varieties the flesh colour is striking red, whereas fruit of the domesticas and damsons is green or yellow. Some newer hybrids of the salicina group show distinct superiority in flavour and in commercial possibilities over the early importations. Varieties of this group appear to be widely adapted in the United States except in the very coldest climates. While the quality is not equal to that of the best domesticas, and the commercial varieties are not so satisfactory for canning and drying, the fresh fruit is delicious in its blend of flavours. The varieties cross readily with one another and with the native americanas. Among the first so-called Japanese plums grown in the United States, Kelsey, Burbank, Abundance and Satsuma are typical. The trees are hardy and productive, and they tolerate a variety of soils as well as climatic conditions. The blossoms open earlier, hŏwever, than those of the domesticas and damsons and are frequently killed by spring frosts in the eastern part of the United States.

The native American plums were doubtless used for food by the Indians long before the white man set foot on the shores of North America. Reports of early explorers mention the finding of plums growing in abundance. According to the descriptions of the early settlers. these plums were inferior to the domesticas of the old world in quality, so that the colonists soon began importing varieties from Europe. As a result. European plums soon became predominant in home fruit gardens as well as commercial orchards in the northeastern United States. Varieties of native species, however, while not grown in commercial orchards, do fill a need in supplying fruit for the home garden in regions where the domesticas are not well adapted, as for example in the southwestern and south central United States. American varieties also have been selected for planting in the northern Great Plains where only cold hardy sorts can survive. Varieties like Xssiniboin and Cheney of the *P. nigra* group, and Wyant and Desoto of the americanas, survive in this region.

Hybrids produced by crossing American and oriental varieties have given larger fruited varieties of better quality, also adapted to the colder climates. Waneta and Underwood are two varieties that have been planted in home gardens. Furthermore, American species hybridize with the sand cherry *(P. pumila)*, and plant breeders have produced new varieties adapted to cold and dry conditions in the northern Great Plains. Important varieties are Opata, Sapa and Oka.

ROCHE

PLUMS (PRUNUS)

In the Gnited States, as well as in Europe, the plum has long been recognized as one of the most delicious of fruits, and among the stone fruits it ranks next to the peach in commercial production. Many of the varieties of plums cultivated in the United States have been introduced from elsewhere, and when these are added to thenative varieties they give plums the largest number and greatest diversity of kinds and species among the stone fruits.

Fortunately varieties can be selected that are adapted to a wide variety of soils and climatic conditions. Plums respond to good soil management practices. As trees come into bearing they do not require much pruning and in the home fruit garden can be grown satisfactorily if insects and diseases are controlled.

Insects and Diseases. — The fruit and tree of the plum are attacked by a number of troublesome insects and diseases that seriously limit production if not controlled by spraying. One of the most serious of the insect pests is the plum curculio, a small beetle that deposits its eggs in the fruit. As the larvae hatch and feed on the fruit, the affected fruits drop prematurely. Sometimes all of the fruits will drop off before harvest. This insect can be controlled by timely spraying with arsenate of lead or by the insecticide malathion.

Brown rot caused by a fungus that gains entrance through breaks in the skin or through punctures caused by the curculio may also be a serious menace. Fortunately this disease can be controlled by the timely application of fungicides of sulfur or copper. A bacterial leaf disease called bacterial spot, or shot hole, is serious in the more southern latitudes of the United States. Some varieties are quite resistant to this disease while others are susceptible. For the successful production of plums in any region a timely spray program must be followed to protect the fruit and foliage against these insect and disease pests.

Prunes. — Prune is a name given to a plum that can be dried without removing the pit into a firm long-keeping product. This term is frequently applied as a group name to plum varieties that have a sufficiently high sugar content and firm flesh so that they can be preserved by drying. The dried plum of commerce is, therefore, called a prune and only certain varieties have the qualities to make a good dried product. In California most of the plums are dried in the sun, while in Oregon and Washington drying is done in specially built dehydrators, where the drying is done with artificial heat. The growing of plums for the production of prunes in the United States is confined largely to the states of California, Oregon, Washington and Idaho. Agen or French, Italian, Sugar and Imperial Epineuse, all of European origin, are the principal varieties in the U.S.

Plums are the most widely distributed of the stone fruits. The fruit is also grown over a wide region in Europe from Italy on the south to Norway and Sweden on the north. Yugoslavia is the leading country with a tree potential of more than a million tons' production. A liqueur called *Slivovica* made from plums is an important article of commerce in Yugoslavia. Germany is the next largest producer of plums in Europe with a tree potential that in some years has equaled that of the U.S. in production. Turkey and Japan are leading countries in plum production in Asia.

BIBLIOGRAPHY.—W. P. Baird, "The Home Fruit Garden on the Northern Great Plains," U.S. Department of Agriculture *Farmers' Bulletin 1522* (1950); F. P. Cullinan, "Plums," U.S. Department of Agriculture *Yearbook,* pp. 703–723 (1937); U. P. Hedrick, *Plums of New York* (1911); C. F. Kinman, "Plum and Prune Growing in the Pacific States," U.S. Department of Agriculture *Farmers' Bulletin 1372* (1943); W. F. Wight, "Native American Species of Prunus," U.S. Department of Agriculture *Bulletin* 179 (1915). (F. P. C.)

PLUMBAGO: see GRAPHITE.

PLUMBING is the system of pipes and fixtures installed in a building for the distribution of potable (drinkable) water and the removal of water-borne waste materials. A plumbing system should perform in such a manner that the building's occupants are never endangered by contaminated drinking water or by contact with harmful wastes. Safe plumbing systems can only result from careful planning which takes account of 'the location of the building. the particular conditions arising from the design of the building and the activity taking place within it, the limitations of the municipal water and sewerage systems, and the plumbing standards enforced by the local, state or national governments. Properly designed, a plumbing system will maintain sanitary conditions over a broad range of both normal and abnormal operating conditions.

The piping system installed within a building is usually distinguished from the water and sewerage systems which serve a building, a group of buildings or a city.

The building plumbing system is usually considered to start at the point where the municipal water and sewerage lines cross the property lines of the building, or at some defined point just outside the building.

History. — One of the problems of every civilization in which the population has been centralized in cities and towns has been the development of adequate water and sewerage systems. In certain parts of Europe the complex aqueducts built by the Romans to supply their cities with potable water can still be seen. However, the early systems built for the disposal of human wastes were not quite so elaborate. Human wastes were often transported from the cities in carts or buckets or else discharged into an open, water-filled system of ditches which led from the city to a lake or stream.

Improvement in plumbing systems was very slow. Virtually no progress was made from the time of the Romans until the 19th century. The relatively primitive sanitation facilities were inadequate for the large, crowded population centres which sprang up during the Industrial Revolution, and outbreaks of typhoid fever and dysentery were often spread by the consumption of water contaminated with human wastes. Eventually these epidemics were curbed by the development of separate, underground water and sewage systems which eliminated open sewage ditches. In addition, plumbing fixtures — among them the lavatory basin, bathtub and water closet or toilet — were designed to handle potable water and water-borne wastes within buildings. However, these early fixtures often allowed sewer gases, bacteria and vermin to enter buildings through the open drain pipes with which they were connected to the sewer, and it was not until the latter part of the 19th century that the siphon water closet and the sanitary fixture trap were widely introduced, although the first patent for a water-sealed trap had been granted a century earlier.

Plumbing Fixtures and Materials. — The term plumbing fixture embraces not only showers, bathtubs, lavatory basins and water closets but also such devices as washing machines, garbage-disposal units, hot-water heaters, dishwashers and drinking fountains.

The materials used in a plumbing system must be strong, noncorrosive and durable enough to equal or exceed the expected life of the building in which they are installed. In addition, the materials used in fixtures that are exposed to view should be attractive and easy to clean.

Water closets, urinals and lavatories usually are made of stable porcelain or vitreous china, although they sometimes are made of glazed cast iron or steel or of stainless steel.

Ordinary water pipes usually are made of steel, copper, brass, lead, plastic or other nontoxic material, while the most common materials for sewerage pipes are cast iron, steel, copper, and asbestos cement.

Special fixtures — and entire plumbing systems of special design — are required for chemical laboratories and for plants manufacturing and processing chemicals and food products. Piping and fixtures for such applications may be made of glass, stainless steel, glass-lined metal, plastic, ceramics or special alloys. Drains often must be of special design to ensure proper disposal of corrosive or toxic materials, In the design of food-processing plants, the criterion is ease of cleaning equipment and piping.

Water-Supply Systems. — Usually only potable water is distributed in the water-supply system, but occasionally separate systems are installed for the distribution of nonpotable water used in industrial processes, fire-fighting equipment, or irrigation.

For towns and cities. municipally or privately owned water companies treat and purify water collected from wells, lakes, rivers and ponds and distribute it to individual buildings.

In rural areas water is commonly obtained directly from individual wells.

In most cities, water is forced through the distribution system by pumps, although in rare instances, when the source of water is located in mountains or hills above a city, the pressure generated by gravity is sufficient to distribute water throughout the system.

In other cases, water is pumped from the collection and purification facilities into elevated storage tanks and then allowed to flow throughout the system by gravity.

However, in most municipalities. water is pumped directly through the system; elevated storage tanks may also be provided to serve as pressure stabilization devices and as an auxiliary source in the event of pump failure or of a catastrophe, such as fire. that might require more water than the pumps or the water source are able to supply.

(See WATER SUPPLY AND PURIFICATION.)

The pressure developed in the water-supply system and the friction generated by the water moving through the pipes are the two factors which limit both the height to which water can be distributed and the maximum flow rate available at any point in the system. For example, if no water is drawn from the system in fig. 1. the pressure at any point in the building is equal to the pressure developed by the water tank less the pressure exerted by the column of water in the building below the point where the pressure is being measured.

If water is drawn from the system, the pressure at any point in the building will drop by an amount equal to the pressure required to overcome friction generated by the water moving in the pipes. As more and more fixtures draw water, the pressure will continue to drop, and eventually all the pressure developed by the water tank will be expended in overcoming friction and in pushing water up into the building against the force of gravity.

Subsequently, if more water is drawn by the fixtures on the lower floors of the building, the pressure used to overcome the increased friction will be balanced by a lowering of pressure on the upper floors, resulting in a decreased flow rate from the higher fixtures. In some instances, water may even stop flowing on the upper floors of a building.

Because friction losses increase approximately as the square of the velocity of the water flowing in the pipes, water pressure can be increased without decreasing the amount of water drawn from the pipes only by increasing the pipe diameter or providing booster pumps. Larger pipes can carry the same volume of water at lower velocities and, hence, with lower frictional pressure losses.

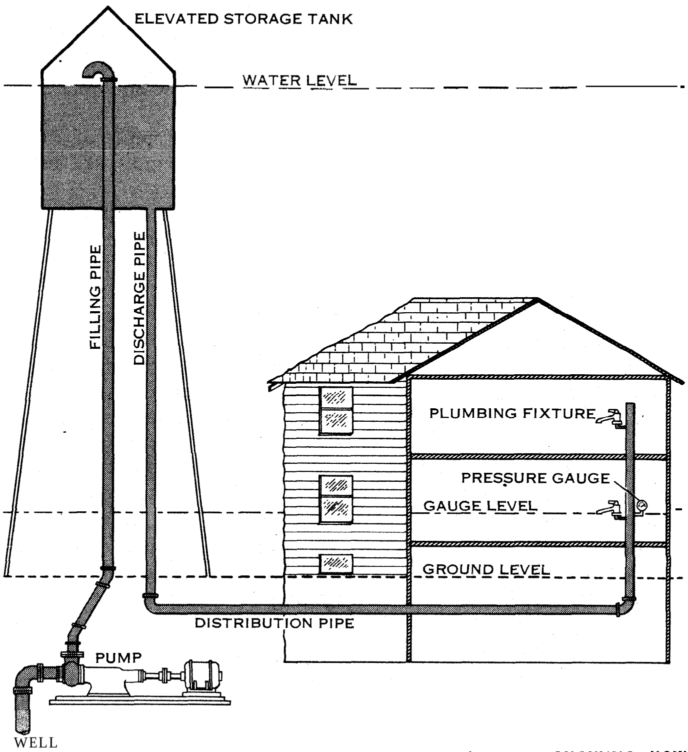


FIG. 1.— SIMPLIFICATION OF A WATER-SUPPLY SYSTEM, SHOWING HOW WATER PRESSURE AND HEIGHT ARE RELATED

Pressure losses are also caused by the formation of mineral deposits that decrease the effective diameter of the pipes and increase frictional pressure losses. For this reason, all pipes installed in a building should be large enough to allow for the restrictions caused by normal formation of mineral deposits during the life of the building.

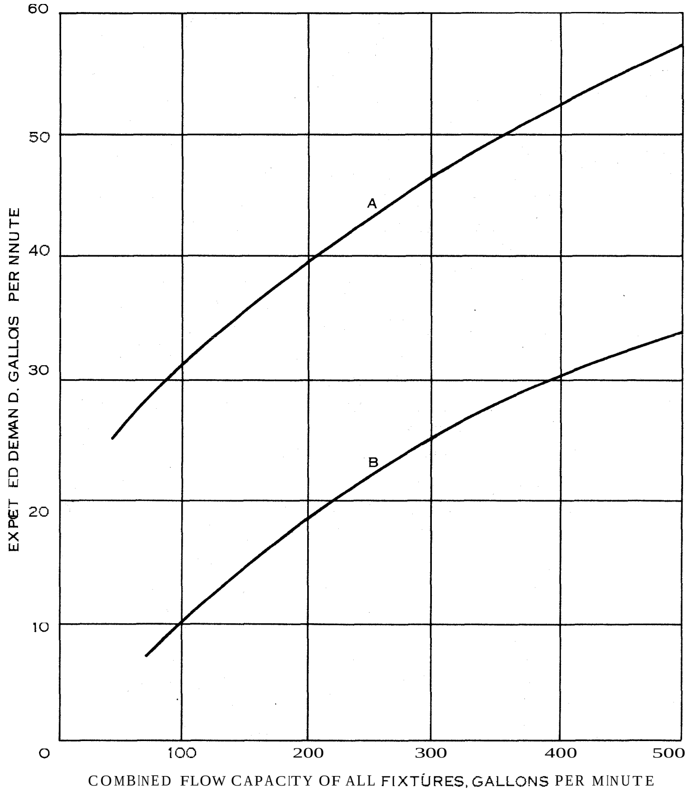


FIG. 2.— GRAPH SHOWING WATER DEMAND AS A FUNCTION OF TOTAL FIXTURE CAPACITY

Curve A is for buildings in which majority of toilets are flush-valve type. Curve B should be used if majority of toilets have flush tanks

Because it is extremely unlikely that all the fixtures in a building will be used at the same time. the pipe diameter selected by the plumbing designer is based on the frictional pressure losses caused by the maximum probable flow rate, not upon the maximum potential flow rate. Fig. 2 shows the relationship between the probable maximum demand for water and total potential flow capacities of the installed fixtures. To calculate the maximum probable flow rate for a new building, the plumbing designer refers to statistical tables which list the observed water demands of fixtures installed in buildings housing equivalent activities.

Pressures and Flow Rates for Common Plumbing Fixtures

Fixture	Recommended Pressure at Fixture (p.s.i.)	Ordinary Maximum Flow Rate (g.p.m.)
Lavatory basin	8	3.0
Bathtub	5	6.0
Shower	12	5.0
Water closet (with flush tank)	15	3.0
Water closet (with flush valve)	10 to 20	15 to 40

Recommended operating pressures and customary maximum flow rates for some common plumbing fixtures are shown in the accompanying table.

Booster pumps are sometimes installed in outlying areas of municipal water systems to offset the frictional head losses in long supply lines. Likewise, booster pumps are used in tall buildings when supply pipes of adequate size would be either too expensive or too bulky. The additional pressure supplied by the booster pump offsets the increased frictional losses of the smaller pipe and ensures that enough pressure will be available to maintain the flow of water to the upper floors during peak periods of consumption.

Sewerage System.—The sewerage system of a building consists of two parts: the drainage system and the venting system. The drainage portion comprises pipes leading from the various fixture drains to the central main, which is connected to the municipal or private sewerage system.

The venting system consists of pipes leading from an air inlet (usually located on the roof of the buildingj to various points within the drainage system; it protects the sanitary traps from siphoning or blowing by equalizing the pressure inside and outside the drainage system. Fig. 3 shows a typical arrangement of plumbing fixtures and drain and vent piping, with the drainage sections shaded.

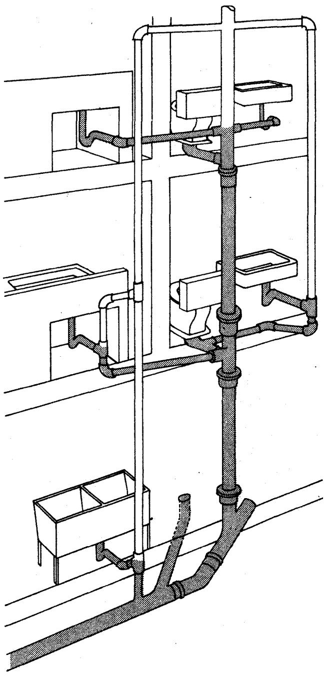


FIG. 3,— BUILDING DRAINAGE AND VENTING SYSTEM (DRAINAGE PIPING SHADED)

Sanitary fixture traps provide a water seal between the sewer pipes and the rooms in which plumbing fixtures are installed. The most commonly used sanitary trap is a U bend, or dip, installed in the drainpipe adjacent to the outlet of each fixture. A portion of the waste water discharged by the fixture is retained in the U, forming a seal which separates the fixture from the open drainpipes. Fig. 4 shows how water standing in the trap seals the pipe.

Sometimes the protection offered by sanitary traps is inadequate, and a device known as an indirect waste must be installed on the fixture to prevent sewage from backing up in a clogged drain pipe. Indirect wastes are designed so that liquids discharged from the fixture fall through an air gap into a receiver; this is connected through an ordinary sanitary trap to the sewer. If the section of pipe connected to the fixture drain ends at a level above that which wastes can reach in the receiver, the air gap between the fixture drain and the receiver top will prevent wastes from backing up into the fixture.

Plumbing regulations usually specify that indirect wastes be installed on restaurant coffee urns, automatic washing machines, dishwashers and other apparatus where great caution must be exercised to prevent contamination.

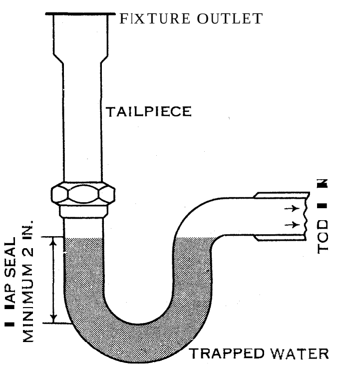


FIG. 4.—SANITARY FIXTURE TRAP SHOWING THE WATER COLUMN WHICH SEALS THE FIXTURE FROM SEWER GASES, BACTERIA AND VERMIN THAT ARE COMMONLY FOUND IN DRAINAGE SYSTEMS

In addition to sanitary traps and indirect wastes, fixture outlets are sometimes equipped with interceptors to separate and retain materials that should not be discharged into the sewerage system. For example, grease interceptors are often installed in restaurants to remove insoluble oils, fats and greases that, in large quantities, may impair the digestive action required for proper sewage treatment. (*See also* SEWER DESIGN AND CONSTRUCTION; SEWAGE DISPOSAL.)

Venting System.—If the drainage system is not vented, or if it is improperly vented. the air in the pipes will be evacuated by the flow of waste materials. For example. when the water discharged from a lavatory basin flows through the drainpipe, it pushes some of the air out of the pipe. If the waste water flows past openings where branch pipes join the system, air may be drawn from these branches by the suction created by the running water. If there were no sanitary traps at the fixture outlets, air drawn from the drainpipes by the flow of waste water would be replaced by air drawn into the pipes through the open drains on the fixtures.

However, the water retained in the sanitary traps blocks such a flow of air into the sewerage system just as it blocks the flow of sewer gases out of the system. Therefore, a partial vacuum may be formed inside an unvented drain, siphoning water from the sanitary trap and breaking the seal between the fixture and the sewer. Conversely, the water in the trap may be blown out through the fixture drain if the pressure within the drainage system should suddenly rise above atmospheric pressure. This could occur in an improperly vented system if air were trapped and forced into side branches by the flow of large quantities of water through the pipes.

In a small dwelling, where all the bathroom and kitchen fixtures can be located adjacent to a large vertical drainpipe, a separate venting system is usually not needed if the top of the vertical drain is open to the atmosphere. However, when this type of venting is used, the drainpipes must be large enough to handle peak waste loads without filling with water; otherwise, air will not be able to reach all parts of the system, and some of the traps may siphon or blow. If some fixtures are far enough from the central drainpipe so that they cannot be vented properly through the drainage system itself, separate air vents must be provided for them.

Water closets are usually provided with individual vents because the volume of water which they discharge makes it difficult to vent them properly through the drainpipes without using excessively large pipes.

Sanitation.— The central problem in the construction and repair of plumbing systems is the maintenance of sanitary conditions. Because both potable water and waste water are in close proximity in plumbing fixtures, such as water closets, lavatories and bathtubs, there is always danger of a cross connection which will allow contaminated water to enter the potable water pipes. Most cross connections are the result of faulty plumbing design and installation; they occur in leaking plumbing fixtures or through back siphonage in water-supply pipes. An example of a cross connection caused by leaking plumbing fixtures is an overhead sewerage pipe which drips sewage into an open laundry tub or sink. This could be eliminated by repairing the leak, but a better way would be to install the drainage pipes so that they never cross above open plumbing fixtures.

Another example of bad design which can lead to hazardous cross connections is a building in which both potable and nonpotable water are distributed in interlocked systems separated only by valves. If one of the interlocking valves fails or is inadvertently opened, the nonpotable water can contaminate the potable water.

Although the pressure in a water-supply system normally remains above atmospheric pressure, abnormal conditions may lower it sufficiently to induce back siphoning. The easiest way to safeguard fixtures against back siphoning is to install the water inlet well above the level of the waste water in the fixture. Most sinks and bathtubs are designed so that the inlet pipe is above the top of the overflow outlet. In these fixtures waste water cannot possibly submerge the inlet pipe and form a cross connection.

However, in some fixtures the space between the inlet pipe and the highest level of the waste water is so small that waste water could be sucked across the air gap and into the supply pipe under certain conditions.

Fixtures which have submerged inlets or improperly sized air gaps should never be installed unless they are safeguarded with vacuum breakers. Whenever the water pressure drops below atmospheric pressure, the vacuum breaker opens and allows air to flow into the water pipes, thus destroying the partial vacuum inside the pipes and eliminating the danger of back siphoning. Because vacuum breakers are mechanical devices subject to wear and corrosion! they should be checked from time to time to make sure that they are operating properly. In the case of the water closet, proper flushing action cannot be achieved unless the water inlet is submerged in the waste-water bowl, and thus plumbing codes specify that both flush-valve and flush-tank water-closets should be equipped with vacuum breakers.

Bibliography. — J. Rawlinson, "Sanitary Engineering: Sanitation," in Charles Singer *et al.* (eds.), *A History of Technology*, vol. 4 (1958); S. B. Bennett, *Manual of Technical Plumbing and Sanitary Science*, 8th ed. (1956); L. Blendermann, *Design of Plumbing and Drainage Systems* (1939); S. Webster, *Plumbing Materials and Techniques* (1959); E. R. Haan, *Home Plumbing Guide* (1957); V. T. Manas (ed.), *National Plumbing Code Handbook* (1957). (F. M. D.)

PLUMER, HERBERT CHARLES ONSLOW PLUMER, 1st Viscount, of Messines, cr. 1929 (1857–1932), British field marshal, was born on March 13, 1857, and entered the army in 1876. He served on the Red sea littoral in 1884, and in 1896 commanded a mounted regiment in the Matabele campaign. Before the outbreak of the South African War (1899) he raised the Rhodesian field force, which he commanded during the early months of the contest. He was promoted major general on the conclusion of hostilities.

In May 1915 Sir Herbert Plumer was selected to lead the 2nd army on the western front. His army was not very actively engaged during the remainder of 1915, nor yet in 1916, but on June 7, 1917, Plumer gained a signal victory at Messines. (See Ypres, Battles of, 1915 and 1917.) In November he took charge of the British troops sent to the basin of the Po after the Italian defeat at Caporetto, and in the following March was recalled to Flanders to resume the leadership of the 2nd army just before the great German offensive started. In the general advance in August, his army took part in the operations for the recovery of Belgian Flanders. At the peace he received a peerage, promotion to field marshal and a grant of £30,000. He subsequently commanded the British forces on the Rhine for a short time. From 1919 to 1925 he was governor of Malta, and from 1925 to 1928 high commissioner for Palestine. He died July 16, 1932.

PLUM RAINS are the persistent precipitation of the "Bai-u" season in Japan and immediately adjacent areas. In Japan proper, particularly from Kyushu to northeastern Honshu, a period of considerable and rather steady precipitation extends from approximately early June to about the middle of July. This is the period when plums are ripening; hence, the popular name of these rains, which are also important to the rice economy.

The rains tend to be of the moderate, prolonged type, rather than the cloudburst type. The sky is overcast for many hours, and the weather is depressing. The phenomenon is much better developed on the east side of Japan than on the west. Tokyo, for example, has an average in June of 1 clear day, 9 partly cloudy and 20 cloudy days; bright sunshine is observed during only about a third of the daylight hours. Tokyo records measurable rainfall on an average of 16 days in June, and the average monthly total is about $6\frac{1}{2}$ in. The accompanying average maximum temperature is 68.5° F.; the average minimum is 62.2° F.

The beginning of the plum rains is earliest in low latitudes and later northward. In Formosa and the Ryukyus, precipitation begins to increase in the middle of May and continues heavy until early July. In northern Korea, the season begins in late June and lasts through July.

The rains are associated with eastward-moving cyclones, decelerated near Japan by the Pacific high-pressure area. Occasional failure of the rains to appear has resulted in damaging droughts. (W. A. Bm.)

PLUNKET, OLIVER (1629–1681), Irish Roman Catholic divine, was born at Loughcrew, County Meath. He was appointed archbishop of Armagh and primate of Ireland in July 1669 and in November he was consecrated at Ghent, reaching Ireland in March 1670. The measures following on the Test act bore hardly upon him, and in Dec. 1678 he was imprisoned in Dublin castle for six weeks. Accused of a share in the Irish branch of the "Popish Plot," he was brought to London, and in June 1681 arraigned in the King's Bench, charged with conspiring to bring a French army to Carlingford. He made a good defense, but on the most absurd of evidence the jury convicted him of treason, and on July 1 he was hanged, drawn and quartered at Tyburn.

PLUNKET, WILLIAM CONYNGHAM PLUNKET, 1st Baron (1764–1854), Irish lawyer, orator and statesman, was born in the county of Fermanagh in July 1764, the son of a Presbyterian minister, and studied at Trinity college, Dublin. Having entered Lincoln's Inn in 1784, Plunket was called to the Irish bar in 1787. He gradually obtained a considerable practice in equity and was made a king's counsel in 1797.

In 1798 he entered the Irish parliament as member for Charlemont. He was an anti-Jacobin Whig of the school of Burke, and a fervent Irish patriot. But he was a sincere admirer of the constitutional government of England as established in 1688; he even justified the ascendancy it had given to the Established Church, although he thought that the time had arrived for extending toleration to Roman Catholics and dissenters. To transfer it to Ireland as thus modified, and under an independent legislature, was the only reform he sought for his country; he opposed the union because he thought it incompatible with this object.

When Plunket entered the Irish parliament, the Irish Whig party was almost extinct, and Pitt was feeling his way to accomplish the union. In this he was seconded ably by Lord Castlereagh, by the panic caused by a wild insurrection, and by the secession of H. Grattan from politics. When, however, the measure was brought forward, among the ablest and fiercest of its adversaries was Plunket, whose powers as a great orator were now universally recognized. His speeches raised him immediately to the front rank of his party; and when Grattan re-entered the moribund senate he took his seat next to Plunket, thus significantly recognizing the place the latter had attained.

After the union Plunket returned to the practice of his profession, and became at once a leader of the equity bar. In 1803 he was selected as one of the Crown lawyers to prosecute R. Emmet. For his speech on this occasion he was exposed to much obloquy, and more especially to the abuse of W. Cobbett, against whom he brought a successful action for damages. In 1803, in Pitt's second administration, he became solicitor general, and in 1805 attorney general for Ireland; and he continued in office when Lord Grenville came into power in 1806. Plunket held a seat in the Imperial parliament during this period, and there made several able speeches in favour of Catholic emancipation, and of continuing the war with France; but when the Grenville cabinet was dissolved he returned once more to professional life.

In 1812 he re-entered parliament as member for Trinity college, and identified himself with the Grenville or anti-Gallican Whigs. He was soon acknowledged as one of the first orators, if not the first, of the house of commons. In 1822 Plunket was once more attorney general for Ireland, with Lord Wellesley as lord lieutenant. One of his first official acts was to prosecute for the "bottle riot," an attempt on his part to put down the Orange faction in Ireland. He strenuously opposed the Catholic Association, which about this time, under the guidance of D. O'Connell, began its agitation. In 1825 he made a powerful speech against it; thus the curious spectacle was seen of the ablest champion of an oppressed church doing all in his power to check its efforts to emancipate itself. In 1827 Plunket was made master of the rolls in England; but, owing to the professional jealousy of the bar, who regarded an Irishman as an intruder, he resigned in a few days. Soon afterward he became chief justice of the common pleas in Ireland, and was then created a peer of the United Kingdom. In 1830 he was appointed lord chancellor of Ireland, and held the office, with an interval of a few months only, until 1841, when he finally retired from public life. He died on Jan. 4, 1853, and was succeeded by his eldest son, Thomas Spen Plunket (1792–1866), bishop of Tuam, as 2nd baron.

See the *Life of the First Lord Plunket* (1869), by his grandson, David Robert Plunket.

PLUNKETT, SIR HORACE (CURZON) (1854–1932), K.C.V.O. (1903), son of the 16th Baron Dunsany, was born on Oct. 24, 1853 and educated at Eton and Oxford. After engaging in cattle ranching for ten years, his interest in agriculture led him to devote himself to the promotion of agricultural co-operation, and in 1894 he founded the Irish Agricultural Organization society. As a member of parliament from 1892 to 1900, he strongly advocated the cause of agriculture. and in 1899 he was appointed vice-president of the department of agriculture and technical instruction for Ireland. Two years later he became commissioner of the Congested Districts board in Ireland. He was elected F.R.S. in 1902, and in 1919 endowed a trust, known by his name, for the development of agriculture. He presided over the Irish convention of 1917-18, and was a senator (1922-23) of the Irish Free state. He died March 26. 1932.

His works include Ireland in the *New Century* (1904); The *Rural* Life Problem of C.S. (1910); *Some Tendencies* of Modern *Medicine* (1913); and *A Better Way* (1914).

PLURALISM AND MONISM are theories giving respectively the answers "many" and "one" to two quite distinct questions: first, how *many* things are there in the world?; and second, how *many kinds* of *things* are there in *the* world? Much confusion is engendered if this distinction is not clearly maintained. Pluralism and monism as theories of substance, answers to the first question, have no necessary connection with pluralism and monism as theories of kinds of substance, answers to the second question. Philosophers can be cited to exemplify the four possible combinations of views: Descartes is a pluralist and Hegel a monist in both senses. Spinoza is a monist of substance and a pluralist of kinds, Bertrand Russell a pluralist of substance and a monist of kinds. Such definitions as "monism attempts to explain the entire universe from a single principle" misleadingly suggest, by compounding the two questions, that Spinoza and Russell are guilty of some inconsistency from which the writings of Descartes and Hegel are free.

A theory of substance seeks to establish the nature of what it is that can properly be said to exist independently or in its own right, or, again. what are the ultimate subjects of discourse: "Substance is that which requires nothing but itself in order to exist" (Descartes). The existence of some subjects of discourse—complexes such as armies, men's characters, material objects—will be dependent on that of others—simples such as soldiers. actions, sense-experiences—in that what we know or believe about the complex will be an inference from, or a convenient paraphrase of, what we know or believe about the simple. An ultimate subject of discourse, then, a simple or substance proper, something that exists in its own right. is something whose existence we can discover directly and without having first to discover or assume the existence of something else. The natural answer to the question "how many simple things, existing and discoverable independently, are there in the world?" is "many." Monism of substance—the theory that the world as a whole is the only true thing, held by Parmenides, Spinoza and Hegel—being at odds with our common beliefs, requires substantiation by argument. The point requiring proof is that nothing but the world as a whole is really independent of anything else. This—the doctrine of internal relations—will be stated and examined below.

A theory of kinds. "ultimate" kinds, of substance seeks to establish how many irreducibly different kinds of knowledge or experience we must admit. Two things are of different kinds, in a very wide sense. if there is any feature that one has and the other lacks. And since, unless there were such a feature, they would not be distinct and thus not be two things at all (the identity of indiscernibles). everything is of a different kind from everything else. But we do not in practice use such a generous criterion of difference in kind. Only some features of things are relevant to answering the question "what kind of thing is that?"; *e.g.,* its being a chair or a tree or a house or a star. Other features are relevant to answering questions about what kind of chair. tree, house or star it may be. Others again are not relevant to answering any questions about kinds at all; *e.g.,* being two feet from the wall, being the property of Ring Farouk. The set of features determining "natural kinds." possible answers to the question "what kind of thing is that?" is wider than the set determining "ultimate kinds." Roughly. the latter set consists of various forms of occupancy of space—location, volume, solidity. Whatever occupies space can be discovered only and always by sensation. Whatever does not occupy space can be discovered only and always by self-consciousness and introspection ("reflection"). The natural answer to the question "how many ultimate kinds of thing, objects of distinct types of knowledge or experience. are there in the world?" is "many." Monism of kinds—the theory that there is only one fundamental type of knowledge or experience. held by Democritus. Berkeley and Russell—being nearly as much at odds with common beliefs as monism of substance, also requires substantiation by argument. The point requiring proof is that there is only one source of knowledge, only one type of experience.

Whether or not parts of the world are independent of one another and whether or not there is more than one source of knowledge are questions whose internal connection, if any, does not at once leap to the eye. Hence the importance of distinguishing the varieties of pluralism and monism to which the attempt to answer them gives rise.

THEORIES OF SUBSTANCE

The Eleatics.—Xenophanes is credited with the remark "All is One." but his main importance is rather as a critic of polytheism than as a philosopher. It is with Parmenides that the first significant statement appears of the view that only the world as a whole ("being") exists in its own right. The world confronts us as a theatre of change; but this becoming; of which the senses inform us, is unreal, an illusory appearance, no proper object of knowledge. Only "being," discovered by reason, is real and truly exists. Being does not change, it never came into existence, it will never pass away, it is timeless. For what could change it, how could it arise from or pass into not-being? It is also. incidentally, spatial, finite and spherical in shape. Since empty space is a contradictory notion, "being" is everywhere. This tinge of materialism, important for its influence on Democritus and the atomists, is hardly consistent with the view that only reason informs us about reality, and it was not taken over by Plato.

Zeno. Parmenides' disciple, reinforced his master's theory with famous arguments against plurality and motion. Of these the most influential and relevant to the present purpose concerns the size of a world of many things, which. Zeno argues, must be both infinitely large and infinitely small and is thus an impossibility: infinitely small, since its ultimate components must be indivisible and thus without size. and no collection. however large, of things without size has any size; infinitely large. since the world, being divisible, has size. and the parts into whichever has size is divided. however far the division is carried, must themselves have size, so that it must consist of an infinite number of parts with size. This is a much harder nut to crack than Parmenides' own arguments against pluralism and secured the attention of Hume, Kant and Russell.

Spinoza.—In Part I of Spinoza's Ethics the classical argument for monism of substance—the proof that only the world as a whole (Deus *sive Natura*—God or Nature) exists independently —is to be found. It depends ultimately on Spinoza's theory of explanation. To understand anything, to have knowledge of it, is to know its cause or explanation. Now the causes of most of the things with which we are familiar are external to them, the changes of state of other things. To have knowledge of something whose cause is external to it requires us. therefore, to look beyond the thing itself to whatever it is that is needed to explain it. A thing of this kind. then being essentially dependent on something other than itself. does not come up to Spinoza's somewhat exigent requirement for being a substance; viz.. "that, the conception of which can be formed independently of another thing." Now either this quest for causes must continue indefinitely or terminate in a thing which somehow explains itself. a *causa sui,* which will be a true substance. All its characteristics being essential or definitive parts of its inner nature. we will be able to deduce all the truths requisite to total "understanding" of it from the conception of the thing by itself.

Spinoza argues that if there is a plurality of things each must be limited by and thus dependent on the others. There can only be one truly independent, self-subsistent, self-explanatory thing, and it must be unlimited, infinite. It follows that the view that God transcends the world that He created is mistaken, a conclusion supported by such unhappy consequences of the creation theory as the problem of evil and the consequent imperfection, in respect of power or goodness, of God. God is therefore immanent in, indeed identical with, created Nature. they are not two things but the same thing viewed in different ways: as creating (*Natura naturans*) and as created (*Natura naturata*). Only the whole, then, is intelligible in itself. for the rather negative reason. it would seem, that it at any rate must be self-explanatory since the existence of anything external to it which could explain it is logically excluded.

Hegel.—It is one of the aims of Hegel to overcome the deficiency last mentioned. He attempts to produce a conception of the world as a whole, the absolute. which will provide a positive ground for thinking it to be self-explanatory and thus to exclude the possibility (compatible with Spinoza's view) that the world as a whole is a brute fact, neither self-explanatory nor to be explained by anything else. This attempt involves the distinction of cause from reason. The cause of something is merely externally connected with it, a mere concomitant happening. The reason for a thing, however, has an internal, logical connection with it, in this case there is real connection not just coincidence. But only thoughts stand in logical relationships to one another. So the absolute is a logically articulated system of thoughts. Hegel, like Spinoza. bases his version of monism on the unintelligibility on its own account of what is finite or limited (for the finite is necessarily limited by something else and so to that extent dependent on it). But his requirement that truly intelligible explanation must be rational or logical. a matter of the logical interrelation of thoughts, is a further development.

Internal Relations.—The monisms of Spinoza and Hegel are both variants of the doctrine of internal relations. Their fundamental thesis may be expressed in two ways: (1) nothing but the world as a whole is independent of everything else; and (2) everything in the world is in its real nature essentially related to everything else. For, it is argued. we do not fully understand anything until we know all of its relations to other things. As against the normal view that things. identified by the set of their defining or essential properties. stand in various external, contingent relations which are not part of their definition or essence, it is held that the true definition of a thing contains all its qualities and relations, everything that can truly be affirmed of it. This sets an ideal of understanding that cannot be attained, since it requires that to understand anything properly one must know everything about it, in effect everything whatever. To "understand" a thing. to know what it is, it is enough to be able to recognize or identify it: by picking out a set of qualities as a thing we obtain a reference point whose relations to other such reference points it is the business of empirical inquiry to establish. Not only is the theory of internal relations no account of our actual conception of things, it is not an account of any conception of things in which inquiry into the nature of the world remains possible, but rather a dream of the termination of science, of a way of thinking fit for an omniscient being.

THEORIES OF KINDS

The question "how many ultimate kinds of thing are there?" is, it has been seen, an inquiry into the number of sources of knowledge or forms of experience. In practice the philosophical debate on this issue has predominantly concerned itself with the nature of our experience of and knowledge about minds. Do we get to know about thoughts, decisions and feelings (our own and those of others) in the same way as we get to know about material. extended, spatially located things? Prima facie, we seem to have independent access to two quite distinct orders of things: by sensation to an outer world of material things and other persons. by introspection to an inner world of our own mental states. Monism of kinds denies this apparent independence and distinctness. Sensation and introspection are assimilated into experience simpliciter, the impassable frontier between inner and outer is dismantled. That there is some distinction. at least prima facie. between the mental and the material is not denied by any but the most ardent materialist. What is objected to is the view that this distinction, this "bifurcation of nature" as A. N. Whitehead calls it. is ultimate, that we are the inhabitants of two distinct worlds. at best contingently connected. For the theory of bifurcation has given rise to two historically obtrusive problems, that of the relation between mind and body and that of our knowledge of other minds (the latter problem, on a wide view, may be seen as a more modern version of the former).

Dualism.—The classical exponent of dualism is Descartes. On his view the created world is composed of two quite distinct kinds of substance. minds and bodies. to be distinguished by their "essential attributes" which are. respectively, thought and extension. In practice Descartes takes these essential attributes as constituting the whole essence of mind and body. so that he comes to hold that the mind is always active and thinking and that matter is extension and empty space an impossibility. Locke complements this account of things with an appropriate account of our knowledge of things when he declares that all knowledge is based on sensation and reflection. For Descartes the distinction of the two kinds of thing depends on his theory of self-knowledge. Our own existence. he holds, is self-evident. since. whatever we may doubt. we cannot doubt that we doubt and. therefore. exist. On the other hand our knowledge of the external world is mediate, indirect. Our natural propensity to infer external causes for our sensations is only to be indulged and trusted if we are assured of the existence of God. The essential feature of dualism. then, is its intuitive theory of self-knowledge which contrasts our immediate and infallible knowledge of our own minds with our more devious and fallible acquaintance with everything else.

The first difficulty to arise from this is the familiar mind-body problem. In human perception and action we are confronted with what seem to be clear cases of the interaction of these two quite distinct orders of things, mental and material. Now there are two grounds on which philosophers have refused to acknowledge this apparent interaction: first, the conservation principles of physics seem to exclude the irruption of mental causes into the physical order; second, it was held that effects must resemble their causes. This did not prevent Descartes from inconsistently accepting the interaction of mind and body. with the pineal gland as a medium of divine agency. But since, by the conservation principle. every physical event is already physically accounted for and. by the metaphysical principle. that cause must resemble effect, mental causes of physical events are impossible as well as superfluous. mental events can at best be occasions and not causes of physical ones. This result leads in Descartes' immediate successors to the view that there are two quite independent but divinely adjusted series of events within which, but not between which, causal relations obtain: on the one hand is the system of inner experiences, the felt, private order of states of mind; on the other is extended nature, a true causal system of material substances with merely geometrical, "primary" qualities. The triumphs of physics tend to degrade the mental world to a shadow play. an epiphenomenon, the view of materialism. The remote and unintelligible character of material substance conceived in purely geometrical terms leads to idealism.

Materialism.—This doctrine regards mental life as a more or less illusory exhalation of physiological processes, on its relation to which experienced mental life depends for such reality as it can be held to possess. Only that which can be mechanically explained is real. Mental life, as experienced, is a by-product, a mere symptom of mechanical transformations at the physiological level. The determination, which this theory evidences. to replace the obvious by the speculative in the interests of tidiness is still to be found among scientists and depends on laying down as universally to be followed in all spheres of inquiry a method notably successful in certain specialized investigations. Even the advances of contemporary neurophysiology do little to transform the speculative metaphysics of physiological materialism into a well-confirmed scientific theory.

Idealism.—Where materialism arises from the triumph of the material conception of cause, idealism is based on the paradox of the material conception of substance. Berkeley attacked the notion of material substance propounded by Descartes and Locke as unintelligible, a nonentity. It could not cause, or, a fortiori, resemble, the ideas of sensation on which all knowledge is based since ex hypothesi it could not be independently observed and compared with them. Material things are not distinct substances of a purely geometrical character on this view, for such things are unknowable, but are, rather, orderly and regular systems of sense experiences. Idealists of a Hegelian type argued that reality to be knowable must be mental in character, a system of ideas, which derives its objectivity for the observer not so much from being the beneficent contrivance of God as from being the logically necessary unfolding of the thoughts of an absolute mind (which is not perhaps very different).

Neutral Monism. — Idealists, while rejecting material substance, still distinguish mental substance, mind, from the ideas that it has. In Berkeley this leads to an uncomfortable and arbitrary proposal of a theory of notions to explain knowledge of mental substance, a theory required because we do not have any ideas of mind. But the "mental" character of ideas is based on their essential dependence on these somewhat feebly supported substances. Neutral monism reverses the relation by construing the ideas of sense as fundamental, the immediate objects of knowledge, and things, mental and material, as constructions out of these basic neutral elements. This view, developed by William James from some ideas of J. F. Herbart, became the foundation of Russell's theory of knowledge.

Other Minds. — The second major problem to which dualism gives rise is that of our knowledge of other minds. For, if dualism is correct, while we know about ourselves directly and infallibly we only find out about the mental life of others on the evidence of their behaviour and can never directly verify what we infer from this. Other minds are as unknowable in themselves, apart from their supposed effects! as the material substance attacked by Berkeley. Attempts have been made to identify our knowledge of self and others, to bridge the abyss exposed by criticism of the argument from analogy, by asserting that. we have direct, "intuitive" knowledge of the mental states of others or that we have to find out about our own mental states by a more or less prolonged, tentative and piecemeal procedure. "Telepathic" idealism comes to grief on the inescapable logical distinctness of your experience of your anger from my, telepathic, experience of your anger. Its diametrical opposite, G. Ryle's "dispositional" materialism, provides a valuable criticism of the Cartesian intuitive theory of self-knowledge in all departments of mental life. But the attempt to construe having pains, sensations and images as tendencies to behave in certain ways comes up against a mass of very ordinary conviction to the contrary. (A. M. Q.)

PLURALITY, a term applied particularly to the holding of two or more offices by the same person (called then a pluralist). In ecclesiastical law, plurality, or the holding of more than one benefice or preferment, was always discountenanced, and is now prohibited in England by the Pluralities Act, 1838, as amended by the Pluralities Act, 1850, and the Pluralities Acts Amendment Act 1885. By the latter act a provision was made that two benefices might be held together, by dispensation of the archbishop on the recommendation of the bishop, if the churches be within four miles of each other, and if the annual value of one does not exceed £200. (See BENEFICE.)

In the United States, the term is used in election law to denote the number of votes which a candidate has received for a public office in excess of the number received by any one of two or more other candidates.

PLURALITY OF CAUSES, in logic, is the view that one and the same kind of effect can be produced in different cases by different causes. This is quite distinct from the question whether the cause of an effect is as a rule a complex or multiplicity of several or many constituent or contributory factors or conditions. Assuming the complexity of each cause, there still remains the further question whether any one of several separate causes can produce the same kind of effect as another. In other words can one cause ever act vicariously for another? (Hence the alternative, and less ambiguous name, "vicarious causes.") J. S. Mill is the best known advocate of the doctrine of plurality of causes. Examples taken from daily experience seem to support the view. Many different causes can produce death for example. For most practical purposes the doctrine holds good. The whole system of substitutes, in peace and in war, is based on it. But for practical purposes many effects are sufficiently similar, although they are really very different when closely scrutinised. The total state called death is very different according as one cause or another led to it. The holding of coroner's inquests is based on the assumption that a close examination of the state of a dead body can help to determine the precise cause of death in each case. Similarly with all cases in which details matter. The total effect produced by one kind of cause is never precisely the same as that produced by any other. So that strictly speaking the doctrine of plurality of causes is not true. But where the interest is centred in broad kinds of effect, and differences of detail do not matter much, there the doctrine holds good for all practical purposes.

See J. S. Mill, *System of Logic* (1875 etc.); J. Venn, *Empirical Logic* (1889); J. Welton, *Manual of Logic* (1896).

PLUSH. Plush fabrics are characterized by a fur-like or velvet pile surface somewhat typical of the short hairy pelts of certain animals as, for example, the seal and otter. A plush pile surface is developed in woven fabrics by causing a series of tufts of pile to project more or less vertically from a foundation texture. The tufts of pile virtually consist of short lengths of warp threads usually of silk, artificial silk or mohair yarn interwoven with the foundation fabric in such a manner that the tufts of pile are looped under the picks of weft by which they are securely retained in the fabric.

PLUTARCH (Gr. Πλούταρχος) (c. A.D. 46–120), Greek biographer and miscellaneous writer, was born at Chaeronea in Boeotia. After having been trained in philosophy at Athens he travelled and stayed some time at Rome, where he lectured on philosophy and undertook the education of Hadrian. (There seems no authority for this statement earlier than the middle ages.) Trajan bestowed consular rank upon him, and Hadrian appointed him procurator of Greece. He died in his native town, where he was archon and priest of the Pythian Apollo. In the Consolation to his Wife on the loss of his young daughter, he tells us (§ 2) that they had brought up four sons besides, one of whom was called by the name of Plutarch's brother, Lamprias. We learn incidentally from this treatise (§ 10) that the writer had been initiated in the secret mysteries of Dionysus, which held that the soul was imperishable. He seems to have been an independent thinker rather than an adherent of any particular school of philosophy. His vast acquaintance with the literature of his time is everywhere apparent.

The celebrity of Plutarch, or at least his popularity, is mainly founded on his 46 Parallel *Lives*. He is thought to have written this work in his later years after his return to Chaeronea. His knowledge of Latin and of Roman history he must have partly derived from some years' residence in Rome and other parts of Italy (Demosth. § 2), though he says he was too much engaged in lecturing (doubtless in Greek, on philosophy) to turn his attention much to Roman literature during that period.

Plutarch's design in writing the *Parallel* Lives — for this is the title which he gives them in dedicating *Theseus* and Romulus to Sosius Senecio — appears to have been the publication, in successive books, of authentic biographies in pairs, taking together a Greek and a Roman. In the introduction to the *Theseus* he speaks of having already issued his Lycurgus and *Numa,* viewing them, no doubt, as bearing a resemblance to each other in their legislative character. Theseus and Romulus are compared as the legendary founders of States. In the opening sentence of the life of Alexander he says that "*in* this *book* he has written the lives of Alexander and Caesar" (Julius), and in his Demosthenes, where he again (§ 1) mentions his friend Sosius, he calls the life of this orator and Cicero the fifth book. (It is quite evident that the original order of the books has been altered in the series of *Lives* as we now have them.) It may, therefore, fairly be inferred that Plutarch's original idea was simply to set a Greek warrior, statesman, orator or legislator side by side with some noted Roman celebrated for the same qualities, or working under similar conditions. Nearly all the lives are in pairs; but the series concluded with single biographies of Artaxerxes, Aratus (of Sicyon), Galba and Otho. In the life of Aratus, not Sosius Senecio, but one Polycrates, is addressed.

The *Lives* are works of great learning and research, long lists of authorities are given, and they must for this very reason, as well as from their considerable length, have taken many years in compilation. It is true that many of the lives, especially of Romans, do not show such an extent of research. But Plutarch must have had access to a great store of books, and his diligence as an historian cannot be questioned, if his accuracy is in some points impeached. From the historian's point of view the weakness of the biographies is that their interest is primarily ethical. The author's sympathy with Doric characters and institutions is very evident; he delights to record the exploits, the maxims and virtues of Spartan kings and generals. This feeling is the key to his apparently unfair and virulent attack on Herodotus, who, as an Ionian, seemed to him to have exaggerated the prowess and the foresight of the Athenian leaders.

The voluminous and varied writings of Plutarch exclusive of the *Lives* are known under the common term *Opera moralia.* These consist of above 60 essays, some of them long and many of them rather difficult, some too of very doubtful genuineness. Their literary value is greatly enhanced by the large number of citations from lost Greek poems, especially verses of the dramatists, among whom Euripides holds by far the first place. The principal treatises in the *Opera moralia* are the following:—

On the Education of Children; How a Young Man Ought to Hear Poetry, on the moral aspect of Homer and the tragedians, with quotations *On the Right Way of Hearing* (Περὶ τοῦ ἀκόυειν) is another educational essay. Among the moral essays may be included: *How a Flatterer may be Distinguished from a Friend, How One May be Conscious of Progress in Goodness,* addressed to Sosius Senecio, consul under Nerva and Trajan; three short essays, *On Having many Friends, On Chance* and *On Virtue and Vice,* mainly valuable for quotations from poets otherwise lost; *Advice to the Married, On the Late Vengeance of the Deity, On the Genius of Socrates, On Superstition, On Exile,* a fine essay plentifully illustrated with quotations; *The Amorous Man,* and the *Gryllus,* an entertaining dialogue proving the moral superiority of many animals over man. The speakers are Circe, Odysseus, and a pig; the pig wins.

Another group includes some physical treatises such as *Precepts about Health,* which do not often coincide with modern ideas; *On the Face of the Moon's Disk,* which throws light on ancient astronomical theory; *Whether Land or Water Animals are the Cleverer; Whether Water or Fire is the More Useful; On Primary Cold; Questiones Naturales* and *On Flesh Eating.* The historical treatises include: *On the Fortune of the Romans,* two essays on the career of Alexander, *Whether the Athenians were More Renowned for War or for Wisdom,* and the famous *De Malignitate Herodoti,* charging Herodotus with unfair treatment of the non-Ionic States. There are also a purely metaphysical work, the *Platonic Questions,* and two political treatises, *Should a Man Engage in Politics when No Longer Young?* and *Political Precepts.* There are also two *Consolations,* one to Apollonius for his son, and one to his own wife for their daughter. There remains a group of his most valuable and interesting works, on archaeological questions generally, and especially religious history. These include *On Isis* and *Osiris, On the Cessation of Omcles, On the Pythian Responses* (an appendix to the last), and *On the E at Delphi,* of the exclusively ritual discussions; and two miscellaneous works, which contain a vast collection of information and discussions on points of almost every kind, the *Symposiaca* (9 books), and the *Quaestiones Romanae* and *Graecae,* which is of considerable importance to classical archaeology. There is also the collection of *Short Sayings,* divided into (1) of kings and commanders, (2) of Spartans, and (3) of Spartan women. Doubt is thrown on the validity of *Tlte Banquet of the Seven Wise Men, On Fate; Parallels; On Accepted Opinions and the Lives of the Ten Orators.*

BIBLIOGRAPHY.—Editio princeps, by H. Stephanus (1572); other complete editions by J. J. Reiske (1774–82), J. G. Hutten (1791–1804), T. Döhner and F. Dübner (1846–55). Of the *Lives,* there are editions by A. Coray (1809–14), C. Sintenis (1839–46; ed. min., 1874–81), and of many separate lives by Siefert-Blass, Sintenis-Fuhr, Holden, Hardy and others; Loeb ed., with trans. (11 vols. 1914–26). There are many English translations, of which the most popular is that by John and William Langhorne; also the old French version by Jacques Amyot (1559) from which Sir Thomas North's (1579) was made, newly edited by G. Wyndham (1895); many of the Roman lives have been translated, with notes, by George Long. The *Moralia* has been edited by D. Wyttenbach (1795–1830), and G. N. Bernardakes (1888–96) Loeb ed. with trans. (1927–). The old English translation by Philemon Holland (1603) has been revised by C. W. King and A. R. Shilleto in Bohn's *Classical Library* (1882–88), and a later translation by various hands (London, 1684–94), edited by W. W. Goodwin with introduction by R. W. Emerson, has been republished at Cambridge, Massachusetts (1874–78). Mention may also be made of P. Holland's *Roman Questions,* edited with introductory dissertations by F. B. Jevons (1892); *Roman Problems,* with essay on "Roman Worship and Belief," by G. C. Allen (1904); H. J. Rose, *The Roman Questions of Plutarch* (Text and Commentary, 1924); *De la Musique,* edit. H. Weil and Th. Reinach (1900); J. Oakesmith, *The Religion of Plutarch as expounded in his Ethics* (1902); Archbishop Trench, *A Popular Introduction to Plutarch* (1873); O. Gréard, *De la Morale de Plutarque* (1866); R. Volkmann, *Leben, Schriften und Philosophie des Plutarch* (1869); R. Hirzel, *Plutarch* (1912). The earlier literature of Plutarch is very extensive, for which W. Engelmann, *Scriptores graeci* (1881), may be consulted.

PLUTARCH OF ATHENS (4th–5th century A.D.), Greek philosopher. preceded Syrianus as head of the Platonic school at Athens and was one of the teachers of Proclus. He died at a good old age in A.D. 431/432. The commentaries that he wrote on a number of Platonic dialogues and on Aristotle's *De Anima* have not survived and are known to us only from allusions in later writers. The commentary on the *De Anima* had a particularly high reputation, ranking with that of Alexander of Aphrodisias. We know too little of Plutarch's teaching to be able to form any estimate of its importance or originality. What we are told by later writers does not suggest that it was notably different from that of other Athenian Neoplatonists, though perhaps he was more interested in and influenced by Aristotle's philosophy than some of them. (All Neoplatonists of course studied Aristotle and were to some extent influenced by him; he was in particular their principal authority in logic and natural philosophy.) Plutarch seems to have been particularly interested in Aristotle's psychology: we are told not only that he wrote a commentary on Aristotle's chief psychological work but that in his own teaching on the soul he combined the Platonic doctrine of recollection with the Aristotelian theory of the intellect. (A. H. AG.)

PLUTO, a euphemistic name for the Greek god of the lower world (Gr. Πλούτων), properly Hades, Aïdes or Aïdoneus, "the Unseen." He was the son of Cronus and Rhea, and brother of Zeus and Poseidon. Having deposed Cronus, the brothers cast lots for the kingdoms of the heaven, the sea, and the infernal regions. The last, "the house of Hades," sometimes loosely called Hades, fell to Pluto. Here he ruled with his wife, Persephone, over the other powers below and over the dead. He is stern and pitiless, deaf to prayer or flattery, and sacrifice to him is of no avail; only the music of Orpheus prevailed upon him to restore his wife Eurydice. His helmet, given him by the Cyclopes after their release from Tartarus, rendered him invisible (like the Tarn—or Nebelkappe of German mythology). Being feared, he is usually alluded to by euphemistic epithets: Polydectes (the receiver of many), Clymenus (the Illustrious), Eubulus (the giver of good counsel). But, perhaps by contamination with a god of the fertility of the earth, he is also Pluto, the "giver of wealth" (a name that first occurs in the Attic poets of the fifth century), and at most of the centres of his cult he was so worshipped; At Elis alone he was Hades, the god of the dead. The plants sacred to him were the cypress and narcissus; black victims were sacrificed to him. as to all underworld powers. In art he was represented like Zeus and Poseidon, but sterner; his attributes are a sceptre and Cerberus; he carries the key of the world below and is frequently in company with Persephone.

PLUTO is the outermost known major planet, ninth in order of distance from the sun. Its mean distance from the sun is 39.5 times that of the earth, but its orbit is so eccentric (e = 0 25) that at perihelion as in 1989, it comes closer to the sun than Neptune does. The inclination (17") and the orientation of its orbit (node to perihelion = 114°) are such that the orbits of Neptune and Pluto do not now intersect. Pluto's period of revolution is 248 years. Pluto is so faint, 15th magnitude, that a 20-in. telescope is necessary to see it. Its diameter has been measured as 3,700 mi., halfway between that of Mars and Mercury. This measurement is difficult because of Pluto's faintness and small angular diameter (0.″23). With a diameter of 3,700 mi., Pluto's volume is 0 1 that of the earth and its mass would probablv be about 0 1 that of the earth also, since it is not likely that its density exceeds that of the earth. Pluto's reflecting power derived from its apparent brightness and measured diameter is about what might be expected (albedo = 0.17). Its mass as derived from its attraction on Neptune is about that of the earth, but this value is also uncertain. If Pluto is as large as the earth, as indicated by its calculated mass, its reflectivity must be extreniely low. It therefore seems probable that Pluto's diameter is about one-half and its mass one-tenth that of the earth.

The brightness of Pluto varies about 10% in a period of 6.39 days, indicating that its surface is not uniformly bright and that the planet rotates on its axis in a period of 6.39 days.

Pluto mas discovered in a systematic search for a trans-Neptunian planet predicted by Percival Lowell on the basis of its attraction on Uranus (*Memoirs of the* Lowell Observatory, vol. i, 1915). William Henry Pickering, using discrepancies in the motion of Neptune. also predicted a trans-Neptunian planet in about the same place as that derived by Lowell (*Harvard Annals*, vol. lxxxii, no. 3, 1919). Pluto was discovered on Feb. 18, 1930, by Clyde William Tombaugh at the Lowell observatory on photographs he had taken on Jan. 23 and 29, 1930 (Scientific *Monthly*, vol. xxxiv, Jan. 1932). He recognized the new planet by its motion, which was much slower than that of the numerous asteroids also recorded on the photographs. In spite of the fact that Pluto was near the position predicted by the computations, its small mass indicates that its discovery was due to the thoroughness of the search rather than to the theoretical calculations. Both Lowell and Pickering predicted that the unknown planet would be much larger and brighter than Pluto is. (S. B. N.)

PLUTO MONKEY, a guenon (*q.v.*), *Cercopithecus mitis*, which takes its name from the black fur of the underparts, passing into blackish gray on the head and back. The violet-coloured face is fringed by large bushy whiskers and surmounted by a white band above the brows. The typical form extends from the Congo to Nyasaland and Angola.

PLUTONIUM. The element plutonium has the chemical symbol Pu and the atomic number 94. It was given its name after the planet Pluto, following the convention used in naming uranium and neptunium. Since all of the isotopes are produced synthetically. the atomic weight depends on the particular isotopic composition of any given sample, which in turn depends on the source of the sample. Plutonium occupies a position in the periodic system of the elements as the fifth member of a transition series, the actinide series. which includes the heaviest known elements and in which an inner electronic shell (the 5f shell) is being filled. For an account of its discovery, see the article TRANSURANIUM ELEMENTS.

The isotope of plutonium which is of greatest importance is the one with mass number 239. This isotope, which decays by the emission of alpha particles with a half life of about 24.000 years. has the property of being fissionable with slow neutrons, a property which makes it useful as a nuclear fuel and a source of atomic or nuclear energy. The first pure chemical compound of plutonium. free from carrier material and all other foreign matter, was isolated by Burris B. Cunningham and Louis B. Werner at the Metallurgical laboratory (now the Argonne National laboratory) of The University of Chicago during Aug. 1942. This isolation marked the first sight of a synthetic element and the first isolation of a weighable amount of an artificially produced isotope of any element. This isotope, Pu^{239}, was the one used for the study of plutonium in weighable amounts.

Occurrence.— Plutonium occurs in nature in uranium-containing ores in a very small concentration. Such plutonium was first discovered in Canadian pitchblende by Glenn T. Seaborg and Morris L. Perlman in 1942. The isotope involved is Pu^{239} which is formed continuously as a result of the absorption of neutrons by U^{238}. The neutrons are those emitted during the spontaneous fission of uranium and those resulting from the action of alpha particles on the nearby light elements. The concentration of Pu^{239} is determined by the equilibrium balance between its rate of formation and its rate of radioactive decay.

TABLE I.—Concentvations of Plutonium in Common Ores

Ore	Pu^{239}/ore*
Pitchblendes:	
Canada (13.5% U)	9.1×10^{-13}
Belgian Congo (38% U)	4.8×10^{-12}
Colorado (50% U)	3.8×10^{-12}
Monazites:	
Brazil (0.24% U)	2.1×10^{-14}
North Carolina (1.64% U)	5.9×10^{-14}

*Fraction by weight of Pu^{239} in ore.

Production.— By far the most important source of plutonium has been its manufacture in nuclear reactors or chain-reacting piles. An example is a nuclear reactor consisting of natural uranium and some neutron-slowing material or moderator such as carbon (graphite) or heavy water (deuterium oxide). In such a reactor a self-sustaining nuclear chain reaction results from the fission of the uranium isotope U^{235} with neutrons. and a large proportion of the excess neutrons are absorbed by U^{238} to form U^{239} which decays by two successive beta-particle emissions to Pu^{239}. In such production methods some of the Pu^{239} captures neutrons to form heavier isotopes such as Pu^{240}, Pu^{241}, etc. Since the isotopic composition of any given sample of plutonium depends on its source, the concept of atomic weight has no meaning in the ordinary sense. The plutonium is separated by chemical means from the highly radioactive fission products and the uranium and other foreign material. The chemical plants for this purpose are massive structures engineered to solve the grave problems inherent in handling extremely high levels of radioactivity due to the fission products. Operations in these plants are carried out entirely by remote control through heavy walls of shielding material.

The earliest industrial process for the isolation of plutonium, used at the Hanford Engineer Works in the state of Washington during World War II, is based on bismuth phosphate and lanthanum fluoride as carrier precipitation agents. This process was conceived by Stanley G. Thompson. Seaborg and their collaborators at the Metallurgical laboratory of The University of Chicago. Neutron-irradiated uranium is dissolved in nitric acid and after the addition of sulfuric acid. plutonium IV is coprecipitated with bismuth phosphate. The precipitate is dissolved in nitric acid. the plutonium IV is oxidized to plutonium VI and a by-product precipitate of bismuth phosphate is formed and removed. the plutonium VI remaining in solution. After the reduction of plutonium VI to plutonium IV, the latter is again coprecipitated with bismuth phosphate and the whole "decontamination cycle" is repeated. At this point the carrier is changed to lanthanum fluoride, and a similar "oxidation-reduction cycle" is carried out using this carrier, which achieves further decontamination and concentration. The plutonium at this point is sufficiently concentrated so that final purification can be carried out without the use of carrier compounds.

Many of the commercial processes for the separation and decontamination of plutonium in use later were based upon extraction into organic solvents. The solvent extraction is performed in packed columns or pulsed columns, or in a series of mixing-settling chambers in which the aqueous phase and solvent phase pass in countercurrent flow in a multistage process. These processes are very similar in principle as used throughout the world and can be illustrated by two of the U.S. processes. In the industrial "Redox" process, uranium and plutonium are separated from fission products and from each other by extraction with methyl n-butyl ketone (hexone). The uranium nitrate dissolver solution is oxidized and contacted with hexone to extract uranium VI and plutonium VI. The hexone is then contacted with an aluminum nitrate solution containing a reducing agent which does not affect the uranium but reduces the plutonium to plutonium III and strips it into the aqueous phase. The plutonium product from this cycle is oxidized to prepare it for re-extraction, and the entire sequence — extraction as oxidized plutonium, followed by reduction and stripping as tripositive plutonium — is repeated once or twice more. In the industrial "Purex" process, tributyl phosphate diluted with a kerosene-type solvent is used. The uranium slugs are dissolved in nitric acid, plutonium is fixed as plutonium IV and the acid strength is adjusted so that plutonium IV and uranium VI are extracted away from the fission products. In a second part of the process, the solvent is contacted with a nitric acid solution containing a reducing agent. Uranium VI is left in the tributyl phosphate phase while plutonium III is removed. Both uranium and plutonium are put through additional purification before complete purification is achieved.

Uses. — The main use for plutonium, dependent on the isotope Pu^{239}, lies in its application for nuclear (or atomic) energy. Nuclear reactors may be built to use the isotope Pu^{239} as fuel, and these reactors can also be operated in conjunction with the abundant isotope of uranium, U^{238}. The reactors can generate energy by "burning" the Pu^{239}, while at the same time they produce more Pu^{239} as a result of the absorption of neutrons in U^{238}. Such a system is known as a "breeder." This process, in theory, should make it possible eventually to convert all the nonfissionable U^{238} into fissionable Pu^{239}. Hence the rate of nuclear power production could be increased steadily. It is possible to use Th^{232} instead of U^{238} in these breeder reactors. In this case the following reaction would occur:

$$Th^{232} \xrightarrow{\eta,\gamma} Th^{233} \xrightarrow{\beta^-} Pa^{233} \xrightarrow{\beta^-} U^{233}$$

The product U^{233} is a long-lived, fissionable isotope similar to Pu^{239} and U^{235}. A fissionable isotope such as Pu^{239} gives rise to an amount of heat energy equivalent to about 10,000,000 kw.hr. per pound when it undergoes the fission reaction completely. In industrial uses the energy may be used in this heat form or, in most cases. converted into the more convenient electrical form by more or less standard turbine equipment. The efficiency with which heat energy can be turned into electrical power in an industrial nuclear reactor depends on the details of the particular machine, but it seemed likely that efficiencies of some 20% to 30% might be realized.

The isotope Pu^{239} can also be used as an explosive ingredient for nuclear (atomic) weapons. An important use of the by-product radioactive tracers, which may be formed by neutron absorption in various chemical elements inserted into a chain reacting unit, is for fundamental and applied investigation in basic science, agriculture and industry, and for fundamental investigations and therapeutic uses in biology and medicine.

Metallic Plutonium. — Plutonium metal has very unusual properties. It exists in six allotropic forms below its melting point

Table 11.—Phase Transitions in Plutonium Metal

Phase Change	Temperature of Transition on Heating (° C.)	
	Dilatometer	Thermal Analysis
a—6	122±2	122
β—γ	206f 3	203
γ—δ	319±5	317
δ—δ'	451±4	453
δ'—ϵ	476f 5	477
ϵ—liquid		639 5±2

(639° C.) at atmospheric pressure, a behaviour unique to this metal The temperatures at which the phase changes occur have been determined by a dilatometric method and by thermal analysis.

The density of a-plutonium (monoclinic) is quite high, 19.737; however. the densities of the other phases are lower, *i.e.*, 17.65 for β-plutonium (body-centred monoclinic), 17.19 for y-plutonium (face-centred orthorhombic), 15.92 for 6-plutonium (face-centred cubic), 15.99 for 6'-plutonium (face-centred tetragonal) and 16.48 for ϵ-plutonium (body-centred cubic).

Marked changes in electrical resistivity and thermal expansion accompany the phase changes. The electrical resistivity of a-plutonium is higher than that of any other metallic element at room temperature, being 145 micro-ohm centimetres. Plutonium metal is highly electropositive.

The metal also forms intermetallic compounds with aluminum, beryllium, cobalt, iron, manganese, nickel and silver. These compounds include $PuAl_2$, $PuAl_3$, $PuAl_4$, $PuBe_{13}$, $PuCo_2$, $PuFe_2$, $PuMn_2$, $PuNi_2$, $PuNi_5$ and Pu_2Ni_{17}.

Table 111.—Isotopes of Plutonium

Isotope*	Half life	Type† and energy of radiation (Mev)
Pu^{232}	36 min.	EC (<98%) α(>2%) 6.58
Pu^{233}	20 min.	EC α (0.1%) 6.30
Pu^{234}	9.0 hr.	EC (95%) α (5%) 6.19
Pu^{235}	26 min.	EC α (3×10^{-3}%) 5.85
Pu^{236}	2.85 yr.	α 5.75
Pu^{237}	45.6 days	EC; α (3×10^{-3}%) 5.65, 5.36
Pu^{237m}	0.18 sec.	IT
Pu^{238}	86.4 yr.	α 5.49 (72%) 5.45 (28%)
Pu^{239}	24.4×10^3 yr.	α 5.150 (69%) 5.137 (20%) 5.099 (11%)
Pu^{240}	6,600 yr.	α 5.16 (76%) 5.12 (24%)
Pu^{241}	13 yr.	β^- ~0.02 α (4×10^{-3}%) 4.893, 4.848
Pu^{242}	3.73×10^5	α 4.898
Pu^{243}	4.98 hr.	β^-0.579 (62%) 0.490 (38%)
Pu^{244}	7.6×10^7 yr.	α
Pu^{245}	10.1 hr.	β^-
Pu^{246}	10.85 days	β^-0.33, 0.15

*The symbol m placed after the mass number refers to an isomeric form of isotope.
†EC = electron capture; α = alpha particle; β^- = negative beta particle; IT = isomeric transition.

Chemical Properties in Aqueous Solution. — The chemistry of plutonium is markedly similar to that of uranium and neptunium, the elements immediately preceding it in the periodic table. The differences in the chemical properties of these elements are due primarily to a progressive increase in the energy required to form their positive ions.

Plutonium exhibits four oxidation states in aqueous solution: 3+, 4+, 5+ and 6+. The ionic species corresponding to these oxidation states vary with the acidity of the solution. In moderately strong (one molar) acid the species are Pu^{3+}, Pu^{4+}, PuO_2^+ and PuO_2^{2+}. The potential scheme of the ions in one-molar perchloric acid is the following:

$$Pu^0 \xrightarrow{+2.03\ v.} Pu^{3+} \xrightarrow{-0.982\ v.} Pu^{4+} \xrightarrow{-1.172\ v.} PuO_2^+ \xrightarrow{-0.9133\ v.} PuO_2^{2+}$$

$$Pu^{4+} \xrightarrow{-1.043\ v.} PuO_2^{2+} \qquad Pu^{3+} \xrightarrow{-1.0224\ v.} PuO_2^{2+}$$

The potentials are in volts relative to the hydrogen-hydrogen ion couple as zero.

The potentials of the various couples are so nearly the same that the intermediate oxidation states are unstable with respect to self-oxidation and reduction:

$$3Pu^{4+} + 2H_2O = 2Pu^{3+} + PuO_2^{2+} + 4H^+$$

and

$$2PuO_2^+ + 4H^+ = Pu^{4+} + PuO_2^{2+} + 2H_2O$$

These net changes do not indicate the mechanisms of the reactions, which are more complex. The disproportionation of PuO_2^+ is accompanied by a simultaneous oxidation of PuO_2^+ by Pu^{4+} (with the products PuO_2^{2+} and Pu^{3+} formed).

The oxidation-reduction relationships of the plutonium ions in acid solution are among the most intricate to be found in the field of inorganic chemistry.

The values given for the potential scheme in one-molar acid may be altered extensively by a change in hydrogen-ion concentration or as a result of the addition of substances capable of forming complex ions with the plutonium species. Among such substances are sulfate, phosphate, fluoride and oxalate ions, and various organic compounds, especially those known as chelating agents. The tetrapositive and hexapositive ions are complexed appreciably even by nitrate and chloride ions. The stability of the complex formed with a specified anion increases in this order: PuO_2^+, Pu^{3+}, PuO_2^{2+}, Pu^{4+}.

The hydrolysis of the ions follows a similar order: Pu^{4+} begins to hydrolyze even in tenth-molar acid and in hundredth-molar acid forms partly the hydroxide $Pu(OH)_4$ and partly a colloidal polymer of variable but approximate composition $Pu(OH)_{3.85}X_{0\ 15}$, where X is an anion present in the solution. Further reduction of the acidity results in the hydrolysis of PuO_2^{2+} near pH 5, of Pu^{3+} at about pH 7, and of PuO_2^+ at about pH 9.

The potentials of the couples involving either of the two lower states with either of the two upper states have an approximately fourth-power hydrogen-ion concentration dependence in moderately acid solution. This dependence, together with the hydrolytic effects just mentioned. causes rapid alteration of the potential values with change in acidity.

The plutonium ions in aqueous solution possess characteristic colours: blue-lavender for Pu^{3+}, yellow-brown for Pu^{4+} and pink-orange for PuO_2^{2+}. Pure solutions of PuO_2^+ have not been prepared, and since the ion shows but little absorption of visible light, its appearance in solution is not definitely known. The colours of the plutonium ions are altered by hydrolysis or complex ion formation. The absorption spectra of plutonium solutions are found to consist of a number of relatively narrow bands. Each oxidation state exhibits a characteristic spectrum that may be used for the quantitative as well as the qualitative analysis for that oxidation state in solution. Absorption bands as sharp as those found in plutonium solutions are observed only in solutions of other actinide elements or of the rare earths. It is inferred that in plutonium. as in the rare earths, the bands originate from transitions occurring in protected inner f electron orbitals.

The aqueous ions of plutonium are strongly paramagnetic, and measurements of the magnetism are in agreement with the assignment of five, four, three and two f electrons, respectively, for the oxidation states from 3+ through 6+.

Pure solutions of the upper and lower oxidation states may be obtained without difficulty. the former by oxidation with oxidizing agents such as bromate, dichromate or ozone, and the latter by treatment with reducing agents such as sulfur dioxide, hydroxylamine or hydrogen in the presence of platinum black. Because of the disproportionation reactions mentioned previously. the intermediate oxidation states are not stable. However, fairly pure solutions of Pu^{4+} may be obtained by dissolving the hydroxide in warm. concentrated perchloric acid, allowing several days at room temperature for reproportionation. and diluting the resulting solution. The disproportionation reaction is rather slow and the concentrations of Pu^{3+} and PuO_2^{2+} remain small for some hours.

The pentapositive state is quite unstable in strongly acid solution, but becomes increasingly stable as the hydrogen-ion concentration is decreased, down to about ten-thousandth molar. Dilute solutions containing a major proportion of plutonium as PuO_2^+ are stable at this acidity.

The precipitation properties of Pu^{3+} are similar to those of the tripositive rare-earth ions, of Pu^{4+} to Ce^{4+}. and of PuO_2^{2+} to the corresponding ions of uranium and neptunium.

Tri- and tetrapositive plutonium ions form salts of low solubility with fluoride, oxalate. ferricyanide and hydroxide ions. The tetrapositive ion is precipitated also by iodate and arsenate, even in strongly acid solution.

Pentapositive plutonium may be precipitated as a potassium salt from strong carbonate solutions, but no other solid compounds of this oxidation state are known.

The plutonyl ion, PuO_2^{2+}, separates as the beautifully crystalline pink salt $NaPuO_2(CH_3COO)_3$, sodium plutonyl acetate, from solutions containing a high concentration of sodium ions and acetate ions. This salt is analogous to sodium uranyl acetate and sodium neptunyl acetate. Under special conditions fluorescence is observed in crystalline tripositive compounds of plutonium.

Nonaqueous Chemistry. — Many of the most important compounds of plutonium are formed by reactions between solid phases or solid and gas phases, rather than in aqueous media. The most interesting and important of these compounds are the oxides, the halides and oxyhalides, and the binary compounds with carbon, nitrogen, silicon or sulfur.

Oxides. — The plutonium oxygen system does not present the degree of complexity exhibited by the uranium oxygen system (see URANIUM) largely because of the stability of the dioxide. Analogous behaviour is shown in the variable composition of the so-called sesquioxide ($PuO_{1.5-1.75}$), a typical mixed oxidation state oxide, similar to those formed by uranium, praseodymium, terbium: titanium and many other metals. Its composition shows continuous variation with changes in temperature and pressure of oxygen above the oxide. The limits of composition given above are only approximate. Near the lower limit of the oxygen range the structure is hexagonal. A higher proportion of oxygen causes the oxide to assume the cubic C type modification of the rare-earth sesquioxides. Plutonium sesquioxide may be formed by the thermal decomposition of the dioxide at about 1,500" C. in high vacuum.

Plutonium dioxide is the most important oxide of the element. Almost all compounds of plutonium are converted to the dioxide upon ignition in air at about 1,000° C. The ignited oxide is chemically inert at ordinary temperatures and has a well-defined composition; for these reasons it is a satisfactory compound for weighing in the gravimetric determination of plutonium.

The dioxide is frequently used as the starting material in the synthesis of other compounds of plutonium. In these cases prolonged high-temperature ignition of the oxide is avoided, since this leads to progressive chemical inertness.

TABLE IV.—*Important Halides and Oxyhalides of Plutonium*

Compound	Colour	Crystal Structure	Density (g./cc.)	M.P. (° C.)	B.P. (° C.)
PuFa	violet	hexagonal, tysonite type	9.32	1,425	2,190*
PuF_4	light brown	monoclinic	7.0	1,037	—
PuFa	deep brown gas, red or reddish-brown solid	orthorhombic	—	50.75	—
$PuCl_3$	emerald green	hexagonal, UCl_3 type	5.70	760	1,770*
$PuBr_3$	green	orthorhombic	6.69	681	1,510*
PuI_3	bright green	orthorhombic, $PuBr_3$ type	6.9	777	1,380*
PuOF	metallic	tetragonal	9.76	above 1,635	
PuOCl	blue green	tetragonal, PbFCl type	8.81	—	—
PuOBr	deep green	tetragoual, PbFCl type	9.07	—	—
PuOI	green	tetragonal, PbFCl type	8.46	—	—

*Estimated value.

Plutonium dioxide was the first compound of the element to be isolated and weighed in pure form and it was in fact the first compound of any synthetic element to be separated in pure form in weighable amounts. It was also the first compound of a synthetic element to be identified by X-ray diffraction methods.

Halides and *Oxyhalides*.—All of the halides except the tri-iodide, the hexafluoride and the oxyfluoride may be prepared by the hydrohalogenation of the dioxide or of the oxalate of plutonium III at a temperature of about 700° C. With hydrogen fluoride the reaction product is PuF_4, unless hydrogen is added to the gas stream, in which case the trifluoride is produced. With hydrogen iodide the reaction product is PuOI, and the other oxyhalides may be formed by the addition of appropriate quantities of water vapour to the hydrogen halide gas. Plutonium tri-iodide is produced by the reaction of the metal with hydrogen iodide at about 400" C.

Plutonium hexafluoride, the volatile plutonium analogue of uranium hexafluoride, can be prepared by the reaction of pure gaseous fluorine with plutonium tetrafluoride at 700" C. It is unstable with respect to dissociation into fluorine and plutonium tetrafluoride and is a powerful fluorinating agent. The rate of decomposition when stored as a vapour is, however, only about 0.1% per day. When it is stored principally as a solid. the radiation decomposition induced by the intense alpha activity destroys about 1.5% of the hexafluoride per day.

Plutonium oxyfluoride has been prepared by heating PuF_3 to 1,635° C. in an atmosphere of argon and oxygen.

The trihalides are appreciably. volatile at moderately elevated temperatures and all except the trifluoride may be purified by sublimation in quartz tubes in high vacuum at around 800° to 1,000° C.

Except for the trifluoride, the halides are so hygroscopic that they must be handled in an anhydrous atmosphere. The trifluoride shows so little tendency to hydration that the anhydrous salt is obtained directly upon precipitation from aqueous solution.

The crystal chemistry of the halides and oxyhalides of plutonium is closely similar to that of the analogous compounds of the rare earths—a consequence of the fact that these compounds are predominantly ionic and that the cations have nearly the same ionic radii. Sharp absorption bands and, under certain conditions, fluorescence similar to that in the analogous rare-earth compounds also are observed.

Carbides, Nitrides, Silicides and Sulfides.--Plutonium forms several binary compounds which are of interest because of their refractory character and stability at high temperatures. These compounds include the carbide, nitride, silicide and sulfide of the element. The monocarbide is formed by the reaction of the dioxide in intimate mixture with carbon at about 1.600" C., and the mononitride may be obtained by heating the trichloride in a stream of anhydrous ammonia at 900° C.; it is prepared more easily, however. by the reaction of finely divided metal with ammonia at 650° C. Although the lower temperatures are favourable to the production of higher nitrides, none is obtained, in contrast with the uranium-nitrogen system in which compositions up to UN, $_{75}$ are easily realized.

The disilicide is formed when a slight stoichiometric excess of calcium disilicide is heated with plutonium dioxide in vacuum at about 1,550° C. The disilicide is only moderately stable in air and burns slowly to the dioxide when heated to about 700° C.

Plutonium "sesquisulfide" may be prepared by prolonged treatment of the dioxide in a graphite crucible with anhydrous hydrogen sulfide at 1,340°–1,400° C., or by reaction of the trichloride with hydrogen sulfide at 900° C.

Only the most important compounds of plutonium have been mentioned in this article. The number of known compounds is very large. See also references under "Plutonium" in the Index volume.

BIBLIOGRAPHY.—G. T. Seaborg and J. J. Katz (eds.), *Actinide Elements,* National Nuclear Energy Series, Div. IV, vol. 14A (1954); G. T. Seaborg, J. J. Katz and W. M. Manning, *The Transuranium Elements,* National Nuclear Energy Series, Div. IV, vol. 14B, 2 pts. (1949); J. J. Katz and G. T. Seaborg, *The Chemistry of the Actinide Elements* (1957); G. T. Seaborg, *The Transuranium Elements* (1958).

(G. T. Sg.)

PLUTUS, properly, the abundant increase of the earth; child of Demeter (*q.v.*) and Iasion; in art, usually shown as a child. alone or in company with Tyche, Eirene, Athena or some other goddess. In popular thought, allegories and comedy, he was represented as Wealth. He was said to be blind.

PLYMOUTH, a city, county and parliamentary borough, naval base and seaport of Devon. Eng.. 42 mi. S.W. of Exeter by road. Pop. (1961) 204,279. Area 20.5 sq.mi.

It lies at the head of Plymouth Sound. stretching westward from the Plym river toward the mouth of the Tamar, from which it is separated by the totvnship of East Stonehouse and the borough of Devonport. both of which were included in Plymouth in 1914. The water frontage of the "Three Tonns" consists of Plymouth Sound, with its inlets, two of which, the Cattewater (east) and Harnoaze (west), are flanked by high ground on which are forts. On the northern side of the entrance to Cattewater is the Citadel, founded in the reign of Henry VIII and rebuilt by Charles II to the plan of an irregular bastioned pentagon. The adjacent Hoe extends along the northern edge of the Sound in which lies Drake's (formerly St. Nicholas) Island. Devonport dockyard fronts the Hamoaze. Stonehouse lies between. The city suffered air raids during World War II, and more than 80,000 houses and buildings were damaged or destroyed. Among churches, St. Andrew's, a Perpendicular building of 1480–1520 restored in 1874, was destroyed, only the walls and clock tower remaining. The beginning of the reconstruction of the city on a new plan was marked by a foundation stone laid by King George VI near the ruined guildhall.

Plymouth is the seat of a Roman Catholic bishopric founded in 1851, the cathedral being completed in 1858. The building is in the Early English style, and adjoining are the bishop's house and the convent of Notre Dame. Plymouth, the Sutton of Domesday, was divided into the town of Sutton Prior, the hamlet of Sutton Valletort and the tithing of Sutton Ralph. The market, established about 1253, became town property in 1311. In 1292 the town first returned members to parliament. In the 14th century it was often used for the transshipment of armies to and from France and it suffered from French attacks. In 1412 the inhabitants petitioned for a charter, which was granted on Nov. 12, 1439, the town being the first in England to be incorporated by act of parliament.

In the discovery of the new world Plymouth played an important part. Sir John Hawkins was a native of Plymouth, and it was from there that in 1577 Sir Francis Drake set out on his voyage round the world and in 1583 Sir Humphrey Gilbert sailed on his second colonizing expedition to America. In 1581 Drake became mayor of Plymouth and represented the borough in parliament during 1592–93. Plymouth supplied seven ships against the Armada and it was in the Sound that the English fleet awaited the Spaniards. A stone on a quay at the Barbican records the fact that this was the last port touched by the Pilgrim Fathers on their voyage to America. During the Civil War the town withstood all efforts by the Royalists to take it, and it early declared for William of Orange. Plymouth was created a city under royal letters patent in 1929 and the title of lord mayor was granted in 1935. Four years later its area was extended by almost 4.000 ac.

The port of Plymouth in 1311 embraced Plympton, Modbury and Newton Ferrers, and received a customs grant from Richard II. In 1435, 65 cargoes were imported, and in the reign of Elizabeth I it rose to be the foremost port in England. The 18th century saw a great development of trade with Virginia and the West Indies, and this resulted in the establishment of a sugar-refining industry that was maintained into the 20th century.

In 1749.the "town's water" was carried to the Barbican to supply shipping. The port of Plymouth as at present constituted embraces the waters of the Plymouth Sound and the Hamoaze. The chief water area within the limits of the port is the Sound with its inlets, the Cattewater, Sutton pool, Millbay, Stonehouse pool and the Hamoaze. The Sound itself covers an area of 4,500 ac. and is sheltered from the southwest gales by a breakwater (built in 1841) a mile long with a lighthouse at its western end. Cattewater, Sutton pool and Millbay constitute the three mercantile harbours of Cattewater harbour, Sutton harbour and the Great Western docks, while Hamoaze was set aside for the royal navy. The royal naval dockyard at Devonport covers 240 ac. Cattewater harbour has an area of 260 ac. and 8,000 ft. of quayage space. Sutton harbour entered from Cattewater has a quayage space of 4,500 ft. Great Western docks at Millbay has an outer basin of 35 ac., an inner one of 13. The port has productive fisheries. It has also a considerable export and import trade. As a naval station it is second only to Portsmouth. The industries of Plymouth include soapmaking, the manufacture of clothing, chemicals and artificial manure, paper staining and electrical engineering. The marine biological laboratory is situated on Citadel hill.

Plymouth returned three members to parliament, from the Drake, Devonport and Sutton divisions, from 1918 to 1950, after which the number was reduced to two, for Devonport and Sutton. Lady Astor, the first woman elected to the house of commons, represented the Sutton division from 1919 to 1945.

PLYMOUTH, the seat of Plymouth county, Mass., U.S.. and site of the first permanent settlement by Europeans in New England, is 37 mi. S.E. of Boston on Plymouth bay. Thousands of visitors are drawn annually by the historic interest of the town and its attractions as a summer resort. The modern town has a large cordage works, supplied by its own ships. Other important industries are cranberry growing and processing. commercial fishing, and varied manufactures such as sheeting for photoengraving and curtains. Seafaring was the heart of the older business life of the community and active wharves and boat yards remain.

Plymouth was founded by Pilgrims (*see* PILGRIM FATHERS)—Separatists from the Church of England who, in their search for religious toleration, had emigrated first to the Netherlands and then to North America. Sailing in the "Mayflower" (*q.v.*), the settlers reached the coast of New England in Dec. 1620, and an exploring party arrived in the Plymouth area on Dec. 21, now celebrated as Forefathers' day. The "Mayflower" anchored in the harbour five days later. (For a more detailed account of the colony's beginnings, and for its subsequent history, *see* MASSACHUSETTS: *History.)* The storied Plymouth Rock, first identified in 1741, became a symbol of freedom in 1774 when it was split by dragging it to Liberty Pole square in pre-revolutionary agitation. It rests today on its original water front site under a protecting portico of granite. Rising behind the rock is Cole's hill. where during their first terrible winter the Pilgrims buried half their number, levelling the ground and sowing it to grain in the spring "lest the Indians know how many were the graves" The first fort and watchtower were on Burial hill, which contains the graves of William Bradford (*q.v.*) and others of the original Pilgrims, although the oldest stone is dated 1681. "Plimoth Plantation," a nonprofit educational foundation, in 1957 began reconstructing an accurate replica of First Street in 1627 and other buildings of the early village. "Mayflower II," a good-will ship sent as a gift from England in 1957, is on display. Several mid-17th century houses still stand in the town. Pilgrim Hall. built in 1824, contains relics of the Pilgrims and early colonial times. Many surviving original records of the colony are in the Registry building. The National Monument to the Forefathers was dedicated in 1889. For comparative population figures *see* table in MASSACHUSETTS: *Population.* (CA M. C.)

PLYMOUTH BRETHREN, a community of Christians who received the name in 1830 when Rev. J. N. Darby (1800–1882) induced many of the inhabitants of Plymouth. Eng., to associate themselves with him for the promulgation of his opinions.

Although small Christian communities existed in Ireland and elsewhere calling themselves Brethren, and holding similar views, the accession to their ranks of Darby so increased their numbers and influence that he is usually called the founder of Plymouthism. Darby had been a curate in Wicklow 1825–27, when he felt himself constrained to leave the Anglican communion; going to Dublin, he became associated with several devout people who called themselves Brethren. Among these were A. N. Groves and J. G. Bellett, who rank among the founders of the movement. In 1830 Darby at Plymouth won over many people to his way of thinking, among them the well-known biblical scholar Samuel Prideaux Tregelles. During the next eight years progress mas rapid, and communities were founded in many towns of England

In 1838 Darby went to reside in French Switzerland and made many disciples. French Switzerland remained the stronghold of Plymouthism on the continent, and for his followers there Darby wrote two tracts, *Le Ministère considéré dans sa nature* and De *la Présence et de l'action du S. Esprit dans l'église.* The revolution in the canton Vaud brought persecution to the brethren in the canton and in other parts of French Switzerland.

He returned to England. and his reappearance was followed by divisions among the Brethren at home. These divisions began at Plymouth. Benjamin Wills Newton, head of the community there, who had been a fellow of Exeter college, Oxford, was accused of departing from the testimony of the Brethren by reintroducing the spirit of clericalism. Unable to detach the congregation from the teacher, Darby began a rival assembly. The majority of the Brethren out of Plymouth supported Darby, but a minority remained with Newton. The separation became wider in 184; on the discovery of supposed heretical teaching by Newton. In 1848 another division took place. The Bethesda congregation at Bristol, where George Müller was the most influential member, received into communion several of Newton's followers and justified their action. Out of this came the separation into Neutral Brethren, led by Miiller, and Exclusive Brethren. or Darbyites, who refused to hold communion with the followers of Newton or Miiller.

The Exclusives, who were the more numerous, suffered further divisions. An Irish clergyman named Samuel O'Malley Cluff had adopted views similar to those of Pearsall Smith, who preached a doctrine of sanctification called "Death to Nature" as an antidote to the supposed prevalent Laodiceanism, and when these were repudiated seceded with his followers. The most important division among the Exclusives came to a crisis in 1881, when William Kelly and Darby became the recognized leaders of two sections who separated on a point of discipline. This was followed (1885) by the disruption of the strict Darbyite section, two communions being formed out of it upon points of doctrine.

The theological views of the Brethren differ considerably from those held by evangelical Protestants. They make the baptism of infants an open question and celebrate the Lord's Supper weekly. Their distinctive doctrines are ecclesiastical. They hold that all official ministry, whether on Episcopalian. Presbyterian or Congregationalist theories, is a denial of the spiritual priesthood of all believers, and sets aside the Holy Spirit's guidance.

Sue W. B. Neatby, *A History* of *the Plymouth Brethren,* 2nd ed. *(1902).*

PLYNLIMON (**PEN** PLYNLIMMON, PUMPLUMON, PLINLIMMON: *pen,* "head"; *pump,* "five"; *lumon,* "chimney." "flag" or "beacon"), a ridge in Cardiganshire, central Wales. about 14 mi. inland from Aberystwyth and 10 mi. W. of Llanidloes. It is the culminating area of a wide moorland plateau stretching about 5 mi. from northeast to southwest, including six summits over 2.000 ft., the highest, Plynlimon, reaching 2,468 ft. The region was heavily glaciated and left with a thin coating of stiff boulder clay over the impervious Ordovician grits of which it is composed. Once forest (see Leland's *Itineraries,* 1500), it is largely covered with rough grass and bracken providing only poor pasture for sheep and summer grazing for young beef cattle. and much of the surface is boggy. Heavy rainfall and deep winter snows feed the many streams that radiate from the ridge—the Severn. Wye and Clywedog flowing southeastward to the Bristol channel and the Rheidol and Llyfnant westward to Cardigan bay. Rlining (for lead and copper) and quarrying are no longer carried on. The region is famous as a nursery of native Welsh tradition. There is a large proportion of short. dark, long-headed people, possibly a relic of ancient races. and ancient customs, songs and tales are preserved in the remote homesteads. (T. HER.)

PLYWOOD, a composite wood panel made of three or more layers glued together with the grain of adjoining plies at right angles to each other. For thin panels veneer is used exclusively, but for thicker panels sawed lumber often is used as the centre ply, or core, in which case it is known as lumber-core plywood.

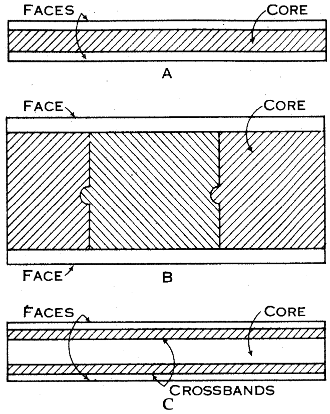
The veneer may be rotary cut (*i.e.*, peeled from the log), sliced or, less commonly. sawed in thin sheets from a flitch or bolt. Rotary-cut veneer always presents a flat-grain or tangential surface, whereas sliced and sawed vcnecrs may be cut in a radial or any other plane through the log. Veneer used for plywood usually varies in thickness from $\frac{1}{28}$ to $\frac{1}{8}$ in.! but both thinner and thicker veneers often are used. Thin veneers have an advantage, especially for the outer or face plies, in that they set up less severe transverse stresses with changes in moisture content. thereby reducing warping arid surface checking of panels. The use of thin veneer also makes valuable wood go farther. In lumber-core panels the plies next to the faces, or the crossbands. usually are thicker than the face plies and largely control the stability of the panel. Plywood is almost always composed of an odd number of plies so that the grain of corresponding plies from the outside in runs in the same direction, thereby balancing and stabilizing the construction.

Plywood has a number of advantages over solid wood: it can be manufactured into large sheets with limited defects; it is stronger across the grain of the face plies than are boards of the same thickness; because the plies cross each other. shrinking and swelling are almost eliminated; splitting in handling and nailing are greatly reduced; and wood of the lower grades can be used for the interior plies. Since veneer can be dried in a matter of minutes. dry plywood can be produced from green logs in a day.

Two types of plywood are made: interior plywood, for use only in dry locations, and exterior plywood, for which water-resistant glues are used.

Since successively cut layers of thin veneers are similar in appearance, identical areas from adjacent sheets can be matched so as to make highly ornamental symmetrical patterns.

In sandwich construction thin facings are bonded on a thick core. The facings are made of strong material, such as thin, dense plywood, and the core of a lightweight material, such as balsa wood, cellular cellulose acetate or paper honeycomb. The core serves primarily to separate and stabilize the thin faces, which are the principal load-carrying portions. The complete assembly is exceedingly strong and stiff for its weight.



FROM "WOOD HANDBOOK," FOREST PRODUCTS LABORATORY, U.S. DEPARTMENT OF AGRICULTURE

PLYWOOD CONSTRUCTION

(A) Three-ply, all veneer; (B) three-ply, lumber core; (C) five-ply, all veneer. Edge views

Utilization.—Plywood is used whenever a material is required to cover large areas with a light but strong and rigid sheeting; *e.g.*, in cabinetmaking (for chests, dressers, wardrobes, tables. etc.), housebuilding (for walls, ceilings, floors, doors, cupboards, cement forms, etc.), coachbuilding (for railway carriage roofs and walls, trucks, vans, trailers, etc.), shipbuilding (for small boat hulls. decks! cabins, etc.), boxmaking (for shipping and storage chests and cases, etc.) and aircraft construction (for fuselages, wings. floors, hydroplane hulls. etc.).

BIBLIOGRAPHY.—A. D. Wood and T. G. Linn, *Plywoods, Their Development, Manufacture and Application* (1942); L. H. Meyer, *Plywood: What It Is—What It Does* (1947); T. D. Perry, *Modern Plywood,* 2nd ed. (1948); Forest Products Laboratory, U.S. Department of Agriculture, *Wood Handbook* (1955). (AR. K.)

PNEUMATIC CONVEYING is the utilization of the conveying power of air in motion. It will be realized that conveyance of material through a pipeline, either by suction or blast, is ideal; since there are no mechanical parts in the path of the material there cannot be any contamination by lubrication. Another advantage is the greater flexibility of pneumatic plant; every part of the hold of a vessel, for instance, can be reached by flexible tubes for the purpose of unloading a grain cargo, whereas a more complex mechanical plant is rigidly fettered to straight lines. The *modus operandi* of a pneumatic plant is extremely simple and is as follows: Into a grain cargo in a vessel, for instance. a hosepipe is lowered, the nozzle at the end of which admits a mixture of air and grain. The other end of the pipeline enters tangentially into the upper part of a cylindrical receiver from which the air is exhausted, while the grain is withdrawn from the cone-shaped lower end by an air trap, without, however, admitting air into the receiver. When comparing pneumatic with mechanical handling devices the former have but one drawback; viz., the greater consumption of driving power for handling a given quantity. This. however, is more than compensated for by the greater flexibility and the hygienic value of the system. The first grain-handling installation on the Duckham system was known as "Mark Lane No. 1" and was built, under the personal supervision of the inventor, by the East Ferry Road Engineering Co. during the closing years of the 19th century. This was one of the most epoch-making revelations of all systems of handling. The plant is mounted on a pontoon and sucks the grain through a nozzle and pipeline from the ship's hold to an elevated receiver. whence it runs by gravity to a given point, via an air trap; an exhauster furnishes a partial vacuum by pipes connected with the receiver.

As has been shown, the material in a pneumatic plant floats. so to speak, in a current of air, from which it is separated by its specific gravity when the air expands in the receiver. The heavier the material to be handled, the greater must be the speed of travel of the air in the conveying pipes in order to ensure the floating of the material in and with the air. If the air speed is too slow the tendency will be for the material to separate from the air and thus block the pipes, especially such portions as are horizontally disposed, or nearly so. Therefore, installations for such heavy materials as coal and ash require more powerful pumps. Similar installations in which draught is induced by steam jets are successfully used for handling ash from boilers.

Because of the advantages accruing from the use of pneumatic handling plants, new avenues for their employment are being constantly opened. Such varied materials as grain, small coal, chemicals, ashes, potatoes, and even red-hot rivets and artillery shells are now successfully handled by pneumatic means. An offshoot of this system is the pneumatic tube, which is largely employed in postal and telegraph offices, as well as in great variety in business offices and stores. (G. F. Z.)

PNEUMATIC DISPATCH, a system of transporting written dispatches through long tubes of small diameter by means of compressed or rarefied air. It was introduced in 1853 by J. Latimer Clark between the Central and Stock Exchange stations of the Electric and International Telegraph company in London, the stations being connected by a tube $1\frac{1}{2}$in. in diameter and 220yd. long, the messages, enclosed in a tight fitting carrier, being drawn through it by the production of a partial vacuum at one end. The system was improved in 1858 by C. F. Varley, who used compressed air to return the carriers in the other direction. By this means it was possible to develop two-way working on single tubes between a central station, equipped with air-compressing plant, and outlying offices.

Pneumatic dispatch tubes are also used for internal communication in offices, hotels and stores. (J. McG.)

PNEUMATIC TOOLS can be divided into two main classes: (1) air-operated portable tools; and (2) air-operated rock drills and associated tools. The first class includes abrasive tools, drills, screw drivers, hammers, riveters and hoists; the second class, hand-held rock drills and paving breakers, mobile earth-boring machines, etc.

The pneumatic tool may be driven by a rotor or a reciprocating piston. In the first case, a rotor with vanes is surrounded by a housing; air enters the housing, pushes on the vanes and thus rotates a central shaft or spindle. A drill, grinder or some other part may be fastened to the spindle. In the second case, compressed air enters a cylinder, expands and pushes a piston back and forth. The reciprocating piston may be connected to or may strike some part such as a riveting hammer or a chisel. Pneumatic tools are usually supplied with compressed air at about 90 lb. per square inch above atmospheric pressure. A compressed-air system with a compressor, piping and an air motor is analogous to an electric system with an electric generator, electric wires and an electric motor.

With compressed air as the power source, it is possible to use tools which are relatively light in weight, compact, portable and easy to operate. Air motors introduce no spark hazard in explosive atmospheres, and they also are employed in wet conditions because they present no danger of electric shock. In underwater service, the compressed air prevents water from entering the motor.

Portable Tools.—Air-driven portable tools include such devices as grinders, buffers, sanders, drills and reamers, screw drivers and nut setters, all of which are powered by rotary-vane motors; trench diggers, riveters and various types of hammers, powered by pistons; and such specialty tools as concrete vibrators, cranking motors and railway roadbed tampers.

Air-driven grinders, drills, screw drivers, etc., are of conventional design except that an air motor is substituted for the more familiar electric motor; operating speeds usually can be varied by throttling the air to the motor.

In the pneumatic chipping or scaling hammer there is an air-operated piston that delivers successive blows to a chisel or forming tool at the end of the hammer. In the valve type of tool there is a separate mechanism to control the flow of air to the piston, thus allowing the operator to govern the speed and force of the blows; in the valveless type, the piston itself performs the valving action and the operator can exercise only an on-off control of the tool. The former type is used for chipping and riveting, for which control of the blows is important; the latter is used for such work as removing scale.

Riveting hammers are of two designs: in a compression riveter the compression or squeezing action on the rivet is obtained from an air piston and cylinder connected to a cam, wedge or toggle; a yoke riveter has an air-operated clamp or vise that holds the work in place; the yoke absorbs the hammering action and thus reduces operator fatigue.

Hoists operated by compressed air are used in operations which require accurate and definite control of lifting and lowering speeds. Air hoists are used outdoors and under conditions where corrosive fumes, explosive gases and inflammable fluids are present. Safety devices prevent sudden dropping of the load when the air pressure falls or the brakes fail.

There are various portable pneumatic tools which are usually classed as specialty tools, such as concrete vibrators, countersinking tools, spike drivers, paint mixers, air cranking motors, railway roadbed tampers, valve grinders, reciprocating filing machines, shank grinders and saws.

Rock Drills. — For mining and general rock excavation the usual air-operated tool is the hammer drill or percussion hammer, composed of a piston and a drill made of high-carbon steel. The shank of the drill is not attached directly to the piston but is held loosely in a chuck at the end of the cylinder and is struck by rapid blows from the freely moving piston.

For downward-sloping holes, some means must be provided to remove drill cuttings, dust and sludge; thus, a hollow bit is used, and water or air is passed through it to remove the cuttings and cool the drill bit. In addition, the bit must be rotated to produce a round, uniform hole, and this may be done either manually by the operator, with a wrench attached to the drill. or automatically by a ratchet-and-pawl mechanism that turns the bit slightly after each blow from the piston.

Hand-Held Rock Drills. — The hand-held rock drill, with a self-rotating hammer, is sometimes called a sinker or a jackhammer. Rock drills are frequently classified on the basis of weight—a drill of less than 25 lb. may be used for drilling shallow holes in brick or concrete; a 55-lb. drill may be used for road construction.

Drifter, Stoper and *Wagon* Drills. — The drifter drill is generally used for horizontal holes in mining operations and tunnel driving. The usual air-cylinder bore diameters are 3 in., 33 in. and 4 in. The drill is mounted on some type of rig or frame. The usual drifter is mechanically fed into the work. Stoper drills are used primarily on up-hole or overhead drilling. The usual stoper is a hammer drill with a self-rotating drill and an automatic feed by means of an air piston.

Large air-operated earth drills, mounted on motor trucks or trailers, are used for putting down water wells and blast holes for quarry operations. A high-capacity compressor provides air not only to power the drilling tool but also to raise and lower the tools in the hole and remove drill cuttings from the hole. Such machines are used to advantage in areas where surface water supplies are insufficient to provide the drilling fluid needed for standard rotary and cable-tool well drilling machines.

Paving Breakers. — Hand-operated pneumatic paving breakers generally use solid drill steels and are not equipped with automatic rotation. One type of tool is valve actuated; the other is valveless. Heavy machines, weighing about 80 lb., are used to break concrete pavement, foundations and boulders. Medium breakers, weighing 50 to 70 lb., are used to break light concrete floors,'macadam and frozen ground. The light tools, weighing less than 50 lb., are used for breaking floors, paving and masonry walls. Heavy- and medium-weight breakers can be adapted for use in driving spikes. (R. C. BR.; X.)

PNEUMATISM. The theory of pneumatism in medicine, based on the premise that life is associated with a subtle vapour called the pneuma, was expounded by the Alexandrian anatomist and physiologist Erasistratus (*q.v.*), who flourished about 300 B.C. The concept of pneumatism had been previously suggested by other commentators.

Unlike Herophilus, who accepted the old theory of humoral pathology, Erasistratus held that health and disease and, in fact, the nature of life were intimately connected with the pneuma, which had affinities with the air man breathes.

Erasistratus drew a distinction between two kinds of pneuma: one was a "vital spirit" formed in the heart from air; the second type was formed in the brain from the first kind. The former was transported by arteries to the parts of the body and the latter, styled the "animal spirit," by the nerves, being the prime cause of movement.

Although Erasistratus held that hindrance of the action of the pneuma, or an excess of blood, was the essential cause of certain diseases, he did not follow the contemporary practice of bloodletting, preferring to attempt to control the blood supply by diet and other less violent measures.

PNEUMATOLYSIS, in petrology, the discharge of vapours from igneous magmas and the effects produced by these vapours on rock masses. See VOLCANISM.

PNEUMONIA, an inflammation of the lung. Pneumonia was recognized as a disease by the ancients. but no progress was made in the knowledge of it until the time of Leopold Auenbrugger (1761) and René Laennec (1819). when order was brought into its classification. From then until the bacteriologic era opened, classification depended on the anatomic or clinical features, and adjectives such as lobar, lobular, broncho-, interstitial, pleural, double, central, croupous and catarrhal were used. Other pneumonias were called aspiration, contusion, hypostatic or terminal pneumonia, depending upon the cause. Although after 1880 various bacteria and viruses were known to cause pneumonia, the modern etiologic classification did not become popular until about 1930. Precise knowledge of the bacterial or other cause permits the use of specific therapeutic or preventive measures and other rational management in the control of the disease. More than 50 different infectious, physical or chemical causes of pneumonia were known by the second half of the 20th century, but of these, relatively few were of common occurrence. Pneumonias may be grouped as follows: (1) primary, *i.e.*, those caused by pathogenic cocci, bacilli, viruses and fungi that attack the lung primarily; (2) pneumonias that occur in more or less specific forms as part of systemic infections such as tularemia, psittacosis, tuberculosis, rheumatic fever, rickettsial and protozoal diseases, lupus erythematosus and others; (3) pneumonias caused by mixed infection induced by physical or mechanical injury of the lung such as shock. debility, passive congestion, aspiration of foreign bodies of fluid, obstruction to airway, atelectasis, trauma and others; and (4) pneumonias caused by the aspiration of oil, chemicals or dusts, by exposure to roentgen rays, by allergic reaction and other causes.

Pneumococcal Pneumonia. — The modern era of this disease began with the discovery of the pneumococcus in 1880 by G. M. Sternberg and its association with pneumonia by A. Fraenke! and A Weichselbaum in 1884. F. Neufeld first pointed out serologic differences among strains of pneumococci in 1910, and shortly afterward F. S. Lister and A. R. Dochez independently classified them into types. Much fundamental work on the bacteriology, etiology, pathogenesis. clinical aspects and treatment of pneumococcal pneumonia was done after 1911 at the Hospital of the Rockefeller Institute under the leadership of Rufus Cole and Oswald Avery. Extensive bacteriologic. clinical and epidemiologic contributions on the subject were also made. notably by Russell Cecil, O. H. Robertson and Maxwell Finland in the United States and by H Loeschke and Max Gundel in Germany. Specific immune serum for treatment reached its greatest effectiveness and popularity as the refined, concentrated form, only to be displaced by the sulfonamide compounds after 1935 and by penicillin in 1942.

Etiology. — There are about 75 types and subtypes of pneumococci of which only a few are of clinical importance. Types 1, 2. 3, 4. 5, 7, 8 and 14 account for about 80% of all pneumococcal lobar pneumonias. The rest are caused by pneumococci of other types that, in contrast with those mentioned, often are present in the throats of healthy persons.

Pneumococci rarely are primary invaders of the lung. In almost all instances there is evidence of some preceding condition that injures the lung and favours invasion, especially minor infections of the respiratory tract commonly called colds; chilling of the body, and debilitation. The pneumococci that become invasive are acquired by inhalation from outside sources or are already present in the pharynx; the first circumstance indicates that pneumonia may be a contagious disease contracted from other patients or carriers of pneumococci, and the second that it may arise as an autogenous infection. Under certain conditions when the general resistance is lowered by serious conditions, and in old age, the pneumonia is apt to be atypical or lobular (bronchopneumonia); in other words, it does not behave like the lobar form. The onset is gradual, pulmonic solidification may not occur and the course is irregular. The pneumococci causing this form are usually of the higher numbered types, indicating that they are part of the normal flora of the respiratory tract and have become invasive.

Pathology.—Pneumococci reach the lung by way of the air passages, settle in an area where they find circumstances suitable for growth and give rise to an area of inflammation conditioned by complex factors. among which partial immunity, allergy and nervous influences seem to play an important role. The inflammation spreads rapidly and soon involves part or most of a lobe, first as congestion and then with an outpouring of fibrin and polymorphonuclear leukocytes into the alveolar spaces. The exudate becomes rather solid and grayish over a period of several days, and finally. when recovery occurs, it softens and is resorbed. Pneumococci often enter the blood stream and may localize on the valves of the heart, the meninges or elsewhere. The pleura may be invaded, resulting in empyema.

Epidemiology.—Pneumococcal pneumonia is contagious at times, but susceptibility to infection is largely controlled by the resistance of the host. The prevalence of pneumonia usually parallels the incidence of minor respiratory tract infections. Both are most common in cold months but may occur at any season. Household and institutional epidemics have been recorded. Pneumonia varies in incidence from year to year and to some extent in its clinical manifestations, depending on the type of pneumococci predominant at the time. It is most prevalent in the temperate climates but may occur anywhere. All races are susceptible. Men are affected more often than women because of greater exposure. It is commonest in early adult life. Pneumococcal pneumonia declined in incidence after 1900. Yet in 1960 pneumonias were the sixth most important cause of death in the United States.

Clinical Features.—Lobar pneumonia is a strikingly clear-cut disease. It often develops in a person who has a cold and begins suddenly with a chill, pain in the chest. high fever, cough and thick rusty sputum. These are present in variable combinations and constitute the chief features. Other symptoms and signs are headache. vomiting, rapid respiration, cyanosis, dyspnea, tachycardia and herpes. The course in untreated patients may last a week or more, during which severe illness occurs. Characteristic signs in the chest in the early stage are those of congestion changing to those of consolidation of a lobe or lobes with dullness, bronchial breathing. bronchophony, egophony, pectoriloquy and occasionally friction sounds. Roentgenography is of great aid in observing the location and course of the pulmonary lesion. In patients who develop pleural effusion or empyema, signs of fluid appear. The leukocyte count and sedimentation rate of red cells usually are increased and the blood culture often becomes positive. In certain patients the onset is gradual and the course is not so characteristic, giving an atypical clinical response.

In those who recover, improvement often begins abruptly as a crisis with rapid fall of temperature and general improvement unless other involvement occurs. Death is caused by toxemia, overwhelming infection, circulatory collapse or extrapulmonary localization the chief of which are empyema. meningitis, endocarditis and arthritis. In patients treated with penicillin or sulfadiazine the course usually is terminated within 24 to 48 hours.

The mortality rate is 30% in untreated patients and about 5% in those treated with antibiotics. Five per cent is probably a minimum rate, since there are instances in which therapy is unsuccessful or for various reasons may be delayed or is not available. The disease is more often fatal in infants, debilitated or senile patients or in those with other chronic disease such as diabetes, hypertension or nephritis, or when treatment is postponed. Overwhelming infection that does not respond to any treatment may occur.

One attack of pneumonia does not necessarily predispose a person to another. There are certain persons who. for unknown reasons, have repeated attacks of pneumonia caused by the same type or by different types of pneumococci, or by other bacteria. There is some evidence of a hereditary tendency to the disease.

Diagnosis should be established by clinical. roentgenologic and bacteriologic methods. Material for tests must be obtained before treatment is begun.

Treatment.—Penicillin should be given promptly by injection or by mouth daily until the temperature becomes normal and for several days afterward. Tetracycline, erythromycin, chloramphenicol or sulfadiazine may be used if penicillin is unavailable or if the patient is sensitive to it. Appropriate symptomatic treatment must be given.

Prevention—The fundamental measures of prophylaxis are the prevention of minor respiratory tract infections and other conditions that predispose to pneumonia and the control of carriers of pneumococci. The maintenance of general health by adequate food, exercise and rest is important. Specific vaccines consisting of pneumococcal polysaccharides are of practical advantage only among well-controlled groups.

Hemolytic Streptococcal Pneumonia.—This form of pneumonia is less common than the pneumococcal forms and occurs often as a complication of influenza, as it did in the pandemic of 1918. It is caused by any of the 27 or more types of group A beta hemolytic streptococci. It may occur in sporadic or in epidemic form, the latter depending on the prevalence of a predisposing viral infection. The bronchi and trachea are involved more often and more severely than in pneumococcal pneumonia. There is lymphangitis and involvement of interstitial tissues. The exudate is thin and hemorrhagic, and streptococci are numerous. The pleura is usually inflamed.

The symptoms are not characteristic. The disease begins as an aggravation of the mild primary disease. There are fever, cough, pain in the chest, chills or chilly sensations and prostration in widely varying degrees of severity. The sputum is thin. mucopurulent and bloody. Bacteremia is uncommon. The leukocytes may be normal or increased in number. Massive pleural effusion with serosanguineous fluid or empyema are common. The patient may be mildly sick or extremely so with ashy pallor, cyanosis and evidence of circulatory collapse. The pulmonary signs are chiefly those of atypical pneumonia with patchy areas of congestion and areas of undeveloped consolidation.

The mortality rate in untreated patients varies from 10% to 60%; not enough patients have been treated with penicillin or sulfadiazine to judge their beneficial effects.

The diagnosis is made chiefly by the epidemiologic characteristics of the disease and by the predominance of hemolytic streptococci of group A in the sputum, blood or exudate. Retrospective diagnosis may be made by the demonstration of specific precipitins, antistreptolysin and antifibrinolysin in the blood. Roentgenography is useful in determining the nature and extent of the pulmonary lesions. Penicillin is indicated and must be given in large dosage. Sulfadiazine is said to be of some value. The symptomatic treatment is the same as for other pneumonias. Pleural effusion should be aspirated repeatedly and, if empyema is present, penicillin may be injected into the cavity.

Staphylococcal Pneumonia.—The staphylococcus, like the hemolytic streptococcus, invades the lung particularly during minor viral infections of the respiratory tract. Staphylococcal pneumonia occurs sporadically or in epidemic form during epidemics of viral diseases of the respiratory tract. Many cases occurred in the influenza pandemics of 1918 and 1957. In recent years. it has increased in incidence due to the overuse of antibiotics. Corticosteroids and radiation therapy given for other diseases lower resistance and favour the invasion of staphylococci. The causative staphylococci usually are those present normally in the patient but they may be acquired from outside sources. Their invasion gives rise to patchy areas of inflammation in the lungs. In the course of several days, multiple small abscesses form and tend to coalesce

The symptoms usually begin gradually. They vary greatly in intensity from mild to severe with high remittent fever, chills or chilliness, sweating, cough, cyanosis, prostration and purulent sputum. The leukocyte count is variable and bacteremia seldom occurs. When abscesses form and discharge through the bronchi, the sputum increases in amount and the signs change from those of patchy pneumonia to those of cavitation. The mortality rate is variable; in some cases studied, most patients recovered and in others 70% died.

Diagnosis is based on the epidemiologic aspects of the disease; the presence of great numbers of staphylococci in the sputum, exudates or the blood stream; and the signs and roentgenographic evidence of the development of multiple cavities.

Penicillin is the agent of choice, but it must be given in large amounts parenterally. Synthetic penicillins, novobiocin and vancomycin are specific for staphylococci.

Klebsiellar (Friedländer's Bacillus) Pneumonia.—This infection occurs chiefly in debilitated or senile persons. The onset often is like that of pneumococcal pneumonia. The disease is characterized by a severe course, irregular fever, occasional abscess formation but less evidence of firm consolidation of the lung than in pneumococcal pneumonia. The sputum is bloody, mucinous or mucopurulent and its bacteriological content consists predominantly of capsulated gram-negative coccobacilli. A chronic form with cavitation resembling tuberculosis may ensue. Because the infection occurs chiefly in weakened persons, the mortality rate is high (about 50% to 70%). The treatment is not so effective as for other forms of pneumonia. Antibiotics must be selected according to the sensitivity of the bacilli; they are used in large dosage singly or in combination.

The Viral **Pneumonias.**—While much attention had been given to the serious bacterial pneumonias, little was paid prior to about 1920 to those of viral origin, chiefly because they seldom caused death and the technique of identifying viruses was undeveloped. It had been known since 1861 that viral diseases such as measles are characterized by pulmonary involvement, but the nature of the pneumonia was obscured by the activity of secondarily invading bacteria. Because of this, the pneumonias that occur during severe colds also were regarded as complications caused by bacteria, although they rarely are. However, the experimental production of pneumonia in animals with the viruses of influenza and vaccinia, and the absence of bacteria in the pneumonic lungs of patients who died during the pandemic of influenza in 1918, left little doubt that viruses do cause pneumonia. Between 1920 and 1938 European and U.S. roentgenologists demonstrated unsuspected pneumonias in many patients with mild, acute respiratory tract infection.

In 1938 Hobart A. Reimann established viral pneumonias as entities and demonstrated their occurrence as the severest forms in 5% to 10% of epidemic viral minor respiratory tract infections. Specific nosography became possible later after the discovery of a number of causative viruses in addition to influenza viruses, namely, adenoviruses, Coxsackie, ECHO (enteric cytopathogenic human orphan). reo-, respiratory syncytial and myxoviruses. Each of these causes epidemics of mild disease with occasional pneumonias. Other agents that are not true viruses, such as the Bedsonias (psittacosis, ornithosis) and mycoplasma (Eaton agent), cause similar disease. Viral pneumonias, in general, outnumber those caused by bacteria. Their incidence varies from year to year depending upon the epidemic prevalence of the respective viral infections, of which they are the severe forms.

The symptoms are similar for each entity. As the mild infection worsens, headache, dry paroxysmal cough, slight sore throat, sweating, chilliness and irregular fever develop although there are few or no abnormal physical signs in the lungs. Roentgenography, however, may reveal extensive infiltration. Later, dullness to percussion. suppressed breath sounds and *râles* appear. The leukocytes may increase slightly in number. The pneumonia often is so mild as to be unsuspected but may be severe with dyspnea, cyanosis and prostration. It may last a week or more. Complications are rare The mortality rate is less than 1%. Death usually is caused by circulatory failure, especially in patients debilitated by other conditions. Pathologically, parts of or all of the respiratory mucous membrane is inflamed with but little exudate. The interstitial tissues of the lungs are inflamed and invaded by monocytic cells. The lesions disappear slowly.

Diagnosis is made by the epidemiologic aspects, the clinical behaviour, the low leukocyte count and the absence of pathogenic bacteria in the sputum. Etiologic proof depends upon the isolation and identification of the causative viruses and seriologic evidence of their activity. It is of importance to diagnose pneumonias caused by the Eaton agent (mycoplasma) and of psittacosis and ornithosis (Bedsonia) that respond to antibiotic therapy. The same is true for the pneumonias of tuberculosis, Q fever and others that resemble viral pneumonias.

Antibiotics now available have no therapeutic value for viral pneumonias. The treatment is symptomatic for the relief of headache, aching and cough.

Miscellaneous Primary Agents.—Rarer forms of pneumonia are caused by *Hemophilus influenzae, H. pertussis, Bacillus anthracis, Pasteurella pestis, P. tularensis, Gaffkya tetragena, Histoplasma capsulatum, Coccidioides immitis, Coxiella burnetii, Toxoplasma, Mycoplasma, Pneumocystis carinii, Bedsoniae* and others.

Pneumonias of Systemic Diseases.—Pneumonia may occur as an integral part of many systemic diseases. It may dominate the clinical picture, or it may be a minor factor or not occur at all in tuberculosis, tularemia, plague, undulant fever, glanders, syphilis, rheumatic fever, ascariasis, polyvasculitis, sarcoidosis and many others. The pneumonia usually is not characteristic clinically and often is obscured by symptoms of the systemic disease. Pathologically it may assume features characteristic of the respective disease. The treatment is that of the primary disease.

Pneumonias of Mixed Infections.—The pneumonias brought about by injury to the lungs or interference with their self-cleansing process usually are caused by a mixture of various kinds of bacteria that reside habitually in the air passages and are enabled to become invasive by the presence of injured tissue. The injury or interference of the cleaning action may be caused by obstruction of the airways by foreign bodies or tumours, failing circulation, submersion in or aspiration of fluids, trauma, atelectasis after surgical operation, shock and many other causes. Pneumococci, influenza bacilli, hemolytic streptococci and staphylococci are most frequently implicated. The iatrogenic reduction of bodily resistance by corticosteroids, radiation and other agents has increased the incidence of pneumonias caused by gram-negative bacilli and fungi. The treatment is directed primarily to the control or removal of the underlying cause. Antibiotic agents are given according to the sensitivity of the invading bacteria or fungi to the respective drugs, and appropriate supportive measures are applied.

Pneumonias Caused by **Noninfective** Agents.—The aspiration of oil over long periods or in large amounts often causes a chronic reaction commonly called lipoid pneumonia. Long exposure to roentgen rays may give rise to a pulmonary reaction called irradiation pneumonitis that leads to fibrosis. The inhalation of irritating chemicals (silo filler's disease), dusts (farmer's lung. byssinosis, bagassosis, berylliosis) and toxic gases used in warfare or industry. or fumes from certain molten metals may cause forms of pneumonia. Allergic pneumonitis or Loffler's syndrome represents the hyperergic inflammatory reaction of sensitized pulmonary tissue to repeated exposure to a specific antigen. The prevention and treatment of each of these conditions is the removal of the offending agent.

See RESPIRATORY SYSTEM, DISEASES OF; DANGEROUS OCCUPATIONS; and references under "Pneumonia" in the Index volume.

BIBLIOGRAPHY.—R. I. Cole, *Acute Pulmonary Infections*, DeLamar Lectures, 1927–28 (1929); R. Heffron, *Pneumonia* (1939); H. A. Reimann, *The Pneumonias* (1938), *Pneumonia (1954).* (H. A. RN.)

PNEUMONOCONIOSIS, also called pneumoconiosis, a term denoting a variety of industrial diseases of the lung, embracing lung response to any type of respirable hazard. Precise definition of the term is a matter of legal consequence, because occupational chest diseases are among the most litigious of medicolegal issues. In several countries many of these conditions are obligatorily compensable. To more than 3,000 naturally occurring minerals presenting respiratory hazard are added yearly an ever-increasing number of synthetic chemical agents. The biological action of less than 1% of these substances is known, yet about 10% of working persons handle such agents. While pneumonoconiosis is a generic term, silicosis has for many years been its chief specific manifestation. Because of the increasing range of dangerous respirable agents, however, emphasis is shifting from silicosis to other forms of pneumonoconioses. The majority of the significant reactions represent insidiously progressive chronic responses, frequently with a distinct latent period during which the workman is symptom-free. Fulminating cases also occur when exposure has been unduly severe or adjuvant factors play a part. A simplified etiological classification of the main varieties of pneumonoconioses is given in the table.

Pneumonoconioses

Siliceous	Nonsiliceous
Free silica (SiO_2)	Carbonaceous
Crystalline	Anthracosis* } ......coal miners
Silicosis proper	Emphysema* }
Mining*	Graphitosis ....graphite
Ceramics*	Smog lung ....carbon and chemicals
Glass industry*	
Abrasives*	Metallogenic
Sandblasting*	Siderosis ....iron
Foundry*	Baritosis ....barium
Etc.	Stannosis............tin
Aberrant silicosis	Cobaltosis...........cobalt
Tridimytosis*	Argyrosis .... silver
Cristobalitosis*	Aluminosis† ....aluminum
Amorphous	Berylliosis*..........beryllium
Natural	Cadmiosis*. ....cadmium
Diatomatosis {raw	Manganosis ....manganese
calcined*	Vanadiosis ....vanadium
Synthetic	Thioconiosis ....sulfur
Submicron, 20Å–4,000 Å	Plumboconiosis ......lead
	Welder's lung†.......iron + ozone or nitrogen dioxide
Silicates (SiO_4)	Brass foundry lung ..copper + zinc
Mineral	
Asbestosis*	Organic
Talcosis*	Byssinosis* ....cotton
Micatosis	Bagassosis*..........sugar cane
Kaolinosis	Ptilosis ....feather
Fuller's earth†	Tabacosis ....tobacco
Artificial	Papricosis ....pepper
Cementosis	Suberosis............cork
Glass wool†	Hemp lung..........hemp
	Flax lung ....flax
Mixed forms	Wood lung? ....wood
Disease in Bauxite extractors*	Rubber lung†........rubber
Granite polishers*	Plastics lung?........plastics
Slate workers*	Farmer's lung*.......fungi
Boiler scalers*	Silo filler's lung*. .....nitrogen dioxide
Kiln liners*	Wheat handler's lung†..............?
Basic slag workers	
Hematite miners*	Miscellaneous
Magnetite miners*	Oleogranuloma ......oil mists
Kolar gold miners	Fume injury*........nitric acid, etc.
Insulation workers*	Gas injury*..........hydrogen fluoride, etc.
Transite pipe workers*	Chemical pneumonitis* ......inorganic, organic

*Disabling and lethal. †Disputed entities.

History.—Man-made lung diseases have been known for the past 2,000 years and were discussed by, among others, Hippocrates and Pliny. "Potters' rot" of ceramic workers, "grinders' rot" of steel implement sharpeners, and "coal miners' asthma" evolved as by-products of the Industrial Revolution. But this group of disorders first assumed major importance when, at the turn of the 20th century, thousands of gold miners in South Africa began to die from "miners' phthisis." Since that time, research and the introduction of rigorous environmental hygiene measures have brought about control over these diseases.

In modern industries, dust hazards have been virtually eliminated by advance engineering planning. Employees in well-controlled plants can anticipate trouble-free working periods of 30 to 40 years in spite of processing highly dangerous substances. Pneumonoconiosis arises in such industries in exceptional cases only. The explanation usually is either extreme individual susceptibility, predisposing disease such as tuberculosis, accidental excessive exposures, hazardous technical innovations or the potentiating effects of exposure to several different substances. The pneumonoconioses have in a few instances affected nonworking persons. Police officers, housewives and school children have contracted berylliosis from the inhalation of smokestack effluvia, dust from soiled working clothes or fluorescent lamp phosphors. The lung injury caused by city smog results from the action of chemical agents adsorbed onto carbon particles emanating in industrial operations. The catastrophic deaths at Donora, Pa. (1946), the Meuse valley in Belgium (1949) and in London (1952) illustrate the disastrous potential of industrial waste products immoderately disseminated into the air of cities.

Causes.—Theories of the causation of pneumonoconiosis include tissue injury by mechanical trauma, protoplasmic poisoning, metabolic changes in cells through a disturbance of pH, protein denaturing through piezoelectric and surface molecular forces, immune and antibody reactions, polymerization and the nonspecific action of submicron particles. No single explanation is universally acceptable. The pathogenic propensity of a number of specific agents has been proved by experimental reproduction of pathognomonic lesions in animals.

Symptoms.—Pneumonoconioses range from innocuous through variably disabling to lethal syndromes. Symptoms are determined by the focus of major lung injury, combinations of lesions, severity and rate of exposure, and infective or other complications. Dominant states include bronchitis, bronchiolitis, bronchiectasis, emphysema, pulmonary fibrosis and pulmonary hypertension. The main complications, which also determine the mode of lethal outcome in most instances, are cor pulmonale with congestive cardiac failure, tuberculosis, pneumonia, pulmonary insufficiency, hemorrhage, lung gangrene and erosion of a blood vessel, a bronchus or the esophagus. Remote lesions may also occur; *e.g.,* portal artery obstruction, metastatic tuberculosis and liver, kidney or suprarenal failure. Respiratory tract cancer is closely associated with exposures to monochromates, asbestos! beryllium, nickel. arsenic and radioactive particles.

Diagnosis and Treatment.—Precise diagnosis depends largely on radiography, but so eclectic and diversified are the manifestations of the pneumonoconioses that interpretation of the X-rays requires great skill and experience. Advanced physiological studies have contributed greatly to understanding of the associated disability. Final diagnosis, however, often must await histopathological and petrographic confirmation.

Once established, the majority of the severe pneumonoconioses are irreversible. Some syndromes may become arrested on cessation of exposure but others, such as silicosis and asbestosis, progress inexorably. Therapy is directed at the alleviation of symptoms such as pain or bronchospasm, support of the failing heart and treatment of complicating infection. Apart from dust suppression, adequate ventilation and the use of exhaust equipment, the only effective prophylactic agent against silicosis is inhaled aluminum administered in the form of aerosols of aluminum oxide, hydroxide or hydroxychloride. Good results have been achieved in cases of berylliosis by means of the chelating agent aurin tricarboxylic acid or by cortisone. No specific therapy is available for other pneumonoconioses. See also DANGEROUS OCCUPATIONS; DUST; INDUSTRIAL MEDICINE. (G. W. H. S.)

PNEUMOTHORAX, the presence of free air in the pleural space (*i.e.,* between the chest walls and lungs), which normally contains no air. Air may be introduced into the pleural space as the result of trauma, by spontaneous rupture of the visceral pleura or by means of a needle inserted through the chest wall.

The chest is divided into two airtight compartments by the mediastinum. A thin membrane called the pleura covers each lung and is reflected at the root of the lung to form the lining of the inner surface of the chest wall. Normally the visceral pleura (covering the lung) is in contact with the parietal pleura (covering the inner surface of the thorax) and the potential space between them is Spoken of as the pleural space. A pneumothorax exists if the two layers of pleura are separated by air and the lung collapses away from the chest wall. Usually, the pleural rent heals spontaneously and re-expansion of the lung follows as the air is absorbed. In some cases, the air must be removed by needle or rubber catheter to aid breathing or speed recovery. In special cases. surgery is necessary.

Traumatic **Pneumothorax.**—Since the lung is an elastic organ and tends to be pulled toward the lung root. the pressure in the pleural space is less than atmospheric, averaging minus five centimetres of water. This means that air under atmospheric pressure will be sucked into the pleural space if the visceral pleura is torn (*e.g.*, by a fractured rib) or if an open wound in the chest wall penetrates the parietal pleura. If a "sucking wound" of the chest wall exists. more air may be pulled into the pleural cavity via the wound than is pulled into the lung via the larynx, with the result that the collapsed lung and mediastinum are pushed toward the healthy side on inspiration and away from it on expiration. This paradoxical motion of the lung and mediastinum causes progressive asphyxia unless the wound is closed.

Spontaneous **Pneumothorax.**—The sudden collapse of the lung without previous trauma. termed spontaneous pneumothorax. is usually accompanied by severe chest pain and difficulty in breathing. Most cases occur in apparently healthy persons. Because spontaneous pneumothorax may occur as a complication of pulmonary tuberculosis. it was assumed for years that almost all cases were due to tuberculosis. This is not true. In 1932 H. Kiaergaard suggested the emphysematous blebs in the pleural surface of the lung were the common cause of spontaneous pneumothorax. and this concept was later confirmed. Superficial blebs on the pleural surface are weakened areas of pleura: they may blow o'ut as a result of suddenly raising the intrapleural pressure by lifting, coughing or laughing. When spontaneous pneumothorax tends to recur it can usually be successfully treated surgically.

Artificial **Pneumothorax.**—In 1882 Carlo Forlanini first reported the successful use of artificial pneumothorax in the treatment of pulmonary tuberculosis and until recently the procedure was used extensively in the treatment of that disease. However. after both the introduction of several highly effective antituberculous drugs in the 1940s and the perfection of thoracic surgery for the resection of the diseased portions of the lung. its therapeutic use was drastically reduced. It has no value in the treatment of other pulmonary diseases.

See M. Pinner, *Pulmonary Tuberculosis in the Adult, p. 395* (1945); E. H. Rubin. *Diseases of the Chest, p.* 564 *(1947).*

(R. H. E,; D. K.-W.)

PO (anc. *Padus*), a river of northern Italy, and the dominating factor in its geography. It is the longest river in Italy (310 mi. direct, 405 mi. including its many windings), and the area of its basin, which includes portions of Switzerland, is estimated at 27.062 sq.mi. For its course and principal tributaries, *see* ITALY.

The lower valley of the Po was at an early period occupied by people of the Palaeolithic and Neolithic stages of civilization, who built houses on piles along the swampy borders of the streams. The river regulation works originated in pre-Roman times. The reclaiming and protecting of the riparian lands went on rapidly under the Romans. and in several places the rectangular divisions of the ground are still remarkably distinct. *(See* ESTE.) During the barbarian invasions much of the protective system decayed but the later middle ages saw the works resumed, so that the present arrangement existed in the main by the close of the 15th century.

The Ligurian name of the Po was Bodincus or Bodencus; *i.e.,* the bottomless. The name Padus was taken from the Celts or the Veneti. Thus Bodincomagus is found as a town name (Industria) on the upper course, and Padua as a name of one of the mouths of the river. The name Eridanus of Greek poetry was identified with it at a comparatively late period.

POBÊDONOSTSEV, KONSTANTIN PETROVICH (1827–1907), Russian jurist and state official. Born in Moscow in 1827, he studied at the School of Law in St. Petersburg, and entered the public service as an official in one of the Moscow departments of the senate.

In the early years of the reign of Alexander II (1855–1881), Pobêdonostsev maintained that occidental institutions were radically bad in themselves and totally inapplicable to Russia. Parliamentary methods of administration, modern judicial organization and procedure, trial by jury, freedom of the press, secular education—these were among the principal objects of his aversion. He therefore persecuted the dissenters, Stundists, Doukhobors and others, and insisted on severe measures of repression in education and in the press.

He exercised considerable influence by inspiring and encouraging the Russification policy of Alexander III (1881–1894). Pobêdonostsev died on March 23, 1907.

POCAHONTAS (1595–1617), daughter of the Indian chief Powhatan is the heroine of one of the best-known traditions connected with the beginnings of American history.

The story is that Capt. John Smith, who was head of a band of soldiers in search of food and exploring the Chickahominy river, was waylaid by Indians and taken prisoner by their chief, Powhatan. Smith had been forced to kneel down while his head was laid on a stone preparatory to having his brains crushed out with heavy clubs, when Pocahontas, a young daughter of the chief, sprang forward, seized Smith's head in her arms, and saved his life. She is supposed to have come again to his aid a year later by revealing a plot made against Smith by her father.

The first story concerning Pocahodtas appears in the *Generall Historie*, first published in 1624, after she had been made much of in England as the attractive daughter of an emperor and the first convert of her tribe to Christianity, and it is to be feared that the temptation to bring her on the stage as heroine in a new character in connection with Smith, ever the hero of his own chronicles, was more than he or the publishers of the *Generall Historie* could withstand.

Many prominent Virginia families trace their ancestry to the son of Pocahontas and her husband, John Rolfe.

POCATELLO, a city of southeastern Idaho, U.S.. the seat of Bannock county, occupies a mountain valley (elevation 4,460 ft.) at the mouth of Portneuf canyon about 15 mi. from the Snake river. Settled in 1882 during railway construction and named for an Indian leader friendly to the whites, Pocatello grew slowly at first because of its location on the Fort Hall Indian reservation. But its strategic position as a major railway junction brought important Union Pacific shops there in 1887; with the opening of the Fort Hall reservation to settlement in 1902, Pocatello grew rapidly and became the most prominent railway centre on the Union Pacific between Omaha and Portland. The Academy of Idaho was established in Pocatello in 1901 and began instruction at college level in 1927; the name mas changed to Idaho State college in 1917. Expansion of nearby irrigation helped the city to become a wholesale distributing centre with a variety of manufacturing and agricultural processing plants. An army air base reverted to a municipal airport after World War II, but the community expanded industrially with the acquisition of a large naval ordnance plant in 1912 and of important phosphate reduction works in 1946. The city has a council-manager form of government, in effect since 1951.

For comparative population figures *see* table in IDAHO: *Population.* (M. D. B.)

POCHARD, a diving duck (*q.v.*), *Nyroca ferina;* the female is sometimes called the dunbird. In the male in full plumage the head is coppery-red, the breast black, and the back and flanks a dull white, closely barred with fine undulating black lines. The tail coverts and quill feathers are black and the lower surface dull white. The female is duller. The pochard breeds throughout the northern hemisphere, migrating to the coast in winter and retiring southward. The American subspecies is larger. A second American species is the much bigger canvasback duck (*q.v.*). Both species are excellent table birds when they frequent fresh water, the canvasback being pre-eminent.

Allied to the pochards are the scaup duck (*N. marila*), the tufted duck and the eiders.

POCKET GOPHER, the name of a group of (chiefly North) American ratlike rodents, characterized by large cheek pouches, the openings of which are external to the mouth, while their inner surface is lined with fur. The second, and third front claws are greatly enlarged, and the fingers are furnished along their sides with bristles. The eyes are small, and the external ears rudimentary. Pocket gophers, which typify a family, the Geomyidae, spend practically all their time underground, their powerful claws being adapted for digging, while the bristles on the toes prevent the earth from passing between them. The upper incisor teeth are employed to loosen the ground, like a fork; and the little rodents are able to move both backward and forward in their runs. The cheek pouches are employed in carrying food, which consists of roots. The common pocket gopher, Geomys bursarius, of the Mississippi valley is about 8 in. long, plus a tail of 3 to 4 in.; colour, rufous brown and grayish beneath. Another is the northwestern plains pocket gopher *Thomomys* talpoides, which is considerably smaller. See RODENTIA.

POCKET MOUSE, the name of a number of small, mouse-like, western North American rodents belonging to the subfamily Perognathinae of the family Heteromyidae and including several genera, all with fur-lined external cheek pouches. The typical pocket mice (*Perognathus*) are small, with rather long tails and hind feet. They live in deserts and on the Great Plains, feeding on seeds. The kangaroo rat (*q.v.;* Dipodomys), subfamily Dipodomyinae, is closely related to the pocket mouse but has a very broad head. Heteromys and *Liomys,* the spiny pocket mice (subfamily Heteromyinae), have bristles mixed in the coat. They are dark gray or blackish in colour. Most species of these two genera are Central American, extending to northern South America. See also POCKET GOPHER; RODENTIA. (J. E. HL.; X.)

POCOCKE, EDWARD (1604–1691), English orientalist and Biblical scholar, the son of a Berkshire clergyman, was born at Oxford and baptized Nov. 8, 1604. He was educated at Corpus Christi college, Oxford. He served as English chaplain at Aleppo (1630–35) and on his return to England was appointed first professor of Arabic at Oxford, succeeding to the chair of Hebrew in 1648. Pococke discovered in a manuscript at the Bodleian library at Oxford the missing Syriac versions of the four New Testament epistles (II Peter, II and III John and Jude) which were not in the old Syriac canon; his edition of these was published at Leyden in 1630. In 1649 he published Specimen *historiae arabum,* a short account of the origin and manners of the Arabs, followed in 1655 by Porta *Mosis,* extracts from the Arabic commentary of Maimonides on the Mishnah, with translation and notes. His *magnum* opus—a complete edition of the Arabic history of Bar-Hebraeus, with a Latin translation, was dedicated to the king in 1663. Pococke died on Sept. 10, 1691.

See L. Twells (ed.), *Theological Works of* ***the Learned*** Dr. *Pocock,* 2 vol. (1740), which contains a biography.

PODEBRAD, GEORGE OF (1420–1471), king of Bohemia, was the son of Victoria of Kunstat and Poděbrad, a Bohemian nobleman, who was one of the leaders of the "Orphans" or modem Taborites during the Hussite wars. George became prominent early as leader of the National, or Calixtine party in Bohemia, becoming its chief at the death of Ptacek of Pirkstein. In 1448, during the minority of Ladislas Posthumus, having raised a force of 9,000 men in northeast Bohemia, where the National cause was strongest and where his own ancestral castle was situated, he marched on Prague and took it, afterward defeating the Romanist or Austrian party led by Ulrich von Rosenberg. In 1451 the emperor Frederick III, Ladislas' guardian, entrusted Poděbrad with the administration of Bohemia. In the same year a diet assembled at Prague also conferred on Poděbrad the regency. The struggle of the Bohemians against Rome continued uninterruptedly, and Poděbrad's position became very difficult when Ladislas, who was crowned in 1453, expressed his sympathies for the Roman Church, though recognizing the compacts and ancient privileges of Bohemia. In 1457 King Ladislas died suddenly. Public opinion from an early period accused Poděbrad of having poisoned him; but the suggestion is undoubtedly a calumny. On Feb. 27, 1458, the estates of Bohemia unanimously chose Poděbrad as king, even the adherents of the Austrian party voting for him. A year later, Pius II became pope, and his hostility proved a serious obstacle to Poděbrad's rule.

Though refusing to let the compacts be abolished, as Pius demanded, PodEbrad placated him by punishing the most advanced enemies of the papacy, including the newly-founded community of the Bohemian brethren; but his endeavours to establish peace with Rome proved ineffectual, although the death of Pius II prevented him from carrying out his planned crusade against Bohemia. Despite the prosperity enjoyed by Bohemia under Poděbrad's rule, the malcontent nobles of the Romanist party, meeting on Nov. 28, 1465, at Zelena Hora, formed a confederacy against him which was supported by the Roman see. On Dec. 23, 1466, Paul II, the successor of Pius II, excommunicated PodEbrad and pronounced his deposition as king of Bohemia, forbidding all Romanists to continue in his allegiance. The emperor Frederick III, and King Matthias of Hungary, Poděbrad's former ally, joined the insurgents. Matthias conquered a large part of Moravia and was crow-ned king of Bohemia at Brünn on May 3, 1469. On March 22, 1471, Poděbrad's death ended the war. He was the only native king of Bohemia, and the only one not a Catholic.

PODGORICA (TITOGRAD), the commercial capital of Montenegro, Yugos. Pop. (1953) 16,324. The town lies in a fertile plain on the Moracha, there spanned by a Turkish bridge. A tributary separates the Turkish town lying within the ruined ramparts, and inhabited by Albanians, from the Montenegrin quarter built in 1878.

PODIATRY (CHIROPODY) is the healing art concerned with the human foot. The Ebers medical papyrus (c. 1500 B.C.) records foot remedies from earlier centuries. Other references are found in the literature of all succeeding cultures. The word chiropody derives from a 1774 treatise, Chiropodologia, by D. Low, of London, where a Dr. Lyons in 1785 applied for a licence limited to practice on the feet. The term podiatry was coined in 1917 by M. J. Lewi of New York.

The first practice act was enacted in New York state in 1895, and by 1938 all the states of the United States, Canada, the United Kingdom, Australia and New Zealand had licensure provisions. In the United States the National Association of Chiropodists was organized in 1912 and adopted the name American Podiatry association in 1958. In Great Britain chiropodists function under the national health service. The first college of podiatry was organized in 1912.

Podiatrists diagnose and treat by medical, surgical and other means diseases and deformities of the human foot; they utilize mechanical devices, special shoes, physiotherapy, pharmaceuticals and surgery. (A. Ru.)

PODIUM, in architecture, a continuous pedestal, a low mall supporting columns, or the lowest portion of the wall of a building when given a separate architectural treatment. Sometimes the basement story of a classic building may be treated as a podium. The podium is usually designed with a molded base and plinth at the bottom, a central plane surface known as a die, or dado, and a projecting cornice or cap. The majority of Etruscan and Roman temples were raised on podiums, and the entrance steps ascended between wing walls, which were the continuations of the podium at the sides. By extension the term has been applied to other raised platforms, particularly those used by orchestra conductors.

PODOCARPACEAE. A family of conifers consisting of large trees and shrubs, found predominantly in the southern hemisphere. Many are important as timber trees and as a source of tanbark. The seven genera commonly admitted are Pherosphaera, *Microcachrys,* Saxegothaea, *Dacrydium, Acmopyle,* Podocarpus and *Phyllocladus.* All occur in the Australasian region except *Saxegothaea,* which is South American; *Podocarpus* and *Dacrydium* also extend their range to that continent. The Podocarpaceae are usually dioecious (having separate male and female plants) and have leaves variously awl-shaped, needlelike or broad, with many parallel veins. In the genus *Phyllocladus,* the foliar leaves are replaced by flattened branchlets (phylloclads) resembling leaves. The staminate, or pollen-bearing, cones are borne in a terminal or axillary position on leafy twigs, each scale bearing two pollen sacs. The ovulate, or seed-bearing, cones may have numerous scales but usually are reduced t~ one or a few scales with a single ovule and several sterile scales below. At maturity the latter become fleshy and sometimes brightly coloured and surmount the fleshy cone axis. Both cleavage and simple polyembryony occur. There are two cotyledons (seed leaves) in the mature embryo.

See also CONIFERS. (R. W. H.)

PODOLSK, a town of the Russian Soviet Federated Socialist Republic, U.S.S.R., 55° 27' N., 37° 28' E., 26 mi. S. of Moscow, on the railway and on the Pakhra river, crossed by a suspension and a railway bridge. Pop. (1956 est.) 113,000. It manufactures cement, lime, silicates and silk goods and has a railway repair shop. Until 1781 it was a dependency of the Danilov monastery of Moscow. Near it is an unkept park on the banks of the Pakhra, on the former estate of Count Tolstoi.

PODOPHYLLIN, a drug obtained from the rhizome of the American mandrake or May apple (*q.v.*). As met with in commerce, the rhizome occurs in cylindrical pieces two or three inches long and about a quarter of an inch in diameter, of a chocolate or purplish-brown colour, smooth, and slightly enlarged where the juncture of the leafy stem is indicated by a circular scar on the upper and a few broken rootlets on the under side. The odour is heavy and disagreeable, and the taste acrid and bitter.

Podophyllin was known to the American Indians, who realized its cathartic and caustic properties. It is no longer included in the *U.S. Pharmacopoeia*. The *British Pharmacopoeia* recognizes preparations from an Indian species, *P. emodi*. Podophyllin is used chiefly for its cathartic properties in patent medicines, often combined with aloes or calomel. It should be used cautiously, since its intense action may lead to inflammation of the bowel and death. It finds some use applied locally to certain types of warts.

The drug is a resinous powder obtained by precipitating an alcoholic tincture of the rhizome by means of water acidulated with hydrochloric acid. The powder is soluble in alcohol and strong solutions of alkalis. There are at least two resins in the powder (which is known officially as *Podophylli resina*), one being soluble and the other insoluble in ether. Each contains an active substance, which can be obtained in crystalline form and is known as podophyllotoxin. It is soluble in alcohol, ether, chloroform and boiling water. The properties of podophyllin resin vary with the reaction of the tissue with which it is in contact; where this is acid the drug is inert, picropodophyllin being precipitated.

PODOSTEMONACEAE, a remarkable family of dicotyledonous plants, living only on rocks in rushing streams. The seeds are shed on the rocks during the dry season, germinating when the rocks become submerged in the rainy season. The vegetative parts consist mainly of a flattened green thallus, usually derived from adventitious roots. There are 40 genera and about 175 species, nearly all tropical, a single representative, *Podostemon ceratophyllum* (river weed), occurring in North America, found in shallow streams from Maine to Minnesota and southward to Georgia and Alabama.

For a treatment of the genera, *see* A. Engler, "Podostemonaceae" in A. Engler and K. Prantl, *Natürlichen Pflanzenfamilien,* 2nd ed., 18a: 3–68, fig. 1–61 (1930).

POE, EDGAR ALLAN (1809–1849), U.S. poet, critic and short-story writer, who cultivated the literature of mystery and the macabre, was born Jan. 19, 1809, in Boston, Mass. He was the son of the English-born actress Elizabeth Arnold Poe and David Poe, Jr., an actor from Baltimore. After both parents died in Richmond, Va., in 1811, the boy was taken into the home of his godfather, the wealthy Richmond merchant John Allan, and his childless wife. He was taken to Scotland and England (1815–20), where he was given a classical education that was continued in Richmond. For a few months in 1826 he attended the University of Virginia, where he studied Greek, Latin, French, Spanish and Italian; but his gambling losses at the university incensed his guardian, Allan, who refused to let him continue, and Poe returned to Richmond to find his sweetheart, Elmira Royster, married. Poe went to Boston where he published a pamphlet of youthful Byronic poems, *Tamerlane* (1827), many of which concern Elmira. Poverty forced him to join the army under the name of Edgar A. Perry. The death of his foster mother caused Allan to purchase his release from the army, and to help in getting him an appointment to West Point. Before going, Poe published a new volume at Baltimore, *Al Aaraaf* (1829), showing the influence of the local poet E. C. Pinkney and an awakened interest in Milton and Thomas Moore. He successfully sought expulsion from the academy, where he was absent from all drills and classes for a week. He proceeded to New York and brought out a volume of *Poems* (1831), containing several masterpieces, some showing the influence of Keats, Shelley and Coleridge. He then returned to Baltimore, where he began to write stories. The rumour that he was again in the army under another name in 1832 seems credible. In 1833 his tale "A MS Found in a Bottle" won $50 from a Baltimore weekly, and by 1835 he was in Richmond as editor of the *Southern Literary Messenger*. There he made a name as a critical reviewer and married his young cousin Virginia Clemm, who was less than 14. Poe seems to have been an affectionate husband and son-in-law and wrote the tribute "Sonnet to My Mother" to his aunt, Mrs. Clemm.

Poe was dismissed from his job in Richmond, apparently for drinking, and went to New York. His drinking was the bane of his life. To talk well in a large company he needed a slight stimulant, but a glass of sherry might start him on a spree; and although he rarely succumbed, he was often seen in public when he did. Poe probably did not use drugs but did experience occasional psychotic episodes.

While in New York he published a long prose narrative, *The Narrative of Arthur Gordon Pym* (1838), combining (as so often in his tales) much factual material with the wildest fancies. It is considered one inspiration of Melville's *Moby Dick*. In 1839 he began editing *Burton's Magazine* in Philadelphia. There a contract for a monthly feature stimulated him to write "William Wilson" and "The Fall of the House of Usher"—stories of supernatural horror. The latter contains a study of a neurotic now known to have been an acquaintance of Poe, not Poe himself.

Later in 1839 his *Tales of the Grotesque and Arabesque* appeared (dated 1840). He resigned from *Burton's* about June 1840 but returned in 1841 to edit its successor, *Graham's Magazine,* in which he printed the first detective story, *"The Murders in the Rue Morgue."* In 1843 his "Gold Bug" won a prize of $100 from the *Philadelphia Dollar Newspaper,* which gave him great publicity. In 1844 he came to New York, wrote the "Balloon Hoax" for the *Sun* and became subeditor of the *Evening Mirror* under N. P. Willis, thereafter another lifelong friend. In the *Evening Mirror* of Jan. 29, 1845, appeared, from advance sheets of the *American Review,* his most famous poem, "The Raven," which gave him national fame at once. Poe then became editor of the *Broadway Journal,* a short-lived weekly in which he republished most of his short stories, in 1845. During this year the poet Frances Sargent Osgood pursued Poe. Virginia did not object, but "Fanny's" indiscreet writings about her literary love caused great scandal.

His *The Raven and Other Poems* and a selection of his *Tales* came out in 1845, and in 1846 Poe moved to a cottage at Fordham (now part of New York), where he wrote for *Godey's Lady's Book* (May–Oct. 1846) on the "Literati of New York"—gossipy sketches on personalities of the day that led to a libel suit.

His wife Virginia, who had burst a blood vessel several years before, died in Jan. 1847. In 1848 Poe went to Providence, R.I., to woo the poet Helen Whitman. There was a brief engagement. Poe had intimate but platonic entanglements with Annie Richmond and with Sarah Anna Lewis, who helped him financially. He composed poetic tributes to all of them.

In 1848 also he published the lecture *Eureka,* a transcendental "explanation" of the universe, which has been hailed as a masterpiece by some critics and as nonsense by others. In 1849 he went south, had a wild spree in Philadelphia but got safely to Richmond, where he again became engaged to Elmira Royster, by then the widowed Mrs. Shelton, and spent a happy summer with only one or two relapses. He enjoyed the companionship of childhood friends and an unromantic friendship with a young poet, Susan Archer Talley.

Poe had some forebodings of death when he left Richmond for Baltimore late in September. There he toasted a lady at her birthday party and began to drink heavily. The indulgence proved fatal, for Poe had a weak heart. He died on Oct. 7, 1849, and was buried in Westminster churchyard in Baltimore.

Poe's work owes much to the drift of romanticism, of which he was a late heir, toward the occult and satanic. It owes much also to his own feverish dreams, to which he applied a rare faculty of shaping plausible fabrics out of impalpable materials. With an air of objectivity and spontaneity, his productions are closely dependent on his own idiosyncrasy and an elaborate technique. His keen and sound judgment as appraiser of contemporary literature, his idealism and musical gift as a poet, his weirdness and dramatic power as a storyteller, considerably appreciated in his lifetime, secured him a prominent place among universally known men of letters.

The outstanding fact in Poe's character is a strange duality. The wide divergence of contemporary judgments on the man seems to point to the coexistence in him of two persons. With those he loved he was gentle and devoted. Others. who were the butt of his sharp criticism. found him irritable and self-centred and went so far as to accuse him of lack of principle. Was it, in the latter case, a double of the man rising from harrowing nightmares, or from the haggard inner vision of dark crimes, or from appalling graveyard fantasies that loomed in Poe's unstable being?

Much of Poe's best work is concerned with terror and sadness, but in ordinary circumstances the poet was a pleasant companion. He talked brilliantly, chiefly of literature, and read his own poetry and that of others in a voice of surpassing beauty. He admired Shakespeare and Alexander Pope. He had a sense of humour, apologizing to a visitor for not keeping a pet raven.

If the mind of Poe is considered, the duality is still more striking. On one side he was an idealist and a visionary. His yearning for the ideal was both of the heart and of the imagination. His sensitiveness to the beauty and sweetness of women inspired his most touching lyrics ("To Helen," "The Sleeper," "Eulalie," "To One in Paradise") and the full-toned prose hymns to beauty and love in "Ligeia" and "Eleonora." In "Israfel" his imagination carried him away from the material world into a dreamland. This Pythian mood was especially characteristic of the later years of his life.

More generally, in such verses as "Valley of Unrest," "Lenore," "The Raven," "For Annie" and "Ulalume" and in his prose tales, his familiar mode of evasion from the universe of common experience was through eerie thoughts, impulses or fears. From these materials he drew the startling effects of his tales of death ("House of Usher," "Red Death," "Valdemar," "Premature Burial," "Oval Portrait." "Shadow"), his tales of uickedness and crime ("Berenice," "Black Cat," "William Wilson," "Imp of the Perverse," "Cask of Amontillado," "Tell-Tale Heart"), his tales of survival after dissolution ("Ligeia," "Morella," "Metzengerstein") and his tales of fatality ("Assignation," "Man of the Crowd"). Even when he does not hurl his characters into the clutch of mysterious forces or onto the untrodden paths of the beyond, he uses the anguish of imminent death as the means of causing the nerves to quiver ("Pit and the Pendulum"), and his grotesque inventions deal with corpses and decay in an uncanny play uith the aftermath of death.

On the other side. Poe is conspicuous for a close observation of minute details, as in the long narratives and in many of the descriptions that introduce the tales or constitute their settings. Closely connected with this is his power of ratiocination. He prided himself on his logic and carefully handled this real accomplishment so as to impress the public with his possessing still more of it than he had; hence the would-be feats of thought reading, problem unraveling and cryptography which he attributed to his Legrand and Dupin. This suggested to him the analytical tales, which introduced into literature the detective story, and his tales of pseudo science.

The same duality is evinced in his art. He was capable of writing angelic or weird poetry. with a supreme sense of rhythm and word appeal, or prose of sumptuaus beauty and suggestiveness, with the apparent abandon of compelling inspiration; yet he would write down a problem of morbid psychology or the outlines of an unrelenting plot in a hard and dry style. In Poe's masterpieces the double contents of his temper, of his mind and of his art are fused into a oneness of tone, structure and movement, the more effective. perhaps. as it is compounded of various elements that give depth and intensity to the total sheen or dismal glow.

Poe's genius was recognized abroad. No one did more to persuade the world and, in the long run, America, of Poe's greatness than Baudelaire and Mallarmé.

The first collected edition of Poe's works is that of R. W. Griswold, 4 vol. (1850–56). That of J. A. Harrison, 17 vol. (1903), includes biography and correspondence; the Ostrom edition of the *Letters* (1948) includes only Poe's side of the correspondence. The standard edition of the *Poems* is by Killis Campbell (1917).

See also AMERICAN LITERATURE: *Early 19th Century;* MYSTERY AND DETECTIVE STORIES.

BIBLIOGRAPHY.—Poe's early biographer, R. W. Griswold (1850), blackened his character. Hervey Allen, *Israfel: the Life and Times of E. A. Poe,* 2 vol. (1926), is partly fictional; J. H. Ingram, *Edgar Allen Poe,* 2 vol. (1880), and A. H. Quinn, *Edgar Allan Poe, a Critical Biography* (1941), were written for the defense. G. E. Woodberry, *The Life of E. A. Poe, Personal and Literary,* 2 vol. (1909), is the most perceptive of the biographies. S. A. Weiss, *The Home Life of Poe* (1907), presents a picture from a friend; Mary E. Phillips, *Edgar Allan Poe, the Man,* 2 vol. (1926), uncritically collects much information. *See* also N. B. Fagin, *The Histrionic Mr. Poe* (1949); Arthur Ransome, *Edgar Allan Poe* (1910).

(C. C.; T. O. M.)

POELZIG, HANS (1869–1936), German architect, was born in Berlin on April 30, 1869. He studied architecture at the Berlin Technische Hochschule and was subsequently director of the Breslau Academy of Arts (1903–16). He mas city architect of Dresden from 1916 to 1920 and also an honorary professor at the Technische Hochschule there. In 1920 he started an advanced atelier for applied arts at the Berlin Academy of Arts. From 1924 to 1935 he was also professor of the architectural faculty of the Berlin Technische Hochschule. With the architect Peter Behrens (1868–1938), Poelzig was a pioneer of the German industrial-art movement: he was president of the Deutscher Werkbund. an association of progressive architects, designers and industrialists, founded in 1907. Poelzig, like Behrens, was much concerned with freeing buildings from all superficial mannerisms: thus his sulfur factory (1912) at Lauban (Luban), Pol., was a group of purely functional block shapes, and the façade of the Berlin radio building (Funkhaus) of the late 1920s was virtually a great expanse of smooth wall pierced by well-balanced ranges of simple windows. However, he was also responsible for the remarkably decorated Grosses Schauspielhaus. Berlin, which he converted for Max Reinhardt from the old Schumann circus building. Poelzig died on June 14. 1936.

POERIO, ALESSANDRO (1802–1848), Italian poet and patriot, was descended from an old Calabrian family, his father, Baron Giuseppe Poerio. being a distinguished Neapolitan lawyer. In 1815 he and his brother Carlo accompanied their father, who had been identified with Murat's cause, into exile, and settled at Florence. In 1818 they were allowed to return to Naples. Alessandro fought as a volunteer, under Guglielmo Pepe (*q.v.*), against the Austrians in 1821, but when the latter reoccupied Naples and the king abolished the constitution, the family was again exiled and settled at Gratz. Alessandro studied in Germany, and at Weimar he became the friend of Goethe. In 1835 the Poerios returned to Naples. In 1848 Alessandro accompanied Pepe as a volunteer to fight the Austrians in northern Italy, and on the recall of the Neapolitan contingent he followed Pepe to Venice. He mas severely wounded in the fighting round Mestre, and died on Nov. 3, 1848. His poetry "reveals the idealism of a tender and delicate mind"; but he could also sound the clarion note of patriotism, as in his stirring poem *Il Risorgimento.*

His brother CARLO (1803–67), after returning to Naples, practised as an advocate, and from 1837 to 1848 was frequently arrested and imprisoned. Under the short lived constitution of 1848 he was minister of education. He resigned office in April and took his seat in parliament, where he led the constitutional opposition. After the Austrian victory Poerio was arrested (July 19, 1849) tried, and condemned to 19 years in irons. Chained in pairs, he and other political prisoners were confined in one small room in the bagno of Nisida, near the lazaretto. The exposure (1851) of the horrors of the Neapolitan dungeons by Gladstone, who emphasized especially the case of Poerio, awakened the indignation of Europe. but he was not released till 1858. He and other exiles were then placed on board a ship bound for the United States, but the son of Settembrini, another of the exiles, who was on board in disguise, compelled the crew to land them at Cork, whence Poerio made his way to London. In the following year he returned to Italy, and in 1860 he was elected deputy to the parliament of Turin, of which he was chosen vice-president in 1861. He died at Florence on April 28, 1867.

See Baldachini, *Della Vita e de' tempi di Carlo Poerio* (1867); W. E. Gladstone, *Two Letters to the Earl of Aberdeen* (1851); *Carlo Poerio and the Neapolitan Police* (1858); Vannucci, *I Martiri della libertà italiana*, vol. iii. (Milan, 1880); Imbriani, *Alessandro Poerio a Venezia* (Naples, 1884); Del Giudice, *I Fratelli Poerio* (Turin, 1899); Countess Martinengo Cesaresco, *Italian Characters* (1901).

POET LAUREATE. The laurel (Lat. *laurea*) was sacred to Apollo, and as such was used to form a crown or wreath of honour for poets and heroes. The word "laureate" or "laureated" thus came in English to signify eminent, or associated with glory, literary or military. "Laureate letters" in old times meant the despatches announcing a victory; and the epithet was given, even officially (*e.g.*, to John Skelton) by universities, to distinguished poets. The term "poet laureate" was ultimately restricted to the office of the poet attached to the royal household, first held by Ben Jonson, for whom the position was, in its essentials, created by James I. in 1617. (Jonson's appointment does not seem to have been formally made as poet-laureate, but his position was equivalent to that). The office was really a development of the practice of earlier times, when minstrels and versifiers were part of the retinue of the king; it is recorded that Richard Coeur de Lion had a *versificator regis* (Gulielmus Peregrinus), and Henry III. had a versificator (Master Henry); in the 15th century John Kay, also a "versifier," described himself as Edward IV.'s "humble poet laureate." Moreover, the Crown had shown its patronage in various ways; Chaucer had been given a pension and a perquisite of wine by Edward III., and Spenser a pension by Queen Elizabeth. Sir William Davenant succeeded Jonson in 1638, and the title of poet laureate was conferred by letters patent on Dryden in 1670, two years after Davenant's death, coupled with a pension of £300 and a butt of Canary wine. This was the beginning of the official laureateship. The successors of Dryden were T. Shadwell (who originated annual birthday and new year odes), Nahum Tate, Nicholas Rowe, Laurence Eusden, Colley Cibber, William Whitehead, Thomas Warton, H. J. Pye, Southey, Wordsworth, Tennyson, Alfred Austin, Robert Bridges (appointed 1913) and John Masefield (appointed 1930).

The poet laureate, being a court official, was considered responsible for producing formal and appropriate verses on birthdays and state occasions. Wordsworth stipulated before accepting the honour, that no formal effusions from him should be considered a necessity; but Tennyson was generally happy in his numerous poems of this class. The emoluments of the post have varied. To Pye an allowance of £27 was made instead of the Canary wine. Tennyson drew £72 a year, and £27 in lieu of the "butt of sack."

See Walter Hamilton, *Poets Laureate of England* (1879), and E. K. Broadus, *The Laureateship* (1921).

POETRY. The term poetry is generally applied to imaginative literature involving language especially heightened by verse, imagery (*qq.v.*), figures of speech or similar devices to affect the imagination and emotions. Perhaps no other term has been so frequently defined in the history of literary criticism; but its various definitions have been less significant as statements of the nature of poetry than as clues to the tastes and interests of the critic or philosopher who produced the definition. Indeed, the term poetry and its synonyms have referred, in various ages and cultures, to works which have nothing in common beyond the use of language as a medium. For example, in certain uses, the term has been applied to any composition in verse, while in others it has been applied to compositions of a certain character, regardless of the presence or absence of verse. It is far less profitable to attempt one more definition than to consider the history of the compositions which have been called poetry, and so offer some notion of the meanings of the term.

Any art has its origin in the nature of man; *i.e.*, in elementary instinctive activities. In its first form it is apparently an activity simply enjoyable in itself, and practised by anyone. Thus children at play practise any art for which they have the means—music, sculpture, painting, dancing and so on—and the fact that children do so in play indicates that these activities are naturally pleasant. In a second stage, art develops in connection with some practical activity which it facilitates or renders more effective; thus work songs grow out of various labours, and hymns and dirges grow out of the charms and prayers of religious or magical ceremonials. In this stage the practitioner of art is naturally the practitioner of the occupation to which art is subordinate. In a third stage, however, art develops in itself, beginning with the development of special skills in its practitioners and resulting in the creation of works which, independently of any practical end, are valuable in themselves. This is not to say that works of art produced in the earlier stages are without artistic value, but that their possession of such value is incidental to some other end.

An art form does not arise immediately, even so. Its materials must first be provided; from some incidental combination of these there must result some effect which is recognized as valuable in its own right, and the materials must be reworked and reorganized specifically to produce that effect. This is the fashion in which drama, for instance, in antiquity and in the middle ages, grew out of liturgical practices. Once established, a given art tends either to move toward its own perfection or to generate other arts, or to perfect these, as in its own development it brings about the conditions requisite for their existence or perfection.

The history of an art is not merely a matter, however, of the genesis, perfection and dissolution of forms; it is also a history of the changing associations of certain materials, techniques and devices with certain forms, and—since art is created by men and addressed to men—of the changing human contexts in which art is pursued. The following account will deal in these terms with the development of European poetry generally from antiquity to the Renaissance, and with the subsequent development of poetry in English.

For accounts of European poetry not in English after the Renaissance *see* FRENCH LITERATURE; PROVENÇAL LITERATURE; SPANISH LITERATURE; ITALIAN LITERATURE; and GERMAN LITERATURE. For accounts of other European poetry *see* ICELANDIC LITERATURE; IRISH LITERATURE; MANX LANGUAGE AND LITERATURE; CORNISH LITERATURE; CELTIC LANGUAGES; WELSH LITERATURE; BRETON LITERATURE; BELGIAN LITERATURE; DUTCH LITERATURE; DANISH LITERATURE; NORWEGIAN LITERATURE; SWEDISH LANGUAGE AND LITERATURE; FINNISH LITERATURE; LETTISH (LATVIAN) LITERATURE; LITHUANIAN LITERATURE; RUSSIAN LITERATURE; POLISH LITERATURE; CZECHOSLOVAK LITERATURE; UKRAINIAN LITERATURE; HUNGARIAN LITERATURE; RUMANIAN LITERATURE; BULGARIAN LITERATURE; GEORGIAN LITERATURE; ARMENIAN LITERATURE; GREEK LITERATURE: *Modern Literature;* SERBO-CROATIAN LITERATURE; AUSTRIAN LITERATURE; SWISS LITERATURE; PORTUGUESE LITERATURE; YIDDISH LANGUAGE AND LITERATURE. For accounts of non-European poetry *see* SANSKRIT LANGUAGE AND LITERATURE; CHINESE LITERATURE; INDIAN LITERATURE; BENGALI LITERATURE; HINDI AND URDU LITERATURE; MARATHI; SIAMESE LANGUAGE AND LITERATURE; JAPANESE LITERATURE; PERSIAN LITERATURE; ARABIC LITERATURE; HEBREW LITERATURE; ETHIOPIAN LITERATURE; SOUTH AFRICAN LITERATURE; CANADIAN LITERATURE; IBERO-AMERICAN LITERATURE; and AUSTRALIAN LITERATURE.

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I. GREEK POETRY

1. Epic.—While Greek poetry begins with the two great epics of Homer. the *Iliad* and the *Odyssey,* there. is no doubt that the poetic arts of the Greeks had already progressed greatly by Homer's time. *(See* EPIC POETRY; GREEK LITERATURE; HOMER.) The Homeric epics themselves tell us a good deal about the earlier poetry. Thus we know that such forms as the marriage hymn. the funeral dirge, the hymn to a god, the victory song, the song in praise of a hero and other kinds of lyric already existed, and that narrative poetry also existed, in the form of the heroic lay, out of mhich the epic itself probably grew. We know, too, that these forms, originally religious and ritualistic, had evolved in certain instances into purely secular forms; that the poetic arts existed in combination with the arts of music and dancing and mere practised by experts—minstrels distinguished for their inspiration and skill—who were at once poets and musicians, accompanying their own songs and stories on the lyre. and perhaps leading the dance as well. There had developed. too, many of the metres which were to be adapted to epic. dramatic and lyric uses *(see* DRAMA: *Greek Drama: Origins;* LYRICAL POETRY) ; and there existed also certain devices which were to lay the foundation for arts as yet unknown. Notable among these was the division between a speaker and a responding group *(Iliad,* xxiv, 718 ff.) mhich led to the division of choragus (chorus leader) and chorus and so gave rise to dialogue, first in the dithyramb and later in drama *(see* DITHYRAMBIC POETRY). Moreover, the direct impersonation of different characters, without which drama is impossible, is everywhere present in the Homeric epics, and had probably originated in the heroic lay. The heroic lay itself seems to have grown out of the narrative portion of the earlier hymns.

The names of a number of poets have come down to us from the half-legendary time before Homer. Orpheus, Musaeus, Eumolpus and Thamyras were all given the title "Thracian." which means that they mere associated with the worship of the Muses, goddesses of poetry. Olen. Chrysothemis and Philammon are said to have made the first hymns to Apollo; Olympus and Hyagnis, the first hymns to Cybele. This earliest sacred poetry must have been composed soon after the migration of the Greeks from Asia. Panegyric or encomiastic poetry seems to have originated as a secular form of the hymn. In general the Greeks show an early tendency to divest poetry of its liturgical character and make it a popular rather than a ritualistic art.

However great the development of poetry before Homer, there is no doubt of his pre-eminence in the art. Aristotle calls him the poet of poets in the serious style, and credits him with many innovations or improvements—for example, with the construction of a single unified action, uhereas other poets had simply related all that befell their heroes, without regard to the connection of events; with the reduction of the poet's speeches in his own person to a minimum, and with the dramatic impersonation, instead, of character after character. "each with his distinctive characteristics"; with the ingenious concealment of improbabilities in his plots, where these could not be avoided; with the use of the "graphic," or especially vivid, metaphor; and even with the foundation of comedy, though this last rests upon the doubtful attribution to Homer of the *Margites*.

The Homeric epics are long narrative poems, in dactylic hexameter verse, the plots of which are serious single actions comprising many episodes. In their grandeur of conception and skill of execution they set a standard which the Greek epic poets who followed could not equal. Between the 8th and the 6th centuries B.C. epic poets of the Ionian school disregarded the principle of unity of action and sought instead to complete the account of the adventures of their heroes. According to the grammarian Proclus (flourished A.D. 140), Stasinus dealt, in *The Cyprian Lays,* with the events leading up to those of the *Iliad;* Arctinus of Miletus, in the *Lay of Aethiopia,* continued the *Iliad* to the death of Achilles, and composed a further continuation in *Tke Sack of Troy;* Lesches of Mytilene, in *The Little Iliad,* composed a similar sequel; Agias of Troezen, in *The Homeward Voyages,* filled in the gap between the *Iliad* and the *Odyssey;* and Eugammon of Cyrene, in *The Lay of Telegonus,* recounted the adventures of the son of Odysseus and Circe. These are poets of the Trojan cycle; others dealt with the Theban War, and still others with the exploits of Hercules. Important as the work of these cyclic poets may have been for Greek drama and art, their work represents a decline from the near perfection of the Homeric epic.

It is probable that until Aristotle there existed no very clear-cut conception of epic as a special art form. Even Plato offers only a crude formulation of the Homeric epic; in common practice, any poet who employed hexameter verses was called an epic poet, and if the name meant anything further, it implied that the verses were recited rather than sung, and that the composition as a whole followed certain conventions. Thus the name of "epic poet" was given to Hesiod, who lived in the 10th or 9th century B.C., and whose *Works and Days* and *Theogony* are not narratives of heroic actions, as were Homer's. but didactic pieces. Hesiod deals, not with noble fictions, but with the truths of daily life, with rules for farming and husbandry, with precepts for moral behaviour and religious beliefs. His poems founded a school of bucolic poetry which the Roman poet Virgil and others were later to bring to exquisite art, but Hesiod is simply concerned with instruction.

2. Elegiac and Iambic.—About 690 B.C. elegiac and iambic verses emerge (*see* ELEGY; IAMBIC). Elegiac verse grew out of the hexameter; the elegiac couplet is simply a specific form of hexameter couplet, though it is often inaccurately described as a hexameter followed by a pentameter. The elegy is a kind of lyric, personal in character, but reflective rather than passionate; originally it was sung to the flute. Callinus and Tyrtaeus, who flourished early in the 7th century are among the early elegists. Archilochus, slightly later, also wrote elegies but is chiefly famous for his iambic verses, and is regarded as the father of satire (*q.v.*). Simonides of Amorgos (flourished about 655 B.C.) wrote iambic satire, including a famous one on women. Other elegists of the 7th and 6th centuries include Minermus of Smyrna, Solon the lawmaker, Theognis of Megara and Phocylides of Miletus. Indeed, the elegy was to retain its popularity for a long time.

3. Lyric.—Greek lyric, or more properly melic (Greek *melikos* from *melos,* "song"), poetry was inseparable from music. Hence traditionally it is said to owe its origin to Terpander's enlargement of the lyre from four strings to seven, so that the instrument encompassed all of the seven modes of Greek music. Alcman and Stesichorus of Himera in the 7th century and Ibycus in the 6th wrote choral lyrics; Alcaeus and his contemporary Sappho, late in the 7th century, were the most famous lyrists of the Lesbian school. Anacreon of Teos in the 6th century, according to tradition, composed many graceful and gay songs which have found imitators through the ages. Arion late in the 7th century brought the dithyramb, a choral hymn to Dionysus, to its most finished form. Simonides of Ceos in the 6th and 5th centuries composed odes, hymns, dirges and other kinds of lyric, and his nephew Bacchylides composed choral lyrics. The literary remains of Pindar include almost every kind of lyric—hymns, choral dithyrambs, processionals, paeans. hyporchemes or choral dance songs, encomia or eulogies, scolia or drinking songs, choral songs for maidens, and dirges. These we possess as fragments, but we have 44 complete epinicia or victory odes celebrating the victors of the Olympian, Pythian, Nemean and Isthmian games.

4. Dramatic.—Greek drama began with the Dionysian festi-

vals. Tragedy takes its name from the "goat song," a hymn sung at these festivals. The dithyramb developed from this hymn; and in the performance of the dithyramb. the impersonation of the god by the choragus led to dialogue betneen nhat were by then distinct dramatic entities. Thespis in the 6th century is said to have detached another member from the chorus to serve as "answerer" (*hypokrites*), introducing an innovation which increased the importance of dialogue; Phrynichus divided the chorus into separate bands, making them in effect different dramatic groups. Even so, these are but the rude beginnings of drama, for such devices permitted the enactment of only a few incidents. It was only with the introduction of a second actor by Aeschylus that dialogue became really independent of the chorus; moreover, the number of actors was now sufficient to permit. by their exits and entrances. the dramatic representation of an extensive succession of episodes. Dialogue now became more important than the choral song to which it had hitherto been subordinate, and itself became subordinate to character, which in turn became subordinate to action or plot.

Thus with Aeschylus the new form of tragedy comes into being, its birth signalized by a revolution in the ordering of parts developed out of earlier forms. The tragic action is a serious one which involves characters of more than ordinary moral stature; consequently the language of tragedy grew dignified in both style and rhythm. Later poets made other improvements. Sophocles introduced both a third actor and painted scenery, thereby permitting greater extension of the action and greater spectacular effect; and Euripides made women important characters in his tragedies, thus extending the subject matter of the art.

Comedy. like tragedy, had its origin in the Dionysian festivals, but grew out of the rustic revelry of the satyrs attending the god, developing from banter, invective and practical jokes into its proper form (see DRAMA: Greek Drama: Origins). Doubtless its technical development closely paralleled that of tragedy. Susarion in the 6th century and Epicharmus in the 5th century, both Megarians, produced brief farces. doubtless extremely crude in their humour; Attic comedy, more refined in character, begins with Rlagnes in the 5th century, and in the same century is carried further by Cratinus, and reaches its culmination in the works of the great Aristophanes.

5. The Decline. — In the Alexandrian period (336–146 B.C.) the great creative spirit of Greek poetry declined. Except for pastoral poetry, no new kind emerged; the poets were frequently learned imitators of their predecessors. Callimachus composed hymns and elegies as aell as epigrams. Apollonius of Rhodes imitated the Homeric epic in his *Argonautica*. Lycophron left a highly artificial Alexandra. The epic became didactic otherwise: Aratus of Soli wrote a versified astronomy. and Nicander composed two versified treatises on medicine, as well as some works. now lost, which influenced the Roman poets Virgil and Ovid. Theocritus, Moschus and Bion wrote exquisite pastorals or idyls. Satire and parody flourished; their most famous exponent was Timon of Phlius. Subsequently Greek poetry became silent until nhat may have been two poets of the same name, Oppian, in the 2nd and 3rd centuries A.D., wrote didactic epics on fishing and hunting; Babrius in the 3rd century versified the Fables of Aesop; and Quintus Smyrnaeus of the 4th century and Nonnus of the 5th revived the mimetic epic. the former offering one more sequel to the Iliad, the latter recounting the adventures of Dionysus. (See also ANTHOLOGY: *The* "Greek Anthology.")

II. ROMAN POETRY

1. Early Period. — Though, like the Greeks, the Romans possessed the germ of drama in their festivals and the germ of epic in their heroic lays, there is no evidence that they cultivated these. Such early poetry as they had was evidently of a rude order. Roman poetry does not evolve naturally and gradually. as does that of the Greeks; it is rather transported bodily, like the other arts, like, indeed. even Roman religion and mythology. from the matured and perfected culture of Greece. The Romans neither originated nor significantly improved any poetic art. but they produced many illustrious poets who kept alive, if only in reflection, the genius of Greek literature, and whose own influence was to extend even to the 20th century. The Romans borrowed the very name for a poet. for neither poeta nor vates is of Latin origin. They seem to have held minstrels in contempt. and the only native Italian rhythm is the so-called Saturnian metre, a crude form of trochaic hexameter. It would seem, thus, that the Romans neglected both poets and poetry until, as the Roman poet Horace says, they came into contact with Greek culture in the interval between the First and Second Punic Wars in the 3rd century B.C.

2. Greek Influence. — Once brought into that contact, however, they were affected as perhaps no other nation has been by a foreign culture; "subdued Greece subdued her savage subduer and brought her arts into rude Latium." Livius Andronicus. an emancipated Greek slave of the 3rd century B.C. who translated at least ten Greek tragedies, and nho even turned the Odyssey into the rough Saturnian measure, achieved fame despite the poor quality of his work. Gnaeus Naevius translated from the Greek and produced tragedies and comedies. as well as praetextae, or historical dramas. He is credited nith the introduction of subplots or underplots. Quintus Ennius composed comedies, tragedies, an epic on Roman history and other pieces. He was the first to replace the Saturnian measure with the epic (dactylic) hexameter. In the and century B.C. Caecilius Statius wrote comedies, and Marcus Pacuvius, tragedies. Lucius Accius was the first to employ Roman subjects for his tragedies. Plautus and Terence made free adaptations from Greek drama. Gaius Lucilius wrote satires which remained unequaled until Horace. Of all these poets, Plautus and Terence alone are still venerated.

3. The Golden Age. — The great age of Roman poetry was still to come. Lucretius in the 1st century B.C. produced his splendid didactic epic in defense of the Epicurean philosophy — De *Rerum Natura*—when the republican spirit in Rome was dying. To the same time belongs G. Valerius Catullus, an extremely gifted poet who composed more than a hundred poems on various subjects and in various metres, of which the most important are the *Atys* and The Marriage *of Peleus* and Thetis. In the new age of imperialism which succeeded, the other arts declined. but Roman poetry came to its highest flower before it, too, took the downward course. P. Vergilius Maro (70–19 B.c.) wrote the Georgics, the Eclogues and the greatest of Latin epics, the Aeneid (see VIRGIL). Q. Horatius Flaccus (6j–8 B *c.)* composed odes, epodes, epistles and satires (see HORACE). P. Ovidius Naso (43 B.C.–A.D. 17) wrote the *Metamorphoses,* the *Art* of Love, the Fasti and elegiacs, as well as a tragedy, *Medea,* which has been lost (see OVID). Albius Tibullus and Sextus Propertius (*qq.v.*) wrote elegies.

4. The Silver Age. — The Augustan age was the golden age of Roman poetry, but the silver age which followed in the 1st century AD. also had its distinguished poets: the satirists Persius and Juvenal and the epigrammatist Martial brought their respective forms to the highest finish these mere to have in Roman letters (see EPIGRAM). On the other hand, the epic poets Lucan, Silius Italicus. Valerius Flaccus and Statius represent at best a marked decline in that form. In the 4th century with Claudian (see CLAUDIANUS, CLAUDIUS) the epic turns into a form of encomium celebrating contemporary heroes — unless we wish to say that that had happened earlier with the Pharsalia of Lucan or the *Punica* of Silius Italicus, or even with the Aeneid. Indeed, the fundamental Roman genius was always for rhetoric. and in Latin nearly all the Greek poetic forms eventually approach forms of rhetoric. Thus tragedy, with Seneca (see SENECA, LUCIUS ANNAEUS), becomes declamatory rather than dramatic; and satire, always a rhetoric of dissuasion, quickly succeeds pure comedy.

5. Conclusion. — Even at its best Roman poetry was derivative, and even its greatest poets followed Greek models closely. To observe this is not to decry Roman poetry, for an art is preserved if not advanced by the Imitation of great models; and in the middle ages, nhen the poetry of the Greeks nas forgotten or but dimly remembered, it was the fortune of the Roman poets to remain as monuments of the greatness of antiquity. After all, the great conductor of Dante in his *Divine* Comedy was Virgil, who was to conduct many another poet from darkness to light. (See also LATIN LITERATURE.)

III. MEDIEVAL POETRY

The history of poetry during the medieval period can be represented here only in the crudest outline, because of its extraordinary complexity. When the poetic arts follow a natural evolution, as in Greece. or are imported totally, as in Rome, their development is continuous and orderly, and the task of the historian is relatively simple. When, on the other hand, tradition is disrupted, and the arts themselves are in a process of disintegration and reintegration, no easy description is possible.

1. Poetry **and** the Church. — During the early middle ages, causes existed which affected every aspect of the poetic arts. The decline of Roman power made access to certain parts of the empire difficult. or even impossible. This fact, together with the incursions of the barbarians, brought about a gradual "corruption" of the Latin language as it used to be called; more accurately, difficulty of access multiplied the differentiation of dialects. These linguistic changes were bound to affect both style and versification. Even more importantly, the rise of the Christian religion and the Christian ethic affected the subject matter of poetry, for both repudiated most of the moral attitudes on which pagan poetry had depended for its emotional power. Indeed, the general hostility which the church fathers felt toward all the arts, on the grounds of their immorality, falsity or idolatry, involved a special hostility toward drama and poetry. Tertullian calls literature "folly in the sight of God"; Jerome calls poetry the "food of devils"; Augustine and Gregory attack poetry as destructive of both religion and morality. Yet too much can be made of this hostility; no branch of literature — with the exception of drama— was completely rejected. Moreover, if pagan poetry, when read literally, offended, it might be read allegorically and found to contain meanings perfectly compatible with, perhaps even confirming, Christian doctrine and morality.

2. The Hymn. — Even so, the process of making poetry a servant of the church w-as no easy one. The Christian hymn itself, against considerable opposition, was introduced into western ecclesiastical use only in the 4th century, through the labours of St. Hilarius of Poitiers and St. Ambrose of Milan *(see* HYMNS). Once definitely established, however, the hymn remained one of the important poetic forms of the medieval period. Ambrose, Hilary, Pope Damasus and the great poet Prudentius wrote hymns in the 4th century; Sedulius. Elpis, Pope Gelasius. Ennodius, Gregory the Great *(see* GREGORY) and Fortunatus *(see* FORTUNATUS, VENANTIUS) composed hymns in the 5th and 6th centuries; and in succeeding centuries Bede. Paulus Diaconus, Hrabanus Maurus, Bernard of Clairvaux *(see* BERNARD, SAINT). Xbelard, Adam of St. Victor, St. Thomas Aquinas and many others produced notable or even great works of this kind. The anonymous "Te Deum," the "Dies Irae" of Thomas de Celano and the "Stabat Mater" of Jacopone da Todi — the first of the 4th century, the other two of the 13th — have been translated repeatedly, and set to music by the greatest composers. *(See* RHYME.)

3. Secular Poetry. — It must not be supposed, however, that medieval Latin poetry was confined to hymnography. We have already noted the epic poet Claudian, and there were many similar secular poets. In the 3rd century Reposianus wrote on the intrigue of Mars and Venus, Modestinus on Cupid asleep, Pentadius on the changes of fortune. on the arrival of spring and on Narcissus. In the 4th century there are such poets as Ausonius and Tiberian, who are primarily secular. Philosophers such as Boethius (5th–6th century) and Bernardus Sylvestris (13th century) wrote verses and veiled their doctrines in poetic allegory. **A** host of student songs, like those of the *Carmina Buruna,* dealt with wine, women and song. Satire, too. flourished, especially satire against the clergy. Wet the greatest medieval Latin literature. so far as intellect, imagination and even technical skill are concerned, is to be found in prose; and the greatest medieval poetry is not in Latin but in the Romance languages which gradually formed from the various dialects, and in the Teutonic languages. *(See* also LATIN LITERATURE : *Mediaeval.)*

4. French Poetry. — The earliest French poetry dates from the 10th century. a poem on St. Eulalia, a *Passion of Christ* and a *Life of St. Leger (see* also FRENCH LITERATURE). The three succeeding centuries saw the unfolding of the four great epic cycles of the *chansons de geste* (*q.v.*). The most venerable as well as most remarkable work is the *Chanson de Roland* (11th century; *see* ROLAND, LEGEND OF), which belongs. with the *Pilgrimage of Charlemagne* and *Huon de Bordeaux,* to the *Geste du roi,* or the cycle of King Charlemagne (*see* CHARLEMAGNE LEGENDS). The three other cycles are the *Geste de Garin de Monglane,* the *Geste de Doon de Mayence* and the *Geste féodale.* There were also romances of the Round Table, of Celtic origin, and brought into France in the 12th century. Among these we may note the Arthurian legends translated by Robert Wace, a Norman, in his *Roman de Brut* (1155); the legends of the Holy Grail; the *Tristan et Yseult* of Béroul (1150?) *(see* TRISTAN); and the *Erkc, Cligēs, Lancelot, Yvain* and *Percivale* of Chrétien de Troyes, composed 1160–80 *(see* ARTHURIAN LEGEND). There were also the *romans antiques,* such as the *Alixandre* and the *Enéas,* as well as the *romans d'aventure,* such as *Aucassin et Nicolette* and *Floire et Blanchefleur,* both from the 13th century *(see* ROMANCE). The lays of Marie de France (12th century) are related to the romances as the short story is to the novel, and are tender and melancholy rather than spirited as are earlier lays. Allegory, satire and lyric also flourished. The great allegory is the *Roman de la rose,* begun about 1230 by Guillaume de Lorris and finished about 1270 by Jean de Meun. Its satiric counterpart is the *Roman de Renart* (13th century), which employs the animal fable as allegory. Fabliaux *(see* FABLIAU), or short jocular tales in verse, were written by such poets as Rutebeuf. Lyric poetry reached exquisite refinement in the work of the troubadours of Provence *(see* PROVENÇAL LITERATURE; SESTINA; TROUBADOURS), of whom the most celebrated were William IX. count of Poitiers, Eble II, viscount of Ventadour, Bertran de Born, Arnault Daniel, Giraut de Bornelh and Sordello. These poets took as their theme a high conception of courtly love; both their subject matter and their elaborate techniques were to start innumerable echoes in western Europe *(see* SESTINA). The trouvères (*q.v.*) of northern France, less subjective, tend toward a kind of lyric narrative resembling the ballad.

French lyric poetry of the 14th and 15th centuries shows a tendency to ard fixed forms of great prosodic intricacy. This tendency is reflected in the work of Guillaume de Machaut, Eustache Deschamps, Christine de Pisan, Alain Chartier, Charles d'Orléans, and especially the *grands rhétoriqueurs*—Georges Chastellain, Jean Molinet, Guillaume Crétin (d. 1525) and Jean le Maire de Belges. These last developed the most intricate technique, so far as the mechanics of verse are concerned, that the world has ever seen *(see* BALLADE; CHANT ROYAL; RONDEAU; RONDEL). Even François Villon, the greatest French poet of the middle ages, uses elaborate verse forms in his *Little Testament* and *Great Testament.* These satirical wills are a powerful counterblast to the singers of kingly majesty and courtly love; they voice the bitter, cynical, often passionate response of the poor and the socially outcast. (For French poetry after the middle ages, *see* FRENCH LITERATURE.)

5. Spanish Poetry. — Of the Spanish epics, or *cantares de gesta,* there remain only three specimens, the *Cantar de mio Cid* (about 1140), the *Crdnica Rimada* (early 15th century) and the *Roncesvalles,* a 100-line fragment of a Spanish version of the *Chanson de Roland.* Beyond these, Spanish poetry of the middle ages falls into two main modes, the *mester de juglaria,* or mode of the minstrels, and the *mester de clerecia,* or mode of the clergy. The former is lyric or narrative; the latter is devotional or didactic, and is largely derived from French or Latin sources. The first known poet of Spain is Gonzalo de Berceo, who in the 13th century produced saints' lives and devotional pieces, the most important of which is the *Miracles of Our Lady. On the Wretchedness of Man,* discovered in the 20th century, is probably of Berceo's school; the attribution to him of a long poem on Alexander is doubtful. Other early Spanish poems include several in the convention of the debate or dispute — one between soul and body, one between two lovers, followed by a debate between water and wine; a long poem on Apollonius of Tyre, drawn from the old Milesian tale; and poems on the adoration of the Magi, on the life of St. Mary of Egypt and on Joseph and his brethren. There survive also a long

poem on the victories of Alphonso XI over the Moors, the versified moral proverbs of a Spanish rabbi, Sem Tob, and, in typical medieval fashion, a "Dance of Death." The first great Spanish poet of original and varied genius, however, is Juan Ruiz. whose *Book of Virtuous Love* is a fantastic medley of tales, fables and devotional poems unified by a history of his love affairs. His poems, together with the equally miscellaneous *Rimado de palacio* of Pedro López de Ayala, offer a fairly full view of medieval life in Spain.

Five hundred and eighty-three poems of the late 14th and early 15th centuries have been preserved in a collection made in 1445, the *Cancionero de Baena*. These are significant chiefly as showing the attempts of poets to master their medium. Better poets follow: the marqués de Santillana (1398–1458) and Jorge Manrique. (For Spanish poetry after the middle ages *see* SPANISH LITERATURE.)

6. Italian Poetry.—The Italian language was extremely slow in developing, and consequently Italian poetry gained no real impetus until about the middle of the 13th century. *(See* ITALIAN LANGUAGE, MODERN: *The Literary Language;* ITALIAN LITERATURE.) In northern Italy, at that time, Giacomino of Verona and Bonvesin of Riva composed religious narratives; in the south, love songs prevailed. A poem often accepted as the first Italian poem is the *contrasto* of Cielo Dalcamo, a debate between lover and lady in which the lover finally gains his suit. It would seem to be a relic of Sicilian popular poetry, as opposed to the literary poetry produced, in close imitation of the troubadours, at the Sicilian court of the emperor Frederick II. This courtly school, headed by Frederick himself, included among others his natural son Enzio, king of Sardinia, Pier della Vigna and Odo and Guido delle Colonne. The school has frequently been derided as imitative of an already decadent literature, but such judgment is hardly sound. The Provençal was the first Latin tongue to develop a cultivated vernacular literature, and though the language lived only three centuries, its poets have found imitators, such as Ezra Pound, even in the 20th century. As for the merits of Frederick's school: we may remember that Guido, at least, was praised by Dante; next to greatness is the praise of the great.

Italian poetry also progressed along other lines. A strong religious movement, strengthened by the rise of the Dominican and Franciscan orders, produced much devotional poetry. Some of this has been attributed—dubiously; however—to St. Francis of Assisi; but the most powerful figure of this Umbrian school is the half-mad mystic and hermit Jacopone da Todi. Tuscany fostered a comic and satiric poetry which was indebted to the Sicilian popular poets. As one might expect, its writers are antichivalric and anti-mystical. Principal among them are Folgore de San Gimignano, Rustico di Filippo, Cecco Angiolieri and Dante of Majano. The last two did not spare the great Dante Alighieri himself; Cecco called himself the goad and Dante the bull, and Dante of Majano interpreted Dante Alighieri's dream sonnet as meaning that the poet needed a purge. Guido Guinicelli led the development of a philosophic poetry of love in which the old chivalry was sublimated to the new mysticism. Allegory also .developed; the *Tesoretto* of Brunetto Latini, brief as it is, prefigures the *Divine Comedy*.

It was the Tuscan lyric school of Cino da Pistoia, Guido Cavalcanti and Dante Alighieri, however, which was to bring Italian poetry of the middle ages to high art; and even that was to be dwarfed—as indeed almost all poetry has been—by Dante's *Divine Comedy*. So much has been written about this great work that perhaps its essential character has been obscured. It is usually styled an epic; but it has little relation to Homer, nor do the principles of Aristotle's *Poetics* apply to it. It is, as Dante's letter to Can Grande della Scala makes clear, a didactic work; indeed, a scholastic treatise. Its thesis is that men must live virtuously, and this thesis is argued by showing that divine justice is everywhere omnipotent: in hell, in purgatory and in paradise. The manner of argument is inductive, from the particular to the general, and Dante continually avails himself of the *exemplum* form so popular in the medieval period—that is. the argument from a concrete instance. In such argument, everything depends upon the power with which the concrete instance is presented, and a great part of Dante's power lies in the vividness with which he conceives incidents of great emotional power, in the swiftness and surety with which he presents them and in the fourfold significance with which he invests them. Critics with a predilection for the "Inferno" have often suggested that the work might have stopped with that part, but this view reflects a basic misunderstanding of its whole design. To cease with the "Inferno" would be to reveal Divine Justice only as punitive, and to show humanity only as vicious, as well as to set aside the Christian doctrines of redemption and salvation, and thus to deny the efficacy of the Passion of Christ; in short. to deny everything to which Dante was dedicated. Too much has been said. also, of Dante's originality. What is more important is that just as the *Comedy* utilizes the vision, the *exemplum*, allegory and every other device of 'medieval literature, so it subsumes the history and mythology. the theology and philosophy, of the medieval period, and so much of antiquity as the middle ages could transmit. It means so much because what went into it had meant so much; the ages prepared it, and it remains for the ages.

The *Divine Comedy* found imitators in Fazio degli Uberti (d. 1367), who wrote a long geographical-historical poem, the *Dittamondo,* and Federigo Frezzi (d. 1416), who wrote the *Quadriregio,* a moral poem of the four kingdoms of Love, Satan, Vice and Virtue. In the former the geographer Solinus takes the place of Dante's guide Virgil, as does Pallas Athena in the latter.

The 14th century witnessed the lyric genius of Petrarch and Boccaccio, as well as much humorous and historical poetry. A number of other poets may be mentioned: Senuccio del Bene, the friend of Petrarch; Domenico Burchiello (1404–49), Giusto de' Conti (d. 1449), Franco Sacchetti and Giovanni Fiorentino. (For Italian poetry after the middle ages *see* ITALIAN LITERATURE.)

7. German **Poetry.**—Of the battle songs and epic lays of the Goths, no trace remains. In the 5th and 6th centuries, however, there gradually arose a body of legends centring around Dietrich of Berne (Theodoric), the Burgundians and Attila the Hun. Some of these materials, gathered into the *Nibelungensaga,* spread through the Teutonic nations and formed part of the Scandinavian *Edda* (*q.v.*). The lays of the *Edda* originate during the period 850–1050; but the German *Nibelungenlied* (*q.v.*) itself is of the 12th century. Charlemagne ordered the collection of popular poetry, but of this. too, there is no vestige. Beyond the fragmentary *Song of Hildebrand* (about 800), in alliterative verse: and the *Waldere,* a fragment of a translation from the Old High German into Anglo-Saxon, the national epic of the Carolingian age is irrecoverably lost.

Two biblical epics date from the 9th century. *Der Heliand* ("The Savior"), together with fragments of a translation of Genesis, may be remnants of an Old Saxon translation of the Bible commanded by Louis the Pious. The *Evangelienbuch* ("Gospel Book") of the monk Otfrid (flourished 840) is the earliest German poem in rhymed verse. The former is interesting as transforming Christ and his disciples into a king and his vassals, after the heroic Saxon mold. The *Muspilli,* a fragment of 106 lines, powerfully depicts the destruction of the world.

The 10th and 11th centuries produced little of importance in German poetry beyond certain ascetic religious pieces, such as the verse sermon *Memento mori* (about 1070) or biblical poems such as the *Ezzolied, Judith* and *The Three Youths in the Fiery Furnace,* all of about 1060. Secular poetry seems not to have flourished, except for the collection of lays known as the *Lombard Cycle*. The 12th and 13th centuries, however, are a splendid epoch in German literature. This is the age of the minnesingers (*q.v.*), chief among whom is Walther von der Vogelweide; of chivalric romances such as the *Parzival* of Wolfram von Eschenbach and the *Tristan* of Gottfried von Strassburg; of the *Heldenbuch* (*q.v.*) ("Book of Heroes"); and of the *Nibelungenlied,* besides a vast body of popular poetry.

With the end of the Swabian dynasty in the 13th century, German chivalry and chivalric poetry declined. The 14th and 15th centuries are chiefly remarkable for the establishment of a guild of poets, the Meistersingers *(see* MEISTERSINGER), which was to last until 1878, for satires such as *The Ship of Fools* and *Friar*

Amis and for beast fables such as *Reynard the Fox* (*q.v.*).

8. Old English Poetry. — The most considerable specimen of Old English poetry, and the oldest of the Teutonic epics, is *Beowulf* (*q.v.;* probably 7th-8th centuries). A fusion of history and legend, of pagan and Christian elements, it is almost certainly an art epic derived from a cycle of heroic lays, rather than a primitive folk epic. Besides *Beowulf* there survive brief epic fragments. such as *Finnsburg* and *Waldere*. A number of lyric poems survive: *Deor's Lament, Wulf and Eadwacer, The Husband's Message, The Ruin, The Seafarer, The Wanderer* and *The Wife's Complaint*. Of Anglo-Saxon Christian poets, Caedmon, who flourished about 670, is the first known and Cynewulf, in the late 8th or early 9th century, is the best. The nine lines of a hymn constitute the only authentic specimen of Caedmon's work, although *Christ and Satan, Daniel, Exodus, Genesis, Judith* and other biblical paraphrases were formerly attributed to him. Certain of Cynewulf's poems, *The Ascension, Elene, Juliana* and *The Fates of the Apostles,* are thought genuinely his because they are signed with runic characters composing his name. Other poems of less certain attribution are *Andreas, the Dream of the Rood, Guthlac* and the *Phoenix*. Besides these forms, there survive certain Anglo-Saxon riddles, charms and gnomic verses. (*See* also ENGLISH LITERATURE: *Earliest Times to Chaucer*.)

9. Middle English and Scottish **Poetry.**—The Anglo-Norman period (1066–1340) offers poetry of somewhat more diversity. There are the usual religious and allegorical works, such as the *Ormulum* (about 1200), a mixture of biblical paraphrase and verse homilies, chiefly remarkable for its adaptation of the Latin *septenarius* (seven-foot line) and for its departure from alliteration (*q.v.*) as a verse principle; *Cursor Mundi* (about 1300), another scriptural poem; and *The Pricke of Conscience* by Richard Rolle de Hampole. There are also poems in the debate form so popular in medieval Europe, such as the *Debate Between Body and Soul* and *The Owl and the Nightingale*. There are also remarkable lyrics, such as "Alysoun," "The Cuckoo-Song" and "The Lenten (Spring) Song," and political and social satires such as *The Fox and the Wolf* and *The Land of Cockaygne*. *Brut,* adapted by Layamon from the *Roman de Brut* of Robert Wace, is a notable landmark in the history of the metrical romance. A copious literature of ballads has survived from the 13th and 14th centuries.

The age of Chaucer (1340–1400) produces nothing so rich as that poet's greatest work, *The Canterbury Tales* (*see* CHAUCER, GEOFFREY), yet it contains other notable poets: John Barbour, the first Scottish poet of merit; William Langland, whose *Piers Plowman* is thought the greatest social satire of the period; John Gower; and the authors of *Pearl* (*q.v.*) and of *Sir Gawayne and the Grene Knight* (*see* GAWAIN). The 15th century saw the rise of many imitators of Chaucer: Thomas Occleve (about 1368–1450), John Lydgate and Stephen Hawes in England; King James I of Scotland, Robert Henryson, William Dunbar, Gavin Douglas and Sir David Lyndsay in Scotland. Perhaps the most original poet of the period is John Skelton. (*See* also SCOTTISH LITERATURE.)

10. Poetic Drama. — Medieval European poetic drama is so complex a topic that little can be said of it here, except that it followed much the same pattern of development as had the drama of ancient Greece (*see* DRAMA: *Medieval Drama*). Liturgical in origin, it arose out of antiphonal uses of dialogue in the Christmas and Easter services. The earliest specimen of this is the *Quem quaeritis* trope. probably of the 9th century. Dialogue presently became dominant, and longer actions were represented; subsequently drama became differentiated into distinct forms, such as the mystery, the morality, the miracle play and various folk forms. It was not until the middle of the 16th century, however, that England produced its first true comedy, *Ralph Roister Doister* (performed about 1554), by Nicholas Udall, and its first true tragedy, *Gorboduc* (performed 1562, new style), by Thomas Sackville and Thomas Norton. Early English tragedy is modeled upon the tragedies of Seneca, which had been popular in the middle ages, though they had not been performed, and which were translated into English 1559–81.

ENGLISH AND AMERICAN POETRY FROM THE RENAISSANCE TO 1900

1. 16th Century. — The situation of English poets in the 16th century had its difficulties as well as its advantages. On the favourable side, poets were supplied—by antiquity, by the middle ages and even by certain oriental literature—with a vast variety of subjects, the rich possibilities of which have not even been exhausted by the 20th century. Poets had, moreover, an almost equally rich variety of models for imitation, as well as a body of critical and poetic theory greatly augmented and broadened by the recent recovery of important works such as the more humanistic rhetorical treatises of Cicero. the *Institutes* of Quintilian and the *Rhetoric* and *Poetics* of Aristotle (*see* RHETORIC; CRITICISM). On the other hand: they were faced, like the poets of continental Europe, with problems arising from the attempt to use the vernacular language as a medium of literature. They had to determine whether the vernacular was suitable for serious literary effort, what style of language was appropriate to a given literary form, whether accent or quantity was the proper basis for English verse, whether rhyme was admissible, what was and what mas not correct usage or even pronunciation. But the problem of "Englishing" the subjects supplied them went beyond questions of mere language; the problem involved also the translation of what had been significant for very different cultures into things significant in terms of the customs and manners, the emotions and beliefs of England.

Although these problems remained the centre of critical dispute for some time, they were resolved by poetic practice rather than by theory, and chiefly by the selection of certain models. Thus Thomas Sackville's *Induction* (1563) to *A Mirror for Magistrates* followed Boccaccio; Sir Thomas Wyat and Henry Howard, earl of Surrey (*see* SURREY, HENRY HOWARD, EARL OF), based upon the love sonnets of Petrarch, thereby establishing a perennial convention of English poetry; George Gascoigne imitated a great number of foreign models, principally Ariosto. A landmark in English poetry is Tottel's *Miscellany* (1557), which set the vogue for a great many similar collections. Translation flourished; by 1600 many of the great poetic works of antiquity, and many even of the contemporary literatures: had been cast into English verse. The sonnet (*q.v.*), the song (*see* SONG: *Early Song* and *English Song*), the pastoral (*q.v.*), the heroic poem, the romantic epic and the verse drama were all brought to high art in Elizabeth's reign.

The last decade of the 16th century alone produced the notable sonnet sequences *Astrophel and Stella* (1591; 1598) by Sir Philip Sidney; *Diana* (1592) by Henry Constable; *Delia* (1592) by Samuel Daniel; *Idea's Mirror* (1594) by Michael Drayton; the sonnets of Shakespeare (written about 1592–98, published 1609); and the *Amoretti* of Edmund Spenser (1595.) More than 20 songbooks were completed from 1585 to 1605, including the exquisite *Book of Airs* (1601) by Thomas Campion. The pastoral was represented by *The Shepherd's Calendar* (1579) of Edmund Spenser, the eclogues in Sidney's *Arcadia* (1590) and the pastoral sonnets of Drayton. Heroic poems on classical themes included *Hero and Leander,* begun by Christopher Marlowe before 1593 and finished by George Chapman in 1598, and Shakespeare's *Venus and Adonis* (1593) and *The Rape of Lucrece* (1594). Narrative poems on historical and national themes included *Albion's England* (1586) by William Warner; the *Complaint of Rosamund* (1592) and the *Civil Wars of York and Lancaster* (1595–1609) by Daniel; *The Barons' Wars* (1603), *England's Heroical Epistles* (1597) and *The Poly-Olbion* (1612–22) by Drayton. The romantic epic reached its height in the didactic moral allegory of *The Faerie Queene* of Spenser (1590–1609).

2. Elizabethan and Jacobean Verse Drama. — Greatest of all achievements, however, was the verse drama, brought to rapid development by John Lyly, Thomas Kyd, Robert Greene. George Peele and Christopher Marlowe and culminating in the tremendous works of William Shakespeare. In a few years the drama progressed from bombastic declamation, melodramatic or crudely comic plots and faltering or monotonous versification to works of incredible power and perfection. Cntil the closing of the English theatres by the puritans (1642), nearly every form was exploited by Shakespeare and his contemporaries or successors: Ben Jonson, George Chapman. Thomas Dekker, Thomas Middleton, Thomas Heywood, Francis Beaumont. John Fletcher (*see* BEAUMONT AND FLETCHER). Philip Massinger, John Webster. John Marston, John Ford; Cyril Tourneur and James Shirley. The comedies of Jonson and the tragedies of Webster almost bear comparison with those of Shakespeare himself.

3. 17th Century. — The 17th century also had its poets of talent or genius. Some, like the so-called Spenserians, followed the model of an English poet; thus the school of Spenser includes Giles Fletcher, whose *Christ's Victory and Triumph* (1610) anticipates John Milton's *Paradise Lost;* his brother Phineas, William Browne, George Wither and William Drummond of Hawthornden. Others, like John Donne and John Milton, based chiefly upon foreign models. The "metaphysical school," of which Donne is usually designated as the founder, includes such men as George Herbert. Richard Crashaw, Henry Vaughan, Thomas Traherne, William Habington and Francis Quarles. There were also the poets of gallantry, "Cavalier poets": Thomas Carew, Sir John Suckling, Richard Lovelace and Robert Herrick.

Brilliant and profound as had been the best poetry of the Elizabethan and Jacobean periods, it seemed "incorrect" to some who followed as compared with the works of antiquity or even of contemporary France, and a "classical reaction" set in. Aimed chiefly in the beginning at producing a more coherent, precise and restrained diction and a more regular and polished versification; it gradually affected every aspect of the poetic arts. The heroic couplets of Edmund Waller and of John Denham evoked extraordinary admiration at their finish and smoothness; on similar grounds, Abraham Cowley was considered the equal of Chaucer and Spenser and the superior of Milton. These judgments are likely to seem absurd unless their historical context is considered. They had at least this foundation, that an age had passed, and with it. the emotional attitudes out of which Elizabethan poetry had sprung; that the language itself was altering, and the old formulas would serve no longer; and that the changing temper of men was to require a style at once more moderate and more easy for its expression. Though this "classical" tendency was to find its justification as well as its culmination in the genius of Alexander Pope in the 18th century, two of the greatest poets of the latter 17th century, John Milton and Andrea Marvell, remained free of it. Marvell followed his own course; Milton forged for himself the mighty style of *Paradise Lost* and *Samson Agonistes.* But another great poet, John Dryden, perhaps the equal of Milton himself, took the newer road of Edward Fairfax and Waller.

4. The Restoration. — The Restoration period in many respects foreshadows the 18th century. The serious lyric declined! as the sonnet had long before; Spanish and French influences, rather than Italian, dominated tragedy, which slowly weakened into the bombastic heroic play or the pathetic tragedy; comedy, satire and didactic poetry flourished; and much that was thought and felt called for prose expression rather than poetic. Yet no one can justly complain that poetic force and skill is wanting in such satirists as Dryden and Samuel Butler or such dramatist-poets (they were accounted such, even though some happened to write in prosej as Dryden, Thomas Otway, Nathaniel Lee, Nicholas Rowe, Sir George Etherege, William Wycherley, William Congreve, Sir John Vanbrugh and Sir George Farquhar. Brilliant as Restoration drama was, its moral laxity brought about attempts to reform it. Most notably, the *Cato* of Joseph Addison was an effort to bring English tragedy into conformance with the standards of ancient tragedy, as the comedies of Sir Richard Steele were efforts to effect the moral reform of comedy.

5. 18th Century. — The poetry of the 18th century is still viewed in the 20th century with contempt or indifference by those who conceive of poetry in terms of the 19th-century romantic poets Shelley and Keats; yet this low estimate results, not from the faulty art of Pope and his followers, but from the historical accident that they were succeeded by brilliant exponents of a poetry almost totally opposite to theirs. Eighteenth-century poetry is essentially didactic rather than imitative, and chiefly moralistic or satiric in its didacticism. It is not unemotional, but it is less interested in the direct expression of emotion than in the rational interpretation of emotion. It is not indifferent to the beauty of nature — what poets, indeed. have talked more continually of nature? — but it sets an intellectual response to nature above an emotional one, and in consequence it is a poetry of ideas rather than images. It is not impersonal. but it is urbane, and its urbanity demands the observance of decorum. It is concerned with certain aspects of human nature and condition, the romantics with others. We can see the achievement of Pope and his disciples, not by comparing them with poets of an entirely different order, but by measuring them against their own kind.

The great poet of the first half of the century is beyond question Alexander Pope, whose *The Rape of the Lock* and *Dunciad* remain unmatched as examples of mock-epic satire, and whose *Moral Essays* and *Essay on Man* are monuments of didactic poetry, not because of what they say, but because they say it so well. It is perhaps worthwhile to observe that next to Shakespeare the most frequently quoted of English poets is Pope. Matthew Prior, John Gay and Thomas Parnell are only less polished than Pope, and their work contains accents of gaiety or gravity not to be found in their master. In the second half of the century. Samuel Johnson and Oliver Goldsmith continued the "classic" tradition with distinction.

It must not be thought, however, that 18th-century poetry is wholly uniform with the school of Dryden and Pope. Milton and Spenser were the models of many poets who, though they are contemporary with Pope or Johnson, are of so different a vein that they have usually been classified as precursors of the romantics. Thus Allan Ramsay anticipates Robert Burns; John Dyer anticipates William Wordsworth; Milton was imitated by Parnell, Edward Young and Robert Blair; Spenser, by William Shenstone, Mark Akenside (*qq.v.*), Joseph Warton and James Beattie; James Thomson imitated Milton in his *Seasons,* Spenser in his *Castle of Indolence.* James Macpherson offered his poems as a translation of Ossian, a supposed Gaelic epicist, and Thomas Chatterton offered his as the work of a monk named Rowley. William Cowper and George Crabbe resemble Wordsworth in their feelings toward men and nature. William Collins, Thomas Gray, Robert Burns and William Blake are often considered outright romantics, figures of the 19th century rather than the 18th. The *Lyrical Ballads* (1798) of Wordsworth and Coleridge were themselves productions of the 18th century; Coleridge wrote "Kubla Khan," the first part of "Christabel" and "The Ancient Mariner" in 1797–98, and the great period of Wordsworth's production was over shortly after 1800.

6. **"Classic"** and "Romantic." — The distinction between "classic" and "romantic" is of such long establishment that it can scarcely be abandoned, but it has come to mean almost anything and everything. The history which lies behind this historical classification is much clearer.

Poetry, like all arts, takes its character from the models and traditions to which it attaches. Dryden, Pope and their followers modeled upon French poets who seemed to them to have best realized the classic tradition of antiquity — Roman antiquity primarily; the precursors of the romantics continued to base upon English models; the romantics themselves either continued the English tradition or modeled, like Coleridge and Scott, upon German poets who themselves imitated the English ballads collected by Thomas Percy in his *Reliques* (1765). One thing more must be said: the middle ages, long held in contempt, were gradually being returned to esteem, and their poetry and legend revealed values that made them at least a quarry for subject matter, and even possibly models for emulation. In England the romantic movement was primarily the return, after a brief and brilliant excursion in foreign realms, to native English traditions.

7. Romantic and Victorian Poets. — Though eminent romantics like Byron still followed the example of Pope when the occasion demanded, the poetry of the 19th century is on the whole different from that of the 18th, and its differences consist chiefly in that it involves an enlargement of the subject matter, of techniques and devices and of forms. It depicts processes of the imagination and of the emotions as well as those of discursive reasoning; it presents images as well as ideas. It addresses itself to the sensibilities as well as to the reason of the reader. It cultivates imitative as well as didactic forms. It finds new uses for old devices or old verse patterns — ballad conventions, for instance, are employed with great diversity, and the sonnet finds uses, lyric and even narrative, undreamed of by the few 18th-century sonneteers. Verse itself became extremely various; rapid narrative and certain kinds of lyric required a rhythmic lightness and speed beyond the possibilities of the heroic couplet, and in consequence, anapest, dactyl and amphibrach flourished in abundance *(see* VERSE). The classic distich itself relaxed its strictness and, in more plastic form, served as the medium for such narratives as *Endymion.*

Nearly every major poet of the century either made technical advances or gave a new significance and vitality to what had been supposed outworn. Thus William Wordsworth and Samuel Taylor Coleridge brought the ode (*q.v.*), the reflective lyric and the ballad to new heights, evoking tones from them that had not been heard before; Robert Southey revived the epic; Sir Walter Scott renovated the ballad and the heroic lay; George Gordon Byron, Lord Byron, carried the lay still further and enriched it with oriental themes, and, in *Don Juan,* created a new kind of romantic epic. Percy Bysshe Shelley produced a new order of philosophical lyric drama in *Prometheus Unbound,* and John Keats gave the narrative romance, in "The Eve of St. Agnes," unprecedented richness and subtlety. Alfred Tennyson brought nearly every species of poetry to technical perfection, and his *The Idylls of the King* remains the most notable achievement in epic in modern times. Robert Browning produced "dramatic lyrics" which had the sharp specificity, in character and circumstances, of drama itself; and his *The Ring and the Book* introduced a device which was to have profound influence upon later prose fiction — the device of viewing characters and incidents from many different points of view. Matthew Arnold and Gerard Manley Hopkins made extraordinary innovations in versification.

These are the great poets of the century; but the era abounds in minor poets of extreme distinction. such as Walter Savage Landor, Thomas Moore, George Darley. Thomas Lovell Beddoes, Elizabeth Barrett Browning, Dante Gabriel Rossetti, Christina Rossetti, William Morris and Algernon Charles Swinburne. Almost half of these would in nearly any other century be accounted great; and the last, Swinburne, is generally considered the most brilliant metrical virtuoso of the English language. George Meredith and Thomas Hardy, though famous primarily as novelists, are also poets of extraordinary merit.

The poets of the 1890s, whatever their virtues, are far inferior in invention and force. Principal among these were Oscar Wilde, Ernest Dowson, Lionel Johnson, Francis Thompson and Stephen Phillips. Phillips briefly enjoyed a reputation as a poet of the first magnitude. worthy of comparison with the great Elizabethans, but is now almost forgotten. Indeed, with the exception of Wilde, whose prose dramas are still popular, these poets are now remembered only for one or two pieces.

After the decline of poetic drama in the 18th century, the 19th century saw a resurgence. Nearly all the major poets composed tragedies; but these, even at their best, are eminently unsuited for the stage; and remain closet dramas merely. It is quite possible that the failure of these works, and the conspicuous success of prose plays, produced the general prejudice against verse in the modern popular theatre.

8. American Poetry. — American poetry, from colonial times to the end of the 19th century, offers little that will bear comparison with English Anne Bradstreet (1612–72), Edward Taylor (1644–1729) and Philip Freneau are the most important of the early poets. William Cullen Bryant. Ralph Waldo Emerson, Henry Wadsworth Longfellow, John Greenleaf Whittier. Oliver Wendell Holmes, Edgar Allan Poe, James Russell Lowell, Walt Whitman, Emily Dickinson and Sidney Lanier are the most famous American poets of the 19th century. Of these, perhaps only Emerson, Poe, Whitman and Dickinson are of remarkable merit Trumbull Stickney (1874–1904), William Vaughan Moody and Richard Hovey came to some fame, but had little effect on most readers by mid-20th century. Poe, Whitman and Dickinson alone anticipate the brilliant outbreak of poetic genius in the 20th century.

V. ENGLISH AND AMERICAN POETRY OF THE 20TH CENTURY

William Butler Yeats affirmed that England produced more good poets in the 20th century than in any period of the same length since the 17th century; Conrad Aiken made a similar claim for America. 4s one might expect, many distinguished poets remained within the English romantic tradition; on the whole, however, perhaps the most interesting and influential work was produced by poets who found their models in other traditions, or who experimented to produce a poetry as new as possible. Indeed, an insistence on the distinctively modern can be found in all the arts of this period. The frequent manifestoes and programs issued by artists reflect the belief that science and technology had produced a civilization which was unique, and that new forms of art must arise to express it.

Twentieth-century poetry must, like any other, await the verdict of other times than its own. Certain things, however, are clear already, as matters of fact rather than of judgment. It was a poetry innovative to an unprecedented degree, and its innovations affected every aspect, from subject matter to style and versification. No other poetry exhibits so wide a variety of techniques; no other shows such rapid interplay between poetry and the other arts. The discovery of a new device in one art led almost instantly to its adoption, where this was possible, in all others.

The causes underlying all this innovation, however. lie far deeper than matters of poetic method. They lie in the fact that the 20th century was, and is, historically self-conscious, peculiarly aware of itself as a historical epoch and as an epoch distinct from any that has gone before. Doubtless this sense of modernity was due in part to mechanical and industrial progress, but man himself had changed more than his machines. The complex structure of emotions, beliefs and moral attitudes on which the arts depend for their effects, and on which, indeed, human conduct at a given time is predicated, had changed significantly since mid-Victorian times. The conception of man, human society and the universe itself had altered; the rupture with artistic tradition was a token of a rupture with a far deeper and older tradition of human nature and conduct.

The new psychology, in particular the Freudian, presented man as far more irrational than rational, and in questioning the principles of motivation and moral responsibility, reinterpreted human action in such fashion as to challenge the very foundations of morality. Comparative anthropology cast doubt on the uniqueness of the Christian religion by emphasizing its similarity with primitive pagan cults; and the comparative study of customs and mores exhibited contradictions so marked as to suggest that standards of right and wrong were themselves only conventional. The natural sciences widened the breach between religion and science which had already been widening in the 19th century. In short, a system of values was conceived either as threatened, or as already in hopeless disrepair. Much of the best modern literature stems from a search for a new system of values; and the spiritual malaise which it expresses has its primary cause in the feeling that 20th-century man was pretty much on his own, unhelped by the past, and confronted with problems peculiar to his age. The true and the false, the beautiful and the ugly, the good and the bad, had to be distinguished anew.

The poetry which was created in these circumstances was bound to be analytic, experimental and various. It is a poetry which permits of no simple description and which exhibits no very clear patterns, and it ranges from the extreme of the objective to the extreme of the subjective. Schools, movements and poetic programs abound; but with few exceptions — suth as the Imagist group of the second decade and the Marxist groups in the fourth and fifth — the dominant influences are exerted by particular poets, such as Ezra Pound, T. S. Eliot, W. B. Yeats and W. H. Auden. These poets affected strongly both the theory and the practice of poetry, but their influence, so far as their better followers were concerned, resulted in variety rather than uniformity.

The modern period began, overtly at least, in a general reaction against conventional poetic diction, versification, technique and subject matter, and shortly thereafter advanced to a general decision to rediscover the principies, or to find new principles, on which a valid modern poetry might be written. Even in the first decade Harold Monro and others in England, Ezra Pound and others in America, protested against the prolixity, vagueness, rhetoricism and vapidity of conventional verse. A number of nearly simultaneous events lent great impetus to the pressure for a new poetry: the publication of the first anthology of "Georgian poets." in 1911. by Monro, followed by his founding, a year later, of the Poetry Bookshop; the rise of the Imagist group, and in the same year. the founding of Poetry: a *Magazine* of *Verse,* in Chicago, by Harriet Monroe. In retrospect, the last seems most important. From the first, it sought to discover new talent and to encourage progressive writing, and by mid-century it had published nearly every English and American poet of distinction, "discovered" many of these and broadened the reputation of many more.

The Georgian poets were not a school. The group included such sharply different poets as W. H. Davies. Walter de la Mare. Lascelles Abercrombie, Ralph Hodgson (1871–) and Rupert Brooke. The last later fell into some disfavour, after a period of extraordinary popularity; nevertheless, he must be reckoned among the early moderns because of his efforts to extend poetic subjects to include the ugly, and because of his deliberate deflation. in certain of his poems, of stock romantic attitudes.

The Imagists had something of a common program in their insistence on certain poetic reforms and on accurate images of the external world. The group included Amy Lowell, Ezra Pound, "H. D." (Hilda Doolittle; 1886–1961), F. S. Flint, John Gould Fletcher and others. Their use of free verse emphasized the importance in poetry of organic rhythms of speech as opposed to mere metre and rhyme; the extreme concision and brevity of some of their poems—especially those in which Chinese or Japanese influence is apparent—greatly affected the conception of poetic style. The restriction of poetry to imagistic techniques proved too severe, however, and Pound, among others. quickly forsook imagism for methods that permitted a greater variety of effect.

The second and third decades saw the rise of a host of new or newly famous poets. Besides those already mentioned—and besides those already well known, such as Robert Bridges, A. E. Housman, John Masefield and Rudyard Kipling, England produced James Elroy Flecker. D. H. Lawrence. Robert Graves, Edward Thomas (1878–1917), Isaac Rosenberg (1890–1918), Wilfred Owen (1893–1918), Wilfrid Wilson Gibson (1878–1962). Edmund Blunden (1896– j, W. J. Turner (1889–1946), Richard Aldington (1892–), Edith Sitwell (1887–), Sir Osbert Sitwell (1892–) and Sacheverell Sitwell (1897–). (*See* also ENGLISH LITERATURE: Twentieth *Century.*) The United States produced E. A. Robinson. Edgar Lee Plasters. Vachel Lindsay, Robert Frost. Carl Sandburg, Edna St. Vincent Millay, Elinor Wylie, Sara Teasdale, Conrad Aiken (1889–), E. E. Cummings (1894–1962). William Carlos Williams (1883–). Robinson Jeffers (1887–1962), T. S. Eliot, Wallace Stevens (1879–1955), Marianne Moore (1857–), Archibald MacLeish (1892–), John Crowe Ransom (1888–), Hart Crane, Allen Tate (1899–), Léonie Adams (1899–), Louise Bogan (1897–) and many others. (See AMERICAN LITERATURE: *The* **New** Poetry.)

Ireland as well had undergone a literary revival after the stimulation of Standish O'Grady's History of *Ireland* (1878–80), and provided many poets, principal among them "Æ" (George William Russell). Katherine Tynan Hinkson (1861–1931), James Stephens. Francis Ledwidge (1891–191j) and, above all, the great William Butler Yeats.

World War I had marked effects upon poetry as upon all else; perhaps the most noticeable are a bitter realism, if not cynicism, a growing introspectiveness, an extreme dislike of obvious thought or "easy emotion" and a preoccupation with disillusion and despair. Whatever optimism had accompanied scientific and technological progress rapidly faded. A sense of chaos, a sense that civilization was disintegrating, underlies much of the reflective poetry of the time. T. S. Eliot's The *Waste* Land (1922) and "The Hollow Men" (1925), violent as were the outbursts against them, were interpreted as epitomizing the feeling of the generation. Other influences affected the directions which poetry was to take. The publication by Robert Bridges, in 1918, of the Poems of Gerard Manley Hopkins made known a poet of the highest eloquence, whose experiments in style and versification gave a new turn to innovations already in progress. The Freudian and Jungian systems of psychology extended the conception of human experience to the subconscious and unconscious mind. The former contributed a symbology. the latter a mythology, which gave modern literature both a method of interpreting and a method of expressing aspects of psychological experience hitherto inaccessible. A resuscitation of interest in Elizabethan and "metaphysical" poets brought about a return to these as models. Most important, however, was the growing influence of the 19th-century French symbolists (see SYMBOLISTS, THE) and their later disciples, such as Guillaume Xpollinaire and Paul Valéry.

It is a matter of some curiosity that while Pound and Eliot had repugned the American poetic tradition, and had in fact become expatriates in the apparent conviction that American culture had little if anything to offer, certain French poets, beginning with Baudelaire, had been greatly impressed with American poets, with Poe in particular. Nearly all the important symbolists read Poe or Whitman with excitement, and many translated and imitated them. Both Pound and Eliot now fell under the spell of an American tradition in a French version. The French version, however, contained elements that the American original did not. It was suggestive rather than explicit; it was concerned with the emotional aura surrounding objects rather than with objects themselves; it was predicated upon the existence of mysteries inaccessible to science and intellect, and its techniques were techniques for the revelation of those mysteries. It seldom presented a literal surface meaning; it depended upon suggestion. implication and allusion; it began where allegory. conventional metaphor and conventional symbol left off. As practised by Yeats, Pound and Eliot. it exerted enormous influence upon English poetry; influence of uhich we have not yet seen the end.

If symbolist poetry, with certain exceptions, had elements of otherworldliness. there were other kinds of poetry that did not. Particularly as a result of the great depression, many poets made themselves the voices of economic, social and political dissatisfaction. In the 1930s Kenneth Fearing (1902–1961), Muriel Rukeyser (1913–) and others in the United States, W. H. Auden (1907–), Stephen Spender (1909–), Cecil Day Lewis (1904–), Louis MacNeice (1907–) and others in England composed poems which in style. versification and theme had nothing to do with the poetry of which Yeats and Eliot had become the chief exemplars. In most instances they based upon poets like John Davidson, Thomas Hardy or Wilfred Owen; the problems which they confronted were practical problems, and they sought practical solutions to them. They were critics of uhat they took to be a sick society, and they were not averse to making poetry openly didactic, or, in the case of such as were Marxists, propagandistic.

World War II wrought changes in belief and feeling which produced a reaction against this poetry as well. A host of new schools arose; different as these were in character, they had in common a greater concern with individual feelings and ideas. German models —in particular, Johann Holderlin and Rainer Marie Rilke—now supplanted the French.

The 1940s brought to wide attention Karl Shapiro (1913–), Elizabeth Bishop (1911–). Richard Eberhart (1904–), Delmore Schwartz (1913–), John Berryman (1914–), Randall Jarrell (1914–), Robert Lowell (1917–), Richard Wilbur (1921–) and Anthony Hecht (1923–) in the United States; in England. Vernon Watkins (1906–), George Barker (1913–), W. R. Rodgers (1911–), Alex Comfort (1920–), Lawrence Durrell (1912–), Roy Fuller (1912–), F. T. Prince (1912–) and. above all, Dylan Thomas (1914–53). The latter produced a mysterious, violent and eloquent poetry which led many to consider him the greatest lyric poet of the age. Many considerable poetic talents began to appear in the 1950s; perhaps Philip Larkin in England and Isabella Gardner in America were the most promising. A number had not, in the 1950s, received the acclaim they deserved; we may mention Jean Garrigue, Stanley J. Kunitz. Reuel Denney and Kenneth Rexroth, all U.S.; Kathleen Raine, Keidrych Rhys, Ruthven Todd, Hugh MacDiarmid and others in Great Britain.

Seen as a whole. 20th-century poetry exhibits certain striking characteristics, It began in antiromanticism; yet, despite T. E. Hulme's prediction in 1913 that a classical age was at hand. the poetry of the period remained essentially romantic; it simply passed from overt to covert romanticism, from romantic exuberance to romantic asceticism. It extended enormously the conception of human 'experience. and with it the subject matter of poems; but certain kinds of subject matter dropped out—most notably the heroic and tragic—and certain poetic forms disappeared almost altogether. There is nothing that can strictly be called epic; indeed, with the exception of Bridges' *The Testament of Beauty,* Stephen Vincent Benét's *John Brown's Body,* Pound's *Cantos,* MacLeish's *Conquistador,* Spender's *Vienna* and a few other pieces, there was a general dearth of long poems. Despite notable plays in verse by Yeats, Eliot, MacLeish, Jeffers. Christopher Fry and others, there was no real restoration of verse drama to the stage; there were simply individual successes. Moreover, many of the verse plays were either too brief or too stylized to find production outside of the "art theatre." The finest poets of the period were highly specialized. even esoteric. Yeats. Frost. Eliot, Stevens, Moore, Auden and Thomas are of almost unquestionable greatness, but whatever their genius. they are poets of very limited range as compared with Chaucer, Shakespeare and Browning, and some of them are so difficult that. once their vogue is past, they may quite possibly appeal to a very restricted audience only.

The period began with protests against poetic "artificiality" and with demands for a more "natural" language; but the greater part of its productions were highly stylized and artificial, and far removed from common speech. It began with the highly experimental, but it gave signs of a return to extreme formalism. It began with a clamour for nationalism, even regionalism; it turned to cosmopolitanism and internationalism. Save for differences of language, the U.S. or British poet of the mid-20th century difiered very little from poets writing almost anywhere else on the face of the earth. Indeed, it could plausibly be maintained that the unity of culture and tradition—the disruption of which so much troubled the poets of the earlier decades—had simply been replaced by the unity of a cosmopolitan. an international culture; that the chaos and disorder were merely part of a reintegration toward a new order, in which poets would draw, not merely from the traditions of their own society and nation, but also from international sources.

See also separate biographies of poets. (E. J. O.)

POEY Y ALOY, FELIPE (1799–1891), Cuban naturalist, author of a ten-volume *Catálogo razonado de los peces cubanos,* was born in Havana on May 26, 1799. He received his degree in law at the University of Madrid (1820) but abandoned practice to devote himself to natural history. He returned to Cuba and formed a collection which he carried back to Paris. There he remained until 1833, publishing many articles and his *Centurie de Lepidopteres de l'ile de Cuba* (1832).

Poey became professor of zoology and comparative anatomy in the University of Havana in 1842 and in 1863 was appointed to the chair of botany, mineralogy and geology. From 1873 until his death at Havana on Jan. 28, 1891, he was professor of philosophy and belles-lettres.

Poey's masterpiece is the *Catálogo,* an atlas describing 800 tropical fish, about half of which he first made known to science.

POGGIO (1380–14jg). Gian Francesco Poggio Bracciolini, Italian scholar of the Renaissance, was born in 1380 at Terranuova, a village. in the territory of Florence. He studied Latin under John of Ravenna and Greek under Manuel Chrysoloras. His distinguished abilities and his dexterity as a copyist of manuscripts brought him into early notice with the chief scholars of Florence. Coluccio Salutati and Niccolo de' Niccoli befriended him, and in the year 1402 or 1403 he was received into the service of the Roman curia. His functions were those of a secretary; and, though he profited by benefices conferred on him in lieu of salary, he remained a layman to the end of his life. It is noticeable that, while he held his office in the curia through that momentous period of 50 years which witnessed the councils of Constance and of Basle and the final restoration of the papacy under Nicholas V. his sympathies were never attracted to ecclesiastical affairs. Nothing marks the secular attitude of the Italians at an epoch which decided the future course of both Renaissance and Reformation more strongly than the mundane proclivities of this apostolic secretary, heart and soul devoted to the resuscitation of classical studies amid conflicts of popes and antipopes, cardinals and councils, in all of which he bore an official part. Thus, when his duties called him to Constance in 1414, he employed his leisure in exploring the libraries of Swiss and Swabian convents. The treasures he brought to light at Reichenau, Weingarten and, above all, St. Gall restored many lost masterpieces of Latin literature. and supplied students with the texts of authors whose works had hitherto been accessible only in mutilated copies. In one of his epistles he describes how he recovered Quintilian, part of Valerius Flaccus and the commentaries of Asconius Pedianus at St. Gall.

Manuscripts of Lucretius, Columella, Silius Italicus, Manilius and Vitruvius were unearthed, copied by his hand and communicated to the learned. Wherever Poggio went he carried on the same industry of research. At Langres he discovered Cicero's *Oration for Caecina,* at Monte Cassino a manuscript of Frontinus. He also could boast of having recovered Ammianus Marcellinus, Nonius Marcellus, Probus, Flavius Caper and Eutyches. If a codex could not be obtained by fair means, he was ready to use fraud. as when he bribed a monk to abstract a Livy and an Ammianus from the convent library of Hersfield.

Poggio embraced the whole sphere of contemporary studies, and distinguished himself as an orator, a writer of rhetorical treatises. a panegyrist of the dead, a violent impugner of the living, a translator from the Greek. an epistolographer and grave historian and a facetious compiler of fabliaux in Latin. Of his moral essays it may suffice to notice the dissertations *On Nobility, On Vicissitudes* of *Fortune, On the Misery of Human Life, On the Infelicity of Princes* and *On Marriage in Old Age.* These compositions belonged to a species which, since Petrarch set the fashion, were very popular among Italian scholars. They have lost their value, except for the few matters of fact which are embedded in a mass of commonplace meditation, and for occasional brilliant illustrations.

Poggio's *History of Florence,* written in avowed imitation of Livy's manner, requires separate mention, since it exemplifies by its defects the weakness of that merely stylistic treatment which deprived so much of Bruni's. Carlo Aretino's and Bembo's work of historical weight. A somewhat different criticism must be passed on the *Facetiae,* a collection of humorous and indecent tales expressed in such Latinity as Poggio could command. This book is chiefly remarkable for its unsparing satires on the monastic orders and the secular clergy.

Among his contemporaries Poggio passed for one of the most formidable polemical or gladiatorial rhetoricians; and a considerable section of his extant works are invectives. One of these, the *Dialogue Against Hypocrites,* was aimed in a spirit of vindictive hatred at the vices of ecclesiastics; another, written at the request of Nicholas V. covered the antipope Felix with scurrilous abuse. But his most famous compositions in this kind are the personal invectives which he discharged against Filelfo and Valla. All the resources of a copious and unclean Latin vocabulary were employed to degrade the objects of his satire; and every crime of which humanity is capable was ascribed to them without discrimination. In Filelfo and Valla, Poggio found his match; and Italy was amused for years with the spectacle of their indecent combats.

About the year 1452 Poggio finally retired to Florence, where he was admitted to the burghership, and on the death of Carlo

Aretino in 1453 was appointed chancellor and historiographer to the republic. His declining days were spent in the discharge of his honourable Florentine office and in the composition of his history. He died in 1459.

Poggio's works were printed at Basle in 1538, "ex aedibus Henrici Petri." Shepherd, *Life of Poggio Bracciolini* (1802), is a good authority on his biography. For his position in the history of the revival, *see* Voigt, *Wiederbelebung des classischen Alterthums*, 3rd ed. (1893); Symonds, *Renaissance in Italy* (1875–86). (J. A. S; X.)

POGROM is a Russian word that became naturalized in other languages about 1903–05. Originally the word for "storm," pogrom came in the course of time to mean any devastation or desolation; then specifically the planned rapine and murder of helpless Jews by their government-led or government-approved Russian neighbours; later, devastation of Jews by their neighbours in other countries (conspicuously Rumania, Poland and Nazi Germany); and finally such devastation anywhere of any helpless, undefended people. Examples include U.S. Negroes as victimized by lynch mobs in the south or in such cities as Chicago, Ill., and Detroit, Mich.; strikers attacked, with the active approval or passive sympathy of police power, by gunmen hired for the purpose; multitudes gathered to protest some grievance shot and ridden down as in the case of the St. Petersburg crowd before the Winter palace in 1905; and the massacre of Hindus at Amritsar, India, in 1919. Massacre is sometimes used as a synonym for pogrom, but pogrom includes looting and destruction of property as well as slaughter of innocents. Looting and destruction without slaughter is called dry pogrom.

The occasion which established pogrom in the world's languages as a contribution of tsarist culture was the devastation of the Jews of Kishinev, in the Ukraine, in April 1903. Widely discussed and condemned throughout the civilized world, it was one pogrom in a series implementing an anti-Jewish program devised by Constantine Pobedonostsev, procurator of the Holy synod under the reactionary tsar Alexander III, and executed by successive ministers of state, of whom Viatscheslaf Plehve was outstanding. Faced by popular discontent and intellectual agitation, the bureaucracy found in the Jews a convenient scapegoat for the government's failures. The Kishinev pogrom was followed by that at Gomel, Russia, in Aug. 1903. The conscription for the unpopular war with Japan brought continuous "mobilization pogroms"; Russia's defeat and the abortive revolution of 1905 brought the "patriotic pogroms" led by the Black Hundreds with the slogan: "The enemies of Christ are the only enemies of the Tsar."

BIBLIOGRAPHY.—S. M. Dubnow, *The History of the Jews in Russia and Poland From the Earliest Times Until the Present Day*, (1916); Heinrich Gratz, *The History of the Jews*, 7 vol.; *R.* G. Horniman, *Amritsar and* Our *Duty to India* (1920); *A.* J. Toynbee, *Armenian Atrocities—the Murder of a Nation* (1920); Walter White, *Rope and Faggot: a Biography of Judge Lynch* (1929). (H. M. K)

POINCARÉ, (JULES) HENRI (1854–1912), French mathematician and philosopher of science, who at the turn of the century was generally acknowledged to be the outstanding mathematician of his age, was born at Nancy on April 29, 1854. He was a first cousin of Raymond Poincaré, president of the French republic during World War I. After attending the École Polytechnique, Henri Poincaré entered the École des Mines. In 1879 he was appointed to a mathematical post at Caen university. In 1881 he moved to Paris university, where he lectured in turn on almost all branches of pure and applied mathematics. He was a prolific writer, producing more than 30 books and 500 original memoirs.

Poincaré's first great achievement was in pure mathematics. He generalized the idea of functional periodicity in his theory of automorphic functions which are invariant under a denumerably infinite group of linear fractional transformations. He showed how these functions can be used to integrate linear differential equations with rational algebraic coefficients and also to uniformize algebraic curves; *i.e.,* to express the co-ordinates of any point of an algebraic curve as uniform functions of a single parameter. The class of automorphic functions which he called Fuchsian, after the German mathematician I. L. Fuchs (1833–1902), he found to be associated with transformations arising in non-Euclidean geometry.

In celestial mechanics he made important contributions to the theory of orbits, particularly in connection with the classical three-body problem. In the course of this work he developed powerful new mathematical techniques, including the theories of asymptotic expansions and integral invariants, and he made fundamental discoveries on the behaviour of the integral curves of differential equations near singularities. His researches on new mathematical methods in astronomy were summed up in his great three-volume treatise *Les Me'thodes nouvelles de la Mécanique céleste* (1892, 1893 and 1899). In his theory of periodic orbits he founded the subject of topological dynamics. His memoirs on *analysis situs,* as it was then called, mark the beginning of modern topology.

Poincaré made important contributions to the theory of the figures of equilibrium of rotating fluid masses, and in particular discovered the pear-shaped figures which played so prominent a part in the researches of G. H. Darwin. J. H. Jeans and A. M. Liapunov. But his greatest contribution to mathematical physics was his famous paper on the dynamics of the electron published in 1906. In this paper he obtained, independently of Einstein, many of the results of the special theory of relativity. The principal difference was that Einstein developed the theory from elementary considerations concerning light signaling, whereas Poincaré's treatment was based on the full theory of electromagnetism and so was essentially restricted to phenomena associated with the latter.

Poincaré's writings on the philosophy of science, gathered together in his books *La Science et l'hypothèse* (1903; Eng. trans., 1905), *La Valeur* de *la Science* (1904) and *Science et Me'thode* (1908; Eng. trans., 1914), were no less important than his contributions to mathematics. He was a forerunner of the modern intuitionist school founded by L. E. J. Brouwer and believed that some mathemetical ideas precede logic. In one of the most famous of his essays he made an original analysis of the psychology of mathematical discovery and invention. But the greatest of his contributions to philosophy was his emphasis on the role played by convention in scientific method.

In his writings on philosophical topics Poincaré revealed himself as a master of French prose and was read by thousands in all walks of life. He was elected to the Académie Française in 1908 to fill the vacancy caused by the death of the poet R. F. A. P. Sully Prudhomme. Poincaré died in Paris on July 17, 1912.

See J. S. Hadamard, *The Early Scientific Work of Henri Poincaré* (1922), *The Later Scientific Work of Henri Poincaré* (1933). (G. J. Ww.)

POINCARÉ, RAYMOND (1860–1934), French statesman, was born at Bar-le-duc on Aug. 20, 1860, the son of Nicolas Poincaré, a distinguished civil servant and meteorologist. Educated at the University of Paris, Raymond was called to the Paris bar, and was for some time law editor of the *Voltaire*. He had served for over a year in the department of agriculture when in 1887 he was elected deputy for the Meuse. He made a great reputation in the chamber as an economist, and sat on the budget commissions of 1890–91 and 1892. He was minister of education, fine arts and religion in the first cabinet (April–Nov. 1893) of Charles Dupuy, and minister of finance in the second and third (May 1894–Jan. 1895). In the succeeding Ribot cabinet Poincaré became minister of public instruction. Although he was excluded from the Radical cabinet which followed, the revised scheme of death duties proposed by the new ministry was based upon his proposals of the previous year. He became vice-president of the chamber in the autumn of 1895, and in spite of the bitter hostility of the Radicals retained his position in 1896–97.

In March 1906 Poincaré became minister of finance in the Sarrien government, but he gave up his portfolio to Caillaux in October of the same year, when Sarrien was succeeded by Clemenceau as prime minister. During the next five years, though he still continued to exercise a powerful influence in the senate, Poincaré devoted himself mainly to his legal career. In 1909 he was elected a member of the French Academy. In Jan. 1912, Caillaux, who had been prime minister from the beginning of the previous year, resigned, whereupon Poincaré formed a government in which he himself held the portfolio of foreign affairs.

Poincaré's cabinet constituted an *entente netionale,* and his first aim was to pursue a more definite foreign policy. In home affairs the problem which presented the greatest difficulties was that of electoral reform. Poincaré induced the chamber to pass a proportional representation bill. But above all diplomatic affairs claimed his constant attention; for during the negotiations with Germany which took place in consequence of the dispatch of a gunboat by that country to Agadir, certain incidents had occurred during the Caillaux administration which had produced a feeling of disquietude in regard to foreign policy. Poincaré therefore sought to re-establish a continuity of policy; and though he maintained courteous relations with Germany his main endeavour was to prove that France would remain faithful to both friends and allies. The ratification by the senate of the Franco-German treaty of Nov. 4, 1911, was followed by France's definite establishment in hlorocco.

Almost immediately after the establishment of the Poincaré government, the Italians, who at that moment were at war with the Turks, seized two French mail steamers. Poincaré, by his calmness and resolution. succeeded in re-establishing amicable relations between the two countries. By the end of October Italian sovereignty in Libya was recognized, and by a mutual declaration of the two governments, full liberty of action was granted to France in Morocco and to Italy in Libya. When in the autumn of 1912 the Balkan War broke out, Poincaré made every effort possible to prevent the conflagration from spreading. On Jan. 17, 1913, Poincaré was elected president of the republic in place of Fallières. In power, he endeavoured to cement the friendships and strengthen the alliances of France. (*See* FRANCE: History.) He claimed that he did his utmost to avert war, holding that the way to prevent the conflict was for those poners against nhom the menace was directed to present a powerful and united front, thus making it imprudent to attempt any act of aggression.

In July 1914 Poincaré went to Russia on a visit which had been planned for some time past. He was on his way home when the news of the Austrian ultimatum to Serbia reached him. After a short stay in Stockholm he returned hastily to Paris; and in a letter to King George V he pleaded for a clear declaration that the entente cordiale. if necessary, would prove its strength on the battlefield, pointing out that such a statement would have a restraining effect on the policy of Vienna and Berlin. In Nov. 1917 he gave proof of his vision and disregard of self by placing in power Clemenceau, who, though undoubtedly the man of the moment, was one with whom he had little sympathy. During the critical months of 1918. Poincaré revealed an inflexible resolution and a supreme confidence in the ultimate victory.

During the peace negotiations divergence of views again became apparent between Poincaré and Clemenceau. On more than one occasion the president found it necessary to write to the prime minister pointing out the errors which. from his point of view, were being committed. His counsels. however, were not followed, and at the beginning of 1920, after having completed seven years as president, he left the Elysée and was shortly after re-elected senator for the department of the Meuse. In Jan. 1922, the Briand cabinet having resigned, Poincaré once more became prime minister and minister for foreign affairs. He made it his chief aim to insist on the fulfillment by Germany of its obligations in regard to reparations. During the first year of his new government he failed to arrive at any agreement on this subject with the British cabinet, whose views differed so widely from his own. The Inter-Allied conference in London in Aug. and Dec. 1922 produced no result. A further conference took place in Paris on Jan. 2 and 5, 1923. But Poincaré rejected the proposals drawn up by Bonar Law.

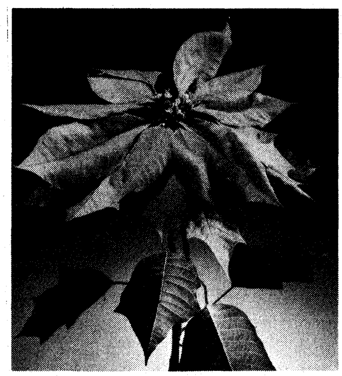
At this moment, the Reparations commission, with Britain dissenting, having declared that Germany had failed to fulfill its obligations in regard to the delivery of coal and coke, Poincaré, in agreement with Belgium, undertook the occupation of the Ruhr (*q.v.*). At first this measure involved merely a method of control, but gradually, because of the passive resistance of the Germans, it became necessary to exploit the railways and to some extent also the mines by means of Franco-British supervision. But by autumn the passive resistance had ceased. and Poincaré awaited the German proposals which never came. He then accepted the U.S. suggestion that a group of experts should be given the task of finding the solution of the reparation problem; this resulted in the adoption of the Dawes plan. But Poincaré had made up his mind not to withdraw from the Ruhr until he was satisfied that this plan was being carried out.

During the first three months of 1924 Poincaré had to face a financial crisis because of the state of the exchange. Not without difficulty he induced parliament to vote new taxes and succeeded in saving the situation. But from now onward he had to withstand strenuous opposition from the parties of the left consisting of the Radicals and Socialists. The policy of these groups met with a marked success at the general elections of May 11, 1924, and resulted in a majority for the left which now formed a coalition under the name of the Cartel des Gauches. Immediately the results were announced, Poincaré stated that he would retire on the day when the new chamber was to assemble, which took place on June 1, 1924.

Thenceforward he took his place in the senate, intervening only rarely in political debates. But he was to come into power once more. When, in the middle of the summer of 1926, the financial crisis, which successive cabinets since 1924 had been unable to check, became more and more serious, public opinion saw in him the only man capable of meeting the situation. After the fall of the Briand-Caillaux cabinet, which only lasted a few weeks, and of the Herriot cabinet. which only existed a few hours, Poincaré, in the last days of July, formed a ministry which included both moderate Republicans and Radical-Socialists, and had as its object the stabilization of French finances by means of a policy of national union. Public opinion was immediately reassured. At the beginning of August the ministry caused the national assembly, meeting at Versailles, to pass, as articles embodied in the constitution, and therefore not at the mercy of political changes, regulations for the establishment of an automatic sinking fund, to which would be attributed funds which could not be touched (death duties, revenues from the tobacco monopoly, etc.).

In three months he succeeded in raising the value of the franc from 264 fr. to the pound sterling, to 124. This rate mas achieved in Dec. 1926, and thenceforward the value of the franc did not fluctuate. For a year and a half Poincaré, who had restored a strict financial equilibrium, maintained this stabilization of the currency *de facto*. The general election of April 1928 having returned a majority which approved of his policy, a law was voted in June by the new assembly, and by the senate, establishing the stabilization *de jure*. It was one of the most successful operations of this nature in history. Withdrawal of the Radical-Socialist support from his government, engineered by Caillaux, caused his resignation on Nov. 7, 1928, but he formed a new ministry on Nov. 12. He resigned because of illness, on July 27, 1929. Poincaré undertook the publication of an important work in 10 volumes, entitled *Au service de la France; neuf années de souvenirs,* the plan of which is to describe the sequence of events from 1911 to 1920 and the role he played in them. Four of these volumes appeared in 1926, 1927 and 1928 under the titles of *Le Lendemain d'Agadir, Les Balkans en feu, L'Europe sous les armes,* and *L'Union sacrée*. He died Oct. 15, 1934. (P. B.)

POINSETTIA, a showy tropical shrub of the Euphorbiaceae (*q.v.*) family, native to Mexico and Central America. It is the traditional flower of the Christmas season, known scientifically as *Euphorbia pulcherrima,* meaning most beautiful. The poinsettia was named after Joel R. Poinsett of Charleston, S.C., who introduced the plant to the Cnited States in 1828 when he was minister to Mexico. The true flowers of the poinsettia are inconspicuous, forming a yellow cluster in the centre of the red, white or pink bracts. In the rarer double poinsettia most of the flowers have been trans-



ROCHE

COMMON POINSETTIA (EUPHORBIA PULCHERRIMA) formed into bracts giving a more showy effect.

The poinsettia is abundantly used as a yuletide gift plant in the north, while in Florida and other tropical lands it is a popular flowering shrub.

When used as a gift plant it should be placed in a room with constant temperature as it cannot tolerate drafts or fluctuating temperatures. It needs plenty of water while blooming. Although it is possible to carry a plant over from one year to the next, it is not advisable unless greenhouse facilities are available. Poinsettias are propagated by cuttings in March. (R. T. V. T.)

POINT FOUR PLAN, a program advocated by Pres. Harry S. Truman as the fourth point of proposed U.S. policy in his inaugural address of Jan. 20, 1949. Point Four called for "a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and grouth of underdeveloped areas." Emphasizing a type of international, intergovernmental educational program that came to be known as technical assistance and that long had been carried out privately by missionaries and overseas branches of industrial corporations. Point Four, with massive economic aid as exemplified by the European recovery program, refugee and disaster assistance and military assistance. later formed one of the principal foreign aid activities of U.S. mutual security programs. Its principal focus has been on health, education and agriculture. *See* FOREIGN AID PROGRAMS; and for similar international activity, UNITED NATIONS.

POINT SETS. The study of the properties of point sets constitutes that branch of mathematics known as point sets, or the theory of sets of points, or the theory of aggregates. A point set is a collection of points selected from a given space. Generally speaking, the properties of a point set may be classified under two heads, (1) topological and (2) metric. For a description of the former *see* TOPOLOGY, GENERAL. *A* brief introduction to the metric properties of point sets is given below.

The Problem of Measure.—In order to approach the subject with as simple an example as possible, let us confine ourselves to the case where the given space is an ordinary straight line, L. If P and Q are distinct points of L. then the point set consisting of P and Q together with all points between them is called an interval and is denoted by [P,Q]. Let us imagine that we have a common foot rule which can be applied to L in order to measure lengths. Then given an interval [P,Q] we can measure its length and say that it is a certain number of feet Of a single point we would say, in accordance with the ordinary geometry notion. that its length is zero. If we are given two intervals which have no point in common, it is not natural to speak of the length of the set of points which they represent, the word length being usually applied only to connected pieces. In this case we shall use the word measure, and say that the measure of this point set is the sum of the lengths of the two intervals.

However, when we speak of a point set on L, this does not necessarily imply that we are thinking of an interval. a single point or a set of intervals; we sometimes mean to indicate a set of points which contains no connected portion; *i.e.,* which contains no interval. One might be tempted to say that since a point has length zero, the measure of such a set would be the sum of the lengths of its individual points; *i e.,* the sum of a set of zeros. and hence zero. Such a hasty decision would not lead to very fruitful results, however. for the following reason. If we determine upon a measure for two point sets, A and B. which have no points in common, the sum of their measures should naturally be the measure of the point set which is made up of A & B taken together. Thus. above, we have stated that the measure of a set consisting of two intervals with no common point is the sum of the lengths of those intervals. Now any interval [P,Q] can easily be shown to be the sum of two sets A and B each of which fails to contain any interval. and if we arbitrarily call the measure of both A and B zero, the sum of their measures would be zero, which is not the length of [P,Q], no matter how small the length of [P,Q]. In other words, we want a measure of a set of points which will correspond to the ordinary idea of length.

We have now introduced what is known, in the theory of sets of points, as the problem of measure. There have been several methods devised for finding a measure of an arbitrary set of points. We shall describe, briefly, the theory of Lebesgue measure. which is the foundation of the theory of integration formulated by H. L. Lebesgue in 1902.

Lebesgue Measure.—Any set, A, is said to be covered by a collection, G, of intervals, when every point of A is in some interval of G. If the set of intervals G is denumerable, then we shall say that it is a covering of A. (The set is called denumerable if its elements can be "tagged" with positive integers in such a way that no two elements of the set are "tagged" with the same integer.) If the sum of the lengths of the intervals of G exists, let us call this the sum-length of the covering. Now of all possible coverings of A consider the corresponding sum-lengths, and let N be the largest number which is not greater than any of these sum-lengths. Then N is called the exterior measure of A and is denoted by m_eA. Suppose, now, that [P,Q] is some interval, whose length we shall denote by d, such that all points of A are within [P,Q]. Let B be the set of all points of [P,Q] that do not belong to A, and let m_eB denote the exterior measure of B, found just as m_eA was found. If it happens that $m_eA + m_eB = d$, then m_eA is accepted as the measure of A, and is what is known as the Lebesgue measure of A. Of course we know at the same time that m_eB is the Lebesgue measure of B, and in accordance with our ideas of length we have required that the sum of the two measures give the length of [P,Q]. To be sure, the Lebesgue measure of a set of points may not exist, but it does exist for all ordinary point sets. Indeed it is not at all easy to give an example of a set of points which has no Lebesgue measure, and all those examples which have been given make use of certain methods which are held to be unacceptable by many mathematicians.

For the measure of a set of points in a plane, areas are employed. Thus, the measure of the set of all points in a square is the area of the square. And to get the measure of a general plane point set M, a covering of M is made by means of squares. In three dimensions cubes are employed, and we deal with sum-volumes.

The introduction of the notion of measure has led to an enriching of the content of general analysis that hardly could have been realized otherwise. The effect has been felt not only in mathematics itself, but in the closely allied fields of mechanics and dynamics. *See* also SET THEORY (THEORY OF AGGREGATES); FOURIER SERIES; FUNCTION: *History;* MATHEMATICS, HISTORY OF: *Modern Period.*

See E. W. Hobson, *The Theory of Functions of a Real Variable and the Theory of Fourier's Series (1921)';* Edward Kasner and James Newman, *Mathematics and the Imagination,* pp. *201–207 (1940).* (R. L. WI.)

POISON is a substance that, when taken into the mauth or stomach, or when absorbed into the blood, is capable of affecting health seriously or of destroying life by its action on the tissues with which it comes into contact immediately or after absorption. Toxicology is the science that embodies the knowledge of the sources, characters and properties of poisons, the symptom they produce, the nature of their fatal effects and the remedial measures that should be employed to combat their actions or effects.

Sale of Poison.—In the United States, the Caustic Poison act, 1927, safeguards the distribution and sale of certain dangerous caustic or corrosive acids, alkalies or other substances in interstate and foreign commerce. This act names 12 materials which are classified as dangerous, caustic or corrosive substances: hydrochloric acid, sulfuric acid, nitric acid, carbolic acid, oxalic acid, salt of oxalic acid, acetic acid, hypochlorous acid, sodium hydroxide, potassium hydroxide, ammonium hydroxide and silver nitrate. The Federal Food. Drug and Cosmetic act, 1938, successor of the Food and Drugs act, 1906, prohibits the movement in interstate commerce of adulterated and misbranded food, drugs, devices and cosmetics. Both the Caustic Poison act and the Federal Food, Drug and Cosmetic act are enforced by the Food and Drug administration. The U.S. public health service administers the Virus, Serum and Toxin act, 1902, which provides for the maintenance of potency and purity of biological products. The Harrison Narcotic act, 1914, and the Marihuana Tax act, 1937, are administered by the bureau of narcotics of the U.S. treasury department. These acts regulate the importation, sale or giving away of preparations of opium or coca leaves and of marijuana, respectively.

The following are the statutes governing the sale of poisons in Great Britain: Pharmacy and Poisons act. 1933; Poisons rules. 1935; Poisons (Colouring) rules. 1936; statutory rules and orders made in connection with the Pharmacy and Poisons act, 1933; Dangerous Drugs act, 1951; and statutory regulations and orders made in connection with them; Therapeutic Substances act, 1925; and Therapeutic Substances regulations. 1931–44.

The objects of these acts, put broadly, are to control the sale of poisons to the public and to reduce the danger to human life from indiscriminate sale by unqualified persons. The Dangerous Drugs acts regulate the use of drugs of addiction such as opium, morphine and cocaine. With certain exceptions, only duly qualified and registered pharmacists and registered medical practitioners are permitted to sell poisons.

Poisoning. — Poisoning may be accidental, suicidal or homicidal. By far the commonest type is poisoning from accidental causes. In spite of the precautions taken by the state in the sale of poisons, far too little care is taken by the public in the safeguarding of poisons in their possession. As a result, these are frequently taken by mistake instead of other substances of a harmless nature, or often an overdose is taken from pure carelessness. Thus, oxalic acid crystals when purchased in a paper packet may be transferred to an unlabeled bottle or jar and then taken by mistake for Epsom salts, which they closely resemble. Similarly. tablets of corrosive sublimate have been taken by mistake. It is the duty of every person possessing a substance of poisonous nature to take the utmost care that this is correctly labeled and kept safely guarded under lock and key.

Two poisons very commonly responsible for poisoning are Lysol and carbon monoxide. Both are usually present in the average home. Carbon monoxide is responsible for many deaths yearly as a result of accident or suicide. It is a constituent of illuminant gas; for example, town gas, when prepared in the vertical retort, may contain as much as 22% of carbon monoxide. Defective gas heaters. especially in bathrooms, and fractured gas pipes and mains may provide a source of poisoning. Exhaust gases from internal-combustion engines also cause poisoning. It has been estimated that such gases contain from 1% to 7% depending on the richness of the mixture. Self-administration of barbiturates is a dangerous practice, since the patient having already become confused by an initial dose of a barbituric compound may continue. on the same occasion, to take further and possibly fatal quantities of the drug without realizing the danger. This is the possible explanation of some of the acute and even fatal cases of barbiturate poisoning which might otherwise appear inexplicable.

ACTION OF POISONS

Poisons may have a local action or a general systemic action after absorption into the circulatory system. or they may act in both ways. Almost all poisons have a general systemic action. Some poisons such as corrosives destroy the mucous membrane or tissues with which they come in contact and cause serious or dangerous injury thereby. Irritant poisons set up a local inflammatory reaction in the mucous membrane of the alimentary tract.

Apart from these local effects, the common result of absorption of a poison is the harmful effect produced on the important organs of the body: for example, the liver, kidneys, heart and nervous system are almost certain to be adversely affected. A poison after absorption attacks all the organs of the body in varying degrees, and it is a mistake to regard poisons as being exclusively selective in their action though some poisons appear to direct the brunt of their attack on a particular system.

Among the conditions affecting the action of a poison may be mentioned the following:

Amount Taken. — From the point of view of dosage, potent drugs can be divided. in an arbitrary manner, into two groups: those in which the lethal dose lies far in excess of the active dose, and those in which it lies close to the active dose. There is a definite distinction between the terms "toxic dose" and "fatal dose," since the former merely causes symptoms of poisoning while the latter induces poisoning to such a degree that death results. The term "fatal dose" when applied to a poison means the smallest dose which is known to have caused death in an adult. Usually the quantity of a poison taken bears a relation to the effects produced. Exceptions to this rule are substances in the case of nhich, as a result of the quantity taken, vomiting occurs so that most of the poison is expelled; oxalic acid and tartar emetic are examples. Frequently larger doses may be taken without death resulting, but much depends on other factors than quantity, and also on whether adequate treatment has been adopted.

Habit. — A tolerance to some poisons occurs after their repeated use, and in some cases doses far greater than a normal fatal dose may be tolerated without serious symptoms developing. Examples of such drugs are arsenic, morphine, opium, cocaine and alcohol. In the case of some of these poisons their repeated use leads to addiction, with all its pernicious symptoms and effects.

Idiosyncrasy. — Some persons are exceedingly intolerant of certain drugs which in moderate doses may thus cause in them dangerous or even fatal symptoms. Examples are morphine, cocaine, quinine, iodine. bromine, salicylates and acetylsalicylic acid (aspirin), which in some persons have a severe cardiac depressant action.

Age. — Usually children are much more susceptible to the effects of a poison than adults. The dosage of drugs in the case of children has been fixed by a pharmacological rule, but exceptions to this are morphine, opium and its preparations which are much more toxic than the rule would indicate; on the other hand, children tolerate belladonna preparations better than adults. Aged persons withstand poisons badly.

State of Health. — A relatively small dose, from which a stronger person would probably recover, may kill a weakly person. In disease, drugs are usually much more toxic, and this is especially so where the excretory organs are affected. For example, in nephritis. medicinal doses of such drugs as morphine, salvarsan, hyoscine, etc., often cause dangerous symptoms; likewise in cirrhosis of the liver there is a greatly increased susceptibility to such drugs. In conditions of gastritis or enteritis, drugs like arsenic are especially toxic. On the other hand, in some conditions associated with delirium or pain, large doses of sedative drugs produce little effect provided that the excretory organs are healthy.

Condition and Mode of Administration. — If a poison is taken in solution, by the mouth, it acts much more powerfully than if taken in an insoluble form. For example, an insoluble preparation of arsenic may produce little poisonous effect even in large doses; similarly strychnine given in hard pills has a much-delayed action.

The presence of food in the stomach has a marked influence on the effect of a poison. If the stomach is empty the effect will be rapid. particularly so when the poison is in a soluble form; on the other hand, if the stomach is full, considerable delay may occur in the action of the poison as is well shown in acute arsenical poisoning.

A poison acts most rapidly when inhaled in a gaseous or vaporous form or when injected intravenously; next in order of rapidity, when injected subcutaneously; and least rapidly when ingested. Poisons may be absorbed by the skin or mucous membrane of the vagina or rectum, with fatal result.

Chemical Combination. — Some substances when in certain combinations are very poisonous, but when in others are comparatively innocuous. While the component parts of a mixture may have a poisonous action when administered singly, the compound may be comparatively inert.

Cumulative Action. — Certain poisons tend to accumulate within the body as the result of slow excretion (for example. strychnine, lead, mercury, digitalis and carbon monoxide) and therefore the continued administration of relatively small doses may occasion symptoms of poisoning.

DIAGNOSIS AND TREATMENT OF POISONING

Evidence of Poisoning.—It must be remembered that the symptoms of poisoning may be closely simulated by the symptoms of natural disease, and the greatest care must be taken before a diagnosis of poisoning is arrived at. Thus, the symptoms of acute arsenical poisoning closely resemble those of cholera or of acute bacterial food poisoning. The only certain differentiation is the finding of arsenic in the vomit. feces or urine, or of the bacteriological evidence of a cholera or food poisoning infection.

Various factors may provide evidence of poisoning: (1) The symptoms are usually sudden in their onset and they occur after the taking of food or drink, or after exposure to poisonous gases or vapours. (2) If several persons are similarly exposed all are affected more or less with similar symptoms. An exception may occur in the case of bacterial food poisoning, where certain persons may be relatively immune and some may be specially susceptible. (3) The analysis which should always be carried out in suspected cases may reveal the presence of the poison in the vomit. urine and feces, and possibly also in some articles of food or medicine.

Post-mortem Evidence.—If death occurs, a post-mortem examination should be made only following instructions from the appropriate official. The post-mortem signs found should be consistent with those occurring from poisoning by the suspected poison. The analysis of the viscera should yield results consistent with that of poisoning by the suspected poison. taking into account the circumstances of administration and death.

Treatment.—The mode of treatment to be adopted varies according to the nature of the poison.

The poison should be removed from the stomach without delay, antidotes should be administered, the poison should be eliminated from the body by natural channels, symptomatic treatment should be undertaken and stimulation of the respiratory and circulatory systems should be resorted to immediately indications present themselves. Emetics are a poor substitute for the emptying and washing out of the stomach by means of the funnel and stomach tube, but they may be employed if the more effective treatment is impossible. Safe emetics are mustard and water, salt and water, ammonium carbonate or apomorphine. The emptying and washing out of the stomach by means of the stomach tube and funnel is, however, contraindicated when poisoning occurs from the corrosive mineral acids or alkalies. In such cases there is a danger of perforation. After the stomach has been emptied and washed out, suitable antidotes should be given, such as chalk and lime water to neutralize oxalic acid and the mineral acids, lime water for carbolic acid. Atropine may be given hypodermically in the case of morphine poisoning. Where morphia and cocaine are taken. the stomach should be washed out with diluted permanganate of potash solution.

Elimination by the bowel is facilitated by colon washes with warm normal saline solution and by free bowel evacuations. The symptoms of poisoning are subdued by the administration of appropriate remedies; thus, pain may be relieved by hypodermic injection of morphine, and the convulsions from strychnine by chloroform inhalation.

CHARACTERISTICS OF DIFFERENT POISONS

Poisons may be classified in many different ways; *e.g.*, according to their chemical composition, to their action on the body, to their physical characters, etc.

The following is a convenient and simple classification.

1. Corrosive poisons are those which destroy by direct action the tissues with which they come in contact. To this category belong the mineral acids, such as sulfuric. hydrochloric, nitric, etc.; the caustic alkalies. such as caustic soda, caustic potash. ammonia. carbolic acid; metallic poisons. such as corrosive sublimate, zinc chloride, silver nitrate. The last mentioned will also be considered under irritant poisons. It should be remembered that corrosive poisons in diluted condition lose their corrosive effect and become irritants.

2. Irritant poisons, by their direct action on the mucous membrane, set up inflammation. Examples are: oxalic acid and its soluble salts; arsenic compounds and antimony compounds; most of the metallic poisons in solution; phosphorus; bromine; iodine; boracic acid, etc.

3. Systemic poisons which act on the nervous system or other important organs such as the heart, liver, lungs or kidneys without having any special irritant or corrosive effect. This group includes the majority of poisonous substances such as the vegetable poisons or their alkaloids, hydrocyanic acid and its salts, chloral, chloroform, alcohol, ether, hypnotic drugs such as veronal, sulfonal, etc. Certain poisons affect the liver and produce toxic jaundice (for example, tetrachlorethane, trinitrotoluene, picric acid, etc.), while others. such as cantharides and turpentine, involve the kidneys.

4. Gaseous poisons such as chlorine, carbon monoxide and coal gas, carbon dioxide, etc.

5. Poisonous foods such as mushrooms, shellfish and food contaminated with dangerous pathogenic bacteria.

Corrosive Poisons

Symptoms.—Corrosive poisons produce severe symptoms immediately they are taken—a burning pain in the mouth, throat and esophagus and pain referred from the stomach and intestines. Vomiting occurs quickly and the vomit contains blood which may be altered in colour by the action of the poison; often also shreds of destroyed mucosa are present. Collapse occurs early; and perforation is common when, should the patient survive, signs of general peritonitis develop.

An examination of the patient will show signs of the corrosive action of the poison on the mouth and throat, and marked tenderness will be present on palpation over the stomach and intestine. Corrosive poisons if swallowed in poisonous quantity are usually fatal within 24 hours unless immediate treatment with a suitable antidote is adopted.

Should the patient survive the immediate effects of the poison, serious aftereffects result from damage to the alimentary tract, and in the case of volatile corrosives serious pulmonary complications often ensue. Post-mortem examination shows evidence of the destructive action of the poison on the mucous membrane of the mouth, throat, esophagus and stomach, there being often extensive hemorrhage in the underlying tissues.

Among examples of corrosive poisons may be named:

Corrosive Mineral Acids.—These include *sulfuric acid,* commonly known as oil of vitriol; this is used in various industries and in all chemical laboratories. It is a most powerful corrosive in the concentrated form, whether taken internally or applied externally as in cases of "vitriol throwing." One dram has caused death in an adult, and half that quantity in a child.

Hydrochloric acid is known also as muriatic acid or spirits of salts. It is used largely for industrial and chemical purposes and is a common article of domestic use. It is readily obtainable and is very commonly used for suicidal purposes. It is a most dangerous corrosive and one dram has caused death in an adult.

Nitric acid, known as aqua fortis and red spirit of nitre, is used for industrial and chemical purposes. It is a most dangerous corrosive and produces characteristic yellow staining of the tissues with uhich the strong acid comes in contact. The vapour of the acid, if inhaled into the lungs, often produces an acute fatal form of pneumonia which is a common cause of death in nitric acid poisoning.

Other mineral acids such as *hydrofluoric, phosphoric* and *sulfurous* acids in concentrated form produce similar effects.

The treatment of poisoning by corrosive mineral acids consists in giving as soon as possible harmless alkaline remedies such as magnesia powder, milk of magnesia, lime water or chalk. These should be administered freely, and plenty of egg albumen (white of egg) should also be given, since this tends to neutralize the acid by forming a protein combination, and also it has a soothing effect on the damaged mucosa.

The stomach should not be washed out for fear of perforation. Pain is relieved by the free use of morphine hypodermically, and after the swallowed acid has been neutralized food should be withheld by the mouth and normal saline given as freely as can be retained per rectum. In urgent cases of circulatory shock, caused by fluid loss and blood concentration, continuous intravenous infusion of normal saline, or saline with glucose, should be carried out.

Caustic Alkalies.—Among these may be named the following: *caustic potash* or potassium hydrate or potash lye is a powerful corrosive, and *potassium carbonate,* known as salt of tartar, has a similar but less powerful effect. Both are used industrially. Forty grains of caustic potash have caused death.

Caustic soda or sodium hydrate or soda lye is a powerful corrosive and quite as dangerous as caustic potash. It is commonly used industrially.

Ammonia, liquid ammonia or spirits of hartshorn is used largely for domestic and industrial purposes. It is also used in the form of smelling salts when mixed with carbonate of ammonia. It is a powerful corrosive poison and in addition the vapour has a very injurious effect on the lungs, giving rise to bronchopneumonia which may assume a septic type.

As regards treatment following ingestion, harmless acid drinks such as diluted vinegar, lemon juice, citric or tartaric acid should be given freely. Olive oil or egg albumen may be usefully employed. Pain should be relieved by the free use of morphine hypodermically and nourishment should not be given by the mouth, but rectal feeding adopted.

Corrosive Organic Acids.—*Carbolic acid,* or phenol, is commonly used as a disinfectant for domestic and surgical purposes. Allied preparations such as creosote or cresol have a similar poisonous effect. Lysol is a combination of cresol with soap and is similar in action to phenol.

Carbolic acid and the allied substances have a powerful corrosive action causing necrosis of the tissues with which they come in contact, the superficial part of which becomes of whitish appearance, the deeper parts becoming dark red as a result of hemorrhage into them. Carbolic acid is one of the poisons most frequently used by suicides, and because of its common use for domestic purposes is also a frequent cause of accidental poisoning.

The symptoms caused by carbolic acid are those of corrosive poisoning, but because of its local anesthetic action vomiting may be absent and pain may be less marked. If death does not result from shock, the profound effect of the poison on the nervous system causes paralysis of the respiratory and cardiac centres, with rapid feeble pulse and stertorous breathing; coma develops in severe cases and is usually followed by death. Death has also resulted from absorption by the skin, and from rectal injections in solution. Usually death occurs within three to four hours following ingestion of a large dose.

The aim of treatment is to limit the absorption of the poison, to sustain the patient and to aid the elimination of the poison from the system. The stomach should be washed out by means of a soft stomach tube with diluted saccharated lime water or fresh lime water; by this means the phenol is converted into calcium phenate which is not poisonous. Alternatively, thorough gastric lavage, using a 10% solution of glycerin, or plain water, should be carried out without delay until the washings no longer emit an odour, and a quantity of medicinal paraffin should be left in the stomach. Egg albumen, since it precipitates phenol, will delay absorption. When necessary, rectal feeding should be adopted for several days.

Irritant Poisons

The more important irritant poisons will be considered under this heading *(see* list, above), but it must be remembered that many of the general poisons (*e.g.,* savin, cantharides, etc.) have an irritant action on the stomach and intestines in addition to their special action on important organs and nerve centres.

Oxalic acid occurs in colourless crystals resembling Epsom salts; it is very soluble in water. *Salts of sorrel* or *salts of lemon* is the quadrioxalate of potash; it is a white powder very soluble in water. Both of these substances are commonly used for domestic purposes; *e.g.,* for cleaning straw hats, removing ink stains, cleaning brasses, etc. They are frequently the cause of accidental and of suicidal poisoning.

When swallowed in solution the typical symptoms of irritant poisoning are set up. but in addition the poison when absorbed into the system has a profound depressant action on the heart and nervous system. Thus an acrid burning taste is experienced and pain occurs which is referred from the throat, esophagus and stomach and later possibly from the intestines. Vomiting is common, the vomit being very acid, and giving positive results to the tests for oxalic acid. It often contains blood. Unless immediate treatment is adopted collapse speedily occurs. the patient becoming cold, pale and faint with a rapid feeble pulse; at this stage death from syncope may occur. In some cases nervous symptoms such as tinglings and numbness, muscular spasms, convulsions, delirium and coma occur, but these symptoms are uncommon. Because of the rapid absorption of the poison death is likely to occur rapidly (*e.g.,* within an hour), but it may be delayed.

For treatment, fresh lime water or, preferably, saccharated lime water which is 15 times as strong, should be given in large quantities and it should be mixed with calcium carbonate in the form of chalk or whiting. Since oxalic acid has only slight corrosive action the stomach should be washed out immediately if no antidote is at hand. It is best to give the antidote freely if immediately available and after a few minutes to wash out the stomach thoroughly with a soft stomach tube and funnel, and then finally introduce a pint of lime water made into a thin cream with an ounce of chalk, leaving this mixture in the stomach. Intravenous injections of calcium chloride or gluconate (calcium Sandoz) are recommended.

Arsenic is the most important of the irritant poisons and because of the tasteless property of many of its compounds and preparations it is the commonest poison used for homicidal purposes.

The most notable and commonest compound is arsenious acid, arsenious oxide or white arsenic. It exists in the form of a white powder or in lumps of a white porcelainlike appearance. The powdered form resembles powdered sugar or flour and when mixed with food is almost tasteless. It is sparingly soluble in cold water, which will dissolve only 0.03 to 0.06 g. in 30 ml. About 4 g. in 30 ml., however, will be held in boiling water. When mixed with alkaline substances, white arsenic becomes freely soluble.

Commercial preparations containing white arsenic mixed with alkalies such as sodium hydrate or carbonate are weed killers, sheep-dip and wood preservatives which may contain from 20% to 40% of white arsenic. Copper arsenite (Scheele's green), lead arsenate and other arsenical preparations are used as insecticides for the spraying of fruit trees. Rat poisons may contain arsenic as the active ingredient. Wallpapers which formerly often contained green pigment (Scheele's green) or the yellow sulfides of arsenic are now coloured with arsenic-free pigments, arsenic being prohibited from use. White arsenic, if sold for other than medicinal purposes, must be mixed with a dye of distinctive colour which is water soluble.

Accidental contamination of food with arsenic has occurred in the past. Thus in 1900 a beer poisoning epidemic occurred as the result of the use of commercial glucose which contained arsenic in the preparation of beer. Prosecutions have been brought for the presence on apples of prohibitive amounts of arsenic alleged to have been caused by spraying of trees.

When arsenic is taken by the mouth in poisonous quantities, symptoms of acute gastrointestinal irritation such as vomiting, diarrhea and abdominal pain usually occur within a few hours. Death may ensue within a period varying from several hours to several days. A dose of 0.12 g. of arsenic has caused death, though larger quantities have been taken without fatal result. In acute arsenical poisoning the heart, kidneys and other organs are seriously affected so that the poison has a systemic action in addition to its irritant properties to the stomach and intestines.

Chronic arsenical poisoning occurs when small quantities of arsenic are absorbed over long periods. The gastrointestinal symptoms may be slight, but other symptoms, such as gradual loss of weight, alopecia, skin rashes and pigmentation and conjunctivitis. become manifest.

In suspected acute arsenical poisoning the diagnosis can be made certain by analysis of the vomit, urine and feces. In chronic cases additional information may be obtained by analysis of the hair and nails.

Antimony is an irritant poison like arsenic. Tartar emetic or potassium antimony tartrate is one of the most commonly used compounds. It has on several occasions been used for homicidal purposes because of the possibility of its being administered without detection by taste or smell.

Metallic poisons if taken by the mouth give rise to irritant poisoning. Examples are:

In large doses, the common salts of lead will cause gastrointestinal irritation. Acute poisoning by lead is rare. Chronic lead poisoning is caused by continued absorption of small quantities of lead and is a dangerous condition as it causes disease of the kidneys, blood vessels, heart and nervous system. Lead tetraethyl is a very poisonous organic compound of lead. It is used commercially as a constituent of ethyl gasoline, and is claimed to counteract "knocking" or "pinking" in motor engines. On inhalation in sufficient quantity it is extremely toxic. The sulfate of copper (blue vitriol) and other copper compounds are irritant poisons. The use of copper salts as a colouring matter of foodstuffs such as preserved green vegetables is reprehensible, and has often led to legal action. The Public Health (Preservatives, etc. in Food) regulations of England, 1925–40, prohibited all save scheduled colours and limited the preservatives to benzoic and sulfurous acids and sodium or potassium nitrate, and these only in specified amounts in certain foods.

Zinc salts are irritant poisons. The sulfate of zinc (white vitriol) occurs in crystals like Epsom salts for which it has been taken in mistake. Zinc chloride has a corrosive as well as an irritant action.

Barium salts, except for the quite insoluble sulfate, are irritant poisons and may also act on the cardiovascular or nervous system.

Chromates especially potassium bichromate are powerful irritant poisons.

The yellow variety of phosphorus is intensely poisonous and formerly was widely used in the manufacture of matches. Yellow phosphorus is used as a constituent of some vermin exterminators. The substance, in addition to being a gastrointestinal irritant, is a deadly poison to the liver and kidneys.

Acute mercurial poisoning usually arises from the taking of mercuric chloride (corrosive sublimate) or from the biniodide of mercury, both of which are extensively used as disinfectants for medical purposes. The immediate symptoms are those of acute gastrointestinal irritation (vomiting, abdominal pain and diarrhea) but they are generally followed by suppression of urine and symptoms of acute ulcerative colitis which latter symptoms are commonly fatal. Chronic mercurial poisoning is characterized by inflammation of the mouth and gums.

Systemic Poisons

The systemic poisons include the following:

Prussic or Hydrocyanic Acid.—Hydrocyanic acid is one of the best known poisons and a very deadly one. In the pure state it is said to kill with lightninglike rapidity. It is met with in commerce only in a dilute state. In Great Britain two kinds of acid are commonly sold—the pharmacopoeial acid, containing 2% of anhydrous prussic acid, and Scheele's acid. containing 4% to 5%. About four millilitres of the 2% acid may cause death.

Hydrocyanic acid and the cyanides must be regarded as true protoplasmic poisons since they arrest the activity of all forms of living matter by inhibiting tissue oxidation and suspending vital functions. Such poisons not only inhibit the enzymic activities, but also act upon the central nervous system.

Given in fatal doses, the symptoms of prussic acid poisoning set in with great rapidity; and. in consequence of the readiness with which the poison is absorbed from the stomach and diffused through the circulation, the onset of symptoms is reckoned by seconds rather than by minutes. Occasionally the victim may be able to perform a few voluntary actions before loss of consciousness. There is first a very brief stage of difficult breathing and slow action of the heart, with a tendency for the organ to stop in the state of dilatation. With widely dilated pupils of the eye, the patient is then seized with violent irregular convulsive movements. The rhythm of the respiratory movements is disturbed, and the countenance assumes a bluish colour. The patient collapses with complete loss of muscular power; and the third or asphyxial stage is reached, in which there are slow gasping respirations, loss of pulse and paralysis of motion. Death is frequently preceded by spasms. The lightninglike character of the illness and the speedy death of the patient, coupled with the peculiar odour of the acid in the breath and atmosphere around the body, seldom leave any doubt as to the nature of the case.

Other soluble cyanides, more especially cyanide of potassium a salt largely used in photography and in the arts, are highly poisonous but are slightly less rapid in action than hydrocyanic acid.

When the poison has been swallowed, the stomach should be washed out immediately and free lavage established. A suitable medium for the purpose is water at body temperature containing a 5% to 10% solution of sodium thiosulfate, or a mixture of the sulfates (ferrous and ferric) of iron followed by a solution of potassium carbonate to form prussian blue which is inert. Sodium thiosulfate (10 to 50 ml. of 20% solution) or methylene blue (50 ml. of 1% solution) may be administered intravenously, provided there is time for either of these preparations to act. Ammonia inhalations, artificial respiration and oxygen, with or without carbon dioxide (7%). should be used to stimulate respiration. In desperate cases, a slow venous injection of five millilitres of a 25% solution of nikethamide has been recommended. Stimulation of the cardiac and respiratory centres may be effected by injections of lobeline and pentylenetetrazol (metrazol, cardiazol).

Strychnine and Strychnine-Yielding Plants.—The alkaloids strychnine and brucine, as well as the plants in which they are found, all act in the same manner, being highly poisonous and causing death after spasms of a severe character. Many vermin killers contain strychnine as their active ingredient.

Strychnine and all substances containing that alkaloid usually produce their effects within 10 or 15 minutes. The patient complains of stiffness about the neck, and his aspect exhibits terror. There is an impression of impending calamity or death. Very speedily the head is jerked back, the limbs extended. the back arched (opisthotonos) so that the body may rest on the head and heels only. In a few moments these symptoms pass off, and there is complete relaxation of the spasm. The spasmodic condition speedily returns. and is brought about by the slightest touch or movement of the patient. Accessions and remissions of the tetanic state ensue rapidly till the patient succumbs, usually within half an hour of the administration of the poison.

The best treatment is to put the patient under the influence of chloroform and wash out the stomach with a solution of potassium permanganate in water, four grams in two gallons. To follow, medicinal charcoal in water is recommended, and this should be freely given and removed from time to time. Sodium amytal or phenobarbital sodium should be given intravenously. Only a sufficient quantity to put the patient to sleep should be given, or, if convulsions are present. only enough to stop them.

Nicotine.—The alkaloid nicotine is obtained from the plant *Nicotiana* tabacum, the common tobacco of commerce, and has a pungent, acrid taste. Its content in tobacco leaves varies from 0.6% to 6%. Poisoning may be caused by absorption through the skin, by inhalation or by ingestion. Industrial poisoning caused by commercial preparations, such as fertilizers and fumigants, has occurred.

Cases of acute poisoning are comparatively rare, but subacute and chronic symptoms may result from the immoderate use of tobacco. When nicotine is absorbed in poisonous dose, the outstanding symptoms are those of successive central and peripheral stimulation, nausea, sickness, tachycardia, cardiac oppression and irregularity and severe prostration and cardiovascular collapse may become manifest. Treatment consists of gastric lavage when the poison has been ingested. Strong coffee or a hypodermic injection of nikethamide should be given.

Opium.—In consequence of the extent to which opium. its preparations and its active alkaloid morphia are used for the relief of pain, poisoning by opium is of frequent occurrence. It is largely used by suicides, and children, being very susceptible to its influence, frequently die from misadventure after administration of an overdose of the drug. The ordinary preparations of the drug itself, which is the dried juice of the capsules of the poppy (*Papaver somniferum*) known in commerce as Turkish, Persian, Indian or European opium, and the tincture, commonly known as laudanum. The British Pharmacopoeia requires opium in its moist state, as imported, to contain not less than 9.5% of anhydrous morphine.

The treatment of opium poisoning is governed by the condition of each case in relation to the time of intake. It consists of free gastric lavage with warm water and then with two grams of potassium permanganate in two gallons of warm water. The use of medicinal charcoal is beneficial. In coma, the airway should be kept clear, the patient catheterized and artificial respiration and inhalations of oxygen, or of oxygen with 7% carbon dioxide, should be employed if thought necessary.

Heroin is an artificial derivative of morphine (diacetyl morphine hydrochloride) and is more toxic than morphine. It has been largely used medicinally. It is a dangerous drug of addiction.

Belladonna.—The belladonna, or deadly nightshade, Atropa belladonna, contains an alkaloid, atropine, which is largely used by oculists to procure dilatation of the pupils of the eye. The brown or black berries of the plant have been eaten by children, who are attracted by their appearance. Besides dilatation of the pupils, belladonna produces rapid pulse, hot, dry, flushed skin with an eruption not unlike that of scarlatina, soreness of the throat with difficulty in swallowing, and intense thirst and delirium.

The treatment consists of gastric lavage with a solution of 1 in 5,000 of potassium permanganate. Excitement should be controlled by sedatives or mild hypnotics. Lumbar puncture may prove beneficial in certain cases.

Stramonium, hyoscyamus (henbane), hyoscyamine, hyoscine and scopolamine all produce symptoms similar to atropine poisoning, the narcotic effects being more marked.

Aconite.—The ordinary aconite, wolfsbane or monkshood (Aconitum napellus), and an alkaloid extracted from it, aconitine, are perhaps the most deadly of known poisons. A dose of 0.004 g. of aconitine has proved fatal to man. The root of aconite has been eaten in mistake for that of horse-radish. All the preparations of aconite produce a peculiar burning, tingling and numbness of the parts to which they are applied. When given in large doses they produce violent vomiting, as a rule, more or less paralysis of motion and sensation and great depression of the heart, usually ending in death from syncope. Intelligence remains unaffected till almost the last.

The treatment consists of free gastric lavage with a solution composed of 12 g. of tannic acid in two gallons of warm water. Tannic acid (1.2 g. in 180 ml. of tepid water) should be given and followed by animal charcoal suspended in water. Cardiac and respiratory stimulants should be administered in accordance with clinical indications. Artificial respiration and oxygen inhalations may prove necessary.

Cocaine.—Cocaine is the active alkaloid of coca leaves—*Erythroxylum* coca—and is chemically methyl benzoylecgonine. The hydrochloric salt is the commonly used preparation. It is a powerful deliriant narcotic poison. If taken by the mouth, given hypodermically or otherwise absorbed, it may cause delirium and coma. Sometimes convulsions and sudden death occur. It acts on the heart and may cause fatal syncope. Cocaine is a dangerous drug of addiction.

Organic Compounds Used as Hypnotics.—These if taken in excessive doses act as poisons, and the symptom which attracts attention is the deep coma produced. Examples are: chloral, barbital and its derivatives, etc. Any hypnotic drug taken in excessive quantity will act as a coma-producing poison. (See BARBITURATES; SULFONAL GROUP.)

Gaseous Poisons and War Gases

Carbon Monoxide.—Poisoning by carbon monoxide may occur from coal gas, water gas or from exposure to the suffocating fumes of fires, smoky grates and stoves; also from the fumes of gas heaters and internal-combustion engines.

The diagnosis may be made at once from the clinical symptoms of drowsiness, collapse and coma, and the cherry-red colour of the face, body and mucous membranes. Examination of the blood will make the diagnosis certain, since the presence of carboxyhemoglobin may be readily detected by the spectroscope.

The treatment consists in giving oxygen with 7% carbon dioxide freely, and employing artificial respiration if necessary. The use of carbon dioxide is important since it stimulates breathing and breaks down the carbon monoxide-hemoglobin molecule. The body warmth must be maintained. This is important since carbon monoxide disturbs the heat-regulating centre with reduction in the processes of oxidation. Stimulants administered hypodermically will also prove beneficial.

Carbon Dioxide or Carbonic Acid.—This occurs in coal mines from chokedamp or afterdamp. Cellars of houses, wells, brewers' vats, lime kilns, etc., frequently contain large quantities of carbonic acid gas.

The treatment consists in fresh air, rest, oxygen, artificial respiration if necessary, and employment of warmth and stimulants.

Sulfureted Hydrogen.—This occurs from contamination of the air with sewer gas, and from the gases evolved when iron slag becomes moistened with water. The gas is frequently produced in various chemical processes.

The treatment consists in giving the patient plenty of fresh air. Oxygen and stimulant treatment must be used.

War Gases.—Despite the fact that a mixture of gases may be employed, it is customary to classify war gases into four groups: (1) gases producing irritation of the lungs (choking gases); (2) gases producing irritation of the nose (nasal irritants); (3) gases producing irritation of the eyes (lachrymators); and (4) gases producing irritation of the skin (vesicants).

Group 1 includes phosgene, diphosgene, chlorine and chloropicrin. All these gases when inhaled produce rapid bronchial and pulmonary irritation which may lead to death within a day or two from cardiac failure brought about by inflammatory edema. A later fatal complication results from bronchopneumonia.

Group 2 includes smokes which are liberated from the highly toxic arsenical compounds diphenylamine chlorarsine or DM, diphenyl chlorarsine or DA, and diphenyl cyanarsine or DC. These are capable of causing profound sensory disturbance which in warfare diminishes physical capacity and undermines morale.

Group 3 includes ethyl iodoacetate or KSK, bromobenzyl cyanide or BBC, and chloroacetophenone or CAP. The vapours of these substances produce transient irritating effects on the eyes, which water copiously. If the liquids from which these vapours arise are brought into contact with the eyes severe and permanent damage may result.

Group 4 includes bis β-chlorethylsulfide or mustard gas, and β-chlorvinyldichlorarsine or lewisite. These liquids give off toxic vapours which affect the lung, eye and skin on account of their irritant action. In their liquid form such fluids cause severe burning with destruction of the tissue with which they are brought into contact. Their power of penetration of the skin is very considerable since they are capable of producing lipoid solubility. Mustard gas has a delayed action and on this account serious delay in treatment may occur. Lewisite acts much more rapidly. The arsenic content of lewisite when absorbed by the skin may produce tissue damage in the secretory and urinary systems. (See CHEMICAL WARFARE.) (W. H. WI.; JO. GR.)

Poisonous Foods

The term food poisoning is generally applied to a group of illnesses occurring after the ingestion of food containing a variety of agents such as chemical, plant and animal poisons as well as certain microbes or their poisons. Ptomaine poisoning is a misnomer since it does not represent a defined chemical entity capable of causing food poisoning.

Toxic chemicals mav find their way into food bv malicious intent. Chemicals such-as insecticides: rodenticides-and herbicides may cause poisoning if allowed to remain in toxic doses on food when eaten. Chemicals that are added to foods to improve quality may be toxic under certain circumstances and not recognized immediately. For example, flour bleached with gaseous nitrogen trichloride (agene) caused convulsions when fed to dogs. As a result. use of agene as a bleaching agent for flour was prohibited.

Plants such as poisonous mushrooms, snakeroot, water hemlock, rhubarb leaves. rye infected with the ergot fungus, seeds of the unripe ackee and tung nuts are poisonous when eaten.

Shellfish, eaten raw or cooked, may be poisonous after ingesting certain toxic plankton. Several tropical fish have been shown to be toxic. Organs such as the liver and ovaries of globe fish and certain sharks may be toxic. The flesh of the Moray eel is also poisonous when eaten.

Microbial food poisoning is of two types: (1) that in which the poison (or toxin) is produced in a food by the growth of microorganisms, and the poison (not the microorganism) gives rise to illness, and (2) that in which living organisms are present in a food in numbers large enough to cause illness. The mechanism of illness caused by living organisms is not understood.

Botulism, caused by a toxin produced by *Clostridium botulinum,* is the most serious type of food poisoning, fatal in approximately 65% of the cases in the United States. It leads to muscle paralysis, and death is due to respiratory failure. The microorganism causing botulism grows in the soil and produces heat-resistant spores that grow in the absence of air in low-acid, underprocessed home-canned foods. Boiling destroys botulinum toxin.

The poison produced by the growth of staphylococci in foods causes severe gastrointestinal disturbances usually within 2½ to 3 hours after ingestion of the food. These bacteria are commonly found in the throat and on the skin of man. where they may cause pimples and abscesses. Staphylococci grow in many foods with a high salt and sugar content. and control of staphylococcic food poisoning depends on adequate refrigeration of perishable foods. The food poisoning toxin of staphylococci is resistant to boiling.

Living microorganisms that cause food poisoning include *Salmonella,* which produce infection with gastrointestinal disturbances usually from seven hours to one day or more following the ingestion of a meal containing them. *Salmonella* grow in the intestines of man and animals and are sometimes found in raw meat and poultry products and food subject to fecal contamination. These microorganisms are readily destroyed at pasteurization temperatures.

Other living microorganisms causing illness are certain types of cocci and bacilli, which produce mild illness characterized principally by vomiting and diarrhea 6 to 1j hours after ingestion of food containing large numbers of them (alpha-type streptococcus. *Clostrzdium perfringens* and *Bacillus cereus).*

See also ADULTERATION; ANTIDOTES; DRUG ADDICTION; FOOD POISONING, BACTERIOLOGICAL; POISONOUS PLANTS; and articles on the various poisonous chemicals, plants, etc. (G. M. DK.)

BIBLIOGRAPHY.—T. M. Legge and K. W. Goadby, *Lead Poisoning and Lead Absorption* (1912); J. Rambousek, *Industrial Poisoning From Fumes, Gases and Poisons of Manufacturing Processes,* trans. and ed. by T. M. Legge (1913); A. H. Allen, *Commercial Organic Analysis,* 5th ed. by various authors, 9 vol. (1923); F. Peterson, W. S. Haines and R. W. Webster (eds.), *Legal Medicine and Toxicology* (1926); W. Autenrieth, *Laboratory Manual for the Detection of Poisons and Powerful Drugs,* 6th ed. (1928); E. Leschke. *Clinical Toxicology* (1934); T. A. Gonzales, Morgan Vance and Milton Helpern, *Legal Medicine and Toxicology* (1937); C. K. Drinker, *Carbon Monoxide Asphyxia* (1938); F. Bamford, *Poisons, Their Isolation and Identification* (1940); M. Sartori, *The War Gases* (1939); W. H. Martindale, *The Extra Pharmacopoeia,* 22nd ed., vol. i and ii (1941–43); Y. Henderson and H. W. Haggard, *Noxious Gases and the Principles of Respiration Influencing Their Action,* 2nd rev. ed. (1943); J. Bebie, *Manual of Explosives, Military Pyrotechnics, and Chemical Warfare Agents* (1943); J. H. Gaddum, *Pharmacology,* 3rd ed. (1948); T. Dewar, *Textbook of Forensic Pharmacy* (1946); J. Glaister, *Medical Jurisprudence and Toxicology,* 9th ed. (1950); G. M. Dack, *Food Poisoning,* 3rd ed. (1956), which contains a complete bibliography.
(JO. GR.; G. M. DK.)

POISON FISH *(Synanceja verrucosa),* an ugly, rather shapeless, tropical, marine-bottom fish, of the family Scorpaenidae, reaching a length of about one foot, inconspicuous as it lies partly buried in the sand or in some hollow of a rock or coral bottom, which it commonly does.

Though veiled in skin, the spines of the dorsal fin of the poison fish have large poison glands at their bases and can inflict a severe wound. Like the related lion fish (*q.v.*) this species is found in the Indian ocean. East Indies and eastward into Polynesia. *See* also SCORPION FISHES. (J. T. N.)

POISON GAS: *see* CHEMICAL WARFARE.

POISON HEMLOCK is a common name (derived from the Anglo-Saxon *hem,* "meadow" or "border"; and *lok* or *lich,* "death") for the Eurasian species *Conium maculatum* of the parsley family Umbelliferae. It is a branching biennial herb from 3 to 10 ft. tall with parsleylike, malodorous leaves, small white flowers in compound umbels and conspicuously purple-blotched stems and leaf stalks It has become widely naturalized in moist areas in North and South America and is not uncommon in gardens, where it has even been grown as an herbaceous hedge under the name of California fern. In the Pacific coast states poison hemlock may form dense thickets in net roadside ditches, the plants reaching 10 ft. or more in height. The leaves are reported to cause dermatitis. All parts of the plant contain the toxic principles coniine, conhydrine, methyconiine and coniceine and are poisonous to eat. The leaves, sometimes mistaken for parsley, are most toxic when the plant is in flower; the roots are least toxic in the spring. Chickens have been killed from eating the seeds. Death occurs in man and animals from respiratory paralysis and differs from water hemlock (*q.v.*) poisoning in that no convulsions occur and the mind reportedly remains clear until the end. Poison hemlock is one of the historically famous plant poisons, presumably the one administered by the Greeks to Socrates and other state prisoners. From Plato's description of the effect of the poison drink on Socrates *(Phaedo)* there is little question of its identity. *See* also ALKALOIDS; POISONOUS PLANTS. (MD. E. M.)

POISON IVY, the name commonly applied to several. mostly white-fruited, trifoliate species of woody vines or shrubs of the genus *Toxicodencron* of the cashew or sumac family (Anacardiaceae), native to North America. The forms with bushy habit and lobed leaflets are often called poison oak, especially in the western United States. The common poison ivy *(Toxicodendron radicans),* the most widespread species, abundant in eastern North America and less common westward, is a variable species with a bushy or climbing habit and leaves with three leaflets which may be smooth and glossy or hairy, entire, toothed or lobed. Many of these not too constant variations have been designated as separate species or varieties. The commoner of these forms with their ranges are: *T. quercifolium,* with deeply lobed leaflets, Maryland to Texas; *T. radicans rydbergi,* with thicker leaves, Great Plains to Rocky mountains; and *T. diversilobum,* with leaflets mostly scalloped on the margin. Pacific coast. The poison sumac *(T. vernix),* native in swamps from Quebec to Minnesota and south to Texas and Florida, is a tall bush or small tree with pinnately compound leaves with 7 to 13 entire leaflets and drooping, axillary clusters of persisting white fruits. (The common nonpoisonous sumacs of the genus *Rhus [see* SUMAC] have distinctive reddish fruit.)

All species of *Toxicodendron* are poisonous to touch, producing in many persons a severe inflammation of the skin, or dermatitis *(see* below). The toxic principle, urushiol, is produced in the resinous juice of the resin ducts of the leaves, flowers, fruits and bark of stems and roots but not in the pollen grains. Being almost nonvolatile, the urushiol may be carried from the plant on clothing, shoes, tools, soil, by animals, by smoke from burning plants, to persons who never go near the poison ivy plants. Poisoning may occur if clothing is worn a year after contact with poison ivy. (W. C. M.)

Poison **Ivy Dermatitis.**—The juice of all portions of the poisonous plants discussed above is not irritating or poisonous on first exposure; but after one or more contacts, most persons become sensitized or allergic and will react to the juice with a rash. The sap must get on the skin for the dermatitis to develop. The hands and clothing may transfer sap to other portions of the body not directly exposed. The rash may develop as early as 6 to 12 hours or as late as a week or more after exposure; most commonly it appears within 24 to 48 hours. No one is born with sensitivity; it is generally acquired during childhood and tends to be highest at this time, but over the years it declines despite exposure to the plants. Once sensitivity is lost, a solid immunity remains and the person cannot easily be made sensitive again. The plants are so common and the juices such highly potent sensitizers that over three-fourths of the American population acquires poison ivy dermatitis at some time.

The severity of the rash varies directly with the quantity of sap deposited on the skin and with the person's inherent degree of sensitivity. Sensitivity may be so great that the sap diluted 50,000,000 times will still induce a rash. Even a mildly sensitive person can develop an intense eruption following a high degree of exposure, but the rash heals in a week or less as contrasted with two or three weeks for the highly sensitized.

A moderate degree of immunity can be established, plant extracts given orally (very small doses at first. increased daily over the next few months) being effective. Although complete desensitization is impossible, and skin rash may occur as a side effect, this prophylactic treatment is justified for the highly sensitive because it lessens the intensity and duration of the rash.

Anointing the skin before exposure with "barrier" or detoxifying creams is generally useless, and washing the skin with solvents, soaps or detoxicants is ineffective unless performed within a few minutes after contact. ACTH and cortisonelike drugs, by mouth or injection. promptly control the rash; this is the only known treatment that has a clear-cut beneficial effect. The great majority of popular and folk remedies for local application are without benefit and many are harmful. Bland compresses and soothing lotions do not restrain the rash, but provide comfort and maintain hygiene until the skin recovers spontaneously. *See* also POISONOUS PLANTS. (A. M. K.)

POISONOUS PLANTS are plants that produce adverse physical effects, and sometimes death, when eaten or touched by man or animals. Most plant species are harmless; a few are poisonous under ordinary conditions. others are poisonous under special conditions. Toxic materials are often very strictly localized in the plant. Opium and its related drugs come from the milky latex of the opium poppy (*Papaver* somniferum) but are absent from the seeds, which may be eaten for food. In the water hemlock (*Cicuta* maculata) the root and fruit are poisonous, whereas in corn cockle (Agrostemma) the poisonous glycoside is confined to the seeds. The leaf blades of rhubarb (Rheum *rhaponticum*) are highly poisonous but the leaf stalks are nonpoisonous. Some plants are harmless when eaten green and fresh but poisonous when wilted or dried. Others are poisonous when raw but nonpoisonous when cooked. While it is not possible to classify poisonous plants by the toxic ingredient, knowledge of the type of toxic substance is helpful in diagnosing symptoms and treatment.

Types of Toxic Substance.—In general the poisonous character of a plant is due to the presence of one of four groups of organic compounds: an alkaloid, a glycoside, a resin or an organic acid.

Alkaloids.—An alkaloid is a nitrogen-containing organic base; it is colourless, odourless, nearly insoluble in water and very bitter. Except for the fungus ergot (Claviceps *purpurea*), a parasite on rye, and poisonous mushrooms, the sources of all alkaloids are flowering plants. Notable among alkaloids are the opiates and codeines of the opium poppy, the atropine-nicotine groups in the Solanaceae (the nightshade family) and the curines (curare poisons) in tropical members of several families. (See ALKALOIDS.)

Glycosides.—A glycoside (glucoside, in part) is a complex carbohydrate which on hydrolysis and in the presence of amino acids or enzymes produces one or more simple sugars and a nonsugar end product called aglycon. These carbohydrates are water-soluble, bitter, often odour producing and may be coloured or colourless. Three primary groups of plant glycosides yielding toxic products on hydrolysis are: (1) cyanogenetic glycosides, in which the poisonous by-product is hydrocyanic acid or prussic acid and found in species of Sorghum, *Prunus* (wild cherries. almonds) and Linum (flax); (2) saponin glycosides, produced in species of Agrostemma (cockle), Digitalis (foxglove), Actinea (rubberweed); and (3) solanine glycosides, produced in members

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POISON IVY (TOXICODENDRON [RHUS] RADICANS)

of the nightshade family, especially berries of *Solanum.* (See also GLYCOSIDES. NATURAL.)

Resins.—The toxic resins or resinoids occur in poisonous members of the heath family (Ericaceae), water hemlock (Cicuta) of the carrot family, and in the milkweeds (Asclepiadaceae). For the most part they are an insoluble gummy material of complex organic structure, localized in resin- or latex-containing ducts.

Types of Physiological Action.—Poisonous plants may be grouped according to the physiological actions they produce. These groups and some plant examples include: (1) blood poisons: species of *Prunus,* seeds of castor bean (*Ricinus*) and rosary pea (Abrus); (2) nerve poisons: poisonous mushrooms. Jimson weed (Datura) and henbane (*Hyoscyamus*); (3) neuromuscular poisons: ergot. foxglove and arrow poisons (curare); (4) muscular poisons: false hellebore (Veratrum); and (5) skin irritants or dermatitis-producing plants: poison ivy (Toxicodendron [Rhus]), parsnip (*Pastinaca*), mustard (Brassica), poisonwood (*Metopium*) and snow-on-the-mountain (Euphorbia marginata).

Plants Poisonous on Contact.—Skin poisoning, or dermatitis, is the typical plant contact poisoning. This type of reaction varies from a minor or temporary irritation to an itching rash or a painful inflammation with watery blisters that may last for days or weeks. In most plants that produce this reaction the toxic ingredient is concentrated in a resinous or milky juice. The severity of the symptoms varies with the susceptibility of the individual and with the amount of contact with the toxic agent. Some persons may be immune to poisoning by one species but susceptible to that by another; immunity may be complete or only partial; it may be lost or acquired over the years.

Plants noted for dermatitis-producing qualities include:

Cashew Family (Anacardiaceae).—Poison ivy and poison oak (Toxicodendron species), poison sumac and poison dogwood (Toxicodendron *vernix*) and Japanese lacauer tree (Toxicodendron *verniciflua*) are native to temperate regions and may be distinguished from nonpoisonous sumacs by the white (not red) fruits. In poison ivy and its relatives the leaves are of three leaflets (never five), are usually coarsely toothed, and are glossy on the upper surface when young. Poison sumac leaves have 7 to 15 leaflets, whose margins are never toothed, and the hairless leaf stalk is usually reddish. The poisonwood of southeastern United States and the West Indies (Metopium toxiferum) resembles the more northern poison sumac.

Spurge Family (Euphorbiaceae).—The milky sap of the following plants produces varying degrees of dermatitis in susceptible individuals: many species of spurge (*Euphorbia*), including the cultivated ornamental snow-on-the-mountain (*E.* marginata). an annual whose leaves are margined white; and the manchineel tree (*Hippomane mancinella*) of the American tropics.

Nettles.—Some plants produce a nonpoisonous but very irritating stinging rash of short duration, termed an urtication. These plants bear sharp, brittle. glandular hairs that are hollow and filled with an irritating watery material which enters the skin when punctured by the hair. Included among these are the common nettle (*Urtica* gracilis, *U. urens*), the stinging nettle (*U.* dioica) and the wood nettle (Laportea *canadensis*).

Others.—Miscellaneous kinds of dermatitis-producing plants include the wild parsnip (*Pastinaca sativa*), which has coarse. celerylike foliage and bright yellow flowers; certain primroses (especially *Primula* obconica, P. malacoides and P. *sinensis*); several kinds of ladyslipper orchids (*Cypripedium* acaule, C. *calceolus*, C. reginae and C. *parviflorum*); several species of milkweed (Asclepias) and osage orange (*Maclura pomifera*). Foods made of buckwheat flower (Fagopyrum *esculentum*) produce dermatitis in some individuals.

Plants Poisonous on **Ingestion.**—Most plants that are poisonous when eaten are not tasty or likely to be eaten. except by children. Unfortunately, the quantity of poison fatal for a child is only a fraction of that fatal for, an adult. These plants may be conveniently grouped according to the plant part that carries the toxic substance.

Roots.—Roots of the following may cause serious or fatal poisoning when eaten: (1) Jack-in-the-pulpit (*Arisaema*); the tuberous rhizome is rich in calcium oxylate crystals and produces inflammation of the membranes of the mouth and the throat when eaten raw; boiling the tubers in water dissolves the crystals and makes them edible. (2) Death camass (Zigadenus); the bulbs are rich in the highly toxic alkaloid zygadenine, and sometimes are eaten by children. (3) Star-of-Bethlehem (*Ornithogalum*); all parts of the plant are poisonous, and the bulbs especially should not be kept where children have access to them. (4) Amaryllis and relatives (*Hippeastrum, Zephyranthes, Crinum* and *Hymenocallis*) produce bulbs containing poisonous alkaloids; they also should not be kept where children may obtain them. (5) Water hemlock (Cicuta) and poison hemlock (Conium *maculatum*) contain a highly toxic yellowish resin in the roots: fatal poisoning may result from eating them. These plants belong to the carrot family. produce flat-topped clusters of white flowers and grow in wet open swales or along streams. (6) Potato (*Solanum tuberosum*) is poisonous when the tuber grows at the surface of the soil and becomes green through exposure to the sun; "greened" potato tubers should never be eaten.

Shoots and Foliage.—Shoots and foliage of the following may cause poisoning: (1) Pokeweed (Phytolacca *americana*); young shoots cooked as a potherb are edible, but the water should be poured off and replaced with fresh to remove the water-soluble toxic material. (2) Poison hemlock (Conium *maculatum*); children have been fatally poisoned by eating small quantities of foliage or stalk. (3) Fool's-parsley (Aethusa *cynapium*), an annual with parsleylike leaves, is sometimes eaten in error for garden parsley with fatal results; the leaves are never mosslike or curly. (4) Tansy (Tanacetum vulgare); a tea made from the foliage is poisonous, and overdoses have been fatal.

Flowers.—Flowers of poisonous plants are rarely eaten deliberately. However, children eating flowers or buds of tiger lily (Lilium tigrinum) have been poisoned with near-fatal results. The anthers contain an alkaloid not known in other lily species.

Fruits and Seeds.—Fruits and seeds of poisonous plants are occasionally eaten with fatal or near-fatal results! especially by children. The following, while by no means complete, is a listing of common poisonous fruits to be avoided: (1) Baneberry (Actaea, a woodland perennial herb bearing bright red or white berries about half an inch long; the berries are not tasty and are moderately toxic. (2) Belladonna (Atropa belladonna), a perennial producing bell-shaped dull-purplish flowers and black berries with violet juice; the toxic alkaloid hyoscyamine is present in all parts of the plant. (3) Bittersweet (Celastrus), a woody vine producing orange-red berrylike fruits in autumn, prized for decorative uses; the outer scarlet pulp contains a moderately toxic, sweetish but disagreeable-tasting alkaloid. celastrin. (4) Black nightshade. or garden huckleberry (*Solanum nigrum*), an annual herb with drooping clusters of black. globose berries about three-quarters of an inch in diameter; the unripe berries are poisonous, but the ripe fruit is edible, and cooking or boiling destroys remnants of the poisonous material. (5) Blue cohosh (Caulophyllum *thalictroides*), a low. perennial herb of moist. rich, woodland areas. produces stiffly erect stalks of pea-sized dark-blue "berries" above the foliage; the very bitter berries contain a poisonous alkaloid. (6) Chinaberry (*Melia* azedarach) is a tree of warm temperate regions producing panicles of fragrant purple flowers followed by pale yellow, berrylike drupes about half an inch across; the fleshy pulp of the fruit contains a paralyzing nerve poison. Coyotillo (Karwinskia humboldtitma), a rangeland shrub with oval, brownish-black berries about half an inch long; the pulp is believed to be nonpoisonous. but the seeds are highly toxic. (7) Daphne (Daphne), a low shrub producing fragrant, showy flowers in spring, followed by orange or red berrylike drupes about one-fourth inch long; a small number of the berries may cause fatal poisoning in children. (8) English ivy (Hedera helix), an evergreen vine, produces umbels of black or orange poisonous berries sometimes eaten by children. (9) Euonymus. burning bush, wahoo (Euonymus *atropurpureus*), a shrub with reddish capsules whose few seeds are each covered by a bright, orange-red, fleshy aril; the fruits and seeds are moderately poisonous when eaten. (10) European bittersweet, or blue nightshade (*Solanum* dulcamara), is a clambering vine, herbaceous becoming woody. with clusters of small white flowers followed by attractive bright red berries about one-third inch across; both leaves and bark have a strong, disagreeable odour, and the berries, moderately poisonous if eaten in quantity. contain the alkaloidal glucoside solanine. (11) Henbane (*Hyoscyamus niger*), a much-branched, clammy-hairy herb with a fetid odour when crushed. produces yellowish, funnel-shaped flowers with purple veins. followed by a seed pod enclosed in a persistent calyx: children eating seed pods or seeds have been poisoned by the alkaloid hyoscyamine. (12) Holly (*Ilex*) produces attractive red yellow or black berries that are someuhat (but not highly) poisonous and should not be eaten. (13) Jerusalem cherry (Solanum pseudo-capsicum) is grown as an ornamental pot plant and prized for its showy globose orange berries nearly an inch across; the fruits contain toxic quantities of several poisonous materials and should never be eaten. (14) Jimson weed (Datura *stramonium*), an annual weed with showy white or purplish funnel-form flowers, three to six inches long, followed by globose prickly pods about one inch across; the soft, unripe seed pods are poisonous when eaten, and the seeds are increasingly toxic. (15) Manchineel tree (Hippomane *mancinella*), a small subtropical tree of the Euphorbiaceae, produces milky sap, spikes of small greenish flowers. followed by berrylike drupes about $1\frac{1}{4}$ in. across; persons eating the fruits in the belief that they were edible have been fatally poisoned. (16) Matrimony vine (Lycium halimifolium), a woody clambering vine of the Solanaceae, somewhat thorny, produces small white funnelform flowers in leaf axils, followed by bright orange-red berries about one-third inch across; the berries are moderately toxic and contain a hyoscyaminelike alkaloid. (17) May apple (Podophyllum) is a perennial herb of rich, open woodlands or pastures. producing large, umbrella-shaped leaves, beneath which appear one or two nodding white flowers an inch across, followed by a yellow or reddish berry about $1\frac{1}{2}$ in. long; when fully ripe the berries are edible, but when hard, green and immature, they contain highly toxic quantities of a purgative resin, podophyllin. (18) Mistletoe (Phoradendron, Viscum *album*), an evergreen parasitic plant growing on trees, produces decorative whitish berries that are reported to have been fatally poisonous when eaten by children. (19) Pokeweed (Phytolacca americana). a coarse tall perennial herb with reddish-purple stems and glossy green leaves, produces dense terminal racemes of small white flowers followed by crimson-juiced. glossy black berries; the berry pulp is believed to be nonpoisonous. but the black glossy seeds contain toxic quantities of saponins and alkaloids. (20) Privet *(Ligustrum),* a common shrub often grown for hedges, has small racemes of white flowers

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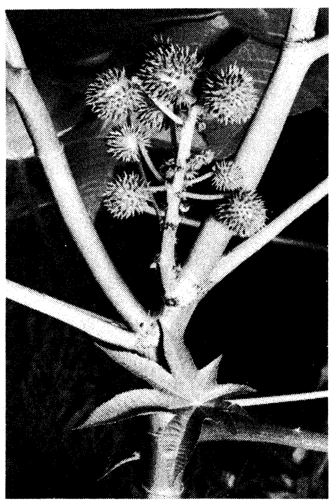
POKEWEED (PHYTOLACCA)

followed by bluish-black berries about one-fourth inch across; the berries are reported to be fatally toxic to children.

Mushrooms.—Mushroom poisoning commonly is fatal to man. Many mushrooms contain toxic alkaloids (muscarine. agaricine, phalline) and identification of poisonous types from the non-poisonous should be made only by an expert. The edible mushroom of commerce is *Agaricus campestris,* but some species of the genus are poisonous. The designation of poisonous types as toadstools and the nonpoisonous as mushrooms is common but meaningless. *(See* also MUSHROOM.)

Stock-Poisoning Plants. — These are of many kinds and vary with the different countries and regions. Refer to the work by W. C. Muenscher. cited in the bibliography.

Arrow Poisons. — These. concocted from the juices and resins of a variety of plants. are of importance to aborigines of many areas. particularly of the tropics. for shooting of animals and fish and in warfare. In the 20th century the active ingredients have proved to be important in medicine. All South American Indian arrow poisons are grouped under the name curare and may be classified as neuromuscular toxins. From them the alkaloid curine has been isolated. Derivatives of this arrow poison have proved useful in anesthetics to induce muscle relaxation. The material as used by the Indians is a black gummy mass. Small quantities carried on the tip of an arrow to the flesh of man or animal induce paralysis of the voluntary muscles followed by stupor and death due to failure of respiratory muscles.



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CASTOR BEAN (RICINUS COMMUNIS)

Crude arron-poisoning material was first introduced to modern civilization in 1595, when Sir Walter Raleigh brought a tiny vial of it to England. From that time onward reports of its preparation, use and efficacy became a mixture of folklore and fact. The aboriginal use of the potion was accurately observed in 1800 and reported in 1807 by Humboldt. Later the German botanist R. H. Schomburgk witnessed its preparation by Indians in British Guiana and reported it in detail in 1844. Preparation of the poison was a closely guarded secret and ritual. handed down from father to son, and today, through the influence of firearms, it is rapidly becoming a lost art in much of South America.

Detailed information on the plants used and procedures for making the poison were learned from the Tecuna Indians of Brazil by B. A. Krukoff,who reported on them in 1937. Bundles of stems of the plants *Strychnos castelnaei* and *Clzondodendron polyanthum* were gathered and brought from the forest. The outer bark was peeled or scraped from the stems, packed into a bundle, wrapped in palm leaves and allowed to set over night. It was then suspended over an empty clay pot and opened at the top. About two quarts of cold water was poured very slowly over the bark and collected in the pot. This extract was transferred to a larger pot and brought to boil over a steady fire. Several collections of the cold-water extract were similarly prepared and added to the concoction, which was kept boiling for at least eight hours, when it was reduced to about one-eighth its original volume. On the third day the extract was triple-strained through a palm spathe and again boiled gently for several more hours. To this a decoction of macerated roots of other plants *(e.g.,* species of *Piper)* were added, boiled and strained. During the process an extract of stems and leaves of *Dieffenbachia insignis* and of tubers of *Aristolochia* were added and the whole boiled down to a thick, gluelike sirup of dark chocolate colour. When cool its potency was tested on some bird or animal. The material was stored in covered pots. gourds or bamboo tubes and kept as dry and cool as possible.

The identity of all the plants used in the preparation of curare remains incomplete, but leaves and stems of the following plants are known to be used: *Chondodendron tomentosum* (Menispermaceae). *Strophanthus* (Apocynaceae), *Strychnos* (Loganiaceae) and *Cocculus* (Menispermaceae).

See also POISON; ANTIDOTES; CURARE; and articles on the various families, genera and species of poisonous plants.

BIBLIOGRAPHY.—L. H. Pammel, *Manual of Poisonous Plants* (1911); A. Bernhard-Smith, *Poisonous Plants of All Countries* (1923); *D. G.* Steyn, *The Toxicology of Plants in South Africa* (1934); *A. R.* McIntyre, *Curare; Its History, Nature, and Clinical Use* (1947); L. V. Blubaugh and C. R. Linegar, "Curare and Modern Medicine," *Econ. Bot.,* 2:73–82 (1948); B. A. Krukoff and A. C. Smith, "Notes on the Botanical Components of Curare," *Bull. Torrey Bot. Cl.,* 64:401–409 (1937). *R.* N. Chopra and R. L. Badhwar, *Poisonous Plants of India* (1949); W. C. Muenscher, *Poisonous Plants of the United States,* 2nd ed. (1951). (G. H. M. L.)

POISSON, SIMÉON DENIS (1781–1830), French mathematician. known for his work on definite integrals, electromagnetic theory and probability. was born at Pithiviers in the *département* of Loiret on June 21, 1781. He studied medicine but gave it up in favour of mathematics. In 1798 he entered the Ecole Polytechnique at Paris, where he attracted the notice of Lagrange and Laplace. Until his death on April 25, 1840, he was almost entirely occupied in mathematical research and in teaching. He was made deputy professor at the École Polytechnique in 1802, and full professor in succession to Fourier in 1806. In 1808 he became astronomer to the Bureau des Longitudes: and when the Faculté des Sciences was instituted in 1809 he was appointed professor of pure mechanics. His most important work was on the application of mathematics to physics. and in particular to electrostatics and magnetism. In the field of pure mathematics, his most important works were his series of memoirs on definite integrals, and his discussion of Fourier's series, which paved the way for the classical researches of Dirichlet and Riemann on the same subject. His studies on probability and the Poisson distribution law are of great importance.

Resides his many memoirs. Poisson published a number of treatises: *Traité de mdcanique,* 2 vol.. (1811 and 1833), which was long a standard work; *Théorie nouvelle de l'action capillaire* (1831); *The'orie mathe'matique de la chaleur* (183j); *Supplément* to the same (1837); *Recherches sur la probabilité des jugements,* etc. (1837). (O. OE.)

POITIERS, a town of western France, formerly capital of Poitou *(q.v.)* and now the chief town of the *département* of Vienne, 61 mi. S.S.W. of Tours on the railway to Bordeaux. Pop. (1954) 45,805. Called Limonum at the time of the Roman conquest, Poitiers afterward took the name of its Gallic founders, the Pictones or Pictavi. Christianity was introduced in the 3rd century, and the first bishop of Poitiers, from 350 to 367, mas St. Hilarius. Fifty years later the city had fallen into the hands of the Arian Visigoths and became one of the principal residences of their kings. Alaric II nas defeated by Clovis at Vouillé. not far from Poitiers, in 507, and the town became a part of the Frankish dominion. This was the first occasion on which the peoples of northern and southern Gaul met in conflict near the town which was to see them so often join battle. By his victory in 732 over the Mohammedans at Moussais-la-Bataille in this region, Charles Martel proved the saviour of Christendom. Eleanor of Guienne frequently resided in the city and in 1199 entrusted it with communal rights. After the battle of Poitiers in 1356 (*see* below), Poitou was recognized as an English possession by the treaty of Brétigny (1360) ; but by 1373 it was recovered by Bertrand du Guesclin.

Between the northwest of the plateau central and the Gâtine, both heights of old rock, lies the relatively low land called the Seuil du Poitou, giving a historic connection between the Paris basin and the basin of the Garonne. In this lowland streams have dissected valleys in the Jurassic rocks, and Poitiers stands on a promontory above the junction of the Boivre and the Clain. Till 1857 Poitiers contained the ruins of a Roman amphitheatre; remains of Roman baths were laid bare in 1877; and in 1879 the tombs of Christian martyrs were discovered to the southeast.

The Cathedral of St. Peter was begun in 1162 by Henry II of England and Eleanor of Guienne on the ruins of a Roman basilica. It was completed by 1379. The Church of St. Jean, most ancient Christian monument in France, was built as a baptistery in the first half of the 4th century, and enlarged in the 7th century.

The Church of St. Radegonde, a great resort of pilgrims, commemorates the consort of Clotaire (d. 587), preserving in its crypt the tomb of Radegonde, who founded at Poitiers the abbey of the Holy Cross: and two others reputed to be those of St. Agnes and St. Disciola. Notre-Dame la Grande (late 11th century) represents a much older collegiate church and has a richly sculptured Romanesque façade. The Church of Montierneuf (hfonasterium Novum) was begun in 1077 by William VI, duke of Aquitaine and count of Poitiers.

Poitiers has a university with various faculties. Trade is in farm produce, wine, wool: honey, and leather. The industries include the preparation of goose and swan skins, printing and the manufacture of hosiery, brushes, oil and paint.

Counts of Poitiem — In the time of Charlemagne the countship of Poitiers, then part of the kingdom of Aquitaine, was represented by a certain Abbon. Renoul (Ranulph), created count of Poitiers by Louis the Pious in 839, was the ancestor of a family distinguished in the 9th and 10th centuries for its attachment to the Carolingian dynasty. One of his successors, Ebles the Bastard (d. 935), took the title of duke of Aquitaine, and his descendants retained the hereditary name of William. In accordance mith the dying wishes of William X his daughter Eleanor was married in 1137 to Louis, the son of Louis VI of France. Sole heiress, she brought her husband Poitou, Saintonge, Aunis, a part of Touraine and Berry, Marche, Angoumois, Périgord, Auvergne, Limousin, Bordelais, Agénois and Gascony. After a divorce in 1152. Eleanor married the count of Anjou, Henry Plantagenet, who became king of England as Henry II. The west of France thus passed into the hands of England. Philip Augustus reconquered Poitou in 1204. When Charles VII ascended the throne he united the countship of Poitiers to the crown.

Battle of **Poitiers.**—The battle of Poitiers, which was fought on Sept. 19, 1356, between the armies of King John of France and of Edward the "Black Prince," was the second of the three great English victories of the Hundred Years' War. From Bordeaux the Black Prince had led an army into central France and had amassed an enormous booty. King John, in Normandy, hurried south to intercept the raiding army and to bar its homeward road. After an unexpected encounter with the French rear, the Black Prince, by forced marching, was able to slip past the French, but reaching Maupertuis, 7 mi. S.E. of Poitiers, with the king's army in chase, he found himself compelled to choose between fighting and abandoning his spoil. He chose the former course, in spite of the enemy's great superiority in numbers (perhaps 16,000 to 6,500), and in order to give his trains time to draw off took up a defensive position on Sept. 18 mith a slight hollow in iront and a wood behind, between the Poitiers-Boideaux main road and the Maussion river. John, instead of maneuvering to outflank the English, alloned the cardinal Hélie de Talleyrand-Périgord to attempt to negotiate a peace. This proving vain, the French army attacked without any attempt at maneuver or reconnaissance, and on a iront so narrow that the advantage of superior numbers was iorieited. Moreover, King John ordrred all but the leading line to attack on ioot and thus condemned the best part of his army to a iatiguing advance on foot across difficult country in iull armour.

The French crossbowmen, who might have crushed the relatively few English archers present, mere mingled with the mounted men in first line, but, as the latter charged, their advance masked the fire of the crossbowmen in the first few seconds, besides leaving the others, dismounted, lines far in rear. Thus the first attack on the Black Prince's line, which was greatly strengthened by trees and hedges in iront of it, was promptly brought to a standstill by the arrows of the archers lining a hedge which overlooked the hollow in front; and the earl of Oxiord, hastily drawing out a body of archers beyond the defenders' left, into the marshy valley of the Maussion, completed their rout by firing up the hollow into their flank. But it mas not so easy to deal with the second line of dismounted men-at-arms, led by the dauphin, which was the next to arrive on the French side. The hedge indeed was held, and the assailants, unable to advance beyond the hollow, gave way, but to achieve this the prince had to use all but 400 of his men. Had the third body of the French advanced with equal spirit the battle mould probably have ended. but the duke of Orleans. who commanded it, led his force off the field without attacking.

Thereupon the king himself advanced furiously with the fourth and last line, and as it came on, the situation of the English seemed so desperate that the prince mas advised to retreat. But his determined courage was unshaken; seeing that this was the last attack he put his reserve into line. He dispatched 60 men-at-arms and 100 archers under the Captal de Buch to ride round the flank oi the enemy and to appear in their rear at the crisis of the fight. When both lines were fighting hand-to-hand, the 60 horsemen of the Captal de Buch appeared in the rear of the French. The iront ranks fought on, but the rearmost Frenchmen melted away rapidly. and at last only a group oi the bravest, with King John and his son Philip, a bop oi 14, in their midst. was left This band continued their hopeless resistance ior a time, but in the end they mere killed or captured to a man The rest of the French army, totally dispersed, was pursued until nightfall Two thousand five hundred oi the French were killed The prisoners included the king and his son Philip The Black Prince then resumed his march to Bordeaux, making no effort to exploit his military ascendancy, ior he had now in his hands a political key which could yield him all the possible profits of victorv, without military cost. ***See*** also FRANCE: *History.*

POITOU, a former province of France, roughly corresponding to the modern *départements* of Vienne, Deux-Sèvres and Vendée. The Seuil du Poitou is a low-lying zone of sedimentary rocks, about 60 mi. wide, separating two higher countries of older rocks (Limousin in the east, the southern part of the Massif Armoricain in the west) and forming the easiest natural passage between northern and southwestern France.

Poitou, incorporated by the Romans into Aquitania, mas for centuries the northern part of Aquitaine (*q.v.*) and, as such. a border country and a battlefield (Vouillé, 507; Poitiers, 732 and 1356: Moncontour. 1569) as well as the meeting place of northern and southern cultures Its golden age (11th–12th centuries) is represented by a great school of Romanesque architecture, sculpture and painting (Saint-Savin). Philip Augustus occupied it in 1204; and the treaty of Paris (1259) recognized the French conquest, after which Poitou was subject to the royal authority (except for a few years after the treaty of Brétigny). From 1417 it was a stronghold of the dauphin Charles. who made Poitiers his capital much more than Bourges. Poitou suffered much in the Wars of Religion; its later history was quieter, apart from the insurrection of the Vendée against the Revolutionary government.

BIBLIOGRAPHY.—G Chagnolleau et al., *Visages du Poitou,* 2nd ed (1946) ; R Crozet, *Histoire du Poitou* (1949), and *L'Art roman en Poitou (1948)* (F. CT)

PQKEBERRY or POKEWEED. the popular name (from the American Indian *pocan,* applied to any plant yielding a red or yellow dye) of *Phytolacca americana,* a strong-smelling perennial herb. a native of North America, with ovate-lanceolate sharp-pointed leaves. racemes of small greenish-white flowers and flattish berries nearly † in in diameter, nhich contain a crimson juice. The young asparaguslike shoots are sometimes used as a potherb, but the roots are poisonous. The plant is often cultivated in Europe, and has become naturalized in the Mediterranean region

POKER, a card game played in various forms throughout the world Its popularity is greatest in the English-speaking countries and after the 1850s it was called "the national card game of the United States." Because Queen Victoria found the principle of the game interesting, poker had a brief vogue in British court circles in the 1870s. but its acceptance in Great Britain and on the continent came chiefly in the decade 1911–20 and was undoubtedly much influenced by the American Expeditionary Forces in World War I. For nearly 100 years in the United States poker nas considered a gambling game for men, unsuited to polite or mixed gatherings, but after the 1920s its popularity extended to both sexes and all levels of society. Surveys made in 1956 shoned poker to be the favourite U.S. game of men and the third-most-favoured (after rummy and bridge) with women; and in Great Britain it ranked next after contract bridge with both sexes.

In one respect poker is rather a family of games than a single game (see History, below). It is played in countless variants and at least 150 are named and described in the literature of the game. All forms of poker, however, share certain essential features: A poker hand comprises five cards. The value of the hand is in inverse proportion to its mathematical frequency; that is, the more unusual the combination of cards, the higher the hand ranks. Each player may bet that he has the best hand, and other players must either "call" or meet his bet or concede. Therefore a player may "bluff" by betting he has the best hand when in fact he does not, and he may win by bluffing if players holding superior hands will not call his bet. See also CARDS. PLAYING.

GENERAL PRINCIPLES OF POKER

The following principles apply to nearly all forms of poker:

Players. — There are forms of poker suitable to any number of players from 2 to 14. but in most forms the ideal number is 6, 7 or 8 players.

Cards. — Poker is almost always played with the standard 52-card deck, the cards in each of the four suits (♠, ♥, ♦, ♣) ranking A (high). K, Q. J, 10, 9. 8, 7, 6, 5. 4, 3, 2, A (low only in the straight or straight flush 5–4–3–2–A and in certain variants described below).

Wild Cards or **"Freaks."**—A wild card stands for any other card its holder wishes to name. There are many methods of introducing wild cards into the game. The most popular are: (1) Joker; a 53-card pack is used, including the joker as a wild card. (2) Bug; the same 53-card pack including the joker is used. but the joker (here called the bug) counts only as a fifth ace or to fill a flush, straight or special hand (described below). (3) Deuces wild or freak pots; all four deuces are wild cards. (4) One-eyes; in the usual British or U.S. pack, the ♦ K. ♠ J and ♥ J are the only cards shown in profile. They are often designated as wild cards.

Rank of Poker Hands. — The traditional, universally accepted ranking of poker hands, from highest to lowest, is:

1. Straight flush: five cards of the same suit and in sequence. The highest straight flush is A-K-Q-J-10 of the same suit, called a royal flush; the lowest straight flush is 5-4-3-2-.4 of the same suit.
2. Four of a kind, as all four 6s, with any fifth card.
3. Full house or full hand: three of one kind and two of another, as 10-10-10-3-3.
4. Flush: five cards of the same suit.
5. Straight: five cards in sequence, in two or more suits. The highest straight is A-K-Q-J-10, the lowest 5-4-3-2-A.
6. Three of a kind or triplets, with any two other cards, not a pair.
7. Two pairs, as A-A-9-9 and any fiith card.
8. One pair, with three unmatched cards.
9. No pair, each such hand being rated by its highest card or cards, as ace high or ace-king high.

When there is any wild card in the game the highest possible hand is five of a kind, which beats any straight flush.

As between two hands having combinations in the same category, the winner is determined as follows:

Straight flushes, flushes, straights or no pair: the one containing the highest card wins; if these cards are identical in rank. the next-highest decides and so on. Four of a kind or three of a kind (or five of a kind): the one composed of the higher-ranking cards. Full house: the higher three of a kind. Two pairs: the highest pair: if these are identical, the higher of the second pairs; if these are identical. the higher of the unmatched cards. One pair: the higher pair; if the pairs are identical, the highest of the unmatched cards and so on. When there are several wild cards there may be identical fours of a kind or threes of a kind, in which case ties are broken by the highest unmatched cards or secondary pairs (in a full house).

Two or more identical hands tie and divide any winning equally. The suits have no relative rank in poker.

In some games value is accorded to one or more (but seldom all) of the following special hands or to other combinations arbitrarily adopted by the players.

1. Big tiger or big cat: king high, 8 low, no pair, as K-J-10-9-8.
2. Little tiger or little cat: 8 high, 3 low, no pair, as 8-7-6-5-3.
3. Big dog: ace high, 9 low, no pair, as A-Q-J-10-9.
4. Little dog: 7 high, 2 low, no pair, as 7-5-4-3-2.

(Tigers and dogs rank in the order listed. Any tiger or dog beats a straight but loses to a flush.)

5. Skeet: five cards, 9 high, including 9,5,2, no pair, as 9-7-5-3-2; beats a straight, loses to a flush.
6. Skip straight or Dutch straight, as 2-4-6-8-10: or round-the-corner straight, as 3-2-.4-K-Q; beats three of a kind, loses to a straight. (The name pelter or kilter is sometimes applied to the skeet or skip straight.)
7. Blaze: five face cards, as K-Q-Q-J-J; beats any two pair, loses to three of a kind.
8. Four-flush: four cards of the same suit; beats one pair, loses to two pairs.

As between two special hands in the same category, ties are broken as between regular poker hands.

Object of the Game. — The object is to win the "pot," which is the aggregate of all bets made by all players in any one deal. The pot may be won either by having the highest-ranking poker hand or by making a bet that no other player calls.

Preliminaries and Rotation. — At the start of the game any player takes a pack of cards and deals them in rotation to his left. one at a time face up. until a knave (jack) appears; the player receiving that card becomes the first dealer. The turn to deal and the turn to bet always pass from player to player to the left. For each deal, any player may shuffle the cards, the dealer having last right. The dealer must offer the shuffled pack to his right-hand opponent for a cut. If that player declines to cut, any other player may cut.

Betting Procedure. — In each deal there are one or more betting intervals. In each betting interval one player, as designated by the rules of the variant being played, has the privilege or obligation of making the first bet. This player and each player in turn after him must place in the pot a number of chips (representing money. for which poker is almost invariably played) to make his total contribution to the pot at least equal the total contribution of any player before him. When a player does this he is said to be in the pot or an active player. If a player declines to do this, he discards his hand and is said to drop or pass and he may no longer compete for the pot.

Before the deal, each player may be required to make a contribution to the pot, called an ante. In each betting interval, the first player to make a bet is said to bet; a player who exactly meets the last previous bet is said to call or stay (in); and a player who bets more than the last previous bettor is said to raise. In some variants a player is permitted to check, which is to stay in without betting, provided no other player has made a bet in that betting interval.

At the end of each betting interval except the last, dealing is resumed; at the end of the last betting interval there is the "showdown," in which each active player shows his full hand and the highest-ranking hand wins the pot. In practice, especially in informal games, players usually announce the values of their hands and show their hands as confirmation only, but on demand of any player the full hand must be shown and any mistaken announcement is not valid: "The cards speak for themselves."

Betting Limits. — In poker legends there were "no-limit" or "sky's-the-limit" games, but in practice some limit is placed on what one may bet in any game. There are three popular methods.

Fixed Limit.—No one may bet or raise by more than the established limit. In draw poker the limit is usually twice as much after the draw as before; for example, two chips before the draw. four chips after. In stud poker the limit is usually twice as much in the final betting interval as in previous betting intervals. (The higher limit applies also when any player's exposed cards include a pair.) These respective forms of the game are described below. In a fixed limit game a limit is often placed on the number of raises that may be made in any betting interval.

Pot *Limit*.—A player may bet or raise by no more than the amount in the pot at the time the bet or raise is made. When raising, he may first put in the pot the number of chips required to call the previous bet and then raise by the number of chips in the pot. When pot limit is played, it is customary also to place a maximum limit on any bet or raise, regardless of the size of the pot or to play table stakes.

Table Stakes.—This method most closely approximates the legendary no-limit game. Each player's limit is the number of chips he has on the table at the beginning of the deal. He may not bet more, but for this amount he may call any higher bet and compete for the pot in the showdown. Other players having more chips may continue to bet, but their further bets go into one or more side pots in which the winner is decided as among the players who contributed fully to the side pot. When a player drops out of any side pot he has dropped out of the original pot as well, in effect surrendering his rights in the original pot to the player whose later bet he did not call.

PRINCIPAL FORMS OF POKER

Poker has two main branches: closed (straight or draw) poker, in which each player's full hand remains concealed until the showdown; and open (stud) poker, in which some but not all of a player's cards are dealt or turned face up. Within each of these branches, but especially in closed poker, there are "pass-and-out" games, in which a player must bet or drop in each turn, and "pass-and-back-in" games, in which in certain circumstances a player is permitted to check.

Straight Poker.—Each player is dealt five cards, face down. There is one betting interval, beginning with the player nearest dealer's left. then a showdown. This was the original form of poker and has almost passed out of existence except, paradoxically, in the highest-stake games among professional gamblers.

Draw Poker.—This game has two main branches: (1) blind opening, played almost to the exclusion of other variants in England, Europe and the British Commonwealth except Canada, and favoured in men's clubs in the U.S. and Latin America; and (2) jackpots, the draw poker variant most played in the U.S. and Canada. In dram poker, each player is dealt five cards, face down. There is a better interval. Then each active player, in turn beginning at dealer's left, may discard one or more of his original cards and receive replacements for them, dealt from the undealt portion of the pack. (A player who declines to draw cards is said to stand pat.) After this process, called the draw, there is a final betting interval, followed by the showdown.

Blind Opening.—There are three contributions to the pot before the deal. The dealers (or in some games, every player) puts in an ante, which does not rank as a bet. The player at dealer's left, formerly called the "age" or "edge," now called the opener. makes an opening bet of one chip or unit, called the blind. The player at his left puts in two or three units, constituting a call of the blind opening bet and a raise of one or two units; this is called the straddle or blind raise. Each player in turn thereafter may call (for the amount bet by the preceding player), raise (by one unit) or drop. The limit before the draw is usually the one unit of the ante. The limit after the dram is twice this amount or more; in some games it is the amount bet by each player before the draw. After the draw the betting begins with the active player nearest the dealer's left, and checking is permitted.

Jackpots.—Before the deal, each player antes one chip of lowest value. The game is pass-and-back-in both before and after the draw. In the first betting interval each player in turn, beginning with the one at dealer's left. may check (called also pass) or open (make the first bet); in most games a player may not open unless he has jacks or better (a pair of jacks or any higher-ranking hand). but the requirements for openers may be set higher or lower. If any player opens, each player in turn after him may call or raise until the betting interval is ended. There follow the draw, a second betting interval beginning with the opener (or if he has dropped, with the active player nearest his left) and a showdown. There are penalties for opening without openers (see Laws, below). In a similar game, called passout, no openers are required and the game is played pass-and-out (see above) before the draw.

Stud Poker.—Each player receives one card face down. called his hole card, then one card face up. The deal is then interrupted for a betting interval. There follow three rounds of dealing, each consisting of one face-up card to each active player, with a betting interval after each. There is a showdown in which the hole cards are shown after the fourth and last betting interval. In each betting interval the first bettor is the player with the highest-ranking poker combination in his face-up cards; if two or more players have the same combinations, the "first" one (nearest the dealer's left) bets first. In the first betting interval the high player must bet at least an established minimum; in any later betting interval he may check. Few games have lost popularity so fast as regular five-card stud. In the 1920s and into the 1930s it mas played in two-thirds of the high-stake and professional games in the United States; in the 1950s it was not played in one-tenth of them.

Seven-Card Stud.—Each player is dealt two hole cards, then a face-up card, followed by a betting interval; then three more face-up cards and one final face-down card, each followed by a betting interval. For the showdown each player selects any five of his seven cards to be his poker hand. There are six-card and eight-card variants of this game, in each of which a player ultimately selects five of his cards.

High-LOW Poker.—The highest-ranking poker hand and the lowest-ranking poker hand divide the pot equally. If there is an odd chip, the high hand gets it. If two or more hands tie for high or low, they divide their half of the pot equally. Nearly any form of poker may be played high-low. In most games the lowest possible hand is 7–5–4–3–2 in two or more suits, but in some games the ace may optionally be treated as the lowest card and 6–4–3–2–A becomes the lowest hand, while a pair of aces is the lowest pair.

High-Low Seven-Card Stud.—The high and low hands divide the pot, but each player may select any five of his cards as his candidate for high hand and any five as his candidate for low hand and so win the entire pot. In some games declarations are required: before the showdown each player must announce whether he is trying for high. for low or for both, and he cannot win unless his entire announcement is fulfilled.

Low Poker or Lowball.—This is draw poker played similarly to jackpots except that a player may open on any hand and the lowest-ranking hand wins the pot. In California, where the game is most popular. straights and flushes never count and the ace is always the lowest-ranking card, so the lowest possible hand is 5–4–3–2–A regardless of suits, called a bicycle or wheel.

Dealer's Choice or Dealer's Option.—In informal poker games, each successive dealer is usually permitted to dictate the variant of poker that will be played. This privilege is most often expressed by the dealer's selecting one of the forms of poker described above and designating certain cards to be wild. Ordinarily the dealer can select or invent any variant he wishes. subject to only two restrictions: the dealer cannot require any player to ante more than any other player; if the game requires a minimum to open (as jackpots) and is passed out, the same dealer deals again.

LAWS OF POKER

No code of poker laws has been universally adopted as the laws of bridge have been. Nearly every club or serious game has certain house rules that may differ in some respects (usually minor) from those of other clubs and groups. The usual practice is to adopt a published code and add the house rules to it. A code prepared by O. Jacoby in 1940 and another (nearly identical in substance) appearing in The *Official Rules* of *Card* Games since 1945, are the ones most often adopted in the United States. Poker laws, unlike those of other card games, provide only rectification and no penalties for irregularities.

Certain departures from regular procedure are necessarily treated differently in draw poker and stud poker. The following summary follows the Jacoby code.

Laws Applying to All Forms of Poker.—Misdeal—The same dealer deals again with the same pack if: a card is exposed in the cut; two or more cards are exposed in the deal; the pack is found to be imperfect (but after the next deal begins, all previous deals stand); a player is dealing out of turn and attention is drawn to that fact by a player who has not looked at any of his cards. If one card is exposed during the deal the player must take it.

Betting.—Money (chips) put in the pot may not be removed for any reason; except that in a jackpots game when a player has opened illegally each other player may remove his chips bet after the pot was opened and before the disclosure of the false openers. A player has no redress if he misunderstood a previous bet or announcement. In table stakes a player may never bet more than his entire stack.

Action Out of *Turn*—An announcement out of turn of intention to drop or bet is binding, but is temporarily canceled pending action by any player rightfully in turn. When the offender's turn comes, he may forfeit the announced amount and drop, if that amount was insufficient to call; he may if necessary add enough to call but not to raise; he is deemed to have raised by any excess of the announced amount over the amount necessary to call. (In some games action out of turn is simply void.)

Incorrect *Number* of Cards.—A player who has only four valid cards may play on but may not make a flush, straight or any special hand based on five cards. (In many games a four-card hand is dead and cannot win the pot.)

Laws Applying to Draw Poker.—Incorrect Hand.—If one player is dealt four cards, another six, and if neither has looked at his hand, the former draws a card from the latter; if either has looked at his hand, the hand is foul (cannot win the pot). If a player has not looked at his hand and has four cards, the dealer gives him another from the top of the pack; if he has six cards, the dealer draws one card and places it on the bottom of the pack.

Card Exposed During *the Draw*.—If the card was faced in the pack, it is discarded and the draw continues. If the card was exposed in dealing, it is discarded and the player is given a replacement after all other players have drawn.

Wrong Number of Cards *Drawn*.—A player must take the number of cards he asked for, unless he corrects himself before he looks at any card drann and before the next player has drawn. If he has discarded, he may discard more to make room for additional cards or he may if necessary play on nith four (but no fewer) cards; he may not reclaim any discard. Ii he has been given too many cards and looks at any of them, his hand is foul. He has no redress whether an error was his or the dealer's.

Insufficient Cards in Pack.—The bottom card of the pack may not be dealt. If there are too few cards remaining to complete the draw, the dealer gathers together all discards of players who have dropped or have already drawn, shuffles them, has them cut and continues the draw. The opener's discards, if identifiable, are exempted.

Laws Applying to Stud Poker.—Incorrect Hand.—If a player, for any reason, has an incorrect number of cards his hand is foul.

Exposed Card.—If a hole card is exposed accidentally in the deal, the dealer gives the player his next card face down. A player may not intentionally expose a hole card and receive a subsequent card face down; he may play on with that card exposed. If a card to be dealt is exposed before a betting interval is ended, then that card and one card for each other active player are buried before the deal is resumed.

Insufficient Cards in Pack.—The bottom card of the pack may not be dealt. If there are not enough cards to complete every active player's hand, the dealer flashes (exposes) a card instead of dealing the last round, and the exposed card is considered the last card of every active player's hand.

SKILLFUL PLAY

Poker better rewards skillful play than any other card game. Though it is not so complex a game as bridge and numerous other games, the player has greater control over the result (largely because he is permitted to drop bad hands); consequently a good player is less likely to lose in a game with inferior players.

Since poker has a mathematical basis (the less probable a particular holding, the higher its rank), the science of the game begins with the relative expectancies of the several hands, though this is only background knowledge that seldom has practical application in play.

There are possible 2,598,960 different five-card hands that may be dealt from a 52-card pack, as follows:

Possible Poker Hands In 52-Card Pack

Hand	*No. possible*	*Chance of being dealt*
Straight flush	40	64,974
Four of a kind	624	4,165
Full house	3,744	694
Flush	5,108	509
Straight	10,200	256
Three of a kind	54,912	48
Two paps	123,552	21
One pair	1,098,240	2.5
No pair	1,302,540	2

A person beginning the study of poker on purely theoretical grounds would find such a table indispensable. It would tell him, for example, that if he is dealt a flush there are only a few thousand possible hands that might beat him while there are more than 2.500.000 he can beat, whereupon he would be justified in making or calling a maximal bet.

From a practical standpoint, the player needs chiefly to know what constitutes a good hand, a fair hand and a poor hand in a given form of poker. Experience as well as mathematics indicates the following as the average winning hands in the forms of poker most frequently played.

Game	*Average winning hand*
Draw poker, nothing wild	Jacks up
Five-card stud	Aces or kings
Seven-card stud	3 eights
Dram poker, joker wild	3 eights
Draw poker, with bug	Aces up
Draw poker, deuces wild	3 aces
Draw poker, high-low	Jacks up high; 10 or 9 low
Lowball	9-6-x-x-x

The fundamental principle of skillful play is that a person should stay in the pot only if: (1) he probably has the best hand or (2) the odds against his drawing the best hand are less than the odds offered by the pot. To illustrate the latter: There are four chips in the pot and the player must put in one chip to stay; thereiore the pot offers 4–to–1 odds. The player has a four-flush or "bobtail" straight (open at both ends as 8–7–6–5), to either of which he can draw one card. The odds against filling either of these hands ranges $4\frac{1}{4}$–5 to 1. The pot offers less than the odds against filling, so the player should drop.

The approximate odds against improving the original hand in draw poker are as follows:

Hand	*Odds against improving*
One pair	$2\frac{1}{2}$ to 1
Two pairs	11 to 1
Three of a kind	$8\frac{1}{2}$ to 1
Straight, open	5 to 1 (39 to 8)
Straight, inside (as 8–7–5–4)	11 to 1
Straight flush, open	2 to 1
Straight flush, inside	3 to 1

In five-card stud poker it is wise to stay in only if one has a pair. a hole card higher than any card showing or a card at least as high as any card showing plus another high card. It is never wise to stay in when another player has showing a pair higher than one's own pair (or if one has no pair). In seven-card stud, it is usually best to stay in only if one has a pair. three cards of the same suit or three cards in sequence. In seven-card high-low stud. the guiding principle is to play for low.

The only hand with which to play for high is three of a kind in the first three cards.

Bluffing and psychological play, though they are of essential importance, depend more on experience and moral ascendancy than on rules of play or maxims.

HISTORY

The principle of poker is very ancient. One of its ancestral games (Sp. primero, It. primiera, Fr. la prime) appears in literature at least as early as 1526. In this game each player had three cards and the counting combinations were three of a kind. a pair and a flux (flush). three cards of the same suit. In later developments certain cards had special value, equivalent to wild cards in modern poker. By about 1700 the betting and bluffing aspects had produced the games brag in England (one of four card games about which Edmond Hoyle wrote) and pochen (Ger. "to bluff") in Germany. From the latter the French developed a similar game called *poque,* played in French America in 1803. when the Louisiana purchase made New Orleans and its environs territories of the United States. During the next 20 years English-speaking settlers in the Louisiana territory adopted the game, anglicized its name to poker and established the essential features of the modern game.

The earliest-known reference to poker in American literature occurs (1829) in the memoirs of Joe Cowell, a touring English actor. From his description it is clear that the original American game was played with a pack of cards that included five cards for each player: all the cards were dealt and the players bet on which had the best five-card combination.

So played. poker is virtually indistinguishable from an older Persian game called *As nas,* a four-hand game played with a 20-card pack. five cards dealt to each player. This coincidence has led some students of games to call poker a derivative of As *nas,* but there is no record of any connection between the two.

By 1834. the date of the second known reference to poker, the game had been adapted to the 52-card deck. No description of poker is given in any book of the rules of games before 1858. but in such books published in the 1860s it is not characterized as a new game. The history of the game since then consists entirely of new features introduced to encourage freer betting: the straight, introduced as an additional valuable hand; the draw, so that players might stay in even when they were not originally dealt good hands; stud poker, to increase the number of opportunities for betting; jackpots, originally only applying to a pot to which each player antes, creating an unusually large pot at the start. Most of these innovations came in the decade 1861–70 and probably were engendered in the great amount of poker played by soldiers on both sides in the Civil War.

The spread of poker to other countries probably began in 1871 when Col. Jacob Schenck, the U.S. minister to Great Britain, explained the game to a group of gentlemen including members of the British court. Queen Victoria heard about the game and expressed interest, whereupon Schenck wrote and had privately printed (1872) a set of rules to send to her. This is the earliest-known work devoted exclusively to poker, although the game had previously (1858. 1864, etc.) been treated in compendiums. Poker was already sufficiently identified with the United States so that Schenck described it as "our national game." However this may have been only because all other card games played in the U.S. were undeniably of European origin.

Whether rapidly or gradually, between 1870 and the end of the 19th century, poker became a matter of general knowledge in the United States, and early in the 20th century it spread to other parts of the world.

See *Oswald Jacoby on Poker* (1947) for the game as played in the U.S.; Maurice Ellinger, *Poker* (1950) for the game as played in England. (O. JY.; A. H. MD.)

POKOMAM, a group of Indians speaking a Maya dialect who live in southern Guatemala. Their territory runs from the upper part of the Motaqua river to the border of Salvador. They inhabit the departments of Chimaltenango (in part). Guatemala. Amatitlán and Jalapa in Guatemala, and at the time of the conquest they extended to Chalchuapa in Salvador. The principal towns where this tongue is spoken are San Martin Jilotepeque, Mixco, Petapa. Jalapa, Jilotepeque and Asunción Mita. They number about 50,000, of whom more than half speak their native tongue.

The ancient capital of the Pokomam was the fortress of Mixco situated on a steep hill in the valley of Xilotepeque.

BIBLIOGRAPHY.—Thomas Gage, *The English-American, His Travail by Land and Sea,* etc. (1648); Domingo Juarros, *History of the Kingdom of Guatemala* (1823). (S. K. L.)

POLABS (Po = on, *Laba* = Elbe), the Slavs (*q.v.*) who dwelt upon the Elbe and eastward to the Oder. Except the Lithuanians they were the last Europeans to be Christianized; their chief sanctuary was at Arcona on the Isle of Rügen. They were converted and conquered in the 12th century and germanized. By the 17th century Slavonic survived only in a tiny patch in the east of Hanover about Lüchow: its scanty remains are corrupt.

POLAND (POLSKA), a country of eastern Europe lying between the Baltic sea to the north and the Sudeten and the Carpathian mountains to the south and bounded, from 1945, on the east by the U.S.S.R., on the south by Czechoslovakia and on the west by Germany. (For population, see below.)

PHYSICAL GEOGRAPHY

The main morphological features have been moulded by two great influences: the northward thrust of the alpine fold mountains against the Hercynian plateaus (represented there by the Bohemian massif and the submerged Polish platform which reaches the surface in the Lysagora) and the southward sweep of the Scandinavian ice-sheet. Conditioned by these influences the natural regions tend to form zones running broadly east and west across the country.

In the extreme south, the mountain frontier zone is divided into two sections. The first, composed of the older, much peneplained rocks of the Sudeten mountains, reaches its highest point in Mt. Sniezka (5.259 ft.): the second. formed by the young fold mountains of the Carpathians, assumes a truly alpine appearance in the High Tatras, the highest point of which, Gerlachovka (8,737 ft.), lies across the frontier in Slovakia. The submontane zone of southern Poland, consisting of upland-rimmed river basins interconnected by narrow gateways, is again capable of subdivision. Thus Silesia, drained northwestward by the Oder, forms a unity centring upon Wroclaw (Breslau); bounded on the north by the Trzebnica hills, this basin represents an extension of the great carboniferous deposits of northwestern Europe. The sub-Carpathian basins. on the other hand, occupy a tectonic hollow running from the Moravian gate through the small Oswiecim basin and the Cracow gate to the wider Sandomierz basin drained by the Vistula and San, with the Przemysl gate separating the latter from the headwaters of the Dniester, within the Soviet frontier. The Little Polish tableland which separates the Silesian and sub-Carpathian basins, consists of the Cracow-Czestochowa limestone plateau (1,653 ft.), opening southeastward to the Tertiary deposits of the Nida basin, and the Holy Cross (Swietokrzyskie) mountains (Lysagora. 1.946 ft.). The southeastern edge of the latter, the level Sandomierz tableland, is noted for its fertile loess deposits. Finally, east of the Vistula the upland rim is represented by the Lublin tableland, with its rich soils derived from chalk marl, and the Roztocze ridge.

The remainder of Poland is dominated by glacial features. The characteristic east-west sectors of the great rivers and their tributaries (*e.g.,* the lines formed by the Bug-Vistula-Notec-Warta and the Warta-Obra-Oder) mark stages in the successive northward retreat of the ice sheet, when drainage was forced toward the west. Central Poland, an undulating country crossed by the great valleys, is subdivided into the Great Polish and Kujavian lowlands around Poznan and the Mazovian Podlasian lowlands around the capital city, Warsaw. The soils are based on fluvioglacial and fluvial deposits. Further north, breached by the Oder and Vistula in their lower courses, lies the Baltic lake zone, Pomorze (Pomerania) to the west and Mazuria to the east of the Vistula. It is a region of classic morainic topography: the boulder clay, sands and gravels form hummocky ridges, reaching often more than 650 ft. in height and interspersed with numerous lake-filled, peaty hollows. The morainic hills descend to a low sandy plain along the Baltic coast. The half-formed deltas of the Oder and Vistula are classic examples of the lagoon-and-bar coastal formation, where the sea currents and prevailing winds drag the river deposits and coastal sands eastward along shore. Modern methods of port maintenance and navigation enabled the old ports to continue their ocean-going trade.

Flora and Fauna.—The natural forests of Poland are transitional between the mainly coniferous stands of northern Europe, closely associated with the podsols, and the deciduous woodlands of central and western Europe growing on the more fertile brown soils. The fauna is that associated nith the temperate forests which once covered most of the country apart from the alpine zone of the high mountains. The reindeer, sable and mild horse, however, survive only in tradition; the bear is restricted to the Carpathians, the elk was found in the former northeastern provinces and the beaver in the Polesian marshes, which became Soviet territory.

About 70% of Poland's forests are coniferous, with the pine dominant, followed by spruce. There are few firs, while larches and yews appear only sporadically. The deciduous trees, more characteristic of the southern provinces, are mainly birch, beech, wych-elm, aspen, ash, oak and alder. One of the best-known forests is that of Bialowieza, famed for its ancient trees and, up to 1918, its herd of aurochs or European bison (later crossbred with animals of Canadian origin). The main timber products are deal boards. building timber, pit props and fuel. Losses incurred in World War II made it necessary to import certain types of timber, whereas before that war the export of timber accounted for one-fifth of the active foreign trade balance.

Climate.—Climatically, Poland belongs to the major zone which includes eastern Germany, most of Finland and western U.S.S.R. It is open to the influence of the prevailing, variable westerly winds. except when these are replaced during winter by the heavy masses of cold air cushioning the interior of the continent. The summers are warm or very warm, according to distance from the sea and latitude, although the latter is offset by the increasing height of the land toward the south. The winters are cold and are particularly unpleasant when pressure conditions are right for the influx of strong winds from the Russian plains. Temperatures are everywhere below freezing point for at least two winter months in the west and three months in the east. The Oder, for example, is frozen for an average of 80 days, the Vistula 80–100 days; and the Baltic harbours, especially where distant from the open sea, are icebound for a considerable period every year —Swinoujscie for 20 days on the average, Szczecin for 61 days. The open Baltic itself is frequently impeded by drift ice, but navigation usually continues along the sea lanes connecting the favourably placed docks of Gdynia-Gdansk (Danzig). The following figures for the mean January and July temperatures, in degrees Fahrenheit, are typical: Szczecin, 30.4 and 64.9; Warsaw, 26.8 and 65.5; Tomaszow Lubelski, 23.9 and 64. Sniezka, with a range between 19.2 and 46.9 and below freezing point for six months, is typical of conditions in the highest mountain regions; even in the Tatras, however, there are no permanent snows.

Precipitation, in winter mostly in the form of snow, is moderate, 20–27.5 in., except along the southern highland fringe. More falls in the summer half-year, because of the development of thundery conditions in early summer and of the passage of depressions in autumn. The skies are on the whole cloudy, mean cloudiness averaging somewhat less than seven out of ten points; the summers are brighter and less humid, although more rainy, than the winters. Wroclaw is representative, with a mean annual rainfall of 23.3 in, and cloudiness of 6.8 points; precipitation is distributed seasonally, in percentages of the total, beginning with winter, as follows: 16, 24, 38 and 22. Sniezka has a mean annual precipitation of 45.6 in.. typical of the narrow mountain fringe.

BIBLIOGRAPHY.—E. de Martonne, "La Pologne," in part 2 of *Europe centrale*, vol. iv of *Géographie universelle*, ed. by L. Gallois and P. Vidal de la Blache (Paris, 1931); W. Nalkowski, La *Pologne, entité géographique* (Paris, 1926). (G. W. S.)

HISTORY

Polish history begins in the year 963 when a German border knight came into contact with Mieczyslaw or Mieszko I, who was prince of Poland till 992. The unity of the Polish state, surrounded as it was by other pagan and mostly Slavonic tribes, had been achieved under the descendants of Piast (said to have been either of peasant origin or an official at the court of an older dynasty), who founded the dynasty which gave his people strong and valiant rulers down to 1370. Mieszko's predecessors had succeeded not only in uniting a number of tribes but in establishing a highly developed political community which had neither enjoyed the benefits nor suffered the disadvantages of contact with the high civilizations of western and southern Europe. To meet the dangers that arose when the Germans began to penetrate the barrier formed by the western Slavonic tribes. Mieszko conceived that policy of deliberately adopting western civilization which was the chief object of the rulers of Poland for several centuries. He secured his state from the aggression of his new neighbours by acknowledging himself a tributary of the western emperor Otto I, and removed all danger of a hostile crusade by accepting Christianity for himself and for his people in 966 with the help of the Czech princess Dubravka or Dabrowka, whom he had married a year before. Finally he placed all his lands in the hands of the pope, thus inaugurating a close relationship that gave Poland the special protection of the Holy See. He seems to have been successful in gaining Pomorze (Pomerania; *i.e.*, the seaboard), but lost part of his eastern territory to Vladimir the Saint.

THE PIAST KINGDOM

Mieszko's son Boleslaw I the Brave (see BOLESLAW I) (992–1025) was one of the great soldiers and statesmen of his time. From the congress of Gniezno (Gnesen) (1000) with his friend the emperor Otto III, where he secured for Poland an independent church, organized in a number of bishoprics under a metropolitan at Gniezno. to his coronation as king (1024), he achieved the transformation of his father's principality into a powerful and independent kingdom. His wars of defense and expansion against Germany and Bohemia ended successfully in 1018; then he turned east and occupied the Russian capital. Kiev, thus recovering the territory lost in the preceding reign. His younger son Ilieszko II (1025–34) succeeded him as king, but the power of the kingdom waned in spite of its partial revival under Mieszko II's son Casimir (Kazimierz) I the Restorer (1038–58) and the strong rule of Casimir's son Boleslaw II the Bold (*see* BOLESLAW II) (1058–79). But under Boleslaw III Wrymouth (*see* BOLESLAW III) (1102–38), a nephew of Boleslaw II, Poland made great advances. Boleslaw maintained the independence of his country when the emperor Henry V invaded Silesia in 1109 by a victory at Glogow. His reign saw a considerable cultural advance, and an anonymous chronicler recorded the earlier history of Poland. He collaborated with Otto, bishop of Bamberg, in converting the Pomeranians to Christianity and occupied the greater part of that province.

The Period of Division, 1138–1314.—Boleslaw III divided Poland among his sons, so that Poland, like its neighbours Germany and Kievan Russia: ceased to be a united state for two centuries. The capital was established at Cracow, the ruler of which held the central provinces of Poland together with Pomorze and had "seniority" over his brothers, who ruled over Silesia, Mazovia, Great (or western) Poland and Sandomierz. In each of these principalities there grew up round the Piast prince a powerful upper class consisting of the officials and the clergy headed by the local bishop, a process which modified the *jus* ducale of the monarchical system. This period of divided loyalties laid the country open to many dangers; while the empire remained strong, a ruler like Frederick I Barbarossa in 1157 could assert his claim to Polish allegiance, and a major disaster like the Mongol invasion in 1241 found the chivalry of Little (or southern) Poland unsupported and the heroic efforts of Prince Henry of Silesia made in vain. Worst of all were the incessant raids of the barbarian neighbours, notably the Lithuanians and Prussians. To avert these, Prince Conrad of Mazovia called in the Teutonic Order, a purely German crusading organization that had lost a sphere for its activities in Palestine. Well established on the northern border, the order was helped by the Poles to occupy not only the borderland but the whole of Prussia, which was speedily colonized mainly by German immigrants. By a brilliant piece of diplomacy the grand master Hermann von Salza persuaded the emperor Frederick II to accept his homage as ruler of the newly acquired lands (1226). The divided Polish states found themselves face to face with a powerful German state on their northern border.

In spite of the political weakness of Poland, of the great Mongol disaster and of the menace from Germany, this age was one of great importance to the development of Poland. In the process of decentralization, each province was able to assert its own individuality, helping its prince and bishop to enlarge its capital city and to intensify their efforts to develop the resources of its small territory. The petty princes were able to imitate western Europe by encouraging the immigration of German peasants, townsmen and artisans, who helped them to raise the level of economic life. The ideal of the 13th-century Polish prince, especially in Silesia, was *melioratio terrae,* to achieve which he was prepared to sacrifice both part of his own sovereign power and vague national ideals. This lack of a Polish patriotism resulted in the loss to Poland of some areas: Lower Silesia and western Pomorze were gradually colonized by Germans. But the economic and cultural advance of the country as a whole was worth the sacrifice. The community thus strengthened was able to maintain its ethnical frontier in spite of political disaster for six centuries. In most of Poland the Germans were ultimately absorbed. The princes further reduced their sovereign power by the granting of charters to different groups and individuals. The Jews, whom crusading zeal had expelled from nearly every country, were granted the right to settle in Poland, to maintain their own schools and to practise their religion. For the Poles they were skilled middlemen who made an important contribution to the economic life of the country but who were never absorbed as the Germans were and hampered the formation of a Polish middle class. The achievements of this period of division, in spite of its difficulties and weaknesses, can be appreciated through a comparison of the low social and economic situation in the 12th century with the resources available to the revived monarchy after 1305, whereby the rulers were able to reunite the divided principalities and to preside over the rapid development of a state that had no need to copy the social and economic life of its neighbours.

Wladyslaw I, 1314–33.—The idea of reuniting the Polish principalities in one state first appears in the experiments of the princes of Silesia, especially in those of Henry I the Bearded. These princes failed partly because they gradually succumbed to the attraction of German civilization and joined the empire under Czech auspices. Przemyslaw II of Great Poland actually assumed the royal title in 1295; but the real task of reunion was undertaken, at a time when Poland had come under the rule of Czech kings, by the hard-fighting Wladyslaw Lokietek (Ladislas the Short) (see WLADISLAUS) of Kujavia. The idea was strongly supported by the ecclesiastical leaders. These men had represented for a long time the links that bound Poles together and led the enlightened magnates who realized that a divided Poland would suffer extinction at the hands of such powerful neighbours as Bohemia, Brandenburg, Hungary and the Teutonic Order. Wladyslaw cleverly availed himself of the support of Hungary and of the traditional protection of the Holy See. After occupying Little Poland in 1305 and Great Poland in 1314, he was crowned king of Poland in 1320 as Wladyslaw I (1314–33). He had many disappointments: the Teutonic Order seized Pomorze in 1308; his country long continued to suffer from the raids of the pagan Lithuanians; and he never reigned over Silesia or Mazovia, which preferred to do homage to John of Bohemia. But he held his own against the order in the battle of Plowce (1331), strengthened his position by his diplomatic friendship with Hungary (which was sealed in 1320 by his daughter Elizabeth's marriage to the new Angevin king Charles I) and ended for a time the Lithuanian raids by marrying his son Casimir to Anne (Aldona), daughter of the grand duke Gedymin, in 1325.

Casimir III the Great, 1333–70.—Unlike his father, Casimir was born in the purple and was a man of peace. A realist and a shrewd diplomatist with a zest for the Latin culture that he learned at the court of his sister in Hungary, he was ready to make great sacrifices to secure the independence, unity and prosperity of his kingdom. Happily for Poland the decline of the empire, the disunity of Germany, the weakness of Russia and the death of the last great khan of the Tatars lessened the dangers on the western and eastern frontiers. Poland had to face in the south the powerful kingdom of Bohemia, whose king in 1355 was crowned emperor as Charles IV, and in the north the great military strength of the Teutonic Knights. Basing his foreign policy on a close alliance with Hungary, he was content to allow Charles IV, another lover of peace, to hold Silesia, and to give up his claim to Pomorze and the border districts held by the order. As compensation for this loss of Polish territory, he found himself able by inheritance and diplomacy to annex Halicz and to begin that policy of conciliation with the Lithuanian princes which was to bring such important results later on. His own prestige grew abroad, and he made Poland a full member of the European community. By thus gaining for Poland a long period of peace and security, he was able to make great changes in the internal relations of the country. He codified the laws of Great and Little Poland and succeeded in persuading these two rival states to cooperate, while the local officials of Little Poland became national ministers. The princes of Mazovia were persuaded to acknowledge Casimir as their king. He acquired great wealth, reformed the currency and introduced western methods in town and country. He befriended the Jews, improved the position of the peasants and encouraged the immigration of Germans and Armenians, so that the cities grew in size and prosperity. especially Cracow and Lwow. He was a great builder and was said to have "found a country of wood and left a country of stone." The administration was made more efficient, and it was mainly to train young men in law that Casimir founded the University of Cracow in 1364. He encouraged learning and was able, through the Italian influences at the court of Hungary and the French connections of Prague, to raise the level of learning among the Poles to western European standards. By his foresight, his patience and genius for creation and adaptation, this great statesman made possible the strong and prosperous position of the Polish kingdom during his lifetime and its great development in the next two centuries.

Louis I of Hungary, 1370–82.—Having no sons, Casimir III bequeathed his kingdom to his sister Elizabeth's son Louis I of Hungary (1370–82), already one of the leading rulers of central Europe, who continued the co-operation of his two realms in the spirit of his predecessor. Like Casimir, he left no sons, and the future of central Europe depended to some extent on the fate of his two daughters. After an interregnum of two years the Poles accepted his younger daughter Jadwiga as their queen (1384–98) and consummated the efforts of Casimir III to conciliate the pagan rulers of Lithuania by arranging the marriage of Jadwiga to Jagiello. grand duke of Lithuania, who became king of Poland as Wladyslaw II (1386–1434).

Social and Constitutional Development, 1138–1384.—The social structure of the Polish state at the time of the dynastic union with Lithuania was very different from what it had been under the early kings. In the period of division there had grown up round each prince a class of ecclesiastical and lay magnates whose function was at first to advise and later to share with the prince the government of his principality. In addition to this privileged class, the general mass of the gentry, organized in their clans, each with its coat of arms and slogan, was becoming conscious of its own importance as a social and political element in the country. As the prince gradually lost his monopoly of political and legal power by the grant of charters to various groups, this body, which came to be called the *szlachta,* began to share political privileges with the magnates. The extinction of the Piast dynasty gave them the opportunity by the pact of Koszyce (Kosice) in 1374 to obtain from Louis a number of privileges, the magna *carta* of Poland. The chief of these was the right to pay no taxes beyond a certain sum, unless they had expressly consented to them. During the period of division the church, which had established its position at the synod of Leczyca in 1180, played a leading part, not only in the social and moral life of the community but also as the sole factor of unity between the numerous principalities. The inhabitants of the towns had received charters mainly under Magdeburg law to encourage the settlement of Germans. Besides Wroclaw (Breslau) and Poznan, the two great cities Cracow and Lwow grew to prosperity on the great eastern trade route. These towns, though at first largely foreign in race, became integral members of the community, able to aid and to advise the prince and to attain political importance. The peasants. with the rise of the gentry, lost in social standing but gained economically by the rights granted under Magdeburg law in the reign of Casimir 111—a situation that only slowly worsened as serfdom grew up a century later. From the small body of educated men who made the court of Boleslaw III superior to that of the early kings (with the famous Otto, later bishop of Bamberg, and the anonymous scholar who wrote the first history of Poland), through the spread of western social and moral ideas (at first chiefly by the Cistercians) to the writing of a real historical work by Wincenty Kadlubek (d. 1223), the great progress of learning in the Polish community can be followed, only temporarily interrupted by the Mongol invasions. The great problem of the Poles was to seek and assimilate western institutions and ideas while retaining and cherishing their own native civilization. They were forced to learn mainly from the Germans. But the political exploitation of this position by the latter led to the rise of strong anti-German feeling and to the practice of seeking models in Italy, France or the Low Countries in preference to Germany. The union of Poland and Lithuania was a mortal blow to the position of the Teutonic Order, the greatest German power on the Polish border.

THE JAGIELLON DYNASTY

***Jadwiga and Wladyslaw* II Jagiello.**—The magnates of Cracow, Casimir III's pupils and successors, were able to instruct the girl queen and the pagan king in the arts of government. One of the first acts of the new king was to receive Christianity for himself and his people. The Lithuanians, unlike the Ruthenian members of their grand duchy who were Orthodox, joined the western Catholic Church. So the Poles gained by peaceful agreement what the German Knights had sought by violence during a century and failed to win: the conversion of the last great body of pagans in Europe. The very reason for the existence of the order had gone, and it would have to struggle to preserve its territories which included Pomorze with Danzig (Gdansk) and the whole of Prussia. But the settlement was delayed for some time, partly because of Jadwiga's religious scruples against fighting a crusading body, and partly because Wladyslaw Jagiello had to solve the difficult problem of Lithuania, where he had a rival in his cousin Vytautas (Witold). The order exploited this situation so adroitly that the king was forced to recognize Vytautas as grand duke of Lithuania. This arrangement was successful for a time, and in 1409 the aggression of the order provoked the two cousins to join their forces against their common enemy. Advancing into Prussia they completely defeated the Knights in the great battle of Grunwald (Tannenberg) in 1410. Unfortunately, though the victory was followed by the union of Horodlo (1413), which established in Lithuania institutions based on those of Poland, the two cousins did not always agree; and Poland was exposed in the south to the hostility of Sigismund of Bohemia, who had succeeded to the possessions of Louis of Hungary in 1387 and to the German kingdom in 1410. Jagiello lost his wife Jadwiga in 1398 and remained without male issue by his next two wives; but his fourth, whom he married in 1422, the Lithuanian princess Sophia Holszanska, gave him what Poland needed: two sons. Throughout his long reign he continued to collaborate amicably with the Polish leaders or, occasionally, to oppose them, knowing well that the union with Lithuania depended on his own person. He suffered great anxiety from the ambitions of Vytautas, who was a great warrior and statesman and planned to conquer the Tatars and to annex Moscow. Beloved by the Lithuanian people, Vytautas died in 1430. Wladyslaw Jagiello died in 1434, after a reign of 48 years, at a great age. He was, like most of his family, a prudent, tolerant and tenacious ruler, and he founded a dynasty that was to be one of the greatest in Europe.

***Wladyslaw* III, 1434–44.**—Jagiello was succeeded by his ten-year-old son Wladyslaw III, the chief position in the realm being held by the most eminent of the Cracow magnates, Zbigniew Olesnicki, bishop of Cracow and one of the previous king's chief advisers, who became a cardinal. Olesnicki had to deal with a number of urgent problems: the spread of Hussitism among the gentry; the threat to European civilization from the Turks on the Danube; the possibility of the recovery of Silesia from the Czechs and of Pomorze from the Teutonic Order; and the dangerous rise of rebellion in Lithuania among the Orthodox Ruthenians. A highly cultured scholar, a great orator and diplomatist, he played a leading part in the council of Basel. The Lithuanian rebels, though supported by the master of Livonia (the Knights of the Sword had been amalgamated with the Teutonic Order in 1237), were decisively defeated in 1435 near Wilkomierz (Vilkomir, Ukmerge). A churchman. Olesnicki was, like Queen Jadwiga, prepared to conciliate the Teutonic Order and to concentrate the national forces against the heretical Czechs (so as to recover Silesia) and against the Turk in the south. He failed in the first project, and his great crusade, which involved securing the throne of Hungary for Wladyslaw III (who thus became Ulaszlo I of Hungary), was brought to a disastrous end by the defeat at Varna (1444), where Wladyslaw was killed and his supporter John Hunyadi routed. Until his death was certain, Poland remained without a ruler for three years (1444–47), when Wladyslaw II Jagiello's second son, Casimir, who had made himself popular in Lithuania, ascended the Polish throne. (A. B. Bo.)

Casimir IV, 1447–92.—The difficulties which confronted Casimir were great. He recognized not only the vital necessity of the maintenance of the union between the two states but also the fact that the chief source of danger to the union lay in Lithuania. For political reasons, during the earlier years of his reign, Casimir was obliged to reside for the most part in Lithuania, and his interest in the grand duchy was always resented in Poland, where, to the very end of his reign, he was regarded with suspicion. In particular, he could never rely on adequate Polish support in the struggle, which he inherited from his predecessors, with the Teutonic Order.

The struggle assumed a new form in 1454, when Casimir accepted the suzerainty offered to him by the Prussian league, which had repudiated the authority of the order and needed a protector. The acquisition of the Prussian lands was vital to the existence of Poland. It meant the command of the principal rivers of Poland, the Vistula and the Niemen, and the acquisition of a seaboard with its corollaries of sea power and commerce. Yet, except in the border province of Great Poland, which was interested commercially, the king received little support, military or financial, and it was only with his victory at Puck (Sept. 17, 1462) that he obtained any decisive success against the order. The war was ended in 1466 by the second treaty of Torun (Oct. 14), by which Poland recovered the provinces of Pomorze, Chelmno and Michalow, with the bishopric of Warmia (Ermeland), numerous cities and fortresses, including Marienburg, Elbing, Danzig and Torun. The territory of the Knights was now reduced to Prussia proper, embracing, roughly speaking, the district between the Baltic, the lower Vistula and the lower Niemen, with Konigsberg as its capital. For this territory each grand master within nine months of his election was in future to render homage to the Polish king, who undertook not to make war or to engage in any important enterprise without Prussian consent. Prussia had now become a Polish province, and Poland had acquired a seaboard.

The whole foreign policy of Casimir IV was influenced by the

Prussian question. At the beginning of the war both the empire and the papacy were against him. He therefore allied himself with George of Podebrad, whom the Hussites had placed on the throne of Bohemia. On the death of George (1471), Casimir's eldest son, Vladislav (*i.e.,* in Polish, Wladyslaw), was elected king of Bohemia by the Utraquist party, despite the determined opposition of Matthias Corvinus (Matthias I Hunyadi), the king of Hungary, who thenceforward deliberately set about traversing all the plans of Casimir. He encouraged the Teutonic Order to rebel against Poland; he entertained at his court anti-Polish embassies from Moscow; he encouraged the Tatars to ravage Lithuania; he thwarted Casimir's policy in Moldavia. His death in 1490 came, therefore, as a distinct relief to Poland, and all danger from the side of Hungary was removed when Vladislav, already king of Bohemia, was elected king of Hungary also.

It was in the reign of Casimir IV that Poland first came into direct collision with the Turks. The Jagiellons, as a rule, prudently avoided committing themselves to any political system which might irritate the still distant but much-dreaded Turk, but when their dominions extended so far southward as to embrace Moldavia the observance of a strict neutrality became exceedingly difficult. Poland had established a sort of suzerainty over Moldavia as early as the end of the 14th century, but at best it was a loose and vague overlordship which the hospodars repudiated whenever they were strong enough to do so. The Turks themselves were too much occupied elsewhere to pay much attention to the Danubian principalities till the middle of the 15th century, and it was not till 1484 that they became inconvenient neighbours to Poland. In that year a Turkish fleet captured the strongholds of Kilia and Akkerman, commanding, respectively, the mouths of the Danube and Dniester. This aggression seriously threatened the trade of Poland, and induced Casimir IV to accede to a general league against the Porte. In 1485, after driving the Turks out of Moldavia, the Polish king, at the head of 20,000 men, proceeded to Kolomyja on the Pruth, where Bayezid II, then embarrassed by an Egyptian war, offered peace; but as no agreement concerning the captured fortresses could be arrived at, hostilities were suspended by a truce. During the remainder of Casimir's reign the Turks gave no trouble.

John Albert and Alexander.—The death of Casimir was followed by the temporary separation of Poland and Lithuania and by a strong aristocratic reaction in Poland itself. Casimir's third son, John Albert, was elected king of Poland, and his fourth son, Alexander, became grand duke of Lithuania. On the death of John Albert in 1501, Alexander succeeded him as king, and the union of Poland and Lithuania assumed a more definite character, the senate of each country agreeing that in future the king of Poland should always be grand duke of Lithuania. The acquiescence of Lithuania was essentially the result of a new danger which had arisen in the east. Till the accession of Ivan III in 1462 Moscow had been a negligible factor in Polish politics. During the earlier part of the 15th century the Lithuanian princes had successfully contested Muscovite influence even in Pskov and Great Novgorod. Many Russian historians even maintain that, but for the fact that he had simultaneously to cope with the Teutonic Order and the Tatars, Vytautas would have extinguished struggling Moscow altogether. But since the death of Vytautas (1430) the military efficiency of Lithuania had sensibly declined, and the natural attraction of the Orthodox Greek element in Lithuania toward Moscow threatened the integrity of the grand duchy. During the reign of Alexander, who was too poor to maintain any adequate standing army in Lithuania, the Muscovites and Tatars ravaged the whole country at will and were prevented from conquering it altogether only by their inability to capture the chief fortresses. In Poland, meanwhile, Alexander had practically surrendered his authority to an incapable aristocracy, while the dependent states of Prussia in the north and Moldavia in the south made strenuous efforts to break away.

Sigismund I, 1506–48.—Fortunately for the integrity of the Polish state, the premature death of Alexander in 1506 brought upon the throne his capable brother Sigismund, the fifth son of Casimir IV. Eminently practical, Sigismund I recognized that the first need of Poland was a standing army, that Poland, in order to hold its own, must in future follow the example of the west and wage its warfare with trained mercenaries. The great financial and military liberties of the Polish gentry for long prevented both the organization of an adequate national army and the development of a modern fiscal system. Much of the internal history of Sigismund's reign turns on the various proposals made toward these ends, most of which were defeated or mutilated by the aristocratic opposition in the *sejm.* The long, open frontiers of the Polish kingdom invited invasion, and the misfortunes which fell on Poland at a later time largely resulted from the failure of the defensive measures proposed by Sigismund and his advisers. Throughout his reign, the king was hampered by lack of resources. In 1525 he was compelled to grant autonomy to the province of Prussia instead of annexing it; he was unable to succour his unfortunate nephew, Louis II of Hungary, against the Turkish peril, or to prevent the occupation of one Lithuanian province after the other by the Muscovites.

To this period belong the first attempts to provide for the defense of the dzikie *pola,* or "savage steppe," as the vast plain was called which extended from Kiev to the Black sea. In the reign of Alexander, the fugitive serfs who had escaped into this wilderness (they were subsequently known as Kazaks, or Cossacks, a Tatar word meaning "freebooters") had been formed into companies (c. 1504) and placed at the disposal of the frontier *starostas*, or lord marchers, of Kaniow, Kamieniec Podolski (Kamenets-Podolsk), Cherkask on the Don and other places. But these measures proved inadequate, and in 1533 the lord marcher Ostafi Daszkiewicz, the hero of Kaniow, which he had successfully defended against a countless host of Turks and Tatars, was consulted by the diet as to the best way of defending the Ukraine permanently against such inroads. The veteran expert advised the populating and fortifying of the islands of the Dnieper. But nothing was done officially. The selfish prudence of Bona Sforza, Sigismund's second wife, did more for the national defense than the Polish state could do. To defend her immense possessions in Volhynia and Podolia, she converted the castles of Bar and Krzemieniec into first-class fortresses and placed the former in the hands of her Silesian steward, who acquitted himself so manfully of his charge that "the Tatars fell away from the frontier all the days of Pan Pretficz," and a large population settled securely beneath the walls of Bar, henceforth known as "the bastion of Podolia."

The most important political event in eastern Europe during the reign of Sigismund was the collapse of the ancient Hungarian monarchy at Mohacs in 1526. After the death of King Louis in the battle, the emperor Ferdinand and John Zapolya, voivode of Transylvania, competed for the vacant crown, and both were elected almost simultaneously. In Poland Zapolya's was the popular cause, and he also found powerful support in the influential and highly gifted Laski family, represented by the Polish chancellor and his nephews Jan and Hieronymus. Sigismund, on the other hand, favoured Ferdinand of Austria. He argued that the best way to keep the Turk from Poland was for Austria to incorporate Hungary, in which case the Austrian dominion would be a strong and permanent barrier against a Moslem invasion of Europe. History more than justified him, and the long duel which ensued between Ferdinand and Zapolya (see HUNGARY: History) enabled the Polish monarch to maintain to the end a cautious but observant neutrality. More than once, indeed, Sigismund was seriously compromised by the diplomatic vagaries of Hieronymus Laski, who entered the service of Zapolya (since 1529 the protégé of the sultan) and greatly alarmed both the emperor and the pope by his disturbing philo-Turk proclivities. As a result of Laski's intrigues, the new hospodar of Moldavia, Petrylo, after doing homage to the Porte, intervened in the struggle as the foe of both Ferdinand and Sigismund, and besieged the grand hetman of the crown, Jan Tarnowski, in Obertyn, where, however, the Moldavians (Aug. 22, 1531) sustained a crushing defeat, and Petrylo was slain. Nevertheless, so anxious was Sigismund to avoid a collision with the Turks that he forbade Tarnowski to cross the Moldavian frontier and sent a letter of explanation to Constantinople. On the death of John Zapolya, the Austro-Polish alliance was still further cemented by the marriage of Sigismund's son and heir, Sigismund Augustus, with the archduchess Elizabeth. In the reign of Sigismund was effected the incorporation of the duchy of Mazovia with the Polish crown, after an independent existence of 500 years. In 1526 the male line of the ancient dynasty became extinct, and on Aug. 26 Sigismund received the homage of the Mazovians at Warsaw, the capital of the duchy and before long of the whole kingdom.

(R. N. B.; F. M. S.; X.)

Sigismund II Augustus, 1548–72.—Already in the 15th century the University of Cracow had brought forth humanist scholars of European repute and begun to attract distinguished lecturers and numerous students from abroad. Thanks to Sigismund I's marriage to a Sforza of Milan, the royal court at Cracow became the home of the highest Renaissance art of Italy, and the royal castle on Wawel hill at Cracow, rebuilt by Italian architects and their Polish disciples, became one of the finest monuments of Renaissance style north of the Alps. Under Sigismund II the third great spiritual factor of the age, next to humanist scholarship and Renaissance art—the doctrine of the Reformation—entered potently into Poland's intellectual life, uniting with Italian culture on the common ground of literature and helping to produce the first great age of Polish poetry and prose. There followed the clash between the New Learning and the strong tradition of Poland's chivalrous Catholicism; the difficulties with the Scandinavian powers and the rising empire of the Moscow tsars; the dilemma produced between the evolution of the Polish parliamentary system and the Renaissance tendency toward the strengthening of central government authority. Even a king of genius could be only partially successful in coping with all these tasks, and the reign of Sigismund II, in many respects one of the most brilliant in Polish annals, left the seeds of decay and failure behind it.

Reformation and Counter Reformation.—The new king having shown his temper by marrying a lady of the noble house of Radziwill without asking for the opinion of the senate, the reign began in a storm of demands for constitutional guarantees to secure the parliamentary "gentry democracy" against the powers of the crown and the nobility. The king resolutely allied himself with Austria abroad and with the bishops and the nobles at home, against a threatened revolt of the gentry. In doing so, he had to take the bishops' side in the issue between the Reformation and Catholic orthodoxy, and he affirmed this by an edict against heresy in 1550. But this act only opened up the long-maturing dispute about the creation of a national church after the recent example of Henry VIII of England. The king, a man of enlightened mind, the first Polish monarch who habitually used the vernacular language instead of Latin at public functions, showed in many ways a sympathetic understanding for the tendencies of the new era. The influence of the Bohemian Hussite movement of 100 years before combined with nascent modern nationalism to inspire definite programs for a Reformed Polish state church with Polish ritual, independent of Rome, and with a priesthood subject to government authority. The large Greek Orthodox element among the citizens of the eastern provinces of the monarchy furnished an additional stimulus, which gave strength to such demands as that for the abolition of clerical celibacy in the Lutheran fashion. The bishops resorting to highhanded measures of repression, the *sejm* of Piotrkow in 1552 voted, at the king's own suggestion, the suspension of clerical courts for a twelvemonth. This was extended afterward and solemnly renewed by another *sejm* in 1555, during which masses were actually said in Polish and the communion was administered in two kinds. A religious interim of about ten years followed, during which Protestantism in Poland flourished exceedingly. Presently reformers of every shade of opinion, even those who were tolerated nowhere else, poured into Poland, which speedily became the battleground of all the sects of Europe. Soon the Protestants became numerous enough to form ecclesiastical districts of their own. The first Calvinist synod in Poland was held at Pinczow in 1550. The Bohemian Brethren, expelled from their own country, ultimately coalesced with the Calvinists at the synod of Kozminek (Aug. 1555). In the sejm itself the Protestants were absolutely supreme and invariably elected a Calvinist to be their marshal. The king, however, perceiving a danger to the constitution in the violence of the gentry, not only supported the bishops but quashed reiterated demands for a national synod. The *sejm* of 1558–59 indicates the high-water mark of Polish Protestantism. From this time forward it began to subside, gradually but unmistakably, chiefly because of the division among the reformers themselves. From the chaos of creeds resulted a chaos of ideas on all imaginable subjects, politics included. The anti-Trinitarian heresy proved to be the chief dissolvent, and from 1560 onward the relations between the Lutherans and the Calvinists were fratricidal rather than fraternal; Jan Laski (*q.v.*) vainly strove to unite all Polish Protestants round the Helvetian standard, and a federation of all Poles of the Reformed faith—the "concord of Sandomierz," 1570, predominantly Calvinist in character—met resolute Lutheran opposition and led to nothing.

While the strong individualism of the Polish national character thus thwarted all endeavours at Protestant consolidation, the wars against Orthodox Moscow effectively united Poles round their old Catholic banners, and the vigorous Protestant propaganda conducted from Konigsberg by Poland's vassal Albert, duke of East Prussia, appeared to the bulk of the nation under the guise of a German menace. These political factors told in favour of Catholicism; so did presently the wiser policy of Rome. Pope Pius IV, unlike his predecessor, adopted a conciliatory attitude toward the Polish crown in the matter of disputed appointments of bishops. The new bishops were holy and learned men, very unlike the creations of Queen Bona Sforza, and capable papal nuncios reorganized the scattered and faint-hearted Catholic forces in the land. From one of the ablest of them, Giovanni Commendone, the king, at the *sejm* of 1564, accepted the book of the decrees of the Council of Trent; immediately afterward he issued decrees banishing the more extreme heretics from the country. In 1565 the Jesuits, the vanguard of the Catholic Counter Reformation, appeared in Poland.

At their best, the various forms of Protestantism had never won more than a scanty noble and intellectual elite of the nation; they had never taken root among the peasantry or the petty bourgeoisie. While the gradual effacement of Reformed creeds removed a powerfully creative intellectual and literary factor from Poland's life, the re-establishment of Catholicism restored to the country that spiritual unity which was to be the chief source of national strength in the coming struggle against the aggression both of Orthodox Russia and of Lutheran Germany.

The Incorporation of Livonia.—Access to the Baltic had been a vital question since the dawn of the Polish state in the 10th and 11th centuries. Poland's expansion eastward, which began definitely in the 14th century through the acquisition of Halicz by Casimir the Great and was continued in the 15th through the dynastic union with Lithuania, made an extension of its foothold on the Baltic shore imperative. At the same time, the knights of the Teutonic Order (*q.v.*) had threatened to cut Poland off from access to the sea altogether. They had been beaten down by the earlier Jagiellons, and access to the sea was secured by way of Danzig. But in the 16th century the foe began to regain strength in the secular and Protestant duchy of East Prussia, formally owning allegiance to Poland. Sigismund II was naturally attracted by an opportunity to outflank this foe and to gain a separate outlet to the sea.

In the middle of the 16th century the Order of the Knights of the Sword (the Livonian Order), whose territory embraced Estonia, Livonia, Courland, Semigalliia and the islands of Dago and Oesel, was tottering. All the Baltic powers were more or less interested in the apportionment of this vast tract of land, whose geographical position made it not only the chief commercial link be. tween east and west but also the emporium whence the English, Dutch, Swedes, Danes and Germans obtained their grain, timber and most of the raw products of Lithuania and Moscow. Poland and Moscow as the nearest neighbours of this moribund state, which had so long excluded them from the sea, were vitally concerned in its fate. After an anarchic period of suspense, lasting from 1546 to 1561, during which Sweden secured Estonia while

Ivan the Terrible fearfully ravaged Livonia, Sigismund II, to whom both the master of Livonia and the archbishop of Riga had appealed more than once for protection, at length intervened decisively. At his camp before Riga in 1561 the last master, who had long been at the head of the Polish party in Livonia and had embraced Protestantism, and the archbishop of Riga gladly placed themselves beneath Sigismund's protection, and by a subsequent convention signed at Wilno (Nov. 28, 1561) Livonia was incorporated with Lithuania in much the same way as Prussia had been incorporated with Poland 36 years previously; that is to say, as a new Protestant duchy and as a fief of the Polish crown, with local autonomy and freedom of worship.

Union with Lithuania, 1569.—The danger to Lithuania, revealed in the Baltic wars with Ivan the Terrible, as well as the apathy shown in these matters by the Polish sejm, must have convinced so statesmanlike a prince as Sigismund II of the necessity of preventing any possibility of cleavage in the future between the two halves of his dominions. A personal union under one monarch had proved inadequate. A further step must be taken—the two independent countries must be transformed into a single state. The principal obstacle was the opposition of the Lithuanian magnates, who feared to lose their dominance in the grand duchy if they were merged in the szlachta (gentry) of the kingdom. When things came to a deadlock in 1564, the king tactfully intervened and voluntarily relinquished his hereditary title to Lithuania, thus placing the two countries on a constitutional equality and preparing the way for fresh negotiations. The death in 1565 of Nicholas Radziwill the Black, the chief opponent of the union, still further weakened the Lithuanians, but the negotiations, reopened at the sejm of Lublin in 1569, at first also led only to rupture. Then Sigismund executed his master stroke. Knowing the sensitiveness of the Lithuanians regarding Volhynia and Podolia, he suddenly, of his own authority, formally incorporated both these provinces with the kingdom of Poland, whereupon, amid great enthusiasm, the Volhynian and Podolian deputies took their places on the same benches as their Polish brethren. The hands of the Lithuanians were forced. Even a complete union on equal terms was better than mutilated independence. Accordingly they returned to the sejm and the union was unanimously adopted on July 1, 1569. Henceforth the kingdom of Poland and the grand duchy of Lithuania were to be one inseparable and indivisible body politic; all dependencies and colonies, including Prussia and Livonia, were to belong to Poland and Lithuania in common. The retention of the old duality of dignities was the one reminiscence of the original separation; it was not abolished till 1791, four years before the final partition of Poland.

The union definitely shifted Poland's political centre of gravity eastward; it created a common interest in the Russian menace to the long and naturally defenseless eastern frontier and in the millions of Greek Orthodox people living in the eastern borderlands. Warsaw was appointed one of the meeting places of the joint sejm, thus preparing the transfer of the capital from Cracow to Warsaw. The union was the last great historical act of the Jagiellon dynasty; it put the coping stone to the structure of a monarchy which, with growing consolidation, seemed to bear in it the promise of empire.

Political Development.—Simultaneously with the transformation into a great power of the petty principalities which composed ancient Poland, another and equally momentous political transformation was proceeding within the country itself.

The origin of the Polish constitution is to be sought in the *wiece* or councils of the Polish princes during the period of division. The privileges conferred upon the magnates of whom these councils were composed, especially upon the magnates of Little Poland (who brought the Jagiellons to the throne, directed their policy and grew rich upon their liberality), angered the less favoured szlachta, who, toward the end of the 14th century, combined for mutual defense in their *sejmiki* or local diets.

The first sejm to legislate for all Poland was that of Piotrkow (1493), summoned by John Albert to grant him subsidies; but the mandates of its deputies were limited to 12 months, and its decrees were to have force for only three years. John Albert's second sejm (1496), after granting subsidies the burden of which fell entirely on the towns and peasantry, passed a series of statutes benefiting the nobility at the expense of the other classes. These were followed by others of the same kind under his successor, Alexander, which, by facilitating import and crippling export trade in the interests of the gentry, enfeebled and degraded the middle class and thereby seriously disturbed the social equilibrium of the state. Nevertheless, so long as the Jagiellon dynasty lasted, the political rights of the cities were jealously protected by the crown against the usurpations of the nobility. The burgesses of Cracow, the most enlightened economists in the kingdom, supplied Sigismund I with his most capable counsellors during the first 20 years of his reign (1506–26). Sigismund's predecessor, Alexander, had been compelled to accept the statute *Nihil novi* (1505), which gave the sejm and the senate an equal voice with the crown in all executive matters. Under Sigismund I some of the royal prerogatives were recovered, but in his later years the influence of the gentry returned and the sejm succeeded in controlling all the great offices of state, The Polish parliamentary system, vesting supreme powers in the two houses of the sejm, was an established fact. Sigismund II knew that only a strengthening of the central authority could save the state. But his endeavours to manoeuvre his way between the two rival powers of the magnates and the lesser gentry were, on the whole, unsuccessful. A patriotic party of gentry democrats arose, veiling its program of democratic reforms under the conservative watchword of the "execution of the laws" and dealing further legislative blows at the trade of the towns and the social status of the middle class. The king, who at first sided with the great nobles against the "executionists," afterward allied himself with the latter to curtail the power of the magnates by a repeal of former royal grants of land and by the imposition of a tax on all tenants of crown lands for the maintenance of the army (1562–63). Beneficial as this was, it was obtained only at the price of further dependence of the crown on the szlachta.

THE ELECTIVE KINGS

The childless Sigismund II Augustus died suddenly in 1572. Fortunately for Poland, the political horizon was unclouded. Domestic affairs, however, were in an almost anarchical condition. The union of Lublin. barely three years old, was anything but consolidated, and in Lithuania it continued to be extremely unpopular. Worst of all, there was no recognized authority in the land to curb its jarring centrifugal political elements. Civil war was happily averted at the last moment, and a national convention assembled at Warsaw in April 1573 for the purpose of electing a new king. Five candidates for the throne were already in the field. Lithuania favoured Ivan IV. In Poland the bishops and most of the Catholic magnates were for an Austrian archduke, while the strongly anti-German szlachta were inclined to accept almost any candidate but a German. It was easy, therefore, for the adroit and energetic French ambassador to procure the election of the French candidate, Henry of Valois, duke of Anjou. Well provided with funds, he speedily bought over many of the leading magnates. Having been one of the instigators of the St. Bartholomew massacre. he was looked at askance by the Protestants; the religious difficulty in Poland, however, had meanwhile been adjusted to the satisfaction of all parties by the compact of Warsaw (Jan. 28, 1573), which granted absolute religious liberty to all non-Catholic denominations without exception—a far more liberal measure than the Germans had made in the religious peace of Augsburg 18 years before. Finally, early in April 1573 the election sejm assembled at Warsaw, and Henry was elected king of Poland.

Henry of Valois, **1573–74.**—The election had been preceded by a correctura *iurum*, or reform of the constitution. which resulted in the famous "Henrician articles" which converted Poland from a limited monarchy into a republic with an elective chief magistrate. The king was to have no voice in the choice of his successor. He was to marry a wife selected for him by the senate. He was to be neutral in all religious matters. He was not to lead the militia across the border without the consent of the szlachta, and then only for three months at a time. Should the king fail to observe any one of these articles, the nation was *ipso facto* absolved from its allegiance. Whatever its intrinsic demerits, the disastrous fruits of this reform were largely caused by the precarious geographical position of Poland, and it must be remembered to Poland's credit that it alone with England preserved the tradition of parliamentary government in the increasingly absolutist Europe of the time.

The reign of Henry of Valois lasted 13 months. The tidings of the death of his brother Charles IX determined him to exchange a thorny for what he hoped would be a flowery throne, and at midnight on June 14, 1574, he literally fled from Poland to become Henry III of France. In Nov. 1575 the senate elected the emperor Maximilian II to the throne; but the gentry democracy, at the suggestion of its new leader Jan Zamoyski (*q.v.*), chose a prince of Transylvania, Stephen Bathory, assigning him for husband to the last surviving princess of the Jagiellon dynasty, and enforced this election by arms.

Stephen Bathory, 1575–86.—The king elected by the "patriotic" party proved one of Poland's greatest kings. The glorious 11 years of his reign, too brief to be permanently effective, yet represent the high-water mark of Poland's international power, and the achievements of his genius both in foreign and domestic policy remain unsurpassed in Polish annals. (See STEPHEN [ISTVÁN] BÁTHORY.)

With the insight of a born statesman he focused his energy on two vital objectives: the maintenance of Poland's access to the sea by way of Danzig, and the defense of its newly gained further seaboard in the northeast against the rising power of Moscow. Danzig, on Bathory's election, began to intrigue against him with the emperor Maximilian (until his death in Oct. 1576) and with Russia and Denmark. In spite of a deplorable lack of understanding on the part of the Polish gentry for the issue at stake, Bathory, who had throughout the able and strenuous support of his chancellor Zamoyski, conducted a campaign against Danzig both by land and sea and finally enforced its complete submission to his rule.

Before peace was made with Danzig, Ivan the Terrible had raided Livonia once more. Bathory, for the first time in the history of Polish warfare using infantry rather than cavalry and calling peasants and burghers to arms together with the gentry, achieved in the operations against Russia the greatest military triumphs of his reign. In three successive expeditions he pushed his way northeastward as far as Pskov, and the tsar was fain to obtain the pope's intervention by a promise of making Russia Catholic. As a result of Bathory's victories, Poland pushed Russia entirely away from the Baltic for a long time and regained sway over nearly the whole of Livonia.

Brilliant as these foreign successes were, the greatness of Bathory's statesmanship was even more manifest at home. He conciliated, by concessions and privileges, two of the most important minority groups, the Ukrainian Cossacks and the Jews. The Cossacks were largely runaway serfs, who had organized themselves into a sort of military republic on the vast and scantily inhabited plains of the Ukraine or "borderland," stretching from the southeast of the monarchy toward the Black sea along the river Dnieper. The Cossack community had been drawn into the Polish military system under Bathory's predecessors by registration and pay and had already been granted exemption from taxation, as well as their own jurisdiction. Bathory, who needed them for his Russian wars, confirmed and enlarged these privileges. His successors used the Cossacks against the Russians, Turks and Tatars; but soon the Cossacks themselves were to grow into a factor of trouble for Poland, not without serious errors of policy on the Polish side.

The privileges which the Jews had obtained from former kings were augmented; from Bathory's day until 1764 the Polish Jews had a parliament of their own, meeting twice a year, with powers of taxation. It was also chiefly in the interest of the Jews that Bathory restricted, by special edict, the trading rights of Scottish pedlars, of whom as many as 30,000 were abroad in Poland in his time. Among other domestic measures, Bathory reformed the Polish judicial system by the creation of a supreme court of appeal for civil cases, and he founded, in 1579, the University of Wilno as a bulwark of western European culture in the east.

The growing imperial ambitions of the house of Habsburg had developed into a menace to Poland's international position; they now threatened to outflank and encircle Poland on the southern side. Bathory proposed to counteract them by the project of a union with Russia and a joint crusade against Turkey under the auspices of the pope. This grandiose plan would have given Poland again a firm footing on the shore of its "second sea"—the Black sea—which it had reached once before in the time of the Jagiellons. But the idea was carried with Bathory to his grave on his sudden death in 1586.

Sigismund III, 1587–1632.—The Vasa period of Polish history, which began with the election of Sigismund, son of John III of Sweden and of Sigismund I's daughter Catherine, was one of last and lost chances. The collapse of the Muscovite tsardom and the submersion of Germany by the Thirty Years' War presented Poland with an unprecedented opportunity of consolidating, once for all, its hard-won position as the dominating power between central and eastern Europe; it might even have wrested the best part of the Baltic littoral from the Scandinavian powers and pushed Russia back beyond the Volga. That this was not achieved was partly caused by the class spirit and blind selfishness of the Polish gentry. Apathetic toward vital problems of foreign policy and unwilling to make material sacrifices to the cause of national defense, they persisted in a doctrinaire defense of "republican liberty" at the very time when the need of a strong central executive was more urgent than ever.

But other grave causes of failure were not wanting. One of them consists in the very personality of the new foreign-bred king: the tenacity with which he clung to his hereditary rights to the Swedish crown involved Poland in unnecessary wars with Sweden at most inopportune times; and his bigoted devotion to the cause of Catholicism introduced a new spirit of religious fanaticism and persecution into the atmosphere of a country hitherto distinguished for toleration, while the same bigotry served Poland's interests very ill abroad. Poland's greatest statesman of the time, Jan Zamoyski, discovered in the earliest years of the reign that the king, who had married Anne, daughter of the Habsburg Charles of Styria, was willing to surrender the crown of Poland to an Austrian archduke and to return to his native Sweden in order to bring it back to the Catholic fold. Zamoyski, who had himself placed Sigismund on the throne by conquering a rival Austrian candidate. was naturally indignant. and the whole disgraceful affair of the king's secret negotiations with Austria culminated in his having to answer the charges of a special "court of inquisition" (1592)—the first time that the prestige of the crown in Poland was exposed to such an ordeal.

The Uniate Church.—It was only where the expansion of Catholicism served the interests of the Polish state that Zamoyski saw eye to eye with the king's Catholic zeal. Thus, he became instrumental in creating, at the synod of Brzesc in 1596, the Uniate Church as a halfway house for those of the republic's Greek Orthodox citizens who were willing to recognize the supremacy of Rome but desired to preserve their accustomed Eastern ritual and Slavonic liturgy. The Uniate Church served the purpose of drawing a large section of the population of the eastern border provinces out of the orbit of Moscow and into that of Polish influences; but by the antagonisms which soon began between Uniates and non-Uniates, it became in itself a source of new troubles for Poland. Besides this, the pride of Poland's Roman Catholic prelates, who looked down on the Uniate hierarchy, forced the Uniate Church into the position of a "peasant religion" and contributed to making it the social nucleus of anti-Polish Ukrainian nationalism which it henceforth remained. Even in Sigismund's time, Austria, competing with Poland for influence in the eastern Balkans, began to seduce the Ukrainian element (represented in organized form by the military community of the Cossacks) against Poland—a policy which the same Austria was to resume later in changed form and under different conditions when mistress of eastern Galicia.

Swedish, Muscovite and Turkish Wars.—The dispute over Sigismund's rights to the Swedish crown began, from the earliest years of the reign, to drag its weary course of alternate victories and defeats. At first the areas that later became Estonia and Latvia were both the scene and the principal object of the strife; in the later stages, Gustavus Adolphus transferred the ground nearer to the heart of Poland by espousing the cause of the Calvinist elector of Brandenburg. who had come into possession of East Prussia and thus laid the foundation of a large Protestant power on the Baltic. The danger to Danzig and Poland's grain exports roused even the gentry from their apathy; but in spite of some brilliant victories by sea and land. an armistice toward the end of the reign was highly unfavourable to Poland.

Sigismund's persistent Swedish ambitions, his equally persistent Austrian sympathies. but, more than all. his absolutist leanings and cherished plans for a drastic and arbitrary constitutional reform on foreign models and on antiparliamentary lines occasioned in 1606 an armed revolt of the Polish gentry against their king — the *rokosz* (or insurrection) of Mikolaj Zebrzydowski, who was supported by the discontented Protestants. The *rokosz* was at last suppressed in 1607, but it left as its legacy such ruinous precedents as an enforced recognition of the doctrine of the subjects' right to depose their king (de non *praestanda* obedientia) and, being undertaken in justified defense of the native parliamentary tradition against wholesale foreign innovations, had the harmful effect of blocking the way toward any and every reform of the parliamentary system.

Soon after the constitutional cataclysm of the *rokosz,* Poland became embroiled in prolonged wars with Moscow. The motive was partly a vague conception of a Polish-Russian union as opposed to the king's Austrian propensities, but partly also the very real desire of some border magnates for more and more land east of the Dnieper. An occasion was furnished by the extinction of the dynasty of Rurik in Russia and the subsequent struggle for the throne, particularly the emergence of one candidate — the ill-fated Pseudo-Demetrius (see DIMITRI. FALSE)—whom certain Polish nobles and finally also the king supported. The appearance of a second Pseudo-Demetrius after the fall of the first prolonged the strife. Throughout the campaigns against Moscow the king found himself at variance with some leading Polish statesmen and soldiers of the time, such as Zamoyski and, later, Stanislaw Zolkiewski; he thought of the problem only in terms of conquest, of the establishment of Catholicism in Russia and of strong monarchical rule over the united kingdoms, while Zolkiewski, even at the height of military successes against Russia, had a union like that of Poland with Lithuania in his mind and advocated tolerance of Russia's creed and social order. The Poles once actually held the Kremlin of Moscow for a time (1610) and once again laid siege to it (1617); Sigismund's son Wladyslaw was elected tsar, and his opponent did homage to Sigismund as a prisoner. But a national insurrection in Russia and the establishment of the Romanoff dynasty checked the Polish advance, and only certain territorial gains (including Smolensk), as well as a good deal of influence of Polish customs and institutions on the Russian nobility. were definite results of the struggle in Sigismund's time. It was to be continued under his successors.

The wars with hloscow temporarily ended in an armistice at the very moment (1618) when the Thirty Years' War broke out in central Europe. In this Poland remained officially neutral, but Sigismund's favourable attitude toward the Habsburgs entangled Poland in renewed and long wars with Turkey, which the later Jagiellons and their first successors had managed to avoid. A definite success was attained against the Turks at Hotin (1621), a year after Zolkiewski's heroic death at Cecora. But the Swedish trouble began anew in the same year, and Sigismund's long and unlucky reign ended 11 years later amid turmoil abroad and at home, setbacks to Polish power on all sides without and seriously increased constitutional disorder within.

Wladyslaw IV, 1632–48. — Sigismund's son, born in Poland and brought up as a Pole. enjoyed a popularity which had never been his father's lot. As crown prince. he had been successful in military operations against Moscow and Turkey; on his ascension to the throne he ingratiated himself with the gentry by some new concessions, including even exemption from income tax. The "wisest of the Polish Vasas," as he has been called, intended to create a basis of public favour and confidence for the constitutional reforms which he planned.

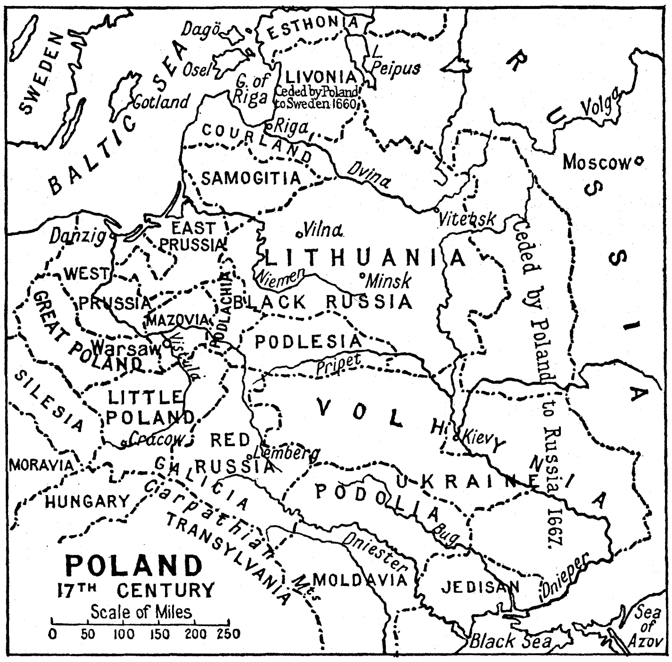
But the international difficulties inherited from his father diverted his energies largely into channels of foreign policy. The very first years of his reign are marked by new victories over Russia and the Turk and also by a new and much more advantageous truce with Sweden He was less fortunate in a ne conflict with Danzig, and with its supporter Denmark, over the tolls he intended to impose on the trade of the Baltic ports; no interest in these matters was to be anakened in the gentry. and the most powerful magnates — those of the eastern border — thought more of expansion into the fertile Ukrainian regions than of sea power. Accordingly, the Polish navy, which had begun to develop in a promising manner under Sigismund III, was allowed to fall into permanent decay, and Wladyslaw's plans for foreign action on a large scale were unrealized. He wavered in his diplomacy between Austrian and French influences, represented by his two successive queens; his tolerant and friendly attitude toward the Orthodox east caused serious trouble with the Vatican; and his project of a great crusade against the Turks, although encouraged by the Venetian republic and acclaimed by the south Slav nations, in the end came to nothing.

The Cossack Revolt. — The chief obstacle which prevented Wladyslaw's Turkish plans from maturing was the impossibility of winning the help of the decisive factor, the Ukrainian Cossacks, who had become too numerous and powerful to be willing instruments of Polish policy. Catholic intolerance toward this Orthodox population, in the time of Sigismund III, had combined with the proud and highhanded behaviour of Polish landowners to produce in the Cossacks a spirit of religious, racial and social enmity against the Polish element; the Polish parliament had not kept the financial terms of its compacts with the Cossacks; repressions inspired by the border magnates had infuriated them. Already in the earlier years of Wladyslaw's reign terrible Cossack revolts had flared up and been unwisely punished by the abolition of ancient privileges. Now, instead of letting themselves be made the tools of Wladyslaw's anti-Turkish plans, the Cossacks made common cause with the Tatars of the Crimea, who were the most immediate objective of the king's crusading plans: and the reign ended amid a wave of Cossack insurrection, engineered by the sultan, assisted by Tatar hordes and led by Bohdan Chmielnicki (*q.v.*), a country gentleman personally wronged by a Polish official, now the rising hero of Ukrainianism. It was only the resistance of the Polish burghers of Lwow that stemmed the Cossack and Tatar tide from flooding the inner provinces of Poland; the same patriotic town was to arrest two other invasions — a Russian and a Transylvanian one—in the next few years. But the defense of Lwow meant only a respite, and on Wladyslaw's death his brother and successor, the last of the Polish Vasas. found himself faced by a powerful renewal of Chmielnicki's attack on central Poland.

John Casimir, 1648–68.—John Casimir, summoned to the throne from France, where he had lived as a priest and become a cardinal, was obliged to begin his reign by negotiating with his rebel subject Chmielnicki. But Chmielnicki's conditions of peace were so extravagant that the negotiations came to nothing. It was only after a second invasion of Poland, in 1639, by a host of Cossacks and Tatars, that the compact of Zborow was concluded, by which Chmielnicki was officially recognized as chief (hetman) of the Cossack community. A general amnesty was also granted, and it was agreed that all official dignities in the Orthodox palatinates of Lithuania should henceforth be held solely by the Orthodox gentry. For the next 18 months Chmielnicki ruled the Ukraine like a sovereign prince. He made Czehryn, his native place, the Cossack capital, subdivided the country into 16 provinces and entered into direct relations with foreign powers. The Orthodox patriarchs of Alexandria and Constantinople were his friends and protectors. His attempt to carve a principality for his son out of Moldavia led to the outbreak of a third war between suzerain and subject in Feb. 1651. But fortune. so long Bohdan's friend. now deserted him, and at Beresteczko (1651) the

Cossack chieftain was utterly routed by John Casimir. All hope of an independent Cossackdom was now at an end, yet it was not Poland but Moscow which reaped the fruits of this great victory.

Chmielnicki, by suddenly laying bare the nakedness of the Polish republic, had opened the eyes of Moscow to the fact that its ancient enemy was no longer formidable. Three years after his defeat at Beresteczko, Chmielnicki, abandoned by his Tatar allies and finding himself unable to cope with the Poles single-



BY JOHN BARTHOLOMEW & SONS

FIG. I.— SEVENTEENTH-CENTURY MAP PRESENTED TO CHARLES II

handed, very reluctantly transferred his allegiance to the tsar Alexius Mikhailovich, whose armies in the same year invaded Poland. The war thus begun is known in Russian history as the Thirteen Years' War and far exceeded even the Thirty Years' War in grossness and brutality.

In the summer of 1655, while Poland was still reeling beneath the shock of the Muscovite invasion, Charles X of Sweden, on the flimsiest of pretexts, forced a war to gratify his greed of martial glory, and before the year was out his forces had occupied the capital, the coronation city and the best half of the land. King John Casimir, betrayed and abandoned by his own subjects, fled to Silesia. Profiting by the cataclysm which, for the moment, had swept the Polish state out of existence, the Muscovites quickly appropriated nearly everything which was not already occupied by the Swedes. At this crisis Poland owed its salvation to two events—the formation of a general league against Sweden, brought about by the apprehensive court of Vienna, and a popular outburst of religious enthusiasm on the part of the Polish people. The first of these events, to be dated from the alliance between the emperor Leopold I and John Casimir (1657), led to a truce with the tsar and the welcome diversion of all the Muscovite forces against Swedish Livonia. The second event, which began with the heroic and successful defense of the monastery of Czestochowa by Prior Augustyn Kordecki against the Swedes, resulted in the return of the king from exile, the formation of a national army and the recovery of almost all the lost provinces from the Swedes, who were driven back headlong to the sea, where with difficulty they held their own. On the sudden death of Charles X, Poland seized the opportunity of adjusting all its outstanding differences with Sweden. By the peace of Oliwa (Oliva) (1660), made under French mediation, John Casimir ceded Livonia and renounced all claim to the Swedish crown. The war with Moscow was then prosecuted with renewed energy and extraordinary success. In 1664 a peace congress was opened, and the prospects of Poland seemed most brilliant; but at the very moment when it needed all its armed strength to sustain its diplomacy, the rebellion of Prince Jerzy Lubomirski involved the country in a dangerous civil war, compelled it to reopen negotiations with the Muscovites and practically to accept the Muscovite terms. By the truce of Andruszowo (1667) Poland received back from Moscow Vitebsk, Polotsk and Polish Livonia, but ceded in perpetuity Smolensk, Severia, Chernigov and the whole of the eastern bank of the Dnieper. The Cossacks of the Dnieper were henceforth to be divided between the dominion of the tsar and the king of Poland. Kiev, the religious metropolis of southwestern Russia, was to remain in the hands of Moscow for two years.

The "truce" of Andruszowo proved to be one of the most permanent peaces in history, and Kiev, though pledged for only two years. was never again to be recovered. Henceforth the political influence of Russia over Poland was steadily to increase, without any struggle at all, although influences of Polish culture and manners, exercised chiefly through the academy of Kiev, still continued to permeate Russia until the advent of Peter the Great.

The "Liberum Veto" in the 17th Century.—Poland had, in fact, emerged from the cataclysm of 1648–67 a moribund state, though its not unskilful diplomacy had enabled it for a time to save appearances. Its territorial losses, though considerable, were, in the circumstances, not excessive, and it was still a power in the opinion of Europe. But a fatal change had come over the country during the age of the Vasas. The period synchronized with and was partly determined by the new European system of dynastic diplomatic competition and the unscrupulous employment of unlimited secret service funds. This system, which dates from Richelieu and culminated in the reign of Louis XIV, was based on the rivalry of the houses of Bourbon and Habsburg, and very soon nearly all the monarchs of the continent and their ministers were in the pay of one or other of the antagonists. Poland was no exception to the general rule. To do them justice, the *szlachta* at first not only were free from the taint of official corruption but endeavoured to fight against it. But they themselves unconsciously played into the hands of the enemies of their country by making the so-called *liberum veto* an integral part of the Polish constitution. The *liberum veto* was based on the assumption of the absolute political equality of every Polish gentleman, with the corollary that every measure introduced into the Polish *sejm* must be adopted unanimously. Consequently, if any single deputy believed that a measure already approved of by the rest of the house might be injurious to his constituency, he had the right to exclaim *"Nie pozwalam,"* "I disapprove," the measure in question falling at once to the ground. Subsequently this vicious principle was extended still further A deputy, by interposing his individual veto, could at any time dissolve the *sejm,* and all measures previously passed had to be resubmitted to the consideration of the following *sejm.* Before the end of the 17th century the *liberum veto* was used so recklessly that all business was frequently brought to a standstill. Later it became the chief instrument of foreign ambassadors for dissolving inconvenient sessions, as a deputy could always be bribed to exercise his veto.

Michael Wisniowiecki, 1669–74.—With the election of Michael Wisniowiecki in 1669 a new era began. A native Pole, he was freely elected by the unanimous vote of his countrymen; but he was chiefly chosen for the merit of his father, a great border magnate who had victoriously kept down the Cossacks, and he proved to be a passive tool in the hands of the Habsburgs. In view of this the French party rallied round John Sobieski, a military commander of rising fame. The dissensions between the two camps cost Poland a new defeat at the hands of the united Turks and Cossacks. Sealed by a shameful treaty of Buczacz (1672), this defeat was only wiped out by a brilliant victory of Sobieski's at Hotin, which also, after King Michael's early death, carried him to the throne against an Austrian candidate.

John **III** Sobieski, **1674–96.**—Connected with France by marriage and by political sympathies, Sobieski, although he had half a lifetime of constant wars against the Turks behind him, stood at first, in accordance with French policy, for peaceful relations with Turkey and directed his eyes toward the Baltic, attempting with French help to check the rising Hohenzollern power in that quarter. But his secret dealings with France turned his o n subjects against him. while continuous Turkish invasions forced him into war. until an attack of unprecedented magnitude, aimed at the very heart of Europe, called forth that unprecedented outburst of Polish heroism — the gallant rescue of Vienna in 1683. That great act was the last noble reflex of the great crusading impulse of the middle ages; it was a unique service, rendered in the old chivalrous spirit by one nation to another in an age of Machiavellian diplomacy and growing national selfishness. It won Poland offers of friendship from all the great powers. Rut its positive gains for Poland proved little; cessions of territory to Moscow did not buy any active support in further campaigns against Turkey, nor did the delivered Austria assist Poland in its endeavour to re-establish the Rumanian outpost against the Turk.

Augustus II, 1697–1733.---On the death of John III no fewer than 18 candidates for the vacant Polish throne presented themselves. The successful competitor was Frederick Augustus I, elector of Saxony, who cheerfully renounced Lutheranism for the coveted croan and won the day because he happened to arrive last of all, with fresh funds, when the agents of his rivals had spent all their money. He was crowned, as Augustus II, in 1697, and his first act was to expel from the country his French rival, François Louis de Bourbon, prince de Conti, whose defeat was also partly caused by the growing Russian influence, which, from the accession of Peter the Great (1700), became a permanent factor in Polish domestic politics.

Good luck attended the opening years of the new reign. In 1699 the long Turkish war, which had been going on since 1683, was concluded by the peace of Karlowitz, whereby Podolia. the Ukraine and the fortress of Kamieniec Podolski were retroceded to the republic by the Ottoman Porte. But the permanent weakening of Turkey brought little good, for the power of Russia soon became a greater menace to Poland than Turkey had ever been.

Shortly after the peace of Karlowitz, Augustus was persuaded by the plausible Livonian exile Johann Reinhold Patkul to form a nefarious league with Frederick of Denmark and Peter of Russia, for the purpose of despoiling the youthful king of Sweden, Charles XII *(see* SWEDEN: *History).* This he did as elector of Saxony, but it was the unfortunate Polish republic which paid for the hazardous speculation of its newly elected king. Throughout the Great Northern War, which wasted northern and central Europe for 20 years (1700–21), all the belligerents treated Poland as if it had no political existence. Swedes, Saxons and Russians not only lived upon the country, but plundered it systematically. The *sejm* was the humble servant of the conqueror of the moment, and the leading magnates chose their own sides without the slightest regard for the interests of their country, the Lithuanians for the most part supporting Charles XII, while the Poles divided their allegiance between Augustus and Stanislam Leszczynski *(see* STANISLAUS I), whom Charles maintained upon the throne from 1704 to 1jog. At the end of the war Poland was ruined materially as well as politically. Augustus offered Courland, Polish Prussia and even part of Great Poland to Frederick William I of Prussia provided that he were allowed a free hand in the disposal of the rest of his kingdom. When Prussia declined this tempting offer for fear of Russia, Augustus went a step further and actually suggested that "the four eagles" (viz.. the black ones of Austria, Prussia and Russia and the white eagle of Poland proper) should divide the other Polish territories between them. He died, however, before he could give effect to this shameless design.

Augustus III, 1733–63.—On the death of Augustus II, Stanislaw Leszczynski, who had, in the meantime, become the father-in-law of Louis XV, attempted to regain his throne with the aid of a small French army corps. Some of the best men in Poland, including the Czartoryski family, were also in his favour, and he was elected king for the second time. But there were many malcontents, principally among the Lithuanians, who solicited the intervention of Russia in favour of the elector Frederick Augustus II of Saxony, son of the late king. A Russian army appeared be'ore Warsaw and compelled a phantom *sejm* (it consisted of but 15 senators and 500 of the *szlachta*) to proclaim Augustus III. Stanislaw and his partisans were besieged by the Russians in Danzig, and with its surrender their cause was lost. He retired to become duke of Lorraine and Bar, keeping the title of king of Poland but leaving Augustus III in possession of the kingdom.

Augustus III left everything to his omnipotent minister, Heinrich, count von Bruhl, and Bruhl entrusted the government of Poland to the noble family of the Czartoryskis, who had close relations of long standing with the court of Dresden. "The Family," as their opponents sarcastically called them, were to dominate Polish politics for the next half-century, and they were honourably determined to save the republic by a radical constitutional reconstruction which was to include the abolition of the *liberum veto* and the formation of a standing army.

Unfortunately, the other great families of Poland were obstinately opposed to any reform or, as they called it. any "violation" of the existing constitution. The Potockis, in particular, whose possessions in southern Poland and the Ukraine covered thousands of square miles, hated the Czartoryskis and successfully obstructed all their efforts. During the reigns of the two Saxon kings, every *sejm* was dissolved by the hirelings of some great lord or, still worse, of some foreign potentate.

It was against this primitive state of things that the Czartoryskis struggled and struggled in vain. First they attempted to abolish the *liberum veto* with the assistance of the Saxon court, but fear of foreign complications and the opposition of the Potockis prevented anything from being done. Then they broke with their old friend Brühl and turned to Russia. Their chief intermediary was their nephew Stanislaw Poniatowski *(see* STANISLAUS II AUGUSTUS), whom they sent, as Saxon minister, to the Russian court in the suite of the English minister Sir Charles Hanbury Williams in 1755. The handsome and insinuating Poniatowski speedily won the susceptible heart of the grand duchess Catherine, but he won nothing else and returned to Poland in 1759 somewhat discredited. Nevertheless, the Czartoryskis looked to Russia again for support on the death of Augustus III. They rejected with scorn and derision the pacific overtures of their political opponents, Prince Fryderyk Michal Czartoryski openly declaring that he preferred the tyranny of the Muscovite to the tyranny of his equals. He had in fact already summoned a Russian army corps to assist him to reform his country, which sufficiently explains his own haughtiness and the unwonted compliance of the rival magnates.

Stanislaw II Poniatowski and the Partitions, 1764–95.— The simplicity of the Czartoryskis was even more mischievous than their haughtiness. Their naive expectations were very speedily disappointed. Catherine II and Frederick II had already determined (treaty of St. Petersburg, 1764) that the existing state of things in Poland must be maintained, and as early as 1763 Catherine had recommended the election of Stanislaw Poniatowski as "the individual most convenient for our common interests." The personal question did not interest Frederick; so long as Poland was kept in an anarchical condition he cared not who was called king. Moreover, the opponents of the Czartoryskis made no serious attempt to oppose the entry of the Russian troops.

Shortly afterward Stanislaw Poniatowski was elected king and crowned. But at the beginning of 1766 Prince Nikolai Repnin was sent as Russian minister to Warsaw with instructions which can only be described as a carefully elaborated plan for destroying the republic. The first weapon employed was the question of the dissidents. At that time the population of Poland was, in round numbers, 11,500 000, of whom about 1,000,000 were dissidents or dissenters. Half of these aere the Protestants of the towns of Polish Prussia and Great Poland, the other half was composed of the Orthodox population of Lithuania. The dissidents had no political rights, and their religious liberties had also been unjustly restricted; but two-thirds of them being agricultural labourers and most of the rest artisans or petty tradesmen, they had no desire to enter public life and were so ignorant and illiterate that their new protectors, on a closer acquaintance, became heartily ashamed of them. Yet it was for these persons that Repnin, in the name of the empress, now demanded absolute equality, political and religious, with the gentlemen of Poland. He was well aware that an aristocratic and Catholic assembly like the *sejm* would never concede so preposterous a demand.

Early in 1767 the malcontents, fortified by the adhesion of the leading political refugees, formed at Radom a confederation whose first act was to send a deputation to St. Petersburg, petitioning Catherine to guarantee the liberties of the republic. With a carte blanche in his pocket, Repnin proceeded to treat the *sejm* as if it were already the slave of the Russian empress. But despite threats, wholesale corruption and the presence of Russian troops outside and even inside the chamber of deputies, the patriots, headed by four bishops, offered a determined resistance to Repnin's demands. Only when brute force in its extremest form had been ruthlessly employed, only when two of the bishops and some other deputies had been arrested in full session by Russian grenadiers and sent as prisoners to Kaluga, did the opposition collapse. The liberum *veto* and all the other ancient abuses were now declared unalterable parts of the Polish constitution, which was placed under the guarantee of Russia. All the edicts against the dissidents were, at the same time, repealed.

Confederation of Bar.—This shameful surrender led to a Catholic patriotic uprising, known as the Confederation of Bar, which was formed in 1768 at Bar in the Ukraine, by a handful of small squires. It never had a chance of permanent success, though, feebly fed by French subsidies and French volunteers, it lingered on for four years, until finally suppressed in 1772. But, insignificant itself, it was the cause of great events. Some of the Bar confederates, scattered by the Russian regulars, fled over the Turkish border, pursued by their victors. The Turks, already alarmed at the progress of the Russians in Poland and stimulated by Charles Gravier, comte de Vergennes,'at that time French ambassador at Constantinople, at once declared war against Russia. Seriously disturbed at the prospect of Russian aggrandizement, the courts of Berlin and Vienna conceived the idea that the best mode of preserving the equilibrium of Europe was for all three powers to readjust their territories at the expense of Poland. Negotiations led to no definite result at first; then Austria took the first step by occupying, in 1769, the county of Spiz (Szepes, Zips), which had been hypothecated by Hungary to Poland in 1411 and never redeemed. This act decided the other powers; in June 1770 Frederick surrounded with a military cordon, ostensibly to keep out the cattle plague, those of the Polish provinces that he coveted. Catherine's consent had been previously obtained.

First Partition, 1772.—The first treaty of partition was signed at St. Petersburg between Prussia and Russia on Feb. 6–17, 1772; the second treaty, which admitted Austria also to a share of the spoil, was signed on Aug. 5–16 the same year. The consent of the *sejm* to this act of brigandage was extorted by bribery and 'force in 1773. Russia obtained the palatinates of Vitebsk, Polotsk, Mscislaw: 34,616 sq.mi. of territory, with a population of 550,000. Austria got Little Poland without Cracow and also Lwow, Tarnopol and Halicz and, by corrupting the name of the last, called the new province Galicia: 32,045 sq.mi., with a population of 816,000. Prussia received the palatinate of Pomorze minus Danzig, the palatinate of Chelmno minus Torun, the northern half of Great Poland and the palatinates of Marienburg and Warmia, calling the new acquisition West Prussia: 14,025 sq.mi., with a population of 378,000. The total area of Poland before 1772 was about 283,200 sq.mi., with an estimated population of 8,750,000.

The partitioning powers presented Poland with a new constitution. The elective monarchy and the *liberum veto* were of course retained. Poland was to be dependent on its despoilers, but they evidently meant to make it a serviceable dependent. The government was henceforth to be in the hands of a permanent council of 36 members, 18 senators and 18 deputies, elected biennially by the *sejm* in secret ballot, subdivided into the five departments of foreign affairs, police, war, justice and the exchequer, whose principal members and assistants, as well as all other public functionaries, were to have fixed salaries. The royal prerogative was still further reduced. The king was indeed the president of the permanent council, but he could not summon the *sejm* without its consent and in all cases of preferment was bound to select one out of three of the council's nominees. Still, the new organization made for order and economy and enabled Poland to develop and husband its resources and devote itself uninterruptedly to the now burning question of national education.

The shock of the first partition had a certain salutary effect on national mentality. Already in the darkest days of Saxon rule, important educational reforms had been carried out in the schools of the Piarist order by Stanislaw Konarski. Now, the dissolution of the Jesuit order in 1773, putting its rich possessions and the system of schools conducted by it into the hands of the state, gave Poland opportunity to secularize as well as modernize the whole educational fabric of the nation. This huge task was admirably performed by the Commission of National Education, the first ministry of education in Europe. It reorganized both the program of teaching and the structure of the schools—including the decayed universities of Cracow and Wilno—in a thoroughly modern and truly enlightened way. Less progress was made with the cause of constitutional reform: the chancellor Andrzej Zamoyski indeed drafted a new comprehensive code of laws, in which a beginning was made with the emancipation of the peasant serfs and of the town population, but this was rejected by the gentry in the *sejm* (1780).

In the meantime, important events in the international field seemed to give Poland another chance of reasserting its independence against its despoilers. The death of Frederick the Great in 1786 loosened the bonds of the alliance between Prussia and Russia. Russia, drawing nearer to Austria, undertook, jointly with Austria, a war against Turkey which proved unexpectedly hard; and Russia was at the same time attacked by Sweden. Prussia, having changed its policy and concluded an alliance against Russia with England and Holland, was now emboldened by Russia's difficulties to go further: it invited Poland also to forsake the Russian alliance and offered to place an army corps of 40,000 men at its disposal.

The Constitution of May 1791.—It was under these exceptional circumstances that the "four years' *sejm*" assembled (1788). Its leaders, Stanislaw Malachowski, Hugo Kollontaj and Ignacy Potocki, were men of character and capacity, and its measures were correspondingly vigorous. Within a few months of its assembling it had abolished the permanent council, enlarged the royal prerogative, raised the army to 65,000 men, established direct communications with the western powers, declared its own session permanent and finally settled down to the crucial task of reforming the constitution on modern lines. But the difficulties of the patriots were commensurate with their energies, and though the new constitution was drafted as early as Dec. 1789 it was not till May 1791 that it could safely be presented to the *sejm*. Meanwhile, Poland endeavoured to strengthen its position by an alliance with Prussia. Frederick William II stipulated at first that Poland should surrender Danzig and Torun; but the Poles proving obstinate and Austria simultaneously displaying a disquieting interest in the welfare of the republic, Prussia in 1791 concluded an alliance with Poland which engaged the two powers to guarantee each other's possessions and render mutual assistance in case either were attacked.

But external aid was useless so long as Poland was hampered by its anarchical constitution. The most indispensable reforms had been frantically opposed; the debate on the reorganization of the army alone had lasted six months. It was only by an audacious surprise that Kollontaj and his associates contrived to carry through the new constitution. Taking advantage of the Easter recess, when most of the malcontents were out of town, they suddenly, on May 3, brought the whole question before the *sejm* and demanded urgency for it. Before the opposition could remonstrate, the marshal of the *sejm* produced the latest foreign dispatches, which unanimously predicted another partition, whereupon, at the solemn adjuration of Ignacy Potocki, King Stanislaw exhorted the deputies to accept the new constitution as the last means of saving their country and himself set the example by swearing to defend it.

The constitution of May 3, 1791, converted Poland into a hereditary limited monarchy, with ministerial responsibility and biennial parliaments. The *liberum veto* and all the intricate and obstructive machinery of the anomalous old system were forever abolished. All invidious class distinctions were done away with. The towns, in a special bill confirmed by the new constitution, got full administrative and judicial autonomy, as well as a certain measure of parliamentary representation; the personal privileges of the gentry, such as possession of land and access to office in the state and in the church, were thrown open to the townsmen. The peasants were placed under the protection of the law, and their-serfdom was mitigated with a view to its entire abolition. Absolute religious toleration was established. Provision was made for further periodical reforms by subsequent parliaments.

The constitution of May 3 had scarcely been signed when Stanislaw Feliks Potocki, Seweryn Rzewuski and Ksawery Branicki, three of the chief dignitaries of Poland, hastened to St. Petersburg and there entered into a secret convention with the empress. whereby she undertook to restore the old constitution by force of arms but at the same time promised to respect the territorial integrity of the republic. Entering Polish territory with Russian troops, the conspirators formed a confederation at the little town of Targowica in the Ukraine. protesting against the new constitution as tyrannous and revolutionary; at the same time the new Russian minister at Warsaw presented a formal declaration of war to the king and the *sejm*. The *sejm* met the crisis with dignity and firmness. The army was at once dispatched to the frontier; the male population was called to arms, and Ignacy Potocki was sent to Berlin to claim the assistance stipulated by the treaty of March 19, 1791. The king of Prussia, in direct violation of all his oaths and promises, declined to defend a constitution which had never had his "concurrence." Thus Poland was left entirely to its own resources. The little Polish army of 46,000 men. under Prince Joseph Anthony Poniatowski, nephew of King Stanislaw II, and Tadeusz Kosciuszko, did all that was possible under the circumstances. For more than three months they kept back the invader, and, after winning three pitched battles, retired in perfect order on the capital (*see* KOSCIUSZKO, TADEUSZ ANDRZEJ BONAWENTURA; PONIATOWSKI, JOSEPH ANTHONY). But the king, and even Kollontaj, despairing of success, now acceded to the confederation; hostilities were suspended; the indignant officers threw up their commissions; the rank and file were distributed all over the country; the reformers fled abroad; and the constitution of May 3 was abolished by the Targowicians as a "dangerous novelty." The Russians then poured into eastern Poland; the Prussians, at the beginning of 1793, alarmed lest Catherine should appropriate the whole republic, occupied Great Poland; and a diminutive, debased and helpless *sejm* met at Grodno in order, in the midst of a Russian army corps, "to come to an amicable understanding" with the partitioning powers.

Second Partition, 1793.—After every conceivable means of intimidation had been unscrupulously applied, the second treaty of partition was signed at three o'clock on the morning of Sept. 23, 1793. By this *pactum subjectionis,* as the Polish patriots called it, Russia got all the eastern provinces of Poland. extending from Livonia to Moldavia, comprising a territory of 96.751 sq.mi., while Prussia got Dobrzyn, Kujavia, Great Poland, Torun and Danzig. Poland was now reduced to less than one-third of its original dimensions, with a population of about 3,500,000.

Kosciuszko and the Third Partition.—The focus of Polish nationality was now transferred from Warsaw, where the Targowicians and their Russian patrons reigned supreme, to Leipzig, whither the Polish patriots, Kosciuszko, Kollontaj and Ignacy Potocki among the number, assembled from all quarters. From the first they meditated a national rising, but their ignorance, enthusiasm and simplicity led them to commit blunder after blunder. The first of such blunders was Kosciuszko's mission to Paris in Jan. 1793. He was full of the idea of a league of republics against the league of sovereigns; but he was unaware that the Jacobins themselves were already considering the best mode of detaching Prussia, Poland's worst enemy, from the anti-French coalition. Kosciuszko received an evasive reply and returned to Leipzig empty-handed. In the meantime, certain officers in Poland had revolted against the reduction of the Polish army to 15,000, imposed upon the country by the partition treaty. Kosciuszko himself condemned their hastiness; but the march of events forced his hand, and in March 1794 he went to Cracow, proclaimed a national insurrection and assumed the powers of a dictator. He called the peasants to arms, and they responded nobly, in return for which he supplemented the provisions of the constitution of 1791 by a manifesto giving them complete freedom. At first, Kosciuszko's arms were almost universally successful. The Russians were defeated in more than one pitched battle; three-quarters of the

FIG. 2.— PARTITIONS IN THE 18TH CENTURY

ancient territory was recovered, and Warsaw and Wilno, the capitals of Poland and Lithuania, respectively, were liberated. The first serious reverse at Szczekociny, was more than made up for by the successful defense of Warsaw against the Russians (July 9–Sept. 6). But even during that heroic defense mob lawlessness in Warsaw and violent dissensions in the supreme council and in the army began to frustrate the superhuman efforts of the unfortunate but still undaunted dictator. The appearance of overwhelming masses of Russian troops, together with the open hostility of Austria as well as Prussia, did the rest, and Kosciuszko's insurrection received its deathblow on the battlefield of Maciejowice, where he himself was wounded and taken prisoner. Warsaw was taken amid a terrible massacre of the population in the suburb of Praga, and the remainder of the troops capitulated a few weeks later.

The greed of the victorious powers nearly led to a rupture between Austria and Prussia, but, after some dissensions, the third partition of Poland was effected by successive treaties in 1795 and 1796. Austria had to be content with Lublin, Siedlce, Radom and Kielce, while Prussia took Suwalki, Bialystok, Lomza and Warsaw. Russia annexed all the rest and was afterward to tear even parts of their booty from the two others. Thus the name of Poland was wiped from the map of Europe, to reappear only after more than a century. (R. N. B.; R. DY.; X.)

THE DUCHY AND FOREIGN RULE

After the third partition, the more high-spirited Poles, chiefly officers and soldiers of Kosciuszko's army, emigrated and formed, on Italian soil, the Polish legions, which, during the next ten years, fought the battles of the French republic and of Napoleon all over Europe and even outside it, from Egypt to the West Indies. They were commanded by Jan Henryk Dombrowski, one of Kosciuszko's ablest generals; but Kosciuszko himself stood aloof, distrusting Napoleon.

The Duchy of Warsaw.—In 1806 and 1807, when Napoleon defeated Prussia and engaged in a war with Russia, Polish soldiers once more appeared on Polish soil, and the hopes of the nation seemed near fulfilment. In fact, the peace of Tilsit resulted in the reconstruction of a Polish state out of the central provinces of Prussian Poland; but Napoleon's anxiety to conciliate Russia effectually prevented him from making his new creation large enough to be self-supporting. The duchy of Warsaw, as it was called, consisted in 1807 of territories taken by Prussia in the second and third partitions, to which territory seized by Austria in the third partition was added in 1809. The total area of the duchy was then about 64,000 sq.mi., with a population of about 4,350,000. The constitution was dictated by Napoleon; it was framed on the French model and on very advanced lines. Equality before the law (implying personal freedom of the peasant), absolute religious toleration and highly developed local autonomy were its salient features. The king of Saxony, Frederick Augustus I (previously elector as Frederick Augustus III; grandson of Augustus III of Poland), whom Napoleon made duke, took the initiative in all legislative matters, but the administration was practically controlled by the French. In spite of being subject to most burdensome financial and military exigencies for the purposes of Napoleon's continuous wars, the small duchy contrived, during the few years of its existence, to do much peaceful, productive, organizing work, especially in the educational and economic spheres.

Poland's hopes for greater things revived once more when Napoleon announced his war against Russia (1812), as his "second Polish war." The duchy, by an immense effort, put an army corps of nearly 98,000 men into the field. But the calamity that overtook Napoleon in Russia also sealed the fortunes of the duchy. The remainder of the Polish troops faithfully followed Napoleon in his campaign of 1813–14, during which the heroic leader of the Poles, Prince Joseph Anthony Poniatowski, perished in covering the emperor's retreat from Leipzig. The duchy was occupied by the Russians.

The Congress Kingdom and Russian Rule.—Tsar Alexander I had been united by youthful friendship to the most eminent Polish noble of his time, Prince Adam Czartoryski, and had even made him, on his accession, foreign minister of the Russian empire. On Napoleon's downfall the Poles, to whom Alexander did not spare promises and flatteries, entertained the highest hopes.

It was not Alexander's fault, indeed, if the congress of Vienna, because of jealousy among the great powers and the entanglement of the Polish question with that of Saxony and other territories, did not lead to a reunion of Poland, even under the Russian sceptre, but confirmed the division of the country among the three partitioning powers. Cracow only, with a small surrounding territory, was erected into a free city republic. Great Poland, with Poznan for its centre and a population of 850,000, was left to Prussia. Austria remained in possession of Galicia with 1,500,000 inhabitants. The eastern borderlands, from Lithuania and White Russia to Volhynia and the Ukraine, continued to be incorporated in Russia. The remnant of central Poland only—about three-fourths of the territory of Napoleon's duchy of Warsaw—was constituted as the so-called Congress kingdom under the emperor of Russia as king of Poland. Guarantees of home rule in all parts of the divided country and of free communication between them were given by all powers concerned, only to prove soon more or less futile.

Alexander, who had a sentimental regard for freedom, so long as it meant obedience to himself, had promised the Poles a constitution. That constitution was soon duly drafted and signed. It contained 165 articles divided under seven heads. The kingdom of Poland was declared to be united to Russia in the person of the tsar, as a separate political entity. Lithuania and the Ruthenian palatinates continued to be incorporated with Russia as the Western Provinces and were divided from the Congress kingdom by a customs barrier till the reign of Nicholas I. The kingdom of Poland thus defined was to have at its head a lieutenant of the emperor (namiestnik), who must be a member of the imperial house or a Pole. The first holder of the office, Gen. Jozef Zajonczek (1752–1826), was a veteran who had served Napoleon. Roman Catholicism was recognized as the religion of the state, but other religions were tolerated. Liberty of the press was promised, subject to the passing of a law to restrain its abuses. Individual liberty, the use of the Polish language in the law courts and the executive employment of Poles in the civil government were secured by the constitution. The machinery of government included a council of state (at which the imperial government was represented by a commissioner plenipotentiary) and a *sejm* divided into a senate, composed of the princes of the blood, the palatines and councillors named for life, and a house of deputies elected for seven years. Poland retained its flag and a national army based on that which had been raised by and had fought for Napoleon. The command of the army was given to the emperor's brother Constantine, a man of somewhat erratic character, who did much to offend the Poles by violence (*see* CONSTANTINE PAVLOVICH).

The sejm met three times during the reign of Alexander, in 1818, in 1820 and in 1825, and was on all three occasions opened by the tsar. But the tsar and the *sejm* soon quarrelled. The third session of the *sejm* (May 13 to June 13, 1825) was a mere formality. All publicity was suppressed, and one whole district was disfranchised because it persisted in electing candidates who were disapproved of at court. All Europe at the time was seething with secret societies organized to combat the reactionary governments of the Holy Alliance. In Poland the National Freemasonry, or National Patriotic society as it was afterward called, had a large membership, especially among the students and the younger officers. Outside Congress Poland, a similar student movement arose in the University of Wilno. Severe measures—imprisonment, deportation and exile—were taken against students and graduates of Wilno (including the poet Adam Mickiewicz), and they added to the excitement in Warsaw.

No open breach occurred during the reign of Alexander I, nor for five years after his death in 1825. On the death of the unpopular Zajonczek in 1826, the grand duke Constantine became imperial lieutenant. His brother, the new tsar Nicholas I, soon became entangled in a war with Turkey. Austria, as usual, desirous of profiting by Russia's difficulties, began to court the favour of the Poles. Nicholas was crowned king of Poland in Warsaw in 1829 and personally opened the *sejm* in 1830. But the *sejm* already in 1828 had refused to sentence to death a group of Polish conspirators accused of dealings with the Russian "Decembrists" who had plotted Nicholas' overthrow, and in 1829 there was even an abortive Polish plot to murder him at his coronation in Warsaw. Fresh excitement was created in Poland by the outbreak of the Revolution in France in July 1830 and the revolt of Belgium; a rumour was current—not without justification—that Nicholas, acting in concert with the other autocrats of the Holy Alliance, intended to use the Polish army to coerce the French and Belgian revolutionaries.

The Rising of *1830*.—On Nov. 29, 1830, a military revolt broke out in Warsaw. It was started by the young hotheads of the officers' training school and began with the murder of several senior officers loyal to the government. Regiments of the army and masses of the civilian population began to join the rising; the weakness of Constantine allowed it to gather strength. He evacuated Warsaw and finally left the country. The war lasted from Jan. till Sept. 1831. The Poles began with some chances of success; they had a well-drilled and well-equipped army of about 30,000 men, which they increased by recruiting to about 80,000. Against this, the Russians, with considerable difficulty, succeeded in putting only about 114,000 men into the field. Their ultimate success resulted partly from the friendly attitude of Prussia, partly from the fact that the Polish *sejm*, having proclaimed the deposition of the tsar at an early stage of the conflict, received no response to its appeal for western European protection. But to a large extent the defeat of the insurrection was caused by certain faults on the Polish side: want of ability and decision on the part of the generals; a succession of rapid changes in the command of the army; fierce party strife within the civil government in the capital; a deplorable outbreak of mob violence in Warsaw at a critical moment of the war; and, finally, an irresolute attitude of the insurrectionary parliament toward the peasant claims.

After the suppression of the insurrection, certain remnants of a constitution were still granted to Russian Poland by the "organic statute" of 1832, but they were soon rendered illusory; the administration avowedly aimed at destroying the nationality and even the language of Poland. The universities of Warsaw and Wilno were suppressed, the Polish students compelled to go to St. Petersburg and Kiev. The recruits from Poland were distributed in Russian regiments, and the use of the Russian language was enforced as far as possible in the civil administration and in the law courts. The customs barrier between Lithuania and the former Congress Poland was removed, in the hope that Russian influence would spread more easily over Poland. A hostile policy was adopted against the Roman Catholic Church. But though these measures cowed the Poles, they failed to achieve their main purpose. Polish national sentiment was intensified. The Poles in Russia, whether at the universities or in the public service, formed an element which refused to assimilate with the Russians. In Poland itself the tsar left much of the current civil administration in the hands of the nobles, whose power over their peasants was hardly diminished and was misused as of old. The Polish exiles who filled Europe after 1830 maintained a constant agitation from abroad. The stern government of Nicholas was, however, so far effective that Poland remained quiescent during the Crimean War.

Alexander *II* and the Rising of 1863.—The reign of the new tsar Alexander II began with certain concessions to Poland in the political and educational field. Exiles were allowed to return, administrative pressure was lightened, the church was propitiated, an "agricultural society" was allowed to be formed and to discuss important affairs of the community, a medical faculty and, later on, a complete university were re-established in Warsaw. Finally, even a Polish council of state and a Polish administrative apparatus for the kingdom began to be organized. In their later stages these reforms were the work of Count Aleksander Wielopolski, who was installed in high office and stood for a national policy of loyal union with Russia. But his autocratic temper lost him the sympathies of the moderate elements of the gentry, while, on the ardent minds of the young, Wielopolski's methods acted like fuel heaped on fire. Religious ceremonies were used as the occasion for demonstrative political processions, there were collisions with the Russian troops and victims fell in the streets of Warsaw. Wielopolski had the unhappy idea of causing the revolutionary youth of the cities to be recruited en masse for the Russian army; the plan became known, numbers of the young people fled into the forests, and a revolutionary committee on Jan. 22, 1863, started an ill-prepared insurrection.

The struggle of the ill-equipped and ill-organized insurgent bands against the Russian garrisons dragged on in the form of guerrilla warfare throughout the country for nearly two years. A secret national government was set up in Warsaw, the movement spread successfully into Lithuania and the insurrection occupied the diplomatic attention of western Europe. But the assistance promised by Napoleon III never became effective; the rising was crushed; wholesale executions, confiscations and deportations followed its suppression; and Poland was now definitely turned into a Russian province.

Russification.—All self-government in Congress Poland was suppressed in 1863; all education was russified in 1869, justice in 1873. On the other hand, the abolition in 1851 of the customs frontier between Russia and Poland had laid the foundation for an extraordinary industrial expansion: Russian Poland, with its great textile factories at Lodz, became the chief industrial region for all Russia. Its vast market in agricultural Russia was protected against western competition by high tariffs; the Russian government took every possible measure (such as the introduction of specially favourable railway tariffs) to assist this expansion. The Poles, being excluded from state service in their own country, busied themselves with productive occupations, and the upper and middle classes achieved a well-being far superior to anything enjoyed by their cousins in Galicia. A second result of this expansion was the growth in Congress Poland of a large and radical proletariat which made common cause with the Russian Social Democratic movement. In the country districts, the agrarian policy of the Russian government was expressly calculated to stir up ill-feeling between the Polish peasants, whom the government demonstratively took under its protection, and the country gentry, whom it was determined to punish in every way for the leading part they had played in the insurrections. The peasant of Russian Poland officially got his freedom from the tsar in 1864. All peasants, whatever their tenure had been, and the mass of the landless proletariat became freeholders, on a far more generous basis than the Russian peasant in 1861. The landlords received compensation in the form of Russian treasury bonds, which stood far below par, and the peasants got the right to use the landlords' pastures and woods.

In the sphere of education, the most thoroughgoing system of russification set in after 1864. All the revived Polish schools of the Wielopolski period were made Russian again, including the University of Warsaw, and no effort was spared to produce in the minds of youth a distorted image of Poland's past. Secret patriotic education, however, counteracted this policy successfully both in town and country, and private Polish schools, struggling against great difficulties, kept the Polish cultural tradition alive.

The civil government of Russian Poland was reorganized strictly on the model of the rest of the Russian empire, the Poles being debarred, however, from certain liberal institutions which the Russians by that time possessed, such as municipal self-government and trial by jury. The Russian language was made compulsory in all official relations and at a later time even in the records of private institutions. A corrupt Russian bureaucracy filled all government offices, a severe censorship strangled every free utterance of the nation in the press and in literature, and a drastic police regime kept the prisons filled with political offenders.

After Russia's defeat in the Japanese war of 1904, the outbreak of a revolution in 1905 kindled all Polish hopes once more. A constitution was granted to the Russians, and 36 Polish deputies sat in the first Russian parliament (duma). A certain measure of freedom in the educational field was obtained and eagerly used for the foundation of new schools by a Warsaw society called the Mother of Schools (Macierz Szkolna). The peasants of Russian Poland spontaneously introduced the Polish language in their self-governing bodies. In the duma itself, the Liberals were not averse to granting Poland a large measure of autonomy within Russia. At the same time, persecution in Prussian Poland increased under Prince Bernhard von Bulow, while the Ukrainian national movement, developing in Austrian Poland especially since the grant of universal suffrage in 1907, was unwelcome both to Poles and Russians. Under these circumstances, Russian propaganda, reviving the pan-Slav ideals of 30 years ago, could count on some success even among the Poles. There were gestures of reconciliation at two Slav congresses, in 1908 and 1910, the Czechs willingly acting as mediators. The idea of uniting all Poles with autonomy within the Russian empire was widely preached; it became the program of the National Democratic, or all-Polish, party, led by Roman Dmowski, the head of the Polish representation in the duma.

Opposed to Dmowski and the followers whom he found even among Austrian Poles there stood the irreconcilable revolutionaries, led by Joseph Pilsudski. Both the insurrectionary movement started by Pilsudski in 1905 and the constitutional endeavour of Dmowski and his friends in the duma were soon stifled by the Russian reaction of the Peter Stolypin period. Pilsudski took refuge in Galicia and began to organize armed resistance to Russia from that base. In the duma, the Polish representation was lowered from 36 to 10 deputies. In the country, all the liberties gained after 1905 soon disappeared. The government's purchase of the railway line from Warsaw to the Austrian frontier resulted in the removal of all Polish railwaymen from the service and was a great blow to the Polish element. In 1912 the separation of the district of Chelm, in the southeast of Russian Poland, from the body of the province and its incorporation in Russia proper was received with indignant protests by Polish opinion as a new partition of Poland.

Prussian Poland. — The regime in Prussian Poland during the first 15 years after the congress of Vienna had been endurable. A Polish nobleman related by marriage to the Prussian dynasty—Prince Antoni Radziwill—was appointed lieutenant governor of the province; there was a provincial assembly and local representative bodies both urban and rural. The landowners were allowed to organize for economic purposes, and the peasants were fully enfranchised in 1823. After the insurrection of 1830, a period of more oppressive government by a German provincial president, E. Flottwell, set in; he revived Frederick the Great's method of German colonization of the Polish province, and he began to germanize the administration and the school system. A period of new concessions to the Poles under Frederick William IV was interrupted by the revolution of 1846–48. The constitution with which Prussia emerged from the revolution put an end to the self-government of Prussian Poland. Another interval of relaxation, in the first years of William I, was soon succeeded by the period of Bismarck's and Bülow's resolutely anti-Polish policy—characterized by the *Kulturkampf*, the "Colonizing committee," the Wrzesnia scandal, the schools' strike, the Expropriation bill and the like, for an account of which *see* POZNANIA. The result of the Prussian methods was to create a sturdy class of peasants and small *bourgeoisie*, disciplined and economically and culturally advanced; and a fellow feeling arose between the peasants and the landowning gentry such as was hardly known in other parts of Poland.

Austrian Poland.—After the insurrection of 1830–31, no remnant of Poland's independent political existence had been left except the minute city republic of Cracow, created by the congress of Vienna. For 30 years this miniature state led a flourishing existence. When the ferment of the approaching European revolution of 1848 was stirring most continental countries to their depths, thefe were active preparations for another rising both in Austrian and Prussian Poland. For Austria the menace was diverted by a peasant revolt in Galicia in Feb. 1846, which led to a massacre of about 2,000 landowners by the peasantry incited by the Austrian governor general Baron Krieg von Hochfelden. At the same time, Austria availed itself of the unrest among its Poles to obtain the consent of Russia and Prussia to the suppression of the city republic of Cracow. But it was not until 1848 that Cracow was finally occupied by Austria and incorporated into Galicia.

Austria under the old autocratic regime oppressed its Polish province politically and exploited it economically in the most ruthless fashion. The revolution of 1848 brought a change, but not until the defeat of Austria by Prussia in 1866 was it realized at Vienna that only a more liberal policy could hold the tottering, mixed monarchy together. The relation with Hungary having been placed on a federal footing, concessions had to be granted to the strong Polish element in Austria. The Poles began to be active in Austrian politics. The numerical strength of Polish deputies in the Vienna parliament was such that no Austrian government could be formed without it. Galicia (as Austrian Poland was officially called), containing a large Ukrainian element in its eastern half, was granted a special minister to represent its interests in the Vienna cabinet. It also got a provincial legislative assembly and a governor, who was invariably appointed from the ranks of the Polish aristocracy. With purely Polish administration, schools and courts of law, Galicia became indeed almost an independent Polish state within Austria and successfully defied the centralizing efforts of the Vienna bureaucracy. The Polish landowning class, which practically governed the country for the next few decades, managed its affairs in a one-sidedly agrarian spirit; the interests of the towns were not properly considered, hardly any attention was given to the development of industries, and Galicia remained economically backward. Even its oil fields were largely developed by foreign capital. On the other hand. political and cultural activities had more scope than in the two other parts of Poland; Galicia became the "Piedmont" of the Polish national movement, and Cracow, with its old university and new Academy of Sciences, an intellectual, artistic and literary centre for the whole nation. With the growth of a new educated class and the introduction of universal suffrage in Austria (1907) the social structure of the country began to change, its politics were strongly democratized, new economic tendencies got the upper hand, and Galicia was at last on the road of material advance when World War I began.

World War I.—World War I found the Poles estranged from one another and without a united national policy. "Brygadier" Pilsudski crossed the frontier from Galicia with a few hundred of his legion and engaged the Russian empire in battle as forerunner of the army of an independent and united Poland. But the Polish Supreme committee, formed in Cracow on Aug. 16, aimed at uniting Galicia and Congress Poland as a third party in the dual monarchy and required the Polish legion to take the oath to the emperor. In Warsaw the Polish National committee under Dmowski denied the right of the Cracow committee to speak in the name of the Polish nation, protested loyalty to the tsar and attempted to form a Polish legion on the side of Russia. Meanwhile the grand duke Nicholas issued a proclamation (Aug. 14) in which he promised to unite the three parts of Poland in an autonomous state with the Russian empire.

In the summer of 1915, however, the Central Powers conquered all Congress Poland. After the fall of Warsaw on Aug. 5, 1915, military governments were set up on behalf of Germany at Warsaw and of Austria-Hungary at Lublin. But fresh difficulties confronted the Austrian solution. The Polish Socialist party (P.P.S.) under Pilsudski declared that no recruiting should take place for Polish legions until an independent Polish government had been formed to conduct it. Meanwhile, Istvan Tisza, the Hungarian premier, had vetoed the Austrian trialist scheme, which was also opposed by Germany. Vienna again rejected the plans put forward b~ Germany of annexing Congress Poland to Germany or of forming an independent Polish buffer state in economic, military and political alliance with the Central Powers.

In Aug. 1916, however, after the defeat of the Austro-Hungarian troops at Luck, the German supreme command acquired complete control of policy on the eastern front. Erich Ludendorff believed it possible to gain a large Polish army if his ideas were adopted. Germany and Austria-Hungary issued a proclamation on Nov. 5, 1916, holding out a prospect of the restoration of an independent Congress Poland as a hereditary constitutional monarchy closely attached to the Central Powers. Francis Joseph promised Galicia increased autonomy within Austria-Hungary. The discussion of details was shelved; the military governments at Warsaw and Lublin continued to administer the country. On Nov. 26, 1916, a provisional council of state of 25 members was appointed; it was solemnly opened on Jan. 14, 1917. Pilsudski, who was one of the members of the council, began to work out the plans for a national Polish army. He refused, however, to raise it for German use, and the German plan of raising a Polish army failed completely.

In March 1917 the Russian dynasty fell. On March 30 the new Russian government recognized Poland's right to self-determination and promised the creation of a new Polish state. These events altered the attitude of the Allies toward Poland. particularly as they were now reinforced by the entry of the United States into the war. The answer of the Entente Powers to the peace proposals of the Central Powers issued on Jan. 10, 1917, had already declared their adhesion to the tsar's manifesto to his armies (Dec. 25, 1916) which had spoken of "the formation of a free Poland in all parts into which it is at present divided."

The danger still threatening Poland from Russia vanished with the breakdown of Alexander Kerensky's offensive (July 1917). The Central Powers were now the only enemy. In May 1917 the Polish members of the Austrian *reichsrat* unanimously demanded "an independent united Poland with an outlet to the sea," and declared that the Polish case was one for "international consideration." At the same time, the Polish council of state in Warsaw asked the occupants for a widening of its powers and split up over the German demand for a recruiting appeal and an oath of loyalty. Pilsudski resigned from the council with his adherents and set about turning his secret military organization against Germany.

On July 22 Polish discontent was increased by the arrest of Pilsudski. On Aug. 25 the council of state, now discredited with the people, resigned. On Sept. 12 Germany and Austria-Hungary introduced a new project of a regency of three, a cabinet and premier and'council of state, elected but enjoying limited powers, the German and Austrian military governments retaining the right of veto. The regency was appointed on Oct. 15; it consisted of the archbishop of Warsaw, Aleksander Kakowski, Prince Zdzislaw Lubomirski and Jozef Ostrowski, a large landowner. The first prime minister, Jan Rucharzewski, was appointed on Nov. 26 and formed his first ministry on Dec. 7.

While Polish affairs were taking this course under Austro-German occupation, Dmowski was making propaganda for the Polish cause in France and Great Britain and I. J. Paderewski was working tirelessly in the United States. In Nov. 1916 the so-called Polish National department in Chicago, Ill., had united all the organizations of the 4,000,000 Poles in the U.S.; and under Paderewski's influence, Pres. Woodrow Wilson, in his tentative peace message of Jan. 22, 1917, alluded to a "united, independent and autonomous Poland." In the course of 1917 a Polish corps was organized by Gen. Jozef Dowbor-Musnicki in Russia, and a Polish army began to be formed in France. The Polish National committee, founded by Dmowski and Paderewski at Lausanne in Aug. 1917 and later established in Paris, was gaining increasing influence in the councils of the Allies. Between Sept. 20 and Dec. 1, 1917, France, Great Britain, Italy and the United States had recognized it as the official representative of the Polish people. The 13th of President Wilson's Fourteen Points (Jan. 8, 1918) declared that a Polish state should be erected which should include the territories inhabited by indisputably Polish population "with an outlet to the sea and an international guarantee of its independence and integrity."

In the meantime, the utter collapse of the Russian army had led to peace negotiations between the Central Powers and the Bolsheviks. The Bolshevik delegates who arrived at Brest-Litovsk (*q.v.*) in Dec. 1917 recognized, in theory, the right of the Polish people to self-determination, but Polish delegates were not admitted to the deliberations. By the treaty as concluded on March 1, 1918, Soviet Russia renounced all claims over Poland; but the treaty (Feb. 9, 1918) between the Central Powers and the Ukraine allotted to the Ukraine the disputed province of Chelm, while Austria-Hungary further pledged itself in a secret clause to form East Galicia and Bukovina into a separate crownland. These clauses became known and Polish opinion was infuriated; the Polish club in the Austrian reichsrat went over to the opposition and the remnant of Pilsudski's legions still fighting for the Central Powers mutinied. Some were interned, some, under Gen. Jozef Haller, fought their way to the coast and joined the new Polish army in France. The council of state in Poland was opened in Warsaw on June 22. Little interest was taken in it, and general feeling in Poland tended to ignore this body in favour of the National committee in Paris. Even before the breakdown of the German offensive in July 1918, the prime ministers of Great Britain, France and Italy had declared in favour of an independent and united Poland at Versailles on June 3, 1918.

The Declaration of **Independence.**—On Oct. 6 the Polish regency council published a manifesto to the Polish nation declaring its intention of dissolving the council of state, forming a representative national government and summoning a *sejm* for a "free and united Poland." On Oct. 15 the Polish representatives in the Austrian reichsrat declared themselves to be "subjects and citizens of a free and re-united Polish State." On Nov. 10 Pilsudski, who had been released from imprisonment at Magdeburg on Oct. 7, arrived in Warsaw. The German troops of occupation were disarmed and expelled, and the Poles assumed the executive power in Warsaw on Nov. 11. The regency council declared on the same day that it appointed Pilsudski to the supreme command of all Polish troops and on Nov. 14 resigned in favour of Pilsudski.

On Nov. 14, too, the Polish members of the German reichstag and of the Prussian *landtag* met in Poznan and formed a supreme popular council. On Dec. 27 the Poznanian Poles rose against the Germans and turned them out of their province. Severe fighting broke out and went on till Feb. 16, 1919, when an armistice was concluded at Trier by Marshal Ferdinand Foch, acting on behalf of the Allies and Poland. Not until after the treaty of Versailles was signed did Poznan send deputies to the constituent assembly in Warsaw.

POLAND RESTORED

Of all the new or resurrected states of Europe, Poland was in many respects in the most difficult position. The territory of Congress Poland and Galicia had been devastated in the war. Most of the factories that had not been actually dismantled were closed for lack of raw material. The fields of the peasants had been laid waste, their livestock slaughtered, their farms burned. Many districts were actually famine stricken, others swept by epidemics. Communications were disorganized and rolling stock was in a deplorable state. Marks, roubles and crowns circulated freely, but their values were low and uncertain, and public and private finances were chaotic. Because of the past policy of Prussia and Russia, a Polish civil service existed only in Galicia. Thirty thousand German troops were still in the country.

Pilsudski, the old revolutionary, had begun by appointing a cabinet of the left, composed mainly of Galician Socialists and peasants' representatives, under the presidency of Jedrzej Moraczewski. But the propertied classes refused him their support, and his attempt to float an internal loan met with little response. In December Paderewski, the second man in Poland enjoying almost unlimited prestige, arrived in the country, composed his differences with Pilsudski and became premier on Jan. 17, 1919. Dmowski was appointed president of the Polish delegation to negotiate peace. It was possible to hold elections for a constituent assembly on Jan. 26, 1919. The constituent sejm met on Feb. 10. It passed a vote of confidence in Paderewski's cabinet and confirmed Pilsudski as head of the state. Paderewski proceeded to Paris to urge Poland's claims; Pilsudski raised an army to defend them. General Haller's 100,000 troops, returning in April from France overland across Germany, were a valuable addition to the 230,000 men then at Pilsudski's disposal. The unification of the army was celebrated on Oct. 19, 1919, the French system of instruction and organization was adopted and by the beginning of 1920 the Polish army grew to about 600,000 men in 21 divisions of infantry and 7 brigades of cavalry. (R. DY.)

The Treaty of **Versailles** and Frontier **Problems.**—On June 28, 1919, on behalf of Poland, Dmowski and Paderewski signed the treaty of Versailles, which, however, left the major part of the country's frontiers undefined. Poland regained Pomorze and Poznan, but in East Prussia and Upper Silesia the Polish-German frontier was to be decided by plebiscite. Danzig (*q.v.*) was to be a free city under the protection of the League of Nations but was to be included within the Polish customs frontier in order to provide Poland with a free and secure access to the sea; in addition, Poland was to have free, unrestricted use of the port and to undertake the conduct of the free city's foreign relations. There was a Polish-Czechoslovakian dispute over Teschen (Cieszyn or Tesin) and also over the territories of Orawa (Orava) and Spisz. Of the eastern frontiers of Poland article 87 of the treaty stated that they would be "subsequently determined by the principal Allied and Associated Powers."

East *Prussia.*—Two plebiscite zones were established, that of Marienwerder (Kwidzyn), an area of 1,036 sq.mi. with 174,000 inhabitants, and that of Allenstein (Olsztyn), about 4,800 sq.mi. with 565,000. All Prussian civil servants were left in the plebiscite areas and the presence of German security police precluded freedom of speech.

The vote was taken on July 11, 1920, when Soviet forces were at the gates of Warsaw. In the Allenstein zone 363,209 votes were cast for Germany and 7,980 for Poland. in the Marienwerder zone 96,923 for Germany and 8,018 for Poland. Making the utmost of a stipulation that not only residents but also persons born in the area had the right to vote. the Germans sent to the plebiscite zones 202,700 "emigrants," who constituted nearly half of the voters. while 40% of the qualified residents abstained from voting. Thus the plebiscite, lost by Poland, could scarcely be described as a fair expression of the popular will.

Upper *Silesia.*—The plebiscite area of Upper Silesia was 4,250 sq.mi. with 1,942,200 inhabitants. Out of 706.820 votes cast for Germany on March 20, 1921, emigrant voters were responsible for 182,288; Poland obtained 479,414 votes. In all, 682 communes voted for Poland and 792 for Germany, but the Poles secured preponderance in the southeastern plebiscite area, which economically was the most important. Disregarding the treaty provisions for the partition of the area according to the wishes of the inhabitants expressed by communes, Germany claimed the whole of Upper Silesia, while Wojciech Korfanty, the leader of the Silesian Poles, demanded that 59% of the area, in which 673 communes voted for Poland and 230 for Germany, be awarded to Poland.

The Inter-Allied commission failed to agree on a unanimous proposal to the Supreme council of the principal Allied Powers, the British and Italian commissioners favouring cession to Poland of only the two southern agricultural districts of Rybnik and Pszczyna (Pless) while the French commissioner proposed a frontier less favourable than the Korfanty line but leaving the industrial basin to Poland. Learning of this basic disagreement, the Polish military organization, of which Michal Grazynski was the chief organizer, thought that only an insurrection could save the Polish cause. Korfanty agreed and gave the order for a rising, .which broke out on May 3, 1921. In a few days almost all the area within the Korfanty line was occupied. Taken by surprise, the Germans were thrown back. After six weeks' fighting the Inter-Allied commission effected a cessation of hostilities on June 24, and both the belligerents withdrew their troops.

The Supreme council assembled in Paris on Aug. 8–12 failed to draw a new frontier across Upper Silesia because David Lloyd George was anxious to save for Germany as much of the industrial area as possible. The only way out of the deadlock was to submit the question to the council of the League of Nations, where Great Britain was represented by Arthur James Balfour. The council's verdict, given on Oct. 12, 1921, was endorsed by the Allied Powers eight days later. The new frontier divided the industrial area: Poland was awarded 1,241 sq.mi. with about 996,-000 inhabitants, 76% of the coal production, 22 out of 37 blast furnaces and 9 out of 14 steelworks. Thus a basis for economic independence was assured. (See also SILESIA.)

Teschen.—On Nov. 5, 1918, close upon the final dissolution of the Habsburg monarchy, the Polish and Czech National council of Teschen Silesia concluded an agreement dividing the four districts of the province into two ethnographic entities. On Jan. 23, 1919, however, on orders from Prague, the Czech forces fell unexpectedly upon insignificant Polish forces in the area and occupied the greater part of the province. The government of Prague argued that Teschen was historically a Czech land and, moreover, that the new Czechoslovakia needed its coal.

The fighting was stopped by the Supreme council on Feb. 3, 1919. After a vain attempt to reach agreement by direct negotiation, the Supreme council decided on Sept. 27 that the dispute should be settled by plebiscite. On July 10, 1920, Poland, whose existence was menaced by the Soviet offensive, agreed a.t Spa that the Conference of Ambassadors should draw a final frontier. On July 28 less than half of Teschen Silesia was awarded to Poland (387 sq.mi. out of 858, with a population of 142,000 out of 435,-000). Czechoslovakia secured all coal mines. No Czechs were left on the Polish side of the new frontier, hut on the opposite side were 140,000 Poles. The decision relating to Orawa and Spisz was likewise disadvantageous to Poland, which kept 27 villages; the 44 villages awarded to Czechoslovakia had a Polish population of 45,000.

Eastern *Galicia.*—Of 4,743,000 inhabitants of Eastern Galicia (18,245 sq.mi.), Ukrainians formed 52.7%, Poles 39.3% and Jews 7.2% ; there was, however, a considerable Polish majority at Lwow (64% of a population of 300,000) and in some other towns. Enabled by the Austrian authorities to assume control of the whole area, the Ukrainians on Nov. 1, 1918, proclaimed at Lwow (Lviv) an independent republic of the Western Ukraine. Thereupon the local Polish population organized military formations, which succeeded in freeing the city by Nov. 22. In May 1919, after the fighting had continued for six months, the Polish army occupied the whole of the disputed province.

In March 1919 the Commission on Polish Affairs at the Paris peace conference considered the following alternatives regarding the future of Eastern Galicia: (a) a Polish mandate over the whole territory for 25 years, after which its fate was to be settled by plebiscite; (b) partition between Poland and a Ukrainian state. There were alternative demarcation lines in connection with these schemes: line A (see fig. 3), to run east of Przemysl, if the whole territory were to be entrusted to Poland under a mandate; and line B, which would leave Lwow and the Drohobycz oil fields to Poland in the event of the creation of a Ukrainian state. On June 25 the Supreme council accepted line A and authorized Poland to occupy the whole area; on Nov. 21, it approved the draft of an autonomous statute for the area with a 25-year mandate; on Dec. 22, 1919, giving satisfaction to Polish demands, the Supreme council rescinded its previous decision and allowed Poland to incorporate the whole area (see also GALICIA).

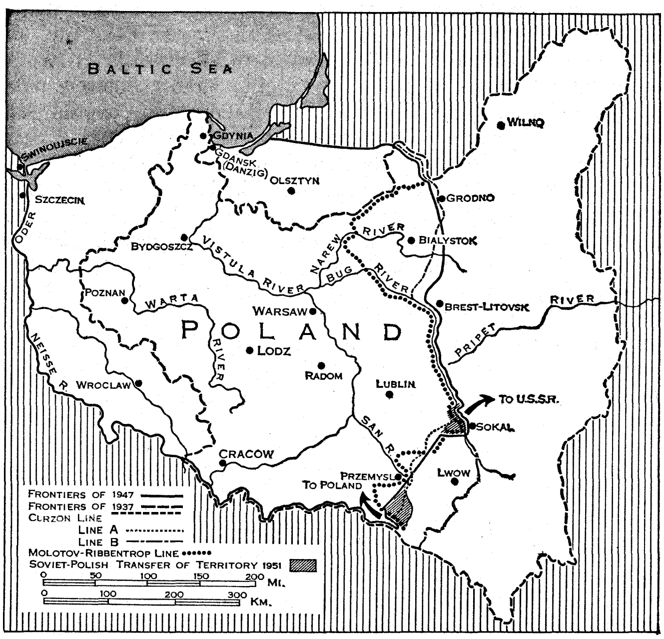


FIG. 3.—POLAND'S FRONTIERS, 1919-51 (SEE TEXT FOR EXPLANATION)

The Soviet Frontier.—Under the terms of the armistice of Nov. 11, 1918, the German armies had to evacuate western Russia and Poland. As the Germans withdrew, the Soviet army was advancing westward. In Nov. 1918 it was still on the Dnieper, but by Feb. 1919 had moved forward to the Bug. "Militant international Bolshevism urgently required contact with revolutionary Germany, and this could only be won over the body of Poland," says Sir Bernard Pares in his *History of Russia* (Alfred A. Knopf Inc. and Jonathan Cape Limited, publishers), thus succinctly indicating the origin of the Polish-Soviet war. The Soviet government hoped, of course, that the Polish workers and peasants would greet its armies as liberators, and was greatly dismayed when they did not. (*See* also RUSSO-POLISH CAMPAIGN.)

A counteroffensive launched by the Polish army under Pilsudski brought the Polish-Soviet front, by the end of 1919, along the river Berezina in Byelorussia, and in the Ukraine Novograd-Volynsk, Starokonstantinov and Bar were in Polish hands. Although in no haste to decide on Poland's eastern frontiers, the Supreme council, on Dec. 8, 1919, authorized Poland to organize a regular administration within a temporary line of demarcation "on the territories of the former Russian empire"; *i.e.,* not encroaching upon the formerly Austrian territory of Galicia. The declaration of Dec. 8 stated explicitly that the line fixed was a provisional minimum frontier, without 'prejudice to later terms which might be designed to fix the final eastern frontier of Poland.

On Jan. 28, 1920, Nicolai Lenin, Georghy Chicherin and Lev Trotsky handed a peace proposal to the Polish government suggesting the actual front as the armistice line. Pilsudski doubted the sincerity of this offer because he had information that the Soviet command was concentrating new divisions on the front and Trotsky himself, in a letter to three prominent French Communists, had written shortly before: "When we have finished with Denikin, we are going to attack the Poles" (Internationale *Com-*

muniste, Dec. 15, 1919). When, however, on March 27, 1920, the Polish government decided to open negotiations the Soviet government's rejection of Borisov, near the front, as a suggested meeting place confirmed Pilsudski's suspicion of a threatened Soviet offensive. On April 22, 1920, he accordingly signed a treaty of alliance with Simeon Petlyura, head of a Ukrainian government at Kamieniec Podolski (Kamenets-Podolsk), and three days later a Polish offensive started in the Ukraine. On May 7 the Poles occupied Kiev, but on June 8 the Soviet cavalry under Simeon (later Marshal) Budenny broke through the Polish line southwest of Kiev, and on July 7 Mikhail (later Marshal) Tukhachevsky attacked north of Borisov. The military situation of Poland became critical. On July 10 Wladyslaw Grabski, the premier, went to Spa where the Supreme council was assembled to ask for immediate help in the shape of war supplies. With the assent of representatives of France and Italy, Lloyd George undertook to act as mediator. He suggested an armistice along the line of Dec. 8, 1919; in Eastern Galicia the armies were to stand on the line reached on the date of the armistice. Grabski agreed, and on July 11 Lord Curzon, the British foreign secretary, suggested an armistice to Moscow and the Polish army's withdrawal to the line of Dec. 8, 1919, and in Eastern Galicia to the line A (see above), an obvious discrepancy with the agreement reached the previous day. Thus was born the "Curzon line."

Meanwhile the situation on the front gradually changed. By mid-August Pilsudski's counteroffensive brought a decisive victory. Poland was saved, but not only Poland. "By attacking Poland," said Lenin in Moscow on Oct. 8, 1920, "we are attacking also the Allies. By destroying the Polish army we are destroying the Versailles settlement." A Soviet-sponsored government for "liberated" Poland, headed by Feliks Dzierzynski, Julian Marchlewski and Feliks Kon, which had already established itself at Bialystok, had to flee back to Moscow. A Polish-Soviet peace treaty, concluded on March 18, 1921, at Riga, added to Poland an area of 51,762 sq.mi. east of the line of Dec. 8, 1919.

The Wilno Dispute.—During the advance of their armies westward, the Soviet government "ceded" Wilno (Vilnius) to Lithuania by a peace treaty signed on July 12, 1920. The city was evacuated by the Russians during their general retreat following the Polish victory and on Aug. 26 was entered by Lithuanian troops. The Poles appealed to the League of Nations and a partial armistice was signed at Suwalki on Oct. 7. Pilsudski was strongly inclined toward a federal solution of the dispute, with Wilno and its region providing an independent link between Poland and Lithuania. Gen. Lucjan Zeligowski accordingly occupied Wilno on Oct. 9 and set up a local government. Pilsudski's scheme, however, was incompatible with the prevailing temper of the Poles and Lithuanians. On Feb. 20, 1922, therefore, the democratically elected regional assembly of 106 members voted the incorporation of the whole province in the Polish republic; 96 members voted for the incorporation, 6 abstained and 4 were absent. It remained only to obtain the approval of the principal Allied Powers. The Soviet government had declared in the Riga treaty its disinterestedness in the Polish-Lithuanian dispute. The council of the League of Nations was no longer interested and on Feb. 3, 1923, adopted a final resolution fixing the Polish-Lithuanian line of demarcation. On March 15, 1923, the Conference of Ambassadors, requested by both the Polish and Lithuanian governments to use their right to fix the frontier, recognized the demarcation line of Feb. 3 as the final frontier between the two states. (See also VILNIUS.)

By the same decision the Conference of Ambassadors recognized as final the Polish-Soviet frontier fixed by the treaty of Riga. On April 5, 1923, both Polish-Soviet and Polish-Lithuanian frontiers were recognized by the government of the United States. The long series of territorial disputes which handicapped Poland's foreign policy and its internal reconstruction was definitely settled, both legally and in fact. The new Poland had a total area of 150,052 sq.mi. with an approximate population of 27,200,000. (K. SM.)

Constitution and Internal Affairs, to 1925.—Under the constitution of March 17, 1921, Poland was a republic. The legislative power was vested in a sejm and a senate, which were summoned, adjourned and dissolved, but not without their own consent, by the president. The sejm was composed of paid members elected for five years, upon a system of proportional representation. Suffrage was universal, all who enjoyed full civic rights and who were over 21 being qualified to vote; soldiers on active service were excluded. Citizens over 25 were eligible for election to the sejm; members of the civil service could not be elected for the district in which they held office. The minimum age for voting in senatorial elections was 30, while no one under 40 was eligible for election. Bills went to the senate after being passed by the sejm, and if no objection was raised within 30 days the bill became law. Taxes and customs duties could be established only by law and a supreme board of control superintended the management of state finance. The executive power was exercised by the president and a council of ministers who were responsible for his official actions. He was elected for seven years by the national assembly; that is, the sejm and senate acting together.

For purposes of administration Poland was divided into 16 palatinates, which again were subdivided into districts and urban and rural communes. The palatine or the wojewoda represented the executive government in the palatinate, the starosta in the district. Local legislation was to be exercised by *sejmiki* in the palatinates and by district councils in the districts. Economic autonomy was established by means of chambers of agriculture, commerce, industry, etc.; judicial control over the whole administration was vested in a supreme administrative tribunal.

Poland was reconstructed out of provinces of three empires in which widely different systems of law were operative. A codifying commission began to work out a body of uniform codes of law for the whole republic; in the meantime, Russian, German and Austrian codes remained in force in the different parts of the country. Gradually many domains of legal relations were covered by parliamentary legislation and, after 1926, by presidential decrees. A supreme court of justice in Warsaw was established at an early date, but it was not until 1928 that the country found itself in possession of a unified judicial organization and a uniform code of judicial procedure. Judges were nominated by the president and irremovable except by judicial decision. Justices of the peace were locally elected by the people. Over property in land, forests and mineral wealth, however, a certain amount of state control was extended by special provisions of the constitution. State protection was given to labour, and insurance against unemployment, illness and accident was guaranteed. The exercise of religion was free, as far as it was in accordance with the law. The Roman Catholic religion, the predominant denomination of the country, was placed by the constitution in a privileged position.

The constituent sejm had 13 political parties, as well as two independent members, and it was difficult to ensure a stable government. The resignation of Paderewski (Nov. 1919) was followed by a succession of quickly changing cabinets, always based on unstable coalitions—chiefly between the Peasant centre and either the Nationalist right or the mainly Socialist left. A coalition government of national defense under the peasant leader Wincenty Witos, with Ignacy Daszynski, the Socialist leader, as deputy premier, succeeded at a critical moment in rousing the country to resist the Bolshevik invasion.

Toward the end of 1922 the prolonged legislative period of the constituent assembly came to an end. An electoral law was passed on July 28, and in November elections for the upper and lower house of the first regular sejm were held. They ended by distributing power in the chamber between the Nationalists (161), the Peasant groups (124) and the Party of Labour (18); the Socialists obtained only 41 seats, but the national minorities, by organizing a bloc for electioneering purposes. got 81 (of whom 35 were Jews) and accordingly, in spite of the large abstention of the Ukrainian element from the elections, became an important and occasionally a decisive factor in the parliamentary system.

The first business of the two houses of the new parliament was jointly to elect a president of the republic. Marshal Pilsudski refused to stand. The parties of the left, supported by the national minorities and the Witos Peasant party, secured the election of Gabriel Narutowicz, a friend of Pilsudski, who had acted as minister of foreign affairs in several cabinets. Polish nationalism was infuriated by the election of a president through the votes of the national minorities, and on Dec. 16 a fanatic assassinated Narutowicz. The new president was Stanislaw Wojciechowski, a former Socialist and father of the Polish co-operative movement. Gen. Wladyslaw Sikorski became premier.

Poland's position in the early part of 1923 was still very unsettled. The Polish mark, a provisional currency, was affected by the collapse of the German mark. A government formed in the spring by Witos, on the basis of an alliance between the Peasant party and the National party, had to struggle against the resolute opposition of the left and the national minorities; the government proved unable to cope with the continued, disastrous fall of the mark and there was serious unrest in the country, culminating in riots at Cracow on Nov. 6; the government was obliged to resign on Dec. 11. It was followed by a nonparty one under Wladyslaw Grabski, who, as prime minister and minister of finance, made financial reform his principal task. The political parties now at last agreed to subordinate all other problems to those of financial reconstruction. On Jan. 3, 1924, Grabski's government was granted emergency powers for the purpose. Fulfilling partly the recommendations of a British financial adviser, Edward Hilton Young (later Lord Kennet), Grabski strenuously reorganized the financial system of the country. A Bank of Poland was once more created on a basis of private subscription. The budget was balanced by Draconian reductions in expenditure, the printing of paper money stopped, the currency became stabilized at the rate of exchange which it had reached (1,800,000 marks to the gold franc), and finally a new currency unit, the zloty, was introduced and declared equal to the gold franc. The drastic manner in which this financial reform was accomplished inevitably brought about its revenge. The too-high level at which the value of the new currency had been fixed caused a period of heavy economic depression.

On Feb. 10. 1925, a concordat with the Holy See was signed. The Catholic Church was granted absolute freedom of execution of its authority and jurisdiction in Poland, the assistance and support of the state being assured it in this respect. The state's interests in connection with nominations for the higher ecclesiastical posts were adequately protected. In religious education, the competencies of church and state were exactly defined. The division of Poland into ecclesiastical provinces was carried out in such a way that no portion of Polish territory remained subject to the jurisdiction of a bishop residing outside the borders of the state. An autocephalous Orthodox Church also established in Poland received the blessing of the synod and of the ecumenical patriarchate in Constantinople on Nov. 11, 1924. The Protestant Church in Poland was likewise placed beyond reach of political influences from abroad.

Alliances and Security.—In the first years of Polish independence, France's support was Poland's greatest asset. At the end of 1920 the French premier, Alexandre Millerand, invited Pilsudski to visit Paris in his capacity of head of state. As a result of discussions during this visit a political agreement was signed in Paris on Feb. 19, 1921, by Aristide Briand and Prince Eustachy Sapieha, ministers of foreign affairs. It provided that the two governments should take concerted measures for the defense of their territory and the protection of their legitimate interests if either or both of the contracting states. in spite of sincere peaceful intentions, should be attacked without provocation. On March 3, 1921, a treaty of alliance with Rumania was signed at Bucharest by Sapieha and Take Jonescu. On March 26, 1926, the Polish-Rumanian alliance was renewed. It stipulated that the two countries should pledge themselves to defend their territorial integrity and political independence against any outside aggression.

A definite alliance between Poland and the Baltic states was attempted on March 17, 1922, when a political treaty was signed in Warsaw by the foreign ministers of Poland, Finland, Estonia and Latvia. It stipulated that in the event of aggression against one of the contracting parties all four governments should cooperate on measures to be taken. On May 12, however, the Finnish parliament refused to ratify the treaty.

By the end of 1921 Polish-Czechoslovakian relations became cordial enough. and Konstanty Skirmunt, the foreign minister, paid an official visit to Prague. On Nov. 6 he signed with Eduard Benes a political convention by which the two governments agreed to act in concert for the application of the treaties which they had signed in common. There was some talk at that time of closer collaboration between Poland and the Little Entente, but the latter's aim, directed against Hungarian revisionism, was from the Polish point of view too limited. In June 1923 Marian Seyda, the Polish foreign minister, suggested the transformation of the Little Entente into a quadruple alliance, providing all the members with a collective guarantee of security, but this idea met with a cool reception in Prague. Count Alexander Skrzynski, Seyda's successor at the foreign office, was less ambitious. Benes paid a visit to Warsaw in April 1925 and a Polish-Czechoslovakian treaty of conciliation and arbitration was concluded.

Great Britain's rejection of the so-called Geneva protocol and of the principle of collective security alarmed Poland, as did the German proposals to France, which treated separately the problems of Germany's western and eastern frontiers. The Polish thesis was that European security was indivisible. A not too satisfactory compromise formula was found. The treaties initialled at Locarno (*q.v.*) on Oct. 16, 1925, and signed in London on Dec. 1 included two agreements concerning Poland: a Polish-German arbitration treaty and a Franco-Polish treaty of guarantee. The former provided for the peaceful settlement of disputes; in the latter France guaranteed the Polish frontier with Germany. Polish opinion was not easily reconciled to the idea of the Locarno treaties. They were accepted, but for the first time the Poles felt that they were abandoned by France.

The Second Coalition Government.—Soon after the breakdown of his financial policy Grabski resigned. He remained in power for 23 months, a record in Polish parliamentary history. On Nov. 20, 1925, Skrzynski formed a coalition cabinet, the second of this kind since the restoration of the state. This time the frontiers were secure, but the country was again in danger. The treasury was almost empty, the shortage of private capital was acute, unemployment was rife and the zloty continued to fall. Another storm centre of embittered dispute was the question of reinstating Marshal Pilsudski In the position of commander in chief of the army. He had resigned the office of chief of staff in May 1923 when a government of the Nationalist-Peasant coalition was formed.

In foreign affairs the Skrzynski administration was under the shadow of a growing feeling of international insecurity for Poland. When, a month after the ratification of the Locarno agreements, the League of Nations proceeded to elect Germany a permanent member of the council, Skrzynski claimed a permanent seat for Poland as well. It was not till after a good deal of dramatic friction in the League that a solution was found, Germany getting a permanent and Poland a so-called quasi-permanent seat in the council.

Pilsudski's Rule, **1926–35.**—Meanwhile internal dissensions intensified while the conclusion of a new Soviet-German treaty in Berlin (March 1926) increased the general nervousness. Pilsudski, in his retreat at Sulejowek, was looked up to by large masses of the people as the only man who could secure a better future for the country. His adherents and opponents formed two opposing camps in the army. In parliament, the right, since the days of his provisional presidency, had used every legislative device to limit his power and influence. Now, in the dispute over his commandership, the right desired to frame the Army Organization bill in such a way as to bring the army under the direct control of parliament, while Pilsudski insisted on complete independence of the commander in chief.

Matters came to a crisis when, because of the dissensions over the budget, the Socialist ministers left the cabinet, and Skrzynski himself resigned in consequence. After a prolonged period of negotiations Witos succeeded in forming a ministry. Rumours were current that he meant to rely exclusively upon the support of the right and to settle the question of the commandership in the sense demanded by the Nationalists. Thereupon, on May 12, Pilsudski suddenly entered Warsaw at the head of troops. The government proclaimed him a rebel. The concentration of government troops in Warsaw, however, was hampered by a strong strike movement in the country, chiefly among the railwaymen; and after two days of heavy fighting in the streets of Warsaw, Pilsudski was master of the capital. The government resigned and the president of the republic abdicated. Maciej Rataj, the speaker of the sejm, became acting head of the state, in accordance with the terms of the constitution. A provisional cabinet under Kazimierz Bartel was appointed, pending the election of a new president. When the two chambers met on May 31 for the presidential election, there resulted a majority of 292 to 193 in favour of Pilsudski. He, however, refused the office in favour of his nominee, Ignacy Moscicki, a scientist not formerly engaged in politics. who was duly elected on June 1 by 281 votes to 200. Pilsudski himself became minister of war and a few months later officially assumed premiership in the cabinet.

Pilsudski met with little opposition when on Aug. 2, 1926, he proceeded to reform the constitution in the sense of limiting the powers of parliament with respect to the budget: if within a period of five months the budget was not passed, the finance bill acquired the force of law. Another provision gave the president the right to dissolve the parliament on a unanimous proposal of the government, the new elections taking place within 90 days.

A year and a half after Marshal Pilsudski's coup d'état, a new parliamentary election became due in Poland. He had left the outward structure of the parliamentary system intact. The practical impotence, however, to which his rule reduced the sometime all-powerful parliamentary parties had a profound effect on them. The largest groups began to disintegrate, and when the elections approached as many as 3j different factions appeared in the field with lists of candidates of their own. This "pulverization of the party system" was the result of splits in the larger groups on the one issue that remained dominant under the circumstances; viz., the question: for Pilsudski or against him. In the midst of this reshuffling of all former groupings, the government created a nonparty bloc of its supporters of various shades of opinion. From the elections held on March 4 and 11, 1928, only the Socialists emerged with a substantial increase in the number of their seats (64 as against 41); the other parties which had once been strong factors—the Peasant, the Party of Labour, the Christian Democratic and the Nationalist—dwindled from 230 to 150 seats. The government bloc obtained 135 seats. (R. Dy.; X.)

The opposition, however, remained strong, and a normal cooperation of the parliament with Pilsudski proved impossible. In the autumn of 1930 the growing tension resulted in the arrest of some of the party leaders, who were imprisoned at Brzesc and treated there very badly. New elections held on Nov. 16 and 23 gave the government bloc an absolute majority of 247 seats in a sejm of 444, the National Democrats winning 63 seats, the Centre-Left coalition 92 and the national minorities 33.

The Constitution of 1935.—After his electoral success Pilsudski said that the principal task of the new parliament was the revision of the constitution. A draft was introduced to the sejm on Dec. 20, 1933; it was passed by it on Jan. 26. 1934, and by the senate on Jan. 18, 1935. On March 23, 1935, the new constitution was definitely adopted by the sejm by 260 votes to 139; it became law on April 23.

It was based on the following principles: the state being considered as the "common good" of all the citizens, the executive became considerably strengthened at the expense of the legislature; the president appointed and dismissed the prime minister and the commander of the army, could dissolve the sejm and was responsible to none; the six "organs of the state"—government, sejm, senate, army, courts of justice and court of supervision—were accordingly under the president's control; the powers of the legislature were strictly limited and the number of its members reduced to 208 in the lower and 96 in the upper house, one-third of the latter being nominated by the president.

Foreign Relations.--During the first six years of Pilsudski's regime, August Zaleski being minister of foreign affairs, Poland's policy was chiefly based upon the League of Nations and the close alliance with France. Poland, which had proposed to the League's assembly of 1927 a resolution outlawing wars of aggression, not only signed the Kellogg pact of the next year but even anticipated its realization by a special agreement with Soviet Russia in 1929. On July 25, 1932, that protocol was developed into a pact of nonaggression. At the disarmament conference of the same year the Polish delegation had played an active part, submitting an elaborate plan of "moral disarmament"; but it became obvious that the idea of collective security had failed, and Poland sought better guarantees in bilateral agreements with its neighbours.

After 1932 this method was developed by the new minister of foreign affairs, Col. Jozef Beck, formerly Pilsudski's chef de cabinet, and found its strongest expression in another ten-year nonaggression pact, concluded on Jan. 26, 1934, with Germany. There was of course a reservation that the new treaty was not to affect Poland's previous engagements, particularly its alliance with France. Nevertheless, it seemed to involve a change in Poland's general attitude. Seeing that nobody in Europe was prepared to fight the new Adolf Hitler regime, Pilsudski found it necessary to accept a direct understanding with Poland's western neighbour also, holding the balance between the Soviet Union and Germany.

Moscicki and **Smigly-Rydz.**—After Pilsudski's death on May 12, 1935, the form of government which he had established continued without much change. The voting regulations, as applied at the elections of Sept. 8 and 15, 1935, without having been defined in the new constitution itself, again raised much discontent; but attempts were started to come to some co-operation with various groups of the opposition. The government bloc was dissolved and replaced by a Camp of National Unity. Both President Moscicki, who had been re-elected in 1933 for another seven-year period, and Marshal Edward Smigly-Rydz, Pilsudski's successor as commander of the army (who was styled "the second person" in the republic), exercised their authority with moderation and in a conciliatory spirit. Such an appeal to internal unity was indeed indispensable in face of the increasing danger of the international situation.

That danger resulted from the policy adopted by Germany. After the annexation of Austria and the destruction of Czechoslovakia, it was clear that Hitler wanted to isolate the eastern European states so as to be able to attack them one by one. Soon after Munich, when Poland had seized the opportunity to claim the contested Teschen territory (see above), there began a new tension with Germany. Yet on Jan. 30, 1939, Hitler reaffirmed the importance of the German-Polish nonaggression pact as a contribution to the peace of Europe; but he had already decided to annex the Free City of Danzig, and on March 27 he officially requested the Polish government to accept that solution as well as the construction of an extraterritorial motor road through the Polish province of Pomorze. Touched in its vital interest and realizing that it was a first challenge against its independence, Poland refused, making counterproposals which were never taken into serious consideration. As soon as Poland had exchanged with Great Britain reciprocal guarantees of independence and integrity, Hitler took it as a pretext to denounce, in his speech of April 28, the nonaggression pact of 1934.

During the next four months he tried to provoke Poland by various incidents in Danzig and started a propaganda campaign against an alleged ill treatment of the German minorities in Poland. But it was not until Germany had concluded, on Aug. 23, a new partition treaty with the U.S.S.R. that he finally decided to attack Poland. Two days later a close alliance was signed between Poland and Great Britain which made it absolutely clear that Great Britain, as well as France, would support its ally in case of war; but in spite of a patient conciliatory effort made by British diplomacy and proposals of a peaceful settlement put forward by various powers and accepted by Poland, Germany invaded Poland on Sept. 1, 1939.

WORLD WAR II

Poland, which had postponed the general mobilization to the last moment, was unable to stand against the overwhelming German forces, the long open frontier stretching from East Prussia to Slovakia being already occupied by German troops; nevertheless, it made a courageous resistance in the centre of the country until Sept. 17, when the Soviet army invaded its territory from the east under the pretext that the Polish state was no more in existence. Even then in various regions desperate fighting was continued, and Warsaw, although severely bombed, like so many other open places, defended itself heroically until Sept. 27. The next day a second German-Russian treaty was signed in Moscow by Joachim von Ribbentrop and Vyacheslav Molotov redistributing the spoils; the eastern provinces, including purely Polish territories, were incorporated in the Soviet republics of Byelorussia and the Ukraine; the western part was left within the German sphere of influence.

Before leaving Polish territory, President Moscicki resigned and designated Wladyslaw Raczkiewicz as his successor. The new president appointed a new government, the former having been interned in Rumania. General Sikorski became prime minister, Zaleski minister of foreign affairs, and both president and government were established at Angers, Fr. The Polish army was also reconstituted in France to fight with the Allies, while some Polish warships, having escaped, joined the British navy.

Sikorski also became the commander in chief of the reorganized Polish army. This was possible because part of the army had passed into Hungary and Rumania and succeeded in assembling in France, where its ranks were swelled by mobilization among the prewar Polish emigrants in that country. The Polish army, numbering nearly 100,000, was ready by the spring of 1940. A Polish brigade fought in the Norwegian expedition of the Allies, especially in the battle of Narvik, and the Poles joined also in the defense of France.

The collapse of France was likewise a heavy blow for Poland. In spite of fresh losses and the capitulation of one of the Allies, the Polish army did not even then dream of ceasing to fight. About 15,000 who had heroically protected the retreat of one of the French armies had to cross into Switzerland, where they were interned. A part of the Polish army was transported to Great Britain, where, at the end of June 1940, the Polish government together with the president transferred itself. The Polish airmen began increasingly to distinguish themselves, acting with the royal air force, and simultaneously Polish divisions, dispersed through the world as of old in the Napoleonic wars, appeared in Palestine and on the Egyptian-Libyan battlefield. (See also **World War II**.) (O. Ha.; X.)

Germany divided the conquered Polish land into two zones. The provinces that had been ruled by Prussia from the Vienna settlement to 1918 and also part of central Poland with Lodz (renamed Litzmannstadt) and Plock were incorporated into the reich on Oct. 19, 1939. All the incorporated lands were destined for complete germanization. The remaining territory between the new German frontier and the Molotov-Ribbentrop line was organized as a General Gouvernement. It was divided into four districts: Warsaw, Lublin, Radom and Cracow. In Aug. 1941, shortly after the German attack on the Soviet Union, the province of Bialystok was incorporated into Germany, while Eastern Galicia, with Lwow, was added as the fifth district to the General *Gouvernement*. This territory was to be used mainly as a reserve pool of labour. All Polish elements were submerged, and it became for a time, as Hans Frank, the governor general, described it, "an intellectual desert."

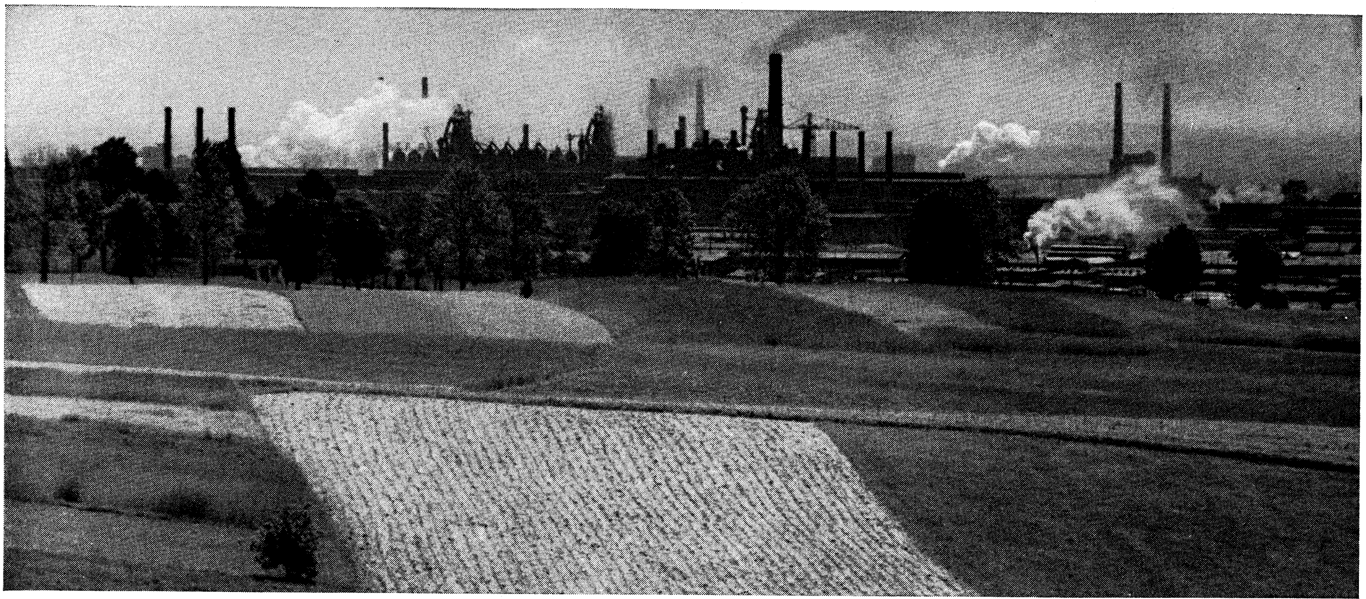
Such a policy was countered by immediate reactions in the community. The professors of Cracow university, who were invited to co-operate in the administration of the General Gouvernement, preferred internment and death to assisting the Germans in any way. Polish property was confiscated, and continual deportations of workers into the reich enabled the Germans to solve their growing problem of manpower. Concentration camps were established, and Oswiecim (Auschwitz) became especially notorious for the deliberate and systematic torture and murder of its inmates. Unknown numbers of Poles perished there and it became the grave of a great part of the 3,000,000 Polish Jews. In opposition to this terror, the Poles organized a powerful underground movement which continued the cultural and social life of the people in secret schools, social services and an active press. A secret home army grew to considerable strength and carried out operations against German communications and institutions. The administration of the underground organization took its orders from the Polish government in London.

Far more complicated was the position of the Poles in the eastern areas occupied by the Soviet Union from Sept. 17, 1939, to late June 1941. There the problem was Ukrainian as well as Polish. All political leaders, Polish and Ukrainian, together with the bulk of the educated classes were deported, but less open violence and more subtlety were used than in the German zone and the annexation to the Soviet Union was effected only after a so-called plebiscite which was claimed to have justified the act. The growing terror under the Soviet police was checked by the German invasion, which made the position of Poles in the U.S.S.R. easier but offered a difficult problem to the Polish government in London. The great mass of the Poles abroad continued to regard the Italians, who had helped many of them to escape, as their friends, and to mistrust Soviet intentions toward their country. But political and military reasons led Sikorski to make an agreement with the U.S.S.R. The terms of this agreement, signed in London on July 30, 1941, ended the state of war between the two countries and raised hopes of an ultimate restoration of Poland in its former boundaries; but it was more immediately important in enabling Gen. Wladyslaw Anders to organize a Polish army in the Soviet Union. Sikorski visited Moscow and on Dec. 4 signed with Joseph Stalin a Polish-Soviet declaration of mutual assistance and collaboration. Stalin agreed that the Polish army in the U.S.S.R., originally projected as two divisions, should be increased to a strength of six divisions. About 75,000 of the men already recruited by Anders were allowed to leave for the middle east in March and Aug. 1942. Unfortunately, as the danger of defeat by the Germans was averted, the Soviet authorities began to adopt a more aggressive attitude to Polish claims.

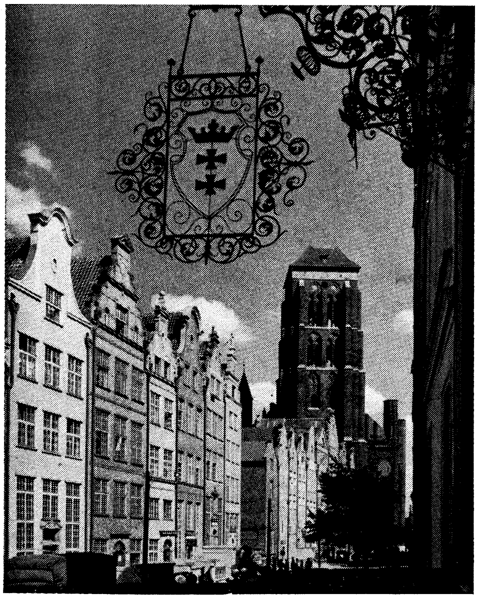
It was possible to form a Polish army in the U.S.S.R. since there were more than 200,000 Polish prisoners of war taken by the Russians in Sept. 1939 and hundreds of thousands of Polish nationals deported. Securing a corps of officers for the new army offered a more serious problem. In Oct. 1939 about 14,300 Polish officers were segregated by the Soviet authorities into three prison camps at Ostashkov, Kozelsk and Starobelsk. The Polish authorities in the Soviet Union and the Polish underground in the homeland failed to find any trace of the missing officers after April 1940, although it was suggested by the Soviet government that they had been exchanged with their German allies in 1940. When in April 1943 mass graves were discovered in Katyn wood near Smolensk, containing the bodies of the men who had been imprisoned in the Kozelsk camp, the Germans accused the Russians of having murdered them. The Soviet government refused an investigation by an International Red Cross commission suggested by Sikorski and, on April 25, 1943, broke off diplomatic relations with the Polish government.

Sikorski was killed in an aeroplane accident at Gibraltar on July 4, 1943, and was succeeded as prime minister by Stanislaw Mikolajczyk, the leader of the Peasant party, and as commander in chief by Gen. Kazimierz Sosnkowski. As their military position improved and they began to reoccupy Polish territory, the Soviet authorities' new policy became more anti-Polish. They revived their claim to the eastern provinces and began to protect a group of Poles who were prepared to accept this claim. This group was joined by a number of Polish Communists including Boleslaw Bierut and came to be known as the "Lublin committee" and then to be a provisional Polish government. All attempts by the London government to co-operate with or oppose them came to nothing, and the Soviet authorities started a great campaign of propaganda to discredit the legal Polish government in London.

Another move was to smuggle Communists into German-occupied Poland ostensibly to help but really to displace the leaders of the underground movement. These leaders continued to carry on their heroic struggle in co-operation with the government in London. As at the end of July 1944 the Soviet army



Rapidly disappearing farmlands overshadowed by the smokestacks of Nowa Huta, an industrial suburb of Crakow developed as Part of the post-World War II reconstruction program. Nowa Huta is the site of the Lenin steel mills



An old street of Gdansk, formerly the free city of Danzig until reabsorbed into Poland after World War II. In the background is the tower of the 15th-century church of the Holy Virgin (formerly St. Mary's, protestant)

Royal Castle square, Warsaw. In the centre is the column of King Sigismund III Vasa. It was first erected in 1643; re-erected in 1949. At left is St. Anne's church, 1454; at right (background) is the Palace of Culture and Science, a gift from the U.S.S.R. in 1955

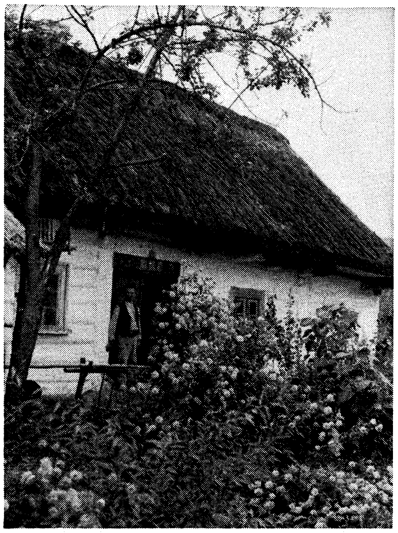
Freighters and harbour craft at Gdynia, Baltic port and naval base which, with Gdansk, is the principal shipping centre of Poland

The old section of Warsaw. Structure at left is a barbican, a protection to the gateway over the moat into the old wailed city. Section of the wall may be seen at centre

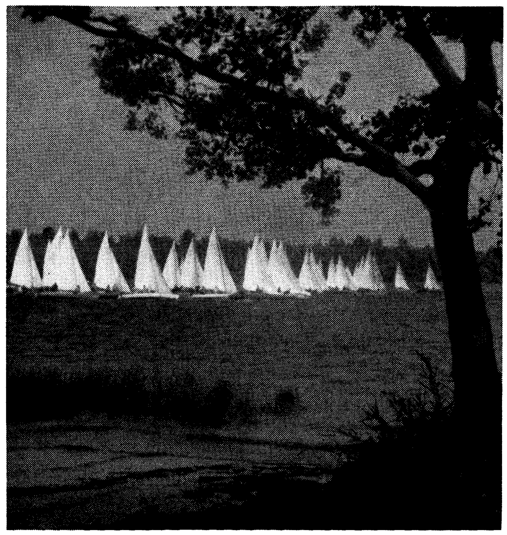
POLISH CITIES AND INDUSTRY

PHOTOGRAPHS, (TOP) HENRYK HERMANOWICZ, KRAKOW, (CENTRE LEFT, CENTRE RIGHT) EDMUND KUPIECKI, WARSAW, (BOTTOM LEFT) C.A.F., WARSAW, (BOTTOM SIGHT) EASTFOTO

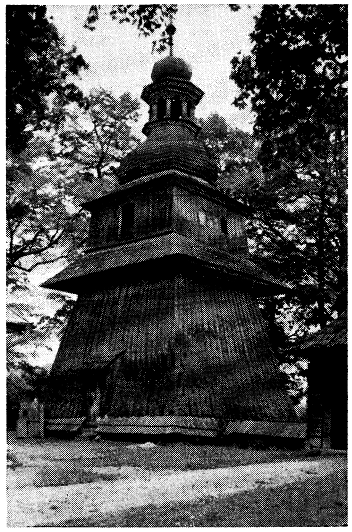
POLAND



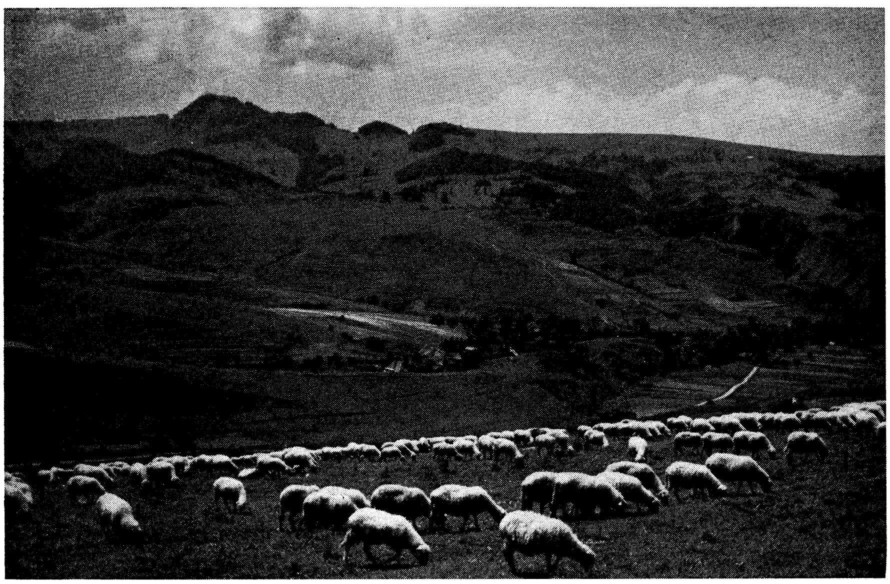
Thatch-roofed farmhouse near Jaslo, south-east Poland, in the Carpathian mountains



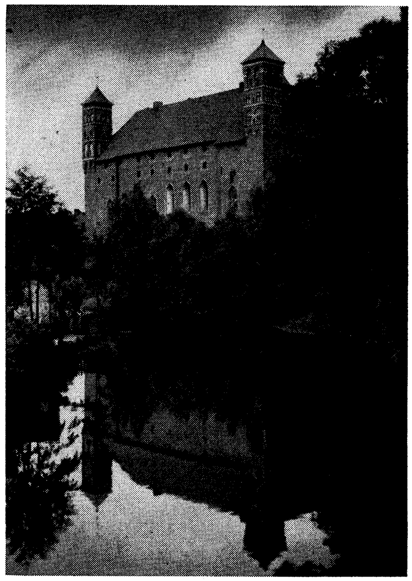
Sailboats on one of the Masurian lakes in northeast Poland (formerly East Prussia)



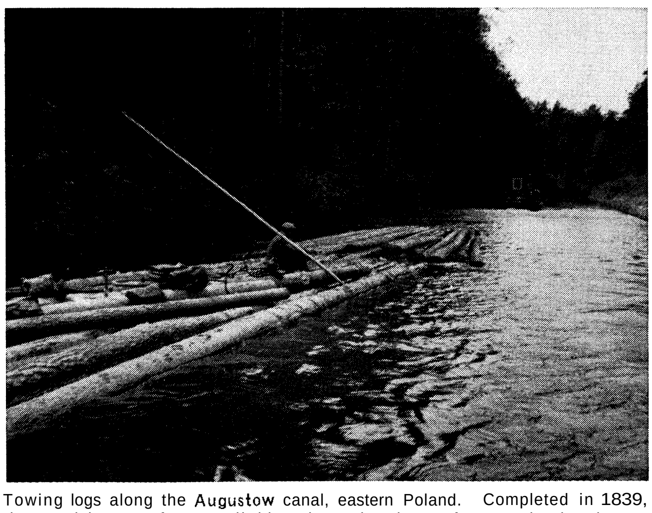
An old belfry in the village of Stykowice, near Zakopane and the Polish-Czechoslovakian border



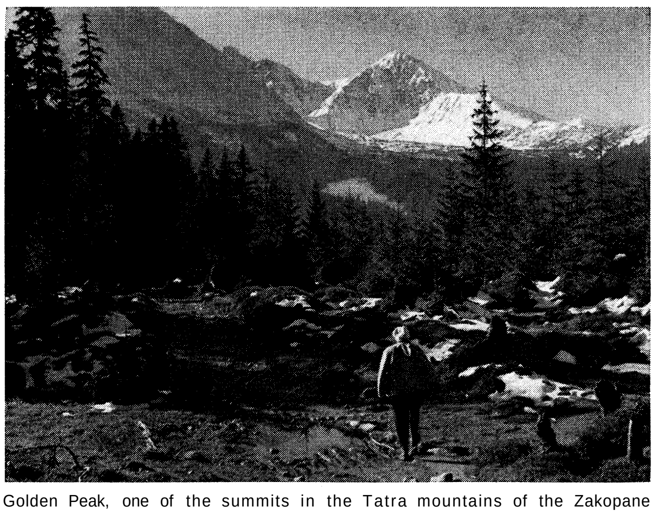
Sheep grazing on the lower slopes of the Pieniny mountains, part of the Carpathian chain



Castle founded by knights of the Teutonic order in 1240 at Lidzbark Warminski, formerly Heilsberg in East Prussia



Towing logs along the Augustow canal, eastern Poland. Completed in 1839, the canal is part of system linking the major rivers of east Poland and western U.S.S.R.



Golden Peak, one of the summits in the Tatra mountains of the Zakopane region at the Czechoslovakian border. The area is popular for mountaineering and winter sports

THE POLISH COUNTRYSIDE

PHOTOGRAPHS, (TOP LEFT TOP RIGHT, CENTRE LEFT) C.A.F., WARSAW, (TOP CENTRE) HENRYK HERMANOWICZ KRAKOW, (CENTRE RIGHT, BOTTOM LEFT, BOTTOM RIGHT) EASTFOTO

reached the Vistula and neared Warsaw the underground was requested by broadcasts from Moscow to support it, and Gen. Tadeusz Bor-Komorowski, commander of the home army. under orders from the military headquarters in London, started an open struggle in Warsaw on Aug. 1, 1944. Despite the efforts of the western Allies to send arms and supplies by air, the sacrifice was made useless by the inactivity of the Soviet armies. which refused to send any support. The struggle continued for 63 days, after which further resistance was impossible.

Even before this tragic event the Soviet generals, as they advanced into Poland, had been disarming and deporting members of the home army which was helping them. Now that the main army of the underground had perished, the task of the Soviet political leaders was made easier. While the Polish forces in the west continued to fight the battle with their Allies on land, sea and in the air, especially in the great advance through Italy, and, after June 6, 1944, in northern France, Belgium and the Netherlands, the Russians did all they could to discredit the Poles fighting against the common enemy in Poland and the government in London to which they gave their allegiance.

The fate of Poland was now taken over by the Great Powers, which at the Yalta conference in Feb. 1945 tried to settle the difficult questions which had arisen. As a result, the Soviet Union was able to obtain recognition of the Lublin committee. Both the Polish government and the underground movement sank out of sight, and when World War II came to an end a Polish "people's republic" was established. (A. B. Bo.)

THE PEOPLE'S REPUBLIC

Pres. Franklin D. Roosevelt, Winston Churchill and Marshal Stalin decided at Yalta, on Feb. 11, 1945, that a "Polish provisional government of national unity" should be created; *i.e.,* that the Soviet-sponsored government formed at Lublin on Dec. 31, 1944, should be reorganized to include "other Polish democratic leaders from Poland and from abroad." The three powers jointly engaged that free and unfettered elections on the basis of universal suffrage and secret ballot should be held as soon as possible. After four months of diplomatic discussion among Moscow, London and Washington concerning the exact interpretation of the Yalta decision, a Polish round-table conference met in Moscow on June 17 to discuss the formation of a Polish government. Among leaders from within Poland and from abroad attending the conference was Mikolajczyk (until Nov. 24, 1944 premier of the Polish government in London). On June 28, 1945, the composition of the government was announced. It showed that the Soviet interpretation of the Yalta declaration had prevailed: of the 21 members of the cabinet only 5 were newcomers, the most important being Mikolajczyk, who became second deputy premier; 16 ministers were former members of the Lublin government, including Edward Osobka-Morawski, leader of a split Socialist group, who remained premier. Bierut, who from July 22, 1944, had been chairman of the presidium of the so-called Polish national home council, became provisional president of the republic. Without waiting for the formation of the provisional government of "national unity," Stalin and Osobka-Morawski on April 21, 1945, signed in Moscow a Soviet-Polish treaty of friendship, mutual assistance and postwar collaboration. On July 5 the British and the U.S. governments recognized the new Warsaw government and withdrew recognition from the London government composed of representatives of the National, Christian Democratic and Socialist parties and presided over by Tomasz Arciszewski (1877–1955), a senior Socialist leader who until July 1944 was the chairman of the underground Council of National Unity in Warsaw.

The New Frontiers. — On Aug. 16, 1945, Molotov and Osobka-Morawski signed in Moscow a treaty demarcating the Soviet-Polish frontier. This demarcation. more or less identical with the Curzon line, restored to Poland the province of Bialystok in the north and a smaller area in the south including Przemysl, which the Molotov-Ribbentrop line had assigned to the U.S.S.R. In a small exchange of territory on Feb. 15, 1951, the U.S.S.R. acquired a strip of land of 185 sq.mi. south of Hrubieszow, while a similar area south of Przemysl, including the town of Ustrzyki Dolne, was returned to Poland.

On Aug. 2, 1945, at Potsdam, Pres. Harry S. Truman, Clement Attlee and Marshal Stalin published a statement establishing a new de facto western frontier of Poland along the Oder and Neisse rivers. The former German territories east of this line, including the free city of Danzig but excluding the portion of East Prussia incorporated in the U.S.S.R., were placed under Polish administration. Poland was also authorized to undertake the transfer to Germany of the German populations east of the Oder-Neisse line. On July 6, 1950, an agreement recognizing the Oder-Neisse line as the permanent frontier was signed at Zgorzelec (Görlitz) by Otto Grotewohl and Cyrankiewicz, premiers of the German Democratic Republic and Poland. The Polish-Czechoslovakian frontier in its prewar half remained as fixed on July 28. 1920; *i.e.,* the disputed territories of Cieszyn or Tesin (349 sq.mi.) and of Orawa and Spisz (70 sq.mi.), which had been seized by Poland in Oct. 1938, were left to Czechoslovakia. As compared with its territory before World War II, Poland was shifted westward considerably. In the east it lost 69,290 sq.mi. and in the west it gained 39,597 sq.mi., its new area being 120,359 sq.mi.

Home Affairs.—Only on Nov. 13, 1946, under pressure of the British and U.S. governments, Bierut signed a decree fixing Jan. 19, 1947 as the date for the Polish elections. The official figures stated that 11,413,618 voted out of 12,701,056 qualified electors: 9,003,682 (89.8%) voted for the Communist-controlled Democratic bloc which secured 382 seats out of 444. It was officially stated in both the United States and Great Britain that the elections were neither free nor fair. The new *sejm* on Feb. 5 elected Bierut president, and two days later he appointed a new government headed by Jozef Cyrankiewicz, a Socialist.

A striking political development took place within the ranks of the Polish Workers' (Communist) party on Sept. 3, 1948, when it was announced that Wladyslaw Gomulka (1905–), its secretary-general and first deputy premier, had been accused of "rightist and nationalist deviation" and had been obliged to recant and to resign from both offices. Although the leadership of the split Polish Socialist party was already purged, there was still resistance against a proposed merger with the Communist party which, for the former, was equal to dissolution. Nevertheless, the merger congress assembled in Warsaw from Dec. 15 to Dec. 22, 1948. The new party was called the Polish United Workers' party (*Polska* Zjednoczona *Partia* Robotnicza or P.Z.P.R.), and Bierut became its chairman. Mikolajczyk, accused on Oct. 12, 1947, of being "an ally of foreign imperialists," escaped and arrived in London on Nov. 3, 1947. On Nov. 30, 1949, the rump of the Polish Peasant party and the two Communist-controlled peasant groups were iused under the name of United Peasant party. In July 1950 the (Christian Democratic) Party of Labour was absorbed into the Democratic party.

The new constitution passed unanimously by the sejm on July 22, 1952, was modelled on the Soviet constitution of 1936. (See below.) The 425 members of the new sejm were elected on Oct. 26, 1952, in Soviet fashion, *i.e.,* there was only one list of official candidates in each of 67 constituencies and 99.8% of valid votes were allegedly cast for them. On Nov. 20, 1952, as the sejm elected a new council of state and Aleksander Zawadzki as chairman, Bierut formed a new government.

The 2nd congress of the P.Z.P.R. was held in Warsaw in March 1954. The party membership at that time was 1,296,938, of whom 413,449 were new members accepted after April 1949, when the membership was 1,368,759, in four years, therefore, 485,270 members had either died or been expelled. The congress adopted a new party statute which defined the P.Z.P.R. as the "organized shock detachment of the Polish working class—the vanguard of the Polish nation." It elected a central committee of 77 members and 50 candidates which named a Politburo of 13 members and 2 candidates. Bierut, the leading member of the Politburo, was appointed first secretary. Following the example of "collective leadership" adopted in Moscow after Stalin's death, he resigned the premiership on March 19. 1954 and was succeeded by Cyrankiewicz.

Return of Gomulka.—Bierut died in Moscow on March 12, 1956, at the age of 64. His death left the party leadership deeply divided. On March 20 the party's plenary session of the central committee unanimously elected Edward Ochab as its first secretary. Though he was believed to be the candidate of N. S. Khrushchev, first secretary of the Communist Party of the Soviet Union, Ochab nevertheless began to prepare for the return of Gomulka to the party leadership. (Arrested in July 1951, Gomulka was released in Dec. 1954, but this became publicly known only after Bierut's death.) On May 6 it was announced that Jakub Berman, a member of the Politburo and deputy premier, had resigned from both posts. With Bierut dead and Berman dismissed, of the original Communist triumvirate only Hilary Minc remained in the Politburo, and the influence of Cyrankiewicz, the premier, was growing and his partnership with Ochab was becoming closer.

On June 28, 1956, an event of historic significance broke down the pretense of popular support for the Communist regime. Industrial workers of Poznan staged a general strike and a procession of 50,000 demanded bread, freedom, free elections and the departure of the Russians. Riots followed, a security police officer was lynched and order was restored the following day only by the army's use of tanks. According to official reports, 53 people were killed and zoo wounded.

The July plenary session of the central committee became a contest during which three trends were apparent. The Stalinists recommended strict censorship of the press and the curtailment of "democratization." They were opposed by the younger generation of Communist leaders who wanted democratization to continue. Between these two groups there were the Realists, led by Cyrankiewicz and Ochab. They, too. were supporters of change, but desired to achieve it more slowly. But the only man who could restore party unity and authority and count on wider support was Gomulka. All three groups desired his return to the Politburo although it was clear that the Stalinists wanted him only as a figurehead. On Aug. 5 Gomulka was officially rehabilitated and restored as a party member. On Oct. 9 it was announced that Minc had resigned from the Politburo and from his office of deputy premier. Agreement was reached among Gomulka, Ochab and Cyrankiewicz as to the composition of the new Politburo.

On Oct. 19 when the party's central committee had assembled to elect a new Politburo. quite unexpectedly Khrushchev, V. M. Molotov, L. M. Kaganovich and A. I. Mikoyan arrived in Warsaw. It was learned that Soviet divisions stationed in southnestern Poland mere moving toward Warsaw, while a Soviet naval squadron appeared before Danzig. The meeting of the central committee, after co-opting Gomulka as its new member, decided that the old Politburo including Gomulka would discuss Polish-Soviet relations with the Soviet guests and, on the night of Oct. 19–20, the Polish leaders succeeded in explaining to the Soviet visitors that the Polish people's democracy must be an equal, independent and sovereign state.

Meanwhile, Polish workers and university students, aroused by the Soviet intervention, demonstrated, through meetings and processions, their protest against foreign pressure and their support for Gomulka. Khrushchev and his colleagues understood that by supporting the Stalinists they were risking bloodshed. They accordingly retreated and on Oct. 20 returned to Moscow. When the Polish central committee reassembled, Gomulka presented his program and the next day his speech was broadcast to the nation. On Oct. 21 the plenary session elected the new nine-member Politburo. In a secret ballot. Gomulka obtained 74 votes. the maximum possible being 75, while Marshal Konstantin Rokossovsky secured only 23 votes. (Rokossovsky, a Russian of Polish origin, had been appointed on Nov. 7, 1949, Polish minister of defense and commander in chief; on May 8, 1950, he had been co-opted to the Politburo.) In quick succession a series of army changes was announced. The most important was the replacement on Nov. 13 of Marshal Rokossovsky as minister of defense by Gen. Marian Spychalski, a friend of Gomulka. Rokossovsky returned to Moscow and on Nov. 15 was appointed deputy minister of defense of the U.S.S.R. In the first week of November 32 Russian officers in the high command of the Polish armed forces were dismissed and replaced by Poles.

Struggle with the Church. — Early in 1950 relations between the regime and the Roman Catholic Church became openly strained when the state took control of church charitable funds. and Cardinal Adam Sapieha (1867–195 ~)archbishop of Cracow, and Mgr. Stefan Wyszynski (1901–), archbishop of Gniezno and Warsaw and primate of Poland, accused the government of bad faith in its dealings with the church. On April 14, however, the government and the hierarchy signed an agreement which made provision for considerable religious toleration and recognized the pope as head of the church; the church, in turn, agreed to support the government's foreign policy and to ask the Holy See to recognize Poland's sovereignty over the recovered territories east of the Oder-Neisse line by appointing diocesan bishops there in place of apostolic administrators. When the bishops were not at once appointed, the government suppressed religious tuition in schools. In Jan. 1951, when the five apostolic administrators had been relieved of their office and in their place the diocesan councils. under the government's pressure, appointed five vicars capitular, Mgr. Wyszynski saved the unity of the church by vesting canonical jurisdiction in them. He visited Rome in April and obtained from the Holy See the appointment of new residential bishops, but the government forbade the nominees to assume their posts and continued to accuse the Vatican and the hierarchy of refusing to recognize the new western frontier as final.

On Feb 9. 1953, the government made a law by which it claimed rights of appointment to ecclesiastical office. In a memorandum of May 8, 1953, the hierarchy protested to the government against this and other steps to create schism. The publication of this document was forbidden in Poland and a bishop was put on trial. On Sept. 24, Wyszynski (made cardinal on Nov. 29, 1952) protested. He nas arrested and secretly detained. On Dec. 17, 1953, the bishops, auxiliary bishops and vicars capitular from all the dioceses took an oath of loyalty to the Polish state.

For three years an uneasy truce existed between the church and the state, but in Oct. 1956, soon after his return to power, Gomulka decided to make peace On Oct. 28 Cardinal Wyszynski. released from internment, returned to Warsaw as head of the Polish hierarchy. Five other bishops and all priests who had been imprisoned were released from confinement. On Dec 8 an agreement between the state and the church was announced. The government promised to replace the law of Feb. 9, 1953, by another one which would respect church jurisdiction. Religious instruction was again to be given in schools as an extracurricular subject. The government agreed to the appointment of five residential bishops in the recovered territories to the sees of Wroclaw, Opole, Gorzow, Gdansk and Olsztyn.

Foreign Affairs. — Besides the bilateral Polish-Soviet treaty of alliance of 1945, Poland nas bound by similar treaties with Czechoslovakia (March 10, 1947), Hungary (June 19, 1948), Rumania (Jan. 26, 1949) and Bulgaria (May 29. 1948). A treaty of alliance with Yugoslavia, signed in Warsaw on March 16, 1946, was denounced in 1948 when Yugoslavia was expelled from the Communist bloc. The net of alliances was completed by a treaty signed in Warsaw on May 14, 1955, by which Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland. Rumania and the U S S R. agreed that in the event of an armed attack in Europe on one or several signatory states each state that was a party to the treaty would render immediate assistance to the state or states so attacked. A joint command for their armed forces was established.

From Kov. 15 to 18, 1956. Gomulka, Cyrankiewicz and Zawadzki were in Moscow discussing the future of Polish-Soviet relations with Khrushchev, Bulganin, Mikoyan and others. Both sides agreed that the Soviet-Polish alliance was a reliable guarantee of their mutual security as well as of the inviolability of the Polish-German frontier on the Oder and the Neisse; and that the temporary presence of Soviet army units on the territory of Poland was still desirable but should in no way infringe the sovereignty of Poland or interfere in its domestic affairs. A special treaty concerning the legal status of Soviet troops stationed in Poland was signed in Warsaw on Dec. 17 by the foreign and defense ministers of the two countries.

BIBLIOGRAPHY.—*The Cambridge* History of Poland, vol. i (Cam-

bridge, 1950), vol. ii (Cambridge, 1941), a standard work on Polish history up to 1935; *Recueil des actes diplomatiques, traités et documents concernant la Pologne*, vol. i, K. Lutostański (ed.), *Les Partages de la Pologne* (Neuchâtel, 1918), vol. ii. S. Filasiewicz (ed.). *La Question polonaise pendant la guerre mondiale* (Paris, 1920); A. Bruce-Boswell, *Poland and the Poles* (London, 1919); O. Halecki. *A History of Poland* (New York, 1943); W. Sobieski, *Histoire de la Pologne des origines à nos jours* (Paris, 1934); B. Winiarski. *Les Institutions politiques en Pologne au XIXe siècle* (Paris. 1921); M. Handelsman, *et ul., La Pologne: sa vie Cconomique et sociale pendant la guerre* (New Haven. Conn., 1933); C. Smogorzewski, *La Pologne restaurée* (Paris, 1927), *Joseph Pilsudski et les activistes polonais pendant la guerre* (Paris, 1931), *La Silésie polonaise* (Paris. 1932) and *Poland's Access to the Sea* (London, 1934); R. Dyhoski, *Poland* (New York, 1933); R. Machray, *The Poland of Pilsudski* (New York, 1937); G. Kaeckenbeeck, *The International Experiment of Upper Silesia* (Oxford, 1942); I. F. D. Morrow and L. M. Sieveking, *The Peace Settlement in the German Polish Borderlands* (Oxford, 1936); W. J. Rose. *The Drama of Upper Silesia* (Brattleboro, Vt., 1935), *The Rise of Polish Democracy* (London, 1944) and *Poland Old and New* (London. 1948); W. F. Reddaway, *Marshal Pilsudski* (London. 1939); B. E. Schmitt (ed.), *Poland*, 2nd ed. (Berkeley. 1951); L. Noël, *L'Agression allemande contre la Pologne* (Paris, 1946); J. Beck, *Dernier rapport: politique polonaise 1926–1939* (Neuchâtel, 1951); W. Anders. *An Army in Exile* (New York, 1949); A. Bliss Lane, *I saw Poland Betrayed* (Indianapolis, 1948); T. Bór-Komorowski, *The Secret Army* (London. 1950); J. Ciechanowski, *Defeat in Victory* (New York, 1947); hi. Norwid-Neugebauer, *The Defence of Poland (September 1939)* (London. 1942); Z. Stypułkowski, *Invitation to Moscow* (New York. 1951); A. Żółtowski, *Border of Europe* (London, 1950); S. L. Sharp, *Poland: White Eagle on a Red Field* (Cambridge, Mass., 1953); H. P. Stern. *The Struggle for Poland* (Washington, 1953); E. Wiskemann, *Germany's Eastern Neighbours* (London, 1956). (K. Sm.)

POPULATION

At the beginning of the historical period the Poles lived between the Baltic sea and the Carpathian mountains and the Oder and Bug rivers. They were one of the western branch of the Slavonic group of peoples. The Polish nation originated from three main tribal groups, the Polanie. the Mazowszanie and the Pomorzanie. Because of their central position! the Polanie, or dwellers in the plains (pole, "field"), gave their name to the country, Polskn, and to the people, *Polacy* (singular *Polak*).

The Polanie themselves were originally composed of many tribes, the most important of them being the Slezanie (now Slazacy or Silesians) who settled on both sides of the middle and upper Oder; the Kujawiacy (Kujavians) who lived between Lake Goplo and the Vistula; and the Wislanie, later called Malopolanie, on both sides of the upper Vistula.

The Mazowszanie or Mazovians lived on both sides of the middle Vistula, and their Baltic neighbours to the northeast were the Lithuanians and the Prussians. The Mazurians of East Prussia were descendants of Mazovian settlers who settled there in the 15th century. The Pomorzanie or Pomeranians, as their name indicates, were living along the seacoast (po, "toward"; *morze*, "sea") between the lower Oder and lower Vistula. They formed an element of transition between the Polanie and the Polabians (*po Labě*, "along the Elbe"). The Polabians were germanized between the 10th and 18th centuries. as were also those Pomeranians who remained outside Poland after the treaty of Torun of 1466.

Linguistically, however, two local Pomeranian dialects remained until the 20th century, the Slovince (Slowinski) and the Cassubian (Kaszubski). Slovince was spoken until World War I along the Baltic coast line between Slupsk (Stolp) and Lebork (Lauenburg). At mid-20th century Cassubian was still spoken west of Danzig in the districts of Wejhercwo and Kartuzy.

The first census (1921) after the restoration of the Polish state revealed a total population of 27,176,717. The second (1931) recorded a total of 32,107,252, while an estimate for Sept. 1, 1939, assessed the population as at 35,339,000 (excluding the Teschen disputed territory). Poland between World Wars I and II was not a homogeneous national state, the Poles amounting, according to the 1931 census. to 68.9% of the population.

No part of Europe was more profoundly affected by the great displacements of population which occurred in World War II and for a few years afterward. Polish citizens were deported by both occupying powers during the German-Soviet partition and by the Germans over the whole of Poland after June 1941. Of Poland's

*Table I.—Area and Population, 1960 Census**

Województwa (Voivodships)	Area sq.mi.	Population	Density
Bialystok	8,937	1,089,700	121.9
Bydgoszcz	8,030	1,706,200	212.5
Cracow (Krakow) city	89	479,000	5,382.0
Cracow (Krakow)	5,927	1,989,200	335.6
Gdansk	4,218	1,220,000	289.2
Katowice	3,675	3,263,500	888.0
Kielce	7,520	1,818,000	241.8
Koszalin	6,940	686,400	98.9
Lodz city)	82	708,400	8,639.0
Lodz	6,589	1,597,600	242.5
Lublin	9,584	1,799,900	187.8
Olsztyn	8,117	876,700	108.0
Opole	3,670	927,400	252.7
Poznan (city)	85	407,800	4,797.6
Poznan	10,318	1,993,600	193.2
Rzeszow	7,199	1,587,100	220.5
Szczecin	4,894	754,800	154.2
Warsaw (city)	172	1,136,000	6,604.7
Warsaw	11,353	2,314,800	203.9
Wroclaw (city)	87	429,200	4,933.3
Wroclaw	7,269	1,798,600	247.4
Zielona Gora	5,604	777,300	138.7
Total	120,359	29,731,000†	247.0

*Preliminary. †Included in the total only are 369,800 persons not included in the breakdown by *województwa*.

3.351.000 Jews (1939 est.) the great majority were exterminated by the Germans, and only about 90.000 remained in post-1945 Poland; by 1956 their number was estimated at 65.000.

The territories annexed by the Soviet Union had a population of 10.864.000 in 1939: by June 30. 1949, only 1.503.800 persons of Polish nationality had been transferred from Soviet territory to the new Poland. while 515.200 Ukrainians. Byelorussians and Lithuanians had been moved from Poland to their respective Soviet republics. According to the 1939 German census. the population of the then German lands east of the Oder-Neisse line incorporated into Poland amounted to 8.372.700. To this total must be added the German population of the free city of Danzig (392,000 in 1939) and the German minority in the pre-1939 frontiers of Poland but there must be subtracted the 1.011.700 Polish population of the recovered territories.

Theoretically. the total number of Germans living within the frontiers of 1945 Poland was 8.494.000. In fact. almost half of that number fled before the Soviet armies and in May 1945 only 4.400.000 remained. According to the census of Feb. 14. 1946. the population of Poland within its new frontiers was 23.929.757. including 2.288.300 Germans. By the end of 1948, a further 2,170,-866 Germans had been repatriated from Poland. while 2.266.000 Polish forced labourers, prisoners of war and demobilized soldiers returned to Poland from Germany and from western Europe. The Polish census of Dec. 3, 1950. revealed a total population of 24.976.926.

By mid-1956 the population of the recovered territories amounted to about 7.280.000. The natural increase in the years 1950–54 was 19.0 per thousand, the highest in Europe. The 1960 census revealed a total population of 29.731.000. with about 550.000 of national minorities (Germans. Jews, Byelorussians. Ukrainians. Lithuanians. Slovaks, Czechs and Gypsies'!. The density of population in 1960 was 247.0 per square mile (228.8 in 1950).

Towns.—In 1931 the urban population of Poland amounted to 27.5%; in 1950 this proportion rose to 40% and in 1960 to 47.5%.

Table II illustrates the main trends of urban population after 1880. It shows clearly the sudden development of Polish cities after 1920 with the restoration of Polish sovereignty, and especially the transformation of Gdynia from a fishing village to a port of international significance—a development which was one of the more remarkable feats of pre-I 939 Poland. The vast losses borne by Warsaw during World War II, the decline of the Silesian towns and the Baltic ports and the changes in other towns appear in the figures for 1946. Those for 1960 show to what extent the losses were reversed.

The population of Warsaw. reduced to 153.000 in Jan. 1945. had recovered by 1960 to 1,136.000 within wider administrative boundaries.

The rate of rehuilding devastated Warsaw was one of the controlling factors; another was the increasing attention given to the

TABLE II.—*Development of Major Towns, 1880–1960*
(in thousands)

Towns	1880	1910	1921	1939	1946	1950	1960
Warsaw	383	781	937	1,289	479	804	1,136
Lodz	48	408	452	672	497	620	708
Cracow	66	143	184	259	299	344	479
Wroclaw (Breslau)	268	506	528*	621	171	309	429
Poznan	65	150	169	272	268	321	408
Gdansk (Danzig)	102	162	195	258†	118	195	287
Szczecin (Stettin)	92*	232	233*	268	73	179	269
Bydgoszcz.	34	53	88	141	135	163	232
Katowice	13	43	50	134	128	175	269
Zabrze	13*	63*	67*	126	104	172	189
Bytom	23*	67	53*	101	93	174	183
Lublin	33	66	94	122	99	117	181
Czestochowa	21	73	80	138	101	112	164
Gdynia	...	0.9	1.3	120	78	103	148
Chorzow.	27‡	73‡	73‡	110	111	129	147
Gliwice	15	65	69*	114	96	120	135

'Including troops in barracks. †1935. ‡Population of Kralewska Huta

development of heavy industry. particularly although not exclusively in Silesia and the recovered lands. An example of the last trend was the development of a new town at Nowa Huta, which at the beginning of 1955 had a population of 75,000, included in the Cracow urban district. In 1960 there were 22 towns with a population of more than 100.000.

In addition to the 16 mentioned in Table II. these included the towns of Sosnowiec (132,000), Ruda Slaska (131,000), Radom (130.000). Bialystok (121,000), Walbrzych (117.000) and Torun (105,000).

Poles Abroad.—Poles abroad are divided into two categories: the autochthonous Poles inhabiting alien territory contiguous with the political frontiers of Poland and the emigrants and refugees. Between 1922 and 1939, the largest groups of autochthonous Poles were in eastern Germany and in the U.S.S.R., where, according to the Soviet census of 1926, there were 792,471 Poles, including 476,435 in the Ukraine and 97,948 in Byelorussia. Poles were estimated in Lithuania at 200,000, in Latvia at 75,000 and in Rumania at 65,000 (including 50,000 in Bukovina). The three last-named territories all formed part of the U.S.S.R. by 1945. To these were added the Poles in the Polish territories incorporated by the Soviet Union in 1945. Finally, according to the Czechoslovakian census of 1930, there were 77,300 Poles living in the disputed Cieszyn area; which later again became part of Czechoslovakian territory; according to Polish official estimates these numbered 170,000.

The largest number of emigrants before 1939 settled in the Americas. By 1951 they included about 180,000 in Canada (mostly in Ontario and the prairie provinces), 300,000 in Brazil (mostly in Paraná), 70.000 in Argentina and 18,000 in Paraguay; but the greatest single group was in the United States, where there were probably 6,000,000 persons of Polish descent. The 1940 census revealed that there were 2,416,320 persons in the United States whose mother tongue was Polish, the largest non-English-speaking group after the German- and Italian-speakers. According to the 1950 census 861,186 of the U.S. population mere born in Poland. Chicago was the largest Polish centre, with about 500,000 Poles; Detroit had 200,000-Buffalo, Cleveland and Milwaukee each more than 100.000 and New York city, Pittsburgh and Philadelphia each 50,000. Poles engaged in agriculture (about one-fifth of the total) were spread across the states of Michigan, Wisconsin, Missouri, North and South Dakota and Texas. Steady assimilation ensued, of course, but these U.S. citizens maintained a strong interest in Polish culture and the homeland. They established innumerable social and cultural organizations, including the Polish National alliance, the Polish Roman Catholic union and the Polish-American congress—all with headquarters in Chicago. By the later 1950s there were about 800 Roman Catholic Polish parishes. The number of Polish-language schools and publications, although tending to decline, remained large; in 1955 there were 600 primary schools, with 300,000 pupils, and 20 higher schools. Out of a total of about 80 Polish periodicals appearing in the United States there were 8 daily, 24 meekly newspapers and 28 other periodicals.

The largest group of emigrants in Europe went to France, settling for the most part in the northern mining areas. After the onset of the economic depression they declined from 800,000 to about 622,000 in 1939. In 1950 they probably numbered about 500,000. There was a daily newspaper, many periodicals and an old established Polish library. In the Ruhr (Ger.), the "Westphalian" Poles formed another considerable group but were somewhat reduced in numbers by World War II and by postwar repatriation, numbering fewer than 100,000 in 1955.

The greatest change brought about by the war was the establishment of a Polish colony in Great Britain, where the Polish government had its seat. The great majority of the 140,000 Poles in Great Britain was constituted by former servicemen and their families who were assisted by the Polish Resettlement corps in finding civilian employment. Most of the political parties—the National, the Freedom-and-Independence, the Christian Democratic, the Socialist and a Peasant group—organized in 1954 in London a Polish Council of National Unity with a "committee of three" as a supreme body whose members were Gen. Wladyslaw Anders, the Socialist leader T. Arciszewski and Count Edward Raczynski, former ambassador to Great Britain. (Arciszewski died on Nov. 20, 1955, and was succeeded by Gen. Bor-Komorowski.) The Peasant leader Mikolajczyk and his followers mere excluded from the council. A Polish research centre, the Sikorski Historical institute and many cultural: social, professional and trade organizations were established. There were more than 20 Polish periodicals in Great Britain at mid-70th century, including an independent daily paper, the *Dziennik Polski.*

BIBLIOGRAPHY.—W. I. Thomas and F. Znaniecki, *The Polish Peasant in Europe and Anzerica,* 2 vol. (New York, 1927) ; G. R. Gayre, *Teuton and Slav on the Polish Frontier* (London, 1944) ; G. Frumkin, "Pologne: dix années d'histoire démographique," *Tr. Inst. Nat. Etudes Démographiques* (Paris, Oct.–Dec. 1949); J. Zubrzycki, *Polish Immigrants in Britain: a Study of Adjustment* (The Hague, 1956).

GOVERNMENT, DEFENSE AND EDUCATION

The first constitution after the restoration of the Polish state, promulgated on March 17, 1921, was modelled on the French system. It was passed by a coalition of Conservatives, Nationalists, Christian Democrats, Middle Class deputies and moderate Peasants (Piast), with the idea of giving much power to the legislature at the expense of the executive. It reflected the prevalent fear of Marshal Pilsudski, then chief of state. Coupled with the electoral system

TABLE IV.—*Composition of the Polish Sejms, 1919–30*

Party	Jan. 1919	Nov. 1922	March 1928	Nov. 1930
Pilsudski bloc	...	...	135	247
Conservative	44	19		
rational	72	101	37	63
Christian Democratic	31	41	61	30
rational Labour	25	18		
Middle Class	63	5	...	...
Peasant *Piast* / Peasants. union	90	53	41	41
		33		
Peasant *Wyzwolenie*	24	26		
Socialist	34	41	64	21
Communist	2	17*	7*	...
Kational minorities				
Jewish	16	35	13	7
Ukrainian.	...	21	43	20
Byelorussian	...	7	6	1
German	2	17	19	5
Other	29	19	18	9
Total.	432	444	444	444

*Including the Communist-controlled Ukrainians and Byelorussians.
Note: The results of the elections of Sept. 1935 and Nov. 1938 are not recorded here because a complicated élite electoral law of July 8, 1935, besides reducing the number of deputies to 208, enabled the government to influence the voting. The opposition parties boycotted these elections.

of proportional representation it produced a *sejm*, or chamber of deputies, of 16 parliamentary groups, four of uhich represented national minorities. (See Table IV.) A parliamentary government could be based only on a coalition, and these did not last long. Another solution, successfully tried by W. Grabski (Dec. 1922 to Nov. 1924), was a nonparty government.

When the Pilsudski bloc won the 1930 election it prepared a new constitution which was promulgated on April 23, 1935. It made the president of the republic virtually a king without a crown, but it did not do auay nith the *sejm* which fixed the budget. imposed the charges upon the citizens and had the right to demand the resignation of the cabinet or of a minister. Under article 24, in time of war the president had the right to appoint his successor. It was by virtue of this provision that Moscicki (1867–

1946) appointed Raczkiewicz (1885–1947) his successor. (See above.) To make the post of president the symbol of true national unity, a constitutional compromise was reached in Paris on Nov. 30, 1939, between the political leaders by which thenceforward the president would exercise his prerogatives "in agreement with the prime minister." The political leaders in exile continued to cling to this "legal continuity" of the constitution of 1935 until it could be modified by a freely elected Polish sejm.

On Feb. 19, 1947, the Warsaw Communist government promulgated a temporary constitutional act which was democratic but never became effective. The new constitution was passed by the sejm on July 22, 1952, and was claimed in the debate to be "modelled on and inspired by the great Stalin constitution of 1936." The supreme organ of state authority was the council of state (rada *stanu,* similar to the Soviet presidium) composed of a chairman, four deputy chairmen, a secretary and nine members. The supreme organ of state administration was the council of ministers (rada *ministrow*) appointed by and responsible to the sejm, or to the council of state if the sejm were not in session.

The electoral law adopted by the sejm on Aug. 1, 1952, accorded the franchise to all citizens of 18 years, including members of the armed forces; citizens of 21 years were eligible for election. There was one deputy for every 60,000 inhabitants; in every constituency there could be only one list of candidates equal in number to the deputies fixed for the constituency. For the 1952 election the council of state divided the country into 67 constituencies electing 42j deputies. The candidates were formally nominated by the National front grouping the three existing political parties, the Communist, the United Peasant and the Democratic, also the Trade Unions federation, the Union of Polish Youth and other "mass social organizations of the working people."

Administration. — From June 1, 1950, the number of provinces (*wojewodztwa*) was increased to 17 by the creation of three new provinces in the western territories. In 1945 in these territories, all Pomorze or maritime land had been divided between the two provinces of Gdansk and Szczecin; in 1950 a new province of Koszalin (Koslin) was created between the two. The province of Poznan, which in 1945 had been extended westward to the Oder, was divided into two, Poznan and Zielona Gora (Griinberg). Recovered Silesia. previously divided into two provinces, was redistributed to form three: a ne province of Opole was created between those of Wroclaw and Katouice. The two largest cities, Warsaw and Lodz, formed separate administrative units. In Sept. 1955 the 17 provinces were divided into 371 districts (*powiaty*).

Defense. — Between the armed forces of pre-World War II Poland and those established after 1945 there was no continuity: personnel, organization, training and equipment were completely changed. The Polish army suffered catastrophically from the German and Soviet invasions, although certain naval, army and air force units escaped abroad and made an uninterrupted and important contribution to the Allied war effort from the Polish headquarters in Britain. The fate of the Polish units in the east, their imprisonment, release and recruitment into the Polish army under Gen. Wladyslaw Anders, their exodus from the U.S.S R. through the middle east and their subsequent battle engagements in the battle of Britain (during which the Polish airmen shot down 14% of the enemy aircraft destroyed), at Narvik in Norway, at Tobruk in Cyrenaica, at Monte Cassino in Italy and at Falaise in France provided one of the great epics of World War II. Out of 215,000 Poles fighting with the Allies in the west, 150,000 chose to remain in exile, and those who returned a-ere not allowed to form any part in the new defense organizations.

A Communist-dominated Polish army was organized in the Soviet Union in 1943 and 1944, eventually numbering ten infantry divisions, an armoured corps and an air force.

Between 1944 and 1947 the Communists were occupied with the liquidation of the Polish home army, the main fighting organization of the underground government. which was supported by the mass of people and directed by the Polish government in London until its derecognition in 1945. By 1947, aided by the presence in strength of the Soviet army and by the Communist militia, a new "people's army" had been established around the nucleus formed in Russia.

Including the forces of the interior (frontier guards and security troops), the Polish armed forces were estimated in Oct. 1956 at 370,000. There were three military areas (Warsaw, Bydgoszcz and Wroclaw) comprising 24 Soviet-type divisions, including 4 motorized and 4 armoured. The number of trained reservists was estimated at more than 2,000,000. The Polish air force was believed to amount to 12 air divisions (all jet) of 9 squadrons each, a fighter squadron comprising 11 aircraft. The Polish navy in 19jj consisted of two destroyers, three submarines and a number of minesweepers and auxiliary craft.

Military service was made universal and compulsory between the ages 20 and 50. In 1950 active service was two years in the army, three years in the air force and the navy, two years in the antiaircraft units and 27 months in the forces of the interior. Women were called up for six months' active service. Premilitary training was afforded by the youth clubs.

Education. — Restored Poland had an enormous task in the organizing of a national system of education. In the formerly Russian part of Poland there was a great need for school buildings and teachers, illiteracy being about 50%. In the German part there were school buildings but no teachers. Only in the Austrian part of Poland was there a system of Polish education, although illiteracy exceeded 20%. On Feb. 7, 1919, the first Polish government issued a decree of compulsory education for all between the ages of 8 and 1j years. Not until 1926 could this act be more or less effectively applied. In 1921 illiteracy in Poland amounted to 33.1%, by 1931 this proportion was reduced to 23.1% and by 1939 illiteracy was estimated at 12%.

Secondary education, which was selective, was provided in two stages, the grammar schools for those aged 12–16 years and the lyceums for those aged 16–18, the latter being maintained by the state, municipalities and private organizations. In addition, there was a great variety of trade and professional schools which afforded theoretical and practical professional training as well as general education. In the great release of Polish intellectual life which began in 1918, the needs of the various national minorities were not forgotten. In 1938 there were 3,525 primary Ukrainian schools with 532,200 pupils; 597 German with 72,800 pupils; 452 Jewish (Yiddish and Hebrew) with 64,900 pupils; 67 Lithuanian with 3,800 pupils; 22 Czech with 1,100 pupils; j Byelorussian with 800 pupils and 6 Russian with 1,200 pupils. There also was an adequate number of secondary schools.

The policy of the post-1945 Polish government was the gradual replacement of the old system by a Stalinist-Marxist system at every level. The state control and censorship of all organs of information rendered this policy more effective. The influence of the state and, therefore, of the Communist party became absolute; private and independent institutions (such as those organized by the Roman Catholic Church, the Lutheran Church, the religious orders and the scientific and historical societies) had by 1952 been closed or subjected to governmental interference. Besides the steady imposition of Marxist uniformity, the government was confronted with the need to supply trained citizens to man the ambitious program of industrial expansion, maintain and if possible improve technical standards and fill the ever-increasing state services. civil, security and military and the public utilities. At mid-20th century there was free, compulsory and universal education for the nursery, primary and intermediate stages, which covered the years from 4 to 6. from 7 to 15 and from 15 to 18 or 19.

From 1952 the ministry of education controlled the lower schools, nursery, primary and intermediate, both general and vocational; the technical and special schools and supplementary courses on the appropriate level; and the central office of vocational training. The ministry of higher schools and learning controlled the universities, colleges of engineering and the increasing number of institutions affording specialist training at the highest level. The organization of the medical, pharmaceutical, dental and nursing professions was the concern of the ministry of health. The medical faculties were detached from the universities, and 11 medical academies had been established by the early 1950s.

The senior learned societies of pre-1939 Poland were the Polish

Academy of Learning in Cracow, founded in 1872, which maintained stations in Paris and Rome, and the Warsaw Scientific society, reopened as a continuation of the Royal Society of the Friends of Science, dating from the 18th century. Both were seriously affected by the depredations of war and postwar political

EASTFOTO
PALACE OF CULTURE AND SCIENCE, WARSAW, BUILT BY THE U.S.S.R. AS A GIFT TO POLAND IN 1955

conditions. At the first congress of Polish science, held in Warsaw in July 1951, a new Soviet-type Polish academy of sciences was initiated; this body, in collaboration with the various government departments and party committees, was created to ensure the conformity of all higher learning and research with Marxist theory.

The oldest Polish institution of higher education (one of the oldest and finest in Europe) is the University of Cracow; although called Jagiellonian it was in fact founded in 1364 by Casimir II the Great, the last king of the Piast dynasty. The loss of the eastern territories deprived Poland of the University of Wilno (Vilnius), founded by King Stephen Bathory in 1578, and of Lwow (Lviv), founded by King John Casimir in 1661. Besides the University of Cracow there were in pre-1939 Poland, state universities in Warsaw and at Poznan, and a Catholic university at Lublin. Four new state universities were founded after 1945, at

TABLE V.—Education in Poland, 1926–54

	1926–27*	1938–39*	1953–54
Nursery schools	1,185	1,654	8,200
Pupils	66,600	83,300	380,000
Primary schools	26,579	28,882	22,980†
Pupils	3,344,500	4,953,000	3,000,000
Teachers‡	63,886	85,763	100,000
Special schools	60	118	111
Pupils	5,300	12,600	13,800
Secondary schools	796	789	702
Pupils	215,500	234,200	195,000
Teachers§	7,521	6,483	...
Vocation schools	720	1,562	3,000
Pupils	67,000	223,300	474,000
Teachers	1,528	6,527	...
Teachers' training colleges	218	74	140
Pupils	38,100	6,600	44,000
Institutions of higher education	10	28	82
Students	40,700	50,000	136,000
Teaching staff	2,039	2,460	...

*In pre-1939 frontiers. †Including 14,116 seven-grade schools. ‡Including teachers in nursery and special schools for mentally defective children. §Including teaching staff in teachers' training colleges.

NOTE: In 1954 there were 133 German primary schools with 6,500 pupils, 1 secondary school with 76 pupils and 1 teachers' training college; 62 Byelorussian primary schools with 4,500 pupils and 3 secondary with 418 pupils; 5 Lithuanian primary and 1 secondary school; 7 Jewish primary schools and 2 secondary; 33 Slovak primary schools and 1 secondary; and 1 Czech primary school.

Wroclaw, Torun, Lodz and Lublin. Before 1939 there were two colleges of engineering, in Warsaw and Lwow. In 1955 there were eight colleges of engineering, in Warsaw and new ones at Wroclaw, Lodz, Gdansk, Gliwice, Poznan, Szczecin and Czestochowa. (See Table V.)

ECONOMIC CONDITIONS

There was a certain similarity between the problems facing the Polish government in 1918 and those in 1945. After World War I losses of national wealth had to be made good and the differing systems of the Austrian, German and Russian zones unified into one viable whole. World War II, it was estimated, destroyed 38% of the total national wealth, more than three times as much as World War I. In addition, Poland had acquired important new territories and lost 45% of its former area. Apart from the work of reconstruction, however, the new state embarked upon an ambitious program of industrial development and was forced to set about transforming the old economy into one based on Stalinist-Marxist theories.

Agriculture. — Between World Wars I and II Poland was a predominantly agricultural country. Out of a total area of 38,863,400 ha. there were 25,589,000 ha. (65.5%) of agricultural land. Arable land alone covered 18,557,000 ha. (47.5% of the total area). In July 1921 Poland had 19,454 estates of 50 ha. or more covering a total area of 10,498,100 ha. and 3,075,700 small holdings of under 50 ha. covering an area of 24,646,200 ha. While the first group included 4,256 large estates of 500 ha. and over, totalling 7,942,300 ha., among the small holdings there were 991,000 of from 2 ha. to 5 ha. and 931,300 of under 2 ha.

A Land Reform act was passed by the constituent sejm on July 15, 1920. It encouraged a redistribution, with compensation under state control. By the end of 1938 a total of 2,654,900 ha. belonging to large estates had been distributed, and in the same period small farms received 595,400 ha. as equivalent of abolished praedial servitudes. Consequently, the amount of land which passed from the large estates to the small farmers and landless peasants amounted to 3,250,295 ha., an area equal to that of all the arable land in England and Wales. The total number of persons who received land in this way in the interwar period was

TABLE VI.—Rural Holdings in Poland, 1931–49
(Number of holdings in thousands)

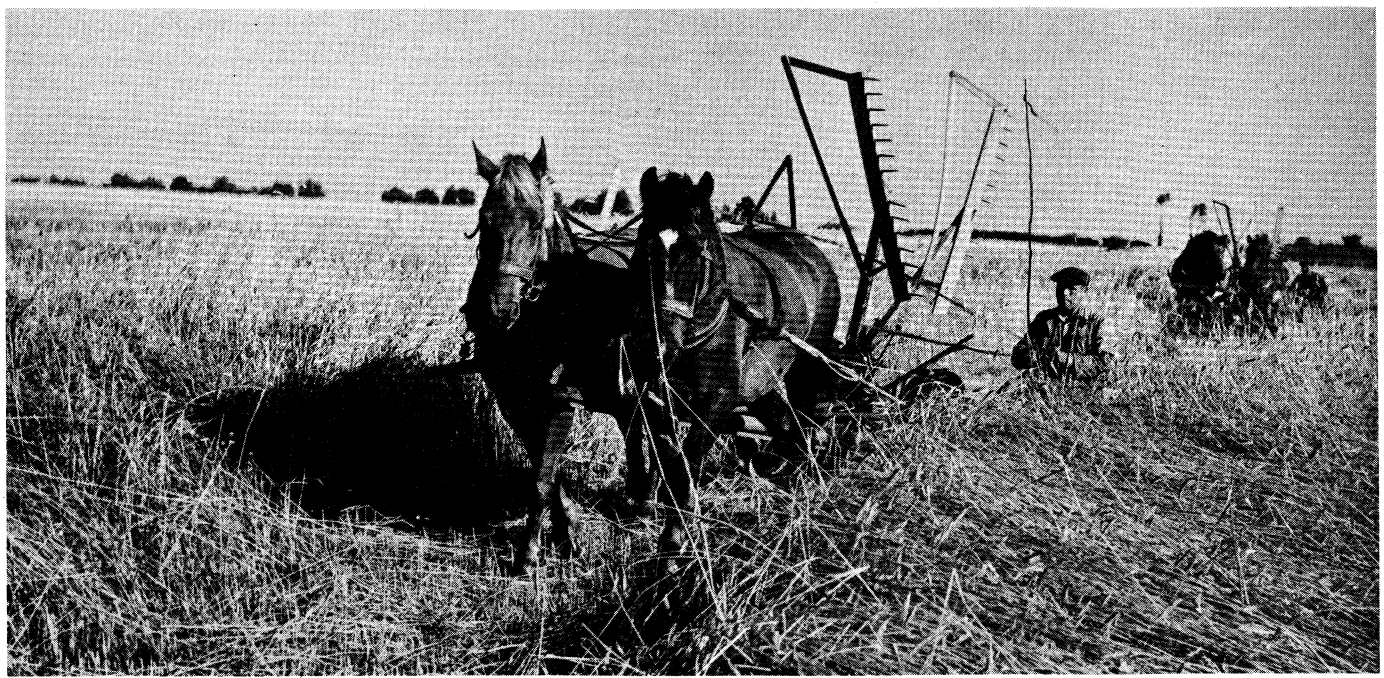
Year	Under 2 ha.	2–5 ha.	5–10 ha.	10–50 ha.	Over 50 ha.	Total
1931	747.1	1,136.1	728.7	309.1	14.7	3,196.0*
1949	962.1	1,084.0	906.3	386.3	3.3	3,342.0
(Number of holdings in percentages)						
1931	25.5	38.7	24.8	10.5	0.5	100
1949	28.8	32.4	27.1	11.6	0.1	100
(Area of holdings in thousands of hectares)						
1949	1,048.8 5.9%	3,790.2 21.2%	6,848.6 38.3%	5,944.3 33.2%	259.4 1.4%	17,891.3 100%

*In 1931 there were also 260,300 small holdings of unknown area, two-thirds of them in the eastern provinces.

734,100. Nevertheless Poland continued to suffer from rural overpopulation.

Although Poland after 1945 was one-fifth smaller than before 1939, the area of arable land was not reduced in the same proportion, for meadows, pastures, forests and barren land occupied a higher percentage of land utilized for agriculture in the east than in the west. The area of agricultural land in post-1945 Poland was 20,864,200 ha. (67.3% of the total area), including 17,891,300 ha. (57.7%) of arable land. By its decree of Sept. 6, 1944, the Polish Committee of National Liberation (the Lublin committee, which later formed the nucleus of the Communist government) expropriated without compensation all private land over 50 ha., except church land, although that too was confiscated in the reform of March 20, 1950. In all, in Jan. 1949, in the territories which were part of Poland before 1939, 1,210,900 ha. of arable land were received by 407,500 peasants. In the recovered territories in the west 4,004,900 ha. were shared out and 483,307 new small holdings were created.

The results of the land reform are given in Table VI. Its effect was to increase both the number and proportion of very small farms of under 2 ha., which were economically unsound, and at the



TRIANGLE PHOTO SERVICE

WHEAT HARVESTING IN THE PROVINCE OF LODZ. SOUTHWEST OF WARSAW

same time to increase the number and proportion of larger holdings between 10 ha. and 50 ha. owned by the richer peasants. Collectivization was not pressed forward rapidly. There were 9,322 producers' co-operatives (*spoldzielnie produkcyjne,* as the Polish kolkhozy are called) by the end of 1954 with a total membership of 191,600 holdings and a combined area of 1,597,400 ha. Progress was slight, for the proportion of collectivized land was about 7.6% of the total agricultural area and socialized holdings were 5.8% of the total number of peasant farms. In addition there were 6.157 state agricultural farms (*panstwowe* gospodarstwa *rolne,* the Polish equivalent of *sovkhozy*), with a total area of 2,482,100 ha., or 11.4% of the agricultural land.

Climate and soil combine to give Poland a mixed type of farming. The main crops are grains (rye, oats, wheat and barley), potatoes, sugar beet and fodder crops. Rye and potatoes are more characteristic of the poorer sandy soils (podzols) of the glaciated regions, wheat and sugar beet of the more fertile brown soils (radzines) of southern Poland. Hops and tobacco are located on favourable soils in the centre and south. Temperate fruit, dairy, poultry and pig products are part of the general farming in most districts of the country. The production of grain and potatoes was more than sufficient for home consumption before World War II, and the surplus was exported.

The tendency in the mid-1950s was to concentrate on foodstuffs of value to the export market; such as sugar, poultry products, bacon and hams, the Soviet Union and the United Kingdom being the chief customers. Sugar production, for instance, was higher than the prewar 506,000 tons and in 1953 was 1,120,000 tons. The demands of the export drive and the victualling of the considerable armed forces, coupled with the direction of labour into heavy industry, imposed heavy burdens upon the ordinary civilian consumer. Changes in the agrarian system, lack of incentives for farmers and shortage of consumer goods also hindered agricultural

TABLE VII.—*Agricultural Production, 1934–55*

(In thousands of metric tons)

Crop	1934–38*	1934–38†	1948–50	1951–53	1954	1955
Wheat	2,064	1,965	1,751	1,600	2,002	2,134
Barley	1,411	1,632	1,038	1,000	1,086	1,239
Rye	6,467	6,854	6,522	6,300	5,844	7,003
Oats	2,558	2,830	2,287	2,000	2,073	2,287
Potatoes	35,006	38,014	34,830	28,200	35,662	27,021
Sugar beet	2,806	5,962	5,229	7,700	6,950	7,286

*Yearly average within pre-1939 frontiers
†Yearly average estimated for post-1945 territory.

production. (See Table VII.) Internal food shortages became apparent in 1948 and increased after 1950. From 1953 Poland had to import annually about 1,000,000 tons of grain. Between 1946 and 1950 a striking restoration of livestock was achieved. (See Table VIII.) The shortage of foodstuffs was attributed to the necessary concentration of the economy on rapid industrialization

TABLE VIII.—*Livestock, 1938–55*

(In thousands of head)

	1938*	1938†	1946	1950	1953	1954	1955
Cattle	10,554	9,900	3,910	7,164	7,385	7,687	7,912
Pigs	7,525	9,700	2,674	9,928	9,730	9,788	10,888
Sheep	3,411	1,900	727	2,194	3,330	4,170	4,243
Horses	3,916	3,100	1,730	2,797	2,722	2,650	2,560

*Within pre-1939 frontiers. †Within post-1945 territory.

and rearmament and also to the fact that, whereas in 1931 the agricultural population had constituted 61.4%, in 1953 the proportion was only 47.1%, as a result of the transfer of workers to industry.

Industry. — After World War II a short-term plan for industry was encouraged, aiming at recovery and producing conditions better than before the war. The physical scars left by the war were far more severe than anything previously suffered by Poland and were to entail prodigious efforts of rehabilitation and reconstruction.

The three-year plan of 1947–49 prepared by the Central Planning board, presided over by Hilary Minc, envisaged a total capital expenditure of $1,950,000,000, of which 39% was to be invested in industry, 24% in transport, 13% in agriculture, 9% in housing and 15% elsewhere. Rapid industrialization, however. was impossible without outside help. The Soviet Union was unable to supply capital goods, engaged as it was in the restoration of its own industry. Only the industrialized countries of the west remained as possible sources of supply, and Minc counted on getting a $600,000,000 loan from the United States. This hope did not materialize, and the only help Poland received from the west was: (1) through the UN Relief and Rehabilitation administration (2,235,000 metric tons of supplies valued at $471,000,000); (2) when the U.S. government, in Dec. 1946, released Bank of Poland gold to the nominal value of $27,000,000 and $10,200,000 of Polish assets in U.S. banks; (3) ontheratificationon June 19, 1947, of a Polish-British agreement for the settlement of outstanding financial questions (signed on June 24, 1946): out of £10,000,000 Polish gold reserves deposited with the Bank of England £7,000,000 were handed back and surplus British military stocks of

£6,000,000 were made available to Poland; and (4) when, on Jan. 14, 1949, a five-year trade agreement was signed with Great Britain for an exchange of goods worth £130,000,000.

When Poland, on orders of the U.S.S.R., rejected the European Recovery program, a Soviet-Polish agreement was concluded in Jan. 1948 for an exchange of goods to the total value of $1,000,000,000 in five years and for a $450,000,000 investment credit. But, as the Soviet machinery and heavy equipment could not be delivered immediately, the three-year plan was not a complete success, and the six-year plan, discussed between Warsaw and Moscow during 1948, had to be revised to make lower demands. The six-year plan 1950–55 was adopted in Dec. 1948 by the first congress of the P.Z.P.R. On Jan. 25,1949, the Council of Mutual Economic Aid was created in Moscow. This central planning authority for the whole Soviet bloc considered the Polish six-year plan too modest, and the plan was therefore speeded up by a substantial increase of capital investment and an augmented output of heavy industry.

On June 29,1950, the Soviet government accorded Poland an additional credit of $100,000,000. The total credit of $550,000,000 was, however, reduced from 2,915,000,000 rb. to 2,200,000,000 rb. by the revaluation of the rouble which took place on March 1, 1950, when a new exchange rate of $1 = 4.00 rb. was introduced instead of $1 = 5.30 rb. This increased by 25% the prices of Soviet supplies and reduced by the same amount the prices of Poland's deliveries to the U.S.S.R. On July 21, 1950, the law on the six-year plan was promulgated. The total capital investment was increased from 120,000,000,000 zl. to 185,000,000,000 zl.; the total industrial output was to increase by 158% between 1949 and 1955 and not by 95% as originally planned.

The progress of industrialization is illustrated by Table IX. The territorial shift to the west considerably increased the country's industrial capacity, except crude petroleum, of which three-quarters of the production was lost, and potassium salts, the production of which amounted in 1938 to 567,000 tons. The progress of industrialization can also be seen in the proportion of persons engaged in nonagricultural occupations: this was 2,730,000 in 1938 and it rose to 5,860,000 in 1955.

TABLE IX.—*Industrial* Production, *1923–55*

(In thousands of metric tons if not otherwise stated)

Item	1923*	1938*	1947	1949	1955 Plan	1955 Actual
Coal	36,100	38,104†	59,130	74,081	[illegible]	94,476
Lignite‡	...	10	4,766	4,621	8,400	6,000
Coke	...	2,328§	4,464	5,800	9,600	10,036
Crude petroleum	737	507	128	154	400	180
Electricity (millions of kw.hr.)	1,600	3.977	6,612	8,300	19,300	17,751
Iron ore (30% met. cont.)	449	872	544	699	3,200	1,856
Pig iron	520	880	867	1,391	3,500	3,112
Crude steel	1,129	1,441	1,579	2.304	4,600	4,427
Zinc, metal	97	108	75	108.3	198	156.2
Cement	660	1,719	1,522	2,334	4,250	3,813
Sulphuric acid	...	181§	156	275.8	540	449.9
Nitrogenous fertilizers‖	...	51.5	41.1	73.9	231	153.4
Phosphatic fertilizers¶	...	36.5	62.7	73.6	250	133.3
Cotton fabrics	...	51.56	47.4	90.7	138.8	114.0
Woollen fabrics	...	20.9§	17.5	38.6	59.0	51.4
Paper, (incl. newsprint)	...	205	136	265.2	530	402.3
Sugar	...	562.1	426.2	745.3	1,100	980.4**
Beer (thousands of hl.)	...	1,502	1,529	2,532	6,000	5,267
Merchant vessels, launched (gross reg. tons)	...	...	...	12,300	150,000	110,300††

*In pre-1939 frontiers. †Estimated production within post-1945 territory amounted to 69,360,000 tons. ‡Average thermic value: three tons of lignite per ton of coal. §1937. ‖In terms of nitrogen. ¶In terms of P_2O_5. **1953 production 1,107,100 tons. ††During period 1950–55 about 345,700 gross register tons of ships were launched.

Finance. — From 1950 Poland had a comprehensive Soviet-type budget including not only all state revenue and expenditure but also those of the whole nationalized economy. The percentage of budget expenditure on national economy after 1952 was over 50% of the total. (See Table X.) As already mentioned, Soviet help amounted to 2,200,000,000 rb., which Poland was to receive between 1950 and 1958 in raw materials, machinery and equipment, to supplement the 185,000,000,000 zl. to be raised from the Polish people themselves to finance the six-year plan.

TABLE X.—*Budget* Estimates, *1950–56*

(In millions of zlotys)

	1950	1951*	1952	1953	1954	1955	1956
Revenue	1,265,800	55,972	63,787	101,070	115,350	122,000	141,310
Expenditure	1,265,800	51,891	62,876	97,126	103,480	114,900	136,869
Investment†	...	21,800	26,000	49,432	53,600	60,800	73,400

*From 1951 in new zlotys. On Oct. 28,1950, the zloty was revalued and brought at par with the Soviet rouble. The new exchange rates were (old in parentheses); £1 = 11.20 (280) zlotys, $1 = 4.00 (100) zlotys. †Part of budget expenditure, extracted from figure.

German reparations were also expected to assist the industrialization of Poland. On Aug. 2, 1945, at Potsdam, Stalin undertook to settle reparations to Poland from the Soviet share. On Aug. 16, 1945, a reparations agreement with the Soviet Union was signed in Moscow, according to which Poland was to receive 15% of all reparations obtained by the U.S.S.R. from Germany. In May 1950 the Soviet government, in agreement with the Polish government, announced the reduction of German reparations. They estimated that by the end of 1950 the German Democratic Republic would have paid an estimated $3,658,000,000 (western calculations estimated a much higher figure) on account of total demands of $10,000,000,000. The sum of reparations still to be paid was reduced by 50%, namely to $3,171,000,000. By the end of 1953 the U.S.S.R. and Poland renounced any further payment of reparations. The amount of the Polish share was not published.

During the visit of Gomulka to Moscow, in Nov. 1956 (see above), the Soviet government agreed to consider as settled as from Nov. 1, 1956, Poland's indebtedness for the credits granted to it by the U.S.S.R., which, on that date, amounted to 2,300,000,000 rb. ($575,000,000). By agreeing to this cancellation the Soviet government indirectly recognized the Polish claim that by delivering to the Soviet Union during 1946–53 about 50,000,000 tons of coal at a nominal price of $1.25 per ton Poland actually lost about $737,500,000. In addition the Soviet government agreed to grant Polanda new long-term credit of 700,000,000 rb.

Foreign **Trade.**—The transition from a mixed to a Communist economy was paralleled by important changes in the economic relations of Poland. The six-year plan was largely dependent upon a vast program of capital investment and the production of capital goods, requiring loans and equipment from abroad as well as an unprecedented internal effort. Poland was to pay principally with coal and goods to be manufactured by the industries developed, particularly iron and steel, shipbuilding and textiles. Relations continued to develop with the U.S.S.R. and other people's democracies.

The Soviet Union was not the only source of assistance in the three-year and six-year plans. The United Kingdom was supplying Poland with a variety of goods, including machinery, machine tools, ships, etc., in return for food and other products. The Scandinavian countries, Switzerland, Austria, the Netherlands, Belgium, France and Italy, anxious to obtain Polish coal (which had little to fear from the competition of the pre-war British and German exporters), all made important contributions to Poland's planning. By the early 1950s, however, increasing political differences induced the countries of the North Atlantic Treaty organization to curtail the export to Poland of goods classified as strategic.

In 1948 the Soviet share in Polish foreign trade amounted to 22.1%, that of people's democracies 19.2%; in 1954 these propor-

TABLE XI.—Estimated *Distribution of* the Polish Trade Turnover

(Exports plus imports; in millions of U.S. dollars)

Trading partners	1937	1948	1952	1953	1954
U.S.S.R.	5	230	530	540	660
German Democratic Republic	20		220	240	270
Czechoslovakia	20		150	190	150
Hungary	5	10	80	80	50
Rumania	5	10	20	20	20
Bulgaria	5	15	20	20	20
Other countries in the eastern group*	...	...	30	40	50
Total with all eastern groups	60	430	1,050	1,130	1,220
Western Europe†	280	530	430	390	370
Overseas countries	130	80	120	90	180
All countries	470	1,040	1,600	1,610	1,770

*Communist China, Mongolia, North Korea and Albania.
†According to trade statistics of western European countries.
Source: United Nations, ***Economic Survey** of **Europe**,* 1954 and 1955.

tions rose respectively to 37.3% and 31.6%. At the same time Polish trade with western Europe and the overseas countries decreased from 58.7% to 31.1% of the total turnover. (See Table XI.)

In April 1956 it was revealed in the debates of the Polish parliament that in the previous year 51.7% of Polish imports consisted of raw materials, and crude petroleum and products; 30.9% of machinery and industrial equipment; 13.1% of foodstuffs and 4.370 of other consumer goods. Exports comprised coal and coke (46.6%), raw materials (17.8%), machinery and transport equipment (13.1%), foodstuffs (15.3%) and other consumer goods (7.3%).

In 1955 the U.S.S.R. took 33.7% of Polish exports of coal, 19.7% of coke, 21% of rolled steel, 59.8% of zinc (55,000 tons out of a total of 92,000 tons), 71% of caustic soda and soda ash (36,800 tons out of a total of 51,800 tons), 57.8% of sugar, 72.6% of wool fabrics, 95.6% of railway rolling stock and 84.5% of ships. The Soviet part in the Polish imports in 1955 were as follows: iron ore 68.1%, crude petroleum 74.3%, petroleum products 27.1%, cotton 73.870 and grain 34.7%. In 1955 Polandimported machines and industrial equipment for a total value of 1,152,000,coo zl.. including 486,000,000 zl. (42.2%) from the U.S.S.R. (See also Table XII.)

TABLE XII.—*Trade by Principal Commodities*
(In thousands of metric tons, if not otherwise stated)

Imports			Exports		
Commodity	1954	1955	Commodity	1954	1955
Iron ore	4,105	4,407	Coal	24,235	24,299
Crude petroleum	463.2	544.9	Coke	1,927	2,240
Petroleum products	716.2	885.7	Steel, rolled	194.6	247.3
Cotton	93.8	95.2	Timber*	964	915
Wool	14.3	16.3	Cement	548	674
Hides and skins'	24.7	30.1	Sugar	540	372.3
Rubber (incl. syn.)	23	25.7	Cotton fabrics†	78,826	57,500
Wheat and rye.	1,204	1,154	Woolfabricst	7,354	5,800
Tobacco (tons).	7,225	11,900	Locomotives‡	259	237
Tea (tons)	1,567	2,020	Railway coachesf	265	277
Rice (tons)	8,743	30,588	Railway box cars‡	2,701	2,136
Shoes ('000 pairs)	635	1,050	Shipping5	...	148

*In thousand cubic metres. †In thousand metres. ‡Units. §In million zlotys.

While relations reached a very low ebb with the United States and became strained with the other western powers, Poland developed trade contacts with the middle east, with Indonesia and with Communist China. With the establishment of new shipping lines, Polish ships became an important factor in the carrying trade of the orient. The two great Polish port authorities, Gdynia-Gdansk and Szczecin-Swinoujscie, achieved major importance, rivalling Hamburg and Trieste in the trade of central Europe.

Transport and Communications — Therestored Poland inherited in 1918 three differing systems of communications, of which the Prussian was most highly developed, the Russian least so. The damage resulting from World War I and the Polish-Soviet war was very great. Roads were singularly ill provided, a disadvantage from which the country was still to suffer despite continuous road building between 1921 and 1939. Cpper Silesia. the economic heart of Poland, remained divided; and, although Danzig formed a customs union with Poland, the Baltic was not freely accessible until after the opening of the new port of Gdynia.

The shiit of frontiers in 1945 enriched the system of communications by bringing in the industrial areas of German Silesia and their outlet through the Oder valley, a region well supplied nith railnays, canals, rivers and roads. War damage was, however, higher than after World War I, and the period 1945–50 was occupied mainly with the work of reconstruction and the improvement of existing facilities.

Railway traffic in 1955 was as follows: passengers, 40,536,700,000 pass.-km. (as compared with 7,493,000,000 pass.-km. in 1938 in prewar territory); ireight, 70,107,800,000 ton-km. (20,371,000,000 ton-km. in 1938). The rolling stock in 1947 comprised: locomotives, 6,874 (5,477 in 1937); passenger stock, 7.796 (10,688 in 1937); freight cars, 144,453 (167,596 in 1937). In 1955 there were 26,985 km. of railways, including 3,862 km. of narrow-gauge track.

Licensed motor vehicles in 1955 were estimated, excluding the military, at 30.000 passenger cars and 57,000 commercial vehicles. *In* 1955 there were 267,611 km. of highways, including 98,679 km. hard surfaced.

The inland waterways have always been oi considerableimportance to Poland. By far the greatest stretches of inland navigation are provided by the Vistula and Oder and their main tributaries. The low sandy banks, the fast-flowing streams and the tendency to flood after the spring thaw necessitated regulation and canalization. The interconnecting glacial valleys provided means of linking by short canals a whole series of east-west tributaries and so, eventually, the main river systems of Germany. Poland and the C.S.S.R. Thus the Oginski and Royal canals (built in the 18th century. north and west of Pinsk) and the Augustow canal (built in 1825) joined the Vistula and Bug with the Niemen, Pripet and Dnieper. They were used between 1921 and 1939 for drifting Polesian timber westward, but later became part of Soviet territory. The Bydgoszcz (Bromberg) canal, built in 1914–16, was used for barge traffic between Germany and East Prussia; it linked Königsberg (Kaliningrad), now in Soviet territory, with the Oder and central Germany by way of the sheltered lagoons of the Baltic coast, the canalized Nogat distributary of the Vistula and the rivers Brda and Notec. This canal was linked in 1949 through Lake Goplo with the canalized river Warta. The Cpper Silesian coalfields are served by a canal leading into the Oder. In 1955 the total length of inland waterways amounted to 6,908 km.

In 1950, the total of 12,453,000 metric tons of exports overseas handled by all Polish ports, Gdynia-Gdansk accounted for 7,894,000 tons; in 1937 Gdynia and Gdansk alone loaded 12,973,000 tons of goods. The imports from abroad through all Polish ports in 1950 amounted to 3,215,000 tons, including 2,234,000 through Gdynia and Gdansk, as compared with 3,234,000 tons in 1937 for the last-named ports alone. In 1955 the total turnover of goods in all Polish ports amounted to 17,066,000 tons. Ships entered in all ports in 1955 totalled 7,913,000 gross tons (as compared with 9,664,000 gross tons in 1937 for Gdynia and Gdansk alone). In 1955 the Polish merchant navy had 147 ships (of 100 tons or over) totalling 316,000 gross tons (121,600 in 1939).

The Polish state-owned air lines, Lot, form part of the interlocking system of services linking the main cities of the Soviet bloc countries. In 1956 Lot maintained services to Moscow, Paris, Brussels, Copenhagen, Amsterdam and Athens. In 1955 Lot's traffic was 4,020,000 km. flown and 65,900,000 pass.-km.; the figures ior 1938 were 1,999,000 km. and 9,447,000 pass.-km.

The number of telephones in use was estimated in 1956 at 453,600 (as compared with 272,300 in 1937). In April 1954 there were about 2,671,000 radio receiving sets.

BIBLIOGRAPHY.—Glowny Urzad Statystyczny Rzeczypospolitej Polskiej, *Maty Rocznik Statystyczny, 1939* (Warsaw, 1939) and *Rocznik Statystyczny 1956* (Warsaw, 1956); F. Bujak, *The Economic Development of Poland* (London, 1925); W. Czerwiński, *Le Problème de l'indépendance économique de la Pologne* (Paris, 1932); R. Górecki, *Poland and Her Economic Development* (London, 193j); L. Wellisz, *Foreign Capital in Poland* (London, 1938); F. Zweig. *Poland between Two Wars: a Critical Study of Social and Economic Changes* (London, 1944); Charles S. Dewey, *Combined Report of the Quarterly Reports of the Financial Adviser to Poland* (Warsaw, 1930); E. Hilton Young, *Report on Financial Conditions in Poland* (London, 1924); Edwin W. Kemmerer, *Reports to the Polish Government* (Warsaw, 1926); R. E. Kimmens, *Poland: Economic and Commercial Conditions* (London, 192j, 1931, 1939); J. Taylor, *The Economic Development of Poland* (Ithaca, N.Y., 1952); T. A. Alton, *Polish Postwar Economy* (New York, 19j5; London, 1956). (*G.* W. S.; K. SM.)

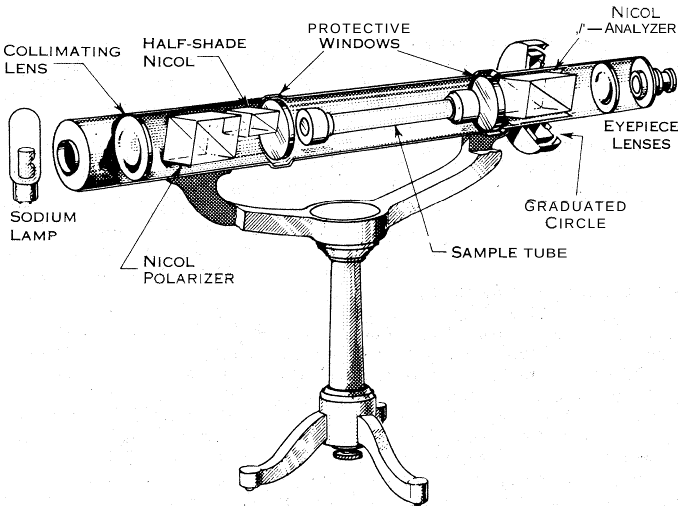
POLAR BEAR: see BEAR; CARNIVORA.

POLARIMETRY. Polarimetry is the science of measuring the angle of rotation of the plane of plane-polarized light (see LIGHT).

Polarimetry is primarily of interest to the chemist, because many compounds. either in the pure state or in solution. possess the power of rotating the plane of polarization of a beam of polarized light. The phenomenon is displayed by compounds, which lack a centre of symmetry in their molecular or crystalline structure, such that the compound and its mirror image are not superimposable. This situation most commonly results from the presence of a carbon atom which is covalently bound to four different atoms or groups of atoms. The angle through which the plane is rotated varies directly with the length of the light path through the sample, and in the case of solutions. with the concentration. For a given path length and concentration, the angle depends on the wave length of the light. the temperature, and the nature of the sample and its solvent, if any. Substances which are capable of producing this effect are said to be optically active. They are characterized by a constant known as the specific rotation, designated by the symbol $[\alpha]$ usually accompanied by a subscript letter to indicate the wave length and a superscript number for the temperature. Thus: $[\alpha]_D^{20}$ means that the value was determined at 20° C. with the D-line of sodium as light source. The specific rotation is defined by the relation,

$$[\alpha]=\frac{a}{dc},$$

where a is the observed angle of rotation in degrees, d is the length of light path through the sample in decimeters and c is the concentration in grams per milliliter.



FROM G. W. EWING, "INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS": BY COURTESY OF MC GRAW-HILL BOOK CO., INC.

DIAGRAM OF A CONVENTIONAL POLARIMETER

The angle of rotation is measured with a polarimeter (see figure). Monochromatic radiation, polarized by a Nicol prism, is passed through the sample and a second Nicol (the analyzer), to the eyepiece for visual observation. Between the first Nicol and the sample a small, auxiliary Nicol is so placed as to cause a slight modification of the polarization angle of one-half of the light beam.

This permits visual balance of the two half-beams at an intermediate level of intensity between dark and light, as the eye is most sensitive under such conditions.

The chief application of polarimetric analysis is in the sugar industry, since sucrose has a much greater specific rotation than impurities likely to be present. Many other compounds, principally organic, are optically active; some are of biological and pharmacological significance.

BIBLIOGRAPHY.—F. J. Bates, *et al., Polarimetry, Saccharimetry, and the Sugars,* National Bureau of Standards Circular C440 (Washington, 1942); George W. Wheland, *Advanced Organic Chemistry,* p. 130 *ff,* 2nd ed. (New York, 1949); Galen W. Ewing, *Instrumental Methods of Chemical Analysis,* p. 241 *ff* (New York, 1954). (G. W. E.)

POLARITY, a term used for discriminating between the positive and negative poles of an electrolytic cell or battery, or referring to the positive and negative terminals of direct current generators or dynamos. In the older conventional sense the electric current flows in these devices from positive to negative. In electrolytic cells positive and negative ions move in opposite directions inside the cell; in metallic conductors negative electrons move to the positive from the negative pole in the external circuit. (H. B. LM.)

POLAROGRAPHY (POLAROGRAPHIC ANALYSIS, VOLTAMMETRY), an electrochemical method of analyzing solutions of reducible or oxidizable substances, invented by Jaroslav Heyrovský at Charles university, Prague, Czech., in 1922.

The aqueous solution to be analyzed is placed in a glass cell containing two electrodes.' One electrode consists of a glass capillary tube (internal diameter about 0.05 mm. or 0.002 in.) from which mercury slowly flows in drops (dropping mercury electrodej, and the other is a pool of mercury or other nonpolarizable electrode. The cell is connected in series with a galvanometer for measuring the flow of current, in an electrical circuit which contains a battery, or other source of direct current, and a rheostat by means of which the voltage applied to the electrodes can be varied from zero up to about two volts. Usually with the dropping mercury electrode connected to the negative side of the polarizing voltage, the voltage is increased by small increments and the corresponding current is observed on the galvanometer. The current is very small until the applied voltage is increased to a value large enough to cause the substance being determined to be reduced at the dropping mercury electrode. The current increases rapidly at first as the applied voltage is increased above this critical value, but gradually attains a limiting value and remains more or less constant as the voltage is increased further. The critical voltage required to cause the rapid increase in current is characteristic of, and serves to identify, the substance being reduced (qualitative analysis). Under proper conditions the constant limiting current is governed by the rate of diffusion of the reducible substance up to the surface of the mercury drops, and its magnitude is a measure of the concentration of the reducible substance (quantitative analysis). Limiting currents also result from the oxidation of certain oxidizable substances when the dropping electrode is the anode.

In 1925 J. Heyrovský and M. Shikata invented an instrument called the polarograph, which automatically applies an increasing voltage to the dropping electrode cell and photographically records the resulting current-voltage curve. Curves thus recorded are called polarograms.

When the solution contains several substances that are reduced or oxidized at different voltages, the polarogram shows a separate current increase (polarographic wave) and limiting current for each. The method is thus capable of detecting and determining several substances simultaneously, and is applicable to relatively small concentrations, *e.g.,* 10^{-5} up to about 0.01 moles per litre, or approximately 1 to 1,000 parts per 1,000,000.

The majority of the chemical elements can be determined by polarographic analysis, and the method is applicable to the analysis of alloys and to various inorganic compounds. Polarography is also used to determine many types of organic compounds, and to study chemical equilibria and rates of reactions in solutions. A kind of volumetric analysis called voltammetry uses the polarographic principle for end-point detection in titrations.

BIBLIOGRAPHY.—I. M. Kolthoff and J. J. Lingane, *Polarography* (1952); *Chemical Reviews,* 24:1 (1939). (J. J. LE.)

POLAR REGIONS: see ANTARCTICA; ARCTIC. THE.

POLDING, JOHN BEDE (1794–1877), English Benedictine, first Roman Catholic bishop in Australia, first archbishop of Sydney. and a man full of zeal for the spiritual welfare of the isolated settlers of the new continent and of the numerous convicts who were constantly being shipped from England; was born at Liverpool on Oct. 18, 1794. He became a Benedictine monk and quickly rose to positions of influence and trust in his order. Consecrated as the first Australian bishop, he arrived at Sydney in Sept. 1835. There were but four Roman Catholic clergymen to meet him. The new bishop vigorously set to work dividing up his territory into missionary districts and providing priests, churches and schools as rapidly and extensively as he could: Visits to Europe enabled him to procure help for his people in various ways. From one of these visits he returned in March 1843 as archbishop of Sydney (appointed April 10, 1842). Kevertheless his kindness and humility were more evident than his administrative gifts. He died on hlarch 16, 1877.

See P. F. Moran, *History of the Catholic Church in Australasia,* (1894); H. N. Birt, *Benedictine Pioneers in Australia,* 2 vol. (1911). (E. McD.)

POLE (FAMILY). The family of the Poles, earls and dukes of Suffolk, which. but for Richard III's defeat at Bosworth. might have given the next king to England, had its origin in a house of merchants at Kingston-upon-Hull. The Poles were among the first English peers whose fortunes had been founded upon riches gained in trade.

William atte Pole (d. *c.* 1329). a merchant of Ravensrode, settled in Hull. His sons. Sir Richard and Sir William atte Pole, were both famous for their nealth.

Sir Richard (d. 1345), the king's butler in 1327. moved to London. and is styled a London citizen in his will. The male line of this, the elder branch of the Poles, failed with a grandson, John Pole, whose daughter was Joan, lady of Cobham, the Kentish heiress. whose fourth husband was Sir John Oldcastle the Lollard.

Sir William atte Pole (d. 1366). the second son of William, joined his brother in advancing large sums to the government while keeping safely apart from politics. The first mayor of Hull, he sat for Hull in five parliaments, and was advanced to be knight banneret and a baron of the exchequer. He was counted "second to no merchant in England," but after his time his descendants left the countinghouse, his four sons all serving in the French wars. The eldest son, MICHAEL DE LA POLE, 1st earl of Suffolk, who had fought under the Black Prince and John of Gaunt, became (1383) chancellor of England. In 138j he was created earl of Suffolk, a grant from the crown giving him the castle and honour of Eye with other East Anglian lands formerly held by the Ufford earls. In 1386 the opposition, led by Gloucester, the king's 'uncle, pulled him down. He was dismissed from his chancellorship, impeached, and convicted. Richard was forced to send his minister into ward at Windsor until the parliament was dissolved, when Suffolk once more appeared as the leader of the king's party. But the opposition was insistent, and Suffolk fled over sea to Calais. He died an exile in Paris in 1389.

The exile's son Michael, 2nd earl, was restored in 1397, died of dysentery at Harfleur, and his son Michael was killed at Agincourt. Michael was succeeded as 4th earl by his brother William. *(See* SUFFOLK, WILLIAM DE LA POLE, DUKE OF.)

John Pole (1442–1492), the only son of the 4th earl, should have succeeded to the dukedom, his father having died unattainted. But the honours were apparently regarded as forfeited, and the dukedom was formally restored to the boy in 1455, the earldom of Pembroke being allowed to lapse. He married King Edward IV's sister Elizabeth. The marriage confirmed him a partisan of the White Rose. Before he mas of age he was steward of England at his brother-in-law's crowning, and at Queen Elizabeth I's crowning he bore her sceptre. Having held many offices under Edward IV he was ready to bear a sceptre at Richard's coronation, and, after Bosworth, to swear fealty to the Tudor dynasty and to bear another sceptre for another Queen Elizabeth. He died in 1491, having safely kept his lands, his dukedom, and his head through perilous years. *(See* SUFFOLK, EARLS AND DUKES OF and POLE, RICHARD DE LA.)

Another family of the name of Pole. having no kinship with the house of Suffolk, owed their advancement and their fall to a match with a princess of the royal house. Sir Richard Pole, a Buckinghamshire knight. was the son of Geoffrey Pole, a squire whose wife, Edith St. John, was sister of the half blood to the mother of Henry VII. About 1490 or 1491 he married the Lady Margaret, daughter of George, duke of Clarence. He died in 1505, and in 1513 King Henry VIII created the widow countess of Salisbury, as some amends for the judicial murder of her brother, the earl of Warwick. Four years later, the barony of Montague was revived for her eldest son Henry. Until the king's marriage with Anne Boleyn, the countess of Salisbury was governess of her godchild, the Lady Mary. When her son. the famous Cardinal Pole, published his *Pro ecclesiasticae unitatis defensione* the whole family fell under the displeasure of the king, who resolved to make an end of them. The Lord Montague was the first victim, beheaded in 1538 on a charge of treasonable conversations, on evidence of his brother, Sir Geoffrey Pole. In 1541 the aged countess, attainted with her son Montague, was also executed. Sir Geoffrey Pole fled the country, and joined the cardinal in exile. He returned with him at Mary's accession, both dying in 1558. His sons Arthur and Edmund, taken in 1562 as plotters against Queen Elizabeth, were committed to the Tower of London, where they died after eight years of imprisonment.

See T. Rymer's *Foedera;* C. Frost, *History of Hull* (1827); *Chronicon de Melsa* (Rolls Series); G. E. *C., Complete Peerage; Testamenta Eboracensia* (Surtees Soc.); Hon. and Rev. H. A. Napier, *Swincombe and Ewelme* (1858); *Dict. Nat. Biog. s.v.* "Pole."

POLE, REGINALD (1500–1558), English cardinal and archbishop of Canterbury, born at Stourton castle. Staffordshire, in March 1500, was the third son of Sir Richard Pole and Margaret, countess of Salisbury, a niece of Edward IV. Intended for the church, he spent five years at the grammar school founded by John Colet at Sheen, where his kinsman Henry VIII contributed to the cost of his education. In his 13th year he went to Oxford. matriculating from Magdalen college. Thomas Linacre and William Latimer were among his tutors. He took his B.A. in 1515. In 1518 the king appointed him to the deanery of Wimborne and then to two prebends in Salisbury cathedral. In 1521 he went, with an annual grant of £100 from the king, to continue his studies at Padua, where during the next few years he corresponded with Desiderius Erasmus and formed friendships with Pietro Bembo, Christophe de Longolius, and other prominent humanists. He paid a brief visit to Rome for the 1525 jubilee.

Two years later he returned to England and was appointed dean of Exeter. He showed, however, little desire to desert his studies for a more active career; and it is possible that Thomas Cromwell, by recommending to him the precepts of Niccolo Machiavelli, helped to encourage this distaste for public life. When the question of Henry VIII's "divorce" from Catherine of Aragon arose, Pole at first sought to avoid taking part on either side. In 1529 he obtained the king's leave, and £100, to continue his studies at the University of Paris. The following year, however, by the king's order he helped to secure that university's pronouncement in favour of the divorce. On returning to England he was offered the archbishopric of York, vacant by Thomas Wolsey's death, but was required first to declare his opinion about the divorce, Henry not wishing to confer so great an honour upon an adversary. Pole suggested that he was ready to satisfy the king, but then apparently changed his mind, for in a stormy interview at York place he roundly denounced the royal policy. He later wrote to Henry. explaining his reasons against the divorce, and in,Jan. 1532 he received permission to go abroad again, without losing the revenues of his benefices. After a brief stay at Avignon, he settled once more at Padua and devoted himself to the serious study of theology. These studies soon led him to become a prominent member of the group of Catholic reformers, headed by Gasparo Cardinal Contarini, Giovanni Giberti and Giovanni Caraffa, who were eager to reform ecclesiastical abuses but regarded the maintenance of papal supremacy as necessary to preserve the unity of Catholic Christendom.

At this point in his development his relations with Henry VIII reached their crisis. In Feb. 1535, after the king's final break with Rome. Pole was called upon to make a formal statement of his opinion about the divorce and the royal supremacy. The executions of Bishop John Fisher and Sir Thomas More (June and July 1535) gave him grim warning of the fate which his answer might bring upon his family as well as upon himself; and the task of answering was not made easier by the genuine admiration which hitherto he had felt for Henry or by his reluctance to abandon all hope of reconciliation. Thus he took a year over writing his reply and by the time that it was dispatched to England (May 1536) it had grown into a full-sized book. Although later published, without Pole's consent, under the title *Pro ecclesiasticae unitatis defensione* (usually known as *De Unitate*). it was meant for the king's eye alone. It contained a severe attack on the royal policy and a strong defense of the pope's spiritual supremacy.

In July 1536, Paul III summoned Pole to Rome to serve with Contarini, Giberti, Caraffa and others on the commission to consider the reform of church discipline. After some hesitation, caused by letters from his mother and brother emphasizing the dangers that his conduct might lead them into. he eventually obeyed this papal call. In December he was made a cardinal and by Feb. 1537 the commission's report, *Consilium de emendanda ecclesia,* was completed. This most important document trenchantly summarized the outstanding abuses in the church and pointed to the remedies with plain-spoken directness. Pole's share in this notable work was hardly completed when a new task was thrust upon him. Paul III, who had already prepared a bull of deposition and excommunication against Henry VIII. now appointed Pole legate *a latere* for England and sent him to persuade the Catholic powers to take advantage of the difficulties created for Henry by the Pilgrimage of Grace. The mission was ill-timed and quite unsuccessful. The pilgrimage had been crushed almost before Pole left Rome (Feb. 1537); Francis I refused to let him stay in France; Charles V's representative would not admit him to the Netherlands; Henry would not negotiate with him in his capacity as papal legate; and in Aug. 1j37 the pope recalled him to Rome. A second mission in 1538–39 to persuade Charles and Francis to enforce the bull resulted in an equally humiliating failure and Pole. his life threatened by Henry's agents. sought refuge with his old friend Jacopo Sadoleto at Carpentras before returning to Rome at the end of 1539. Meanwhile the royal vengeance had fallen upon his family in England. His eldest brother, Lord Montague, and his cousin, the marquess of Exeter. were executed in 1538; his mother and he himself were attainted in 1j39; and his mother executed in 1541.

On Aug. 21. 1541, Pole was appointed legate of the *Patrimonium Petri*, the oldest of the papal states, and took up his residence at. Viterbo. There he gathered around him a group which included Marc-Antonio Flaminio and Vittoria Colonna. the poetess and friend of Michelangelo. With them he discussed many of the great theological questions raised by the German reformers and by the Spanish reiormer Juan de Valdes. Justification by faith, the burning question of the day. was a special subject of discussion. Pole's own attitude at this time may be best summed up in his advice to Vittoria Colonna, that she should believe as though she could be saved by faith alone and act as though she could be saved by works alone. His open-mindedness. the leniency of his rule at Viterbo, and his reluctance to abandon all hope of healing the divisions of Christendom were. however, by now beginning to separate him from Caraffa and those who felt that, after the failure of Contarini's negotiations with the Lutherans at Ratisbon (Regensburg) (1541), the time had come for sterner measures to defend and define the Catholic faith. Indeed, after the conversion to Protestantism in 1542 of Vittoria's friend Bernardino Ochino and of Peter Martyr, whom Contarini had defended. the newly established Roman Inquisition. headed by Caraffa, regarded the entire Viterbo circle as no better than heretics.

Nevertheless Pole was one of the three legates appointed in 1542 to open the Council of Trent and. when the council eventually met in Dec. 1545, he was one of the three who presided over its session. after journeying to Trent by a devious route for fear of assassins hired by Henry VIII. He urged the council very strongly to reform the abuses as well as to define the doctrines of the church and when the question of justification came up for discussion he entreated :he fathers to study the subject well before committing themselves to a final decision. Soon after this discussion began. however. his health broke down and he retired to Padua (June 1546). There is no reason to believe that this was a feigned illness. It is true that the council did not accept the compromise on justification that Contarini had put forward at Ratisbon and which Pole still favoured. Rut Pole kept in touch with its proceedings by letter; his view was well represented in the discussions by Seripando; and he accepted readily enough the decree that the council finally passed.

On the death of Paul III (Nov. 1549) Pole, thanks to Charles V's support, came near to election as pope. After hesitating to let himself he acknowledged by acclamation before all the French cardinals had arrived. he just failed to obtain the necessary two-thirds of the votes. In the end the French and imperialist factions compromised by electing Julius III. Under him reform made little headway. Pole lost his legacy at Viterbo (1550), was openly (though vainly) denounced by Caraffa for heretical leanings. and about 1553 retired to the monastery of Maguzzano on Lake of Garda.

However, on the accession of Mary Tudor (July 1553), the pope at once appointed Pole legate for England. Yet even now his course was not smooth. He had often been spoken of as a possible husband for Mary—he was still only in deacon's orders, so that a papal dispensation might have been obtained—and Charles V n-as therefore determined to keep him out of England until Mary's marriage to his own son Philip had been arranged. Moreover Pole himself thought this marriage a mistake! although he failed to convince the pope. Even when Philip and Mary were safely married (July 1554), other obstacles remained, notably the English parliament's insistence upon adequate guarantees that lay holders of confiscated church lands should not be disturbed. Thus it was not until Nov. 20 that he landed at Dover. Ten days later he formally absolved the realm and received it back into the Roman fold. On Dec. 24 he issued a decree guaranteeing holders of church property against all ecclesiastical censures, though he would not add that they might hold it with a clear conscience. On Philip's departure in Aug. 1j j5, Mary turned more and more to Pole for advice on all matters. He was not responsible for the religious persecution that disfigured the last four years of her reign, although he did nothing to stop it and occasionally himself issued commissions to repress heresy. First and foremost he was still the Catholic reformer. In Nov. 155j he assembled at Westminster a national synod of the two convocations. which quickly agreed to measures to enforce clerical residence, reduce pluralism, increase preaching, compel priests to set a good example to their flocks, and to provide a new book of homilies and a new translation of the New Testament. On Thomas Cranmer's deposition. Pole became archbishop of Canterbury (March 1556), after being ordained priest two days before, and sought to enforce these decrees by a metropolitical visitation. He also attempted to refound some of the monasteries and sent commissioners to carry out a visitation of the universities. All this work, however, went forward too slowly to take any firm root within the few short years of Mary's reign.

hloreover. Pole was thwarted by the papacy itself. In May 1555 Caraffa had become pope as Paul IV. He adopted a violent anti-Spanish policy which soon brought renewal of the war between France and the Habsburgs. Pole's efforts to prevent the conflict only infuriated Paul. In April 1557 he was deprived of his legatine authority and in June, after England's declaration of war on France. he was summoned to Rome. the aged William Peto being appointed legate in his place. At the same time the Pope inveighed against Pole as a heretic and handed his friend Cardinal Morone over to the Inquisition. Doubtless Pole would have shared this fate had Mary not prevented the delivery of the pope's summons. Instead, he remained in England until, broken as much by the unmerited blow of the papal disgrace as by ill-health, he died at Lambeth on Nov. 17, 1j58, 12 hours after Mary. He was buried at Canterbury, near the site of the shrine of St. Thomas à Becket.

BIBLIOGRAPHY.—G. Quirini's *Epistolarum* R. *Poli collectio,* 5 vol. (Brescia, 1744–57) also contains the liie written in Italian by Pole's secretary Beccatelli, which Andrew Dudith translated into Latin (*Vita Poli cardinalis*, Venice, 1563). *See* also A. Zimmermann, *Kardinal Pole, sein Leben und seine Schriften* (Repensburg, 1893); W. Schenk, *Reginald Pole, Cardinal of England* (London, New Eork, 1950). (R. B. WM.)

POLE, RICHARD DE LA (d. 152j). pretender to the English crown. was the fifth son of John de la Pole (1442–92), 2nd duke of Suffolk. and Elizabeth. second daughter of Richard. duke of York, and sister of Edward IV. His eldest brother John de la Pole, earl of Lincoln (c. 1462–87), was named heir to the throne by his uncle Richard III, who gave him a pension and the reversion of the estates of Lady Margaret Beaufort. On the accession of Henry VII Lincoln quickly submitted; but in 1487 he joined the rebellion of Lambert Simnel and was killed at the battle of Stoke. The second brother Edmund (c. 1472–1513) succeeded his father while still in his minority. His estates suffered under the attainder of his brother. and he was compelled to pay £5.000 to Henry VII for the recovery of part of the forfeited lands, and also to exchange his title of duke for that of earl. He fled abroad in 1499; returned in 1500; but fled again in 1501 and intrigued with the emperor Maximilian for an invasion of England. In 1502 Henry seized his brother William de la Pole, with four other Yorkist noblemen. Two of them, Sir James Tyrell and Sir John Wyndham, were executed. William de la Pole was imprisoned and Suffolk outlawed. Then in July 1502 Henry concluded a treaty with Maximilian by which the emperor bound himself not to countenance English rebels. Presently Suffolk, who had been attainted in 1504, fell into the hands of Philip, king of Castile. who imprisoned him at Namur, and in 1jo6 surrendered him to Henry VII on condition that his life was to be spared. He remained a prisoner until 1513, when he was beheaded at the time his brother Richard took up arms with the French king.

Richard de la Pole escaped overseas with Edmund in 1501, and remained at Xix as surety for his elder brother's debts. The creditors threatened to surrender him to Henry VII. but, more fortunate than his brother: he found a refuge with King Ladislaus VI of Hungary. He was attainted in 1504 and excepted from the general pardon proclaimed at the accession of Henry VIII. When England and France went to war in 1512 Louis XII recognized Pole's pretensions to the English crown and gave him a command in the French army. In 1513 after the execution of Edmund, he assumed the title of duke of Suffolk; he was also known as "White Rose." In 1514 he was given 12.000 German mercenaries ostensibly for the defense of Normandy, but really for an invasion of England. These he led to St. Malo, but the conclusion of peace with England prevented their embarkation. Pole was required to leave France and he established himself at Metz, in Lorraine, and built a palace at La Haute Pierre, near St. Simphorien. He had numerous interviews with Francis I and in 1523 he was permitted in concert with John Stewart; duke of Albany and the Scottish regent, to arrange an invasion of England which was never carried out. He was with Francis I at Pavia and was killed on the field on Feb. 24, 1525, so ending the male line.

POLE. For pole star *see* POLE STAR; for polar regions *see* ANTARCTICA; ARCTIC, THE; for magnetic poles *see* MAGNETISM. *See* also BATTERY; CRYSTALLOGRAPHY; GEODESY; GEOMETRY; POLE VAULTING; SPHERE.

POLE AND POLAR, in mathematics. If from a point P outside a circle the two tangents to the circle be drawn, the line joining the points of contact is called the *polar* of the point P, and P is called the *pole* of the secant line. If P is on the circle, the two tangents coincide and the polar of P is the single tangent at P. For Q, a point inside the circle, draw two secants to the circle through it. The line joining their poles is called the polar of Q. If the polar of P passes through Q, the polar of Q passes through P. In the figure shown, $\overline{AB}$ is the polar of P_1; $\overline{CD}$ is the polar of P_2; line *1* is the polar of A; P_1P_2 is the polar of Q. The same principle applies to any conic. In space there is a corresponding theory of points and polar planes as to a sphere or any fixed quadric surface. The idea is due to C. J. Brianchon, who first applied it in 1806, but it was developed by J. V. Poncelet, and presented in final form in 1829. Later the concept was extended to other curves and surfaces, and to other configurations.

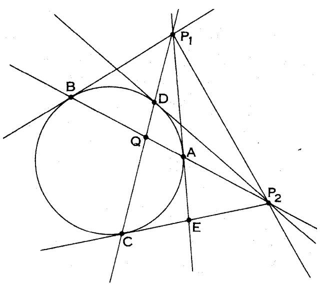
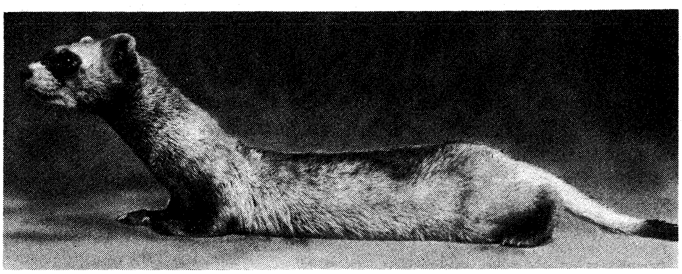


DIAGRAM ILLUSTRATING THE THEORY OF POLE AND POLAR PLANES (SEE TEXT)

POLECAT (FITCH), *Mustela putorius,* of the family Mustelidae. which also includes the weasel, mink, otter, etc. (*See* CARNIVORE.) Polecats are confined to the northern hemisphere, being found in the central and northern parts of the European continent, east to Siberia and Mongolia and south to the Himalayas. The polecat is well known in its domesticated, albino variety as the ferret. The wild polecat is dark brown above and black below, the face being variegated with white. The fur is long, coarse and of little commercial value. It is more powerful than the marten (*q.v.*) but less active and rarely climbs trees. Its food consists of small mammals and any birds it can catch, especially poultry. It also eats snakes. lizards, frogs, fish and eggs. It is extremely bloodthirsty and hunts at night. From three to eight young are produced in April or May, after a two months' gestation. It is tenacious of life and has a fetid smell.



BY COURTESY OF NEW YORK ZOOLOGICAL SOCIETY PHOTO

POLECAT OR BLACK-FOOTED FERRET (MUSTELA NIGRIPES)

On the central plateau of the United States is found the black-footed ferret, *M. nigripes,* a related species with creamy-yellow fur, brown legs and black feet and tail. A related genus, *Vormela,* whose fur is white marbled with reddish spots above, extends from east Poland to Afghanistan. These animals resemble M. *putorius* in habits. *See* also FERRET; WEASEL.

POLEMONIACEAE, the phlox family, consisting of bland dicotyledonous herbs. rarely shrubs or small trees, with about 13 species native in Europe, Asia and America, chiefly North America. Leaves are alternate or opposite, simple or compound, the flowers bisexual, mostly regular and often showy, especially in the garden forms. Among the well-known genera are *Phlox, Polemonium, Cobaea* and *Gilia.*

See PHLOX. (*J. M.* BL.)

POLENTA, DA, the name of a castle in Romagna from which came the noble and ancient Italian family of Da Polenta. The founder of the house is said to have been Guido. surnamed l'Antico or the Elder. who wielded great authority in Ravenna in the 13th century. His grandson Guido Novello upheld the power of the house and was also *capitano del popolo* at Bologna; he was overthrown in 1322 and died in 1323. In 1321 he gave hospitality to the poet Dante who immortalized the tragic history of Guido's daughter Francesca, unhappily married to Malatesta, lord of Rimini, in an episode of the *Inferno.* Guido's kinsman Ostasio I was lord of Cervia and Ravenna from 1322 to 1329, and, after being recognized as a vassal of the Holy See, again became independent and went over to the house of Este whom he served faithfully in their struggles with the church until his death in 1346. His son Bernardino who succeeded him as lord of Ravenna in 1346 was deposed in 1347 by his brothers, Pandolfo and Lamberto II, but was reinstated a few months later and ruled until his death in 1359; he was famous for his profligacy and cruelty. His son Guido III ruled more mildly and died in 1390. Then followed Ostasio II (d. 1396), Obizzo (d. 1431). Pietro (d. 1404) and Aldobrandino (d. 1406), all sons of Guido III. Ostasio III (or V), son of Obizzo, was at first allied with the Venetians; later he went over to the Milanese, and, although he again joined the Venetians, the latter never forgave his intrigue with their enemies and in 1441 they deprived him of his dominions. He died in a monastery in 1447.

POLESIE (POLESYE), at one time the largest and most sparsely populated province of Poland. Area. 14,219 sq.mi. Polesie was taken by the U.S.S.R. in 1939 and by Germany in 1941. After World War II Polesie became part of the Byelorussian Soviet Socialist Republic, U.S.S.R.

Polesie forms an eastward extension of the central Polish plain sloping up to the northern highlands and the plateau of Podolia. It forms the basin of the Prypet, a tributary of the Dnieper. The falls of the lower Dnieper hinder the drainage of Polesie, and the deepening of the channel of the Dnieper tends to dry up the Pinsk marshes. In spring the whole country is flooded. In reality it consists partly of marshes and lakes, partly of damp meadows with islands of clay or sand, on which most of the villages are built. In such a dreary plain the main feature is the vegetation, which consists of wide pine forests on the sand or on the swamps, with invading firs from the north, of mixed forests and birch groves. and of damp meadows grown with grasses, reeds and stunted willotvs. It is the only remaining home of the beaver in Poland, and the elk is still found there.

Polesie originally formed the early Russian principality of Turov or Pinsk. Conquered by the Lithuanians in 1320, it became, after the union with Poland in 1569, the province of Brest Litovsk. The northwest portion formed part of the estates of the great Polish magnates, the Radziwills and Sapiehas. Wolczyn was the seat of the Czartoryski family. The chief towns are Brest, pop. (1959) 73,000, the capital; Pinsk, the seat of an ancient Orthodox bishopric; Kobryn and Kamenets.

POLE STAR (POLARIS), the (naked-eye) star nearest the north celestial pole, is the brightest star in the constellation Ursa Minor (*q.v.*), hence its Bayer designation, α Ursae Minoris. The closeness of the star to the pole (minimum distance 27′.6 in the year 2102) causes its apparent position to remain nearly constant all night and all year. The location and moderate brightness of Polaris make it a convenient object for navigators and surveyors to use in determining latitude and north-south direction in the northern hemisphere.

Polaris. a single star to the naked eye, is a system of three stars. A faint companion is visible in a small telescope; spectrographic observations indicate the presence of a third star very close to the brighter of the visual pair.

The bright star is a pulsating variable of the classical Cepheid type, undergoing changes in diameter and in brightness during a four-day period. (EH. R.)

POLE VAULTING, the art of jumping over an obstacle with the aid of a pole. Originally a means of clearing objects, such as ditches, brooks and fences, pole vaulting for height, clearing a bar supported by two uprights set not less than 12 ft. apart. became a competitive sport. In competition, each vaulter is given three chances to clear a specified height. The bar is raised progressively until a winner emerges. Requirements of the athlete include a high degree of co-ordination, timing, speed and gymnastic ability. The pole may be of any material (most vaulters use bamboo or metal) and of any length or diameter. A slideway is sunk into the ground, the back of which is placed directly below the crossbar. Into this slideway the pole is thrust. A soft pit, generally of sawdust, is provided for the vaulter's landing.

The modern pole vaulter approaches the take-oif with great speed, carrying the pole with his hands about $2\frac{1}{2}$ ft. apart. As the stride, next before the spring, is completed, he performs the shift, which consists of advancing the pole toward the slideway (which is known as the advance) and at the same time allowing the lower hand to slip up the pole until it reaches the upper hand, and raising both hands as high above his head as possible before leaving the ground. He is thus enabled to exert the full pulling power of both arms to raise his body and help the swing-up of his legs. There are two factors the pole vaulter bears in mind —one is height and the other is carry. Height gives him the elevation, and carry takes him across the bar. It is noteworthy that this trick, perfected by Raymond G. Clapp of Yale university. New Haven, Conn., raised the world's record in 1898 to 11 ft. $10\frac{1}{2}$ in.; whereas, not employing the manual shift, H. H. Baxter of the Sew York Athletic club, in 1863, vaulted to a record of 11 ft. $\frac{1}{2}$ in.

The modern pole vaulter generally uses the following techniques: A long run of approximately 100 ft. to 130 ft., great speed donn the runway and exact timing when the shift takes place, so that his hands are extended high above his head at the minute of the take-off. He then runs off the ground (he does not jump) leaving his body hanging by the hands as long as possible, not pulling too soon. He then lets his legs swing upward and to the side of the pole. The athlete's feet should reach a point well above the crossbar, in an attempt to actually make a handstand. At this stage the vaulter shoots his legs high above the crossbar by means of a strong arm pull on the pole. He next turns his body face downward and converts his pulling force into a pushing force. The bar lies in the concavity of the stomach, so that his feet are on one side and his head and shoulders are on the other side. The athlete finally carries his body across the crossbar, by what is known as the carry, which is the speed he has acquired from his run.

Introduction of the bamboo pole, used with the modern technique, added approximately a foot to the records.

Astounding improvements in performance are best illustrated as follows: (1) H. B. Baxter (New York Athletic club), in 1883, 11 ft. $\frac{1}{2}$ in. (using old style). the first man to vault over 11 ft.; (2) Norman E. Dole, 1904 world's record, 12 ft. $1\frac{32}{100}$ in., the first man to vault over 12 ft.; (3) Robert A. Gardner (Yale university), at the I.C.A.A.A.A. games in 1912. 13 ft. 1 in.. the first man to vault over 13 ft.; (4) Sabin W. Carr (Yale university), at the I.C.A.A.A.A. games in 1927, 14 ft.. the first man to vault 14 ft.; (5) Cornelius Warmerdam (Olympic club), at Berkeley, Calif.. in 1940. the first man to vault 15 ft.; (6) John Uelses (U.S. Marine corps), using a fibreglass pole. at Santa Barbara, Calif.. In 1962. the first man to vault 16 ft.

Set: OLYMPIC GAMES; TRACK AND FIELD SPORTS.

BIBLIOGRAPHY.—H. A. Meyer, *Track and Field Athletics* (1955): Richard I. Miller, *Fundamentals of Track and Field Coaching* (1952)'.

(A. C. G.; SY. S.)

POLIANTHES, one of the florists' flowers, commonly called tuberose, probably derived from P. *tuberosa,* which is unknown as a wild plant. See TUBEROSE.

POLICE. In a broad sense, the term police connotes the maintenance of public order and the protection of persons and property from the hazards of public accidents and the commission of unlawful acts; specifically. it applies to the body of civil officers charged with maintaining the public order and safety and enforcement of the law. including the detection and suppression of crime. In its wider aspects, it included at one time such limited activities as street paving and lighting, or scavenging and sanitation, as well as applications broad enough to comprehend the entire range of the domestic policies of government. In modern usage, it comprises various inspectional, licensing and other regulatory activities.

Authoritarian states set up secret political police organizations that operate independently of the regular civil police establishments. Political police are always highly centralized agencies. The nazi gestapo and schutzstaffel, the tsarist ochrana, the soviet cheka, O.G.P.U. and N.K.V.D. and Mussolini's ovra all had common characteristics sharply distinguishing them from other civil police. Their governments, among others, came to be known as "police states." Democratic governments are also impelled to establish their security from subversive elements, but they do not hesitate to entrust it primarily to police forces charged with law enforcement in general. Popular governments permit much local autonomy in police administration while authoritarian states tend to centralize police control. but the intrusion of other factors also may produce centralized police control even under democratic patterns. England. Wales and Scotland have scores of local police forces, whereas the Republic of Ireland and the government of Sorthern Ireland each maintains but a single police establishment. Belgium has dual police systems for the national and local levels with municipal forces resting upon almost complete local autonomy, whereas in Denmark all police activities are administered by functionaries of the crown. For the most part, European countries followed the French pattern of a national police charged with the maintenance of public order, the investigation of all major crimes, and the full policing of the larger cities. together with locally recruited forces concerned with routine law enforcement duties, including local traffic control, in the smaller places. In some countries, such as France and Italy, a branch of the national police force also performs routine police duties in country districts. Japan, under a law of 1954, has centralized all police forces under the Sational Police agency; even so, a certain degree of autonomy as respects authority, administration and finance is left to the prefectural and larger municipal departments. In the United States and Canada, national and state (or provincial) police lie parallel to local police systems.

Police administration in the English-speaking countries has five major aspects: uniformed patrol, criminal investigation (detection of criminals), traffic regulation, special measures for controlling commercialized vice (liquor, narcotics! prostitution and gambling) and procedures and facilities for dealing with women offenders and juvenile delinquents.

United **States.**—Strictly speaking, the United States has no police system. It has about 40.000 police jurisdictions represented by the federal government, the states, the sheriffs and deputy sheriffs of 3,000 counties, a handful of county police forces independent of the sheriffs' offices. the police of 1,000 cities and occasional constables in more than 20,000 townships, magisterial districts or county districts. together with other minor forces in 15,000 villages. boroughs and incorporated towns. In addition, there are a number of special districts concerned with the patrol of parks, parkways, tunnels, bridges and aqueducts. In short, police administration follows the jurisdiction of the civil governments. whether federal. state or local. This produces serious internal strains since in a given area there may be as many as five or six levels of police administration, It also unduly complicates the task of co-ordinating investigations and other police activities. Central clearinghouses for crime records, criminal identification and police training and the vast interstate networks of police teletype and radio serve in part to overcome some of the more flagrant defects, however.

The total numerical strength of all full-time and part-time police in the service of these many jurisdictions was estimated at 295,000 in the latter 1950s. The well-defined trend is away from part-time police, particularly the township constables and deputy sheriffs; but when such as these are found to be inadequate, state and local governments still are prone to create new and additional police bodies without disposing of the outworn agencies.

Local police agencies range in size from only one or two part-time employees to a highly developed force of thousands in New York city. The ratios of police to population generally are highest in the largest cities and decline by graduated steps. Thus, in cities of more than 250,000 population the number of police per thousand of population was 2.4 in the latter 1950s; while in places of less than 10.000 population, the ratio was only 1.4.

Similar variations appear when geographic location is considered. New England led in police ratios for cities over 250,000 population, and the Pacific Coast for places under 25,000. Lowest ratios are most commonly found in the central states.

The general effect of such relationships to size and location is that police strength is not only disproportionately greater in those parts of the country having the larger urban centres. but it is in large degree actually concentrated in the big cities. Thus, of the total number of police employed in about 3,700 urban places more than half were concentrated in less than 50 cities with populations exceeding 250,000.

The inherent weakness of the smallest police establishments and the abdication of police authority by many rural functionaries combined to produce inadequate police defenses throughout most of the U.S. countryside. For many years this condition was ignored, but the advent of the motor age brought with it so many problems of crime control and traffic regulation that the ancient sheriff-constable system was quickly overwhelmed. A new type of police agency thereupon emerged—one destined to have a far-reaching influence upon the future development of police in the United States and upon the ultimate distribution of functions among local and state governments. The 19th century witnessed several limited and tentative experiments in state police administration—in Texas, Massachusetts and Connecticut—but it was not until 1905 that Pennsylvania established its state police force; and when New York and other large commonwealths followed at about the time of World War I, and shortly thereafter, success of the state police idea was assured. Because these agencies were in fact wholly new. they did not inherit the old United States police tradition, parts of which were thoroughly bad. Furthermore they were able to experiment with new devices for selection, training, promotion and discipline.

By the time of World War II every state had acquired a police agency of its own. Some of these were rudimentary in conception and limited in both authority and numbers. Some were charged merely with the patrol of state highways for the single purpose of traffic law enforcement. Others sprang into existence with broad enforcement powers exercised throughout great and populous states but especially in the rural areas where local policing was least adequate. Without exception, state police forces represented a break with the past and with the tradition of local autonomy in police management. But their numbers were nowhere great—and all told they did not total more than 25,000 in the service of the states. The establishment of state police was not accompanied by any large-scale abandonment of the outworn and outdated local police units.

The federal government also was drawn more and more into the police field, because it could not be expected indefinitely to entrust the enforcement of many federal statutes to local and state police bodies. The stresses of the Civil War brought several rudimentary investigative agencies into existence while an expanding field of federal regulation encouraged the development of others. In all but a mere handful of these, law enforcement was either auxiliary to other administrative activities or was performed within a narrowly restricted area or involved in the conduct of military or naval operations.

General police jurisdiction at the national level is exercised only by the Federal Bureau of Investigation, popularly known as the FBI. This select corps of criminal investigators has performed its various law-enforcement functions in such fashion as to encourage repeated additions to the scope of its responsibilities. Extensive crime laboratories and a uniform system of crime reporting for all jurisdictions in the United States and its possessions serve to round out the central services performed by the FBI for state and local law-enforcement agencies.

In a special category are the police patrols maintained by such federal agencies as the Tennessee Valley authority, while the police department of Washington, D.C.. is wholly unique on the United States scene. Commissioners appointed by the president administer the governmental affairs of this federal district and accordingly are responsible for law enforcement within its boundaries.

A prominent feature in a typical police force in the United States is the wealth of equipment, particularly for transportation and communication, Whatever the shortcomings of the various federal, state and local police systems, there can be no doubt that in the use of mechanical aids they lead the world by a wide margin. Also notable is the steady rise in police salary scales after 1910, the shortened work week and the increasing adoption of retirement systems. some established on a sound actuarial basis.

Great Britain. — Modern police administration in Great Britain stems from the establishment in 1829 of the metropolitan police in the sprawling urban and subdrban area surrounding the City of London. This extends in a wide circle of 700 sq.mi., most of it lying within a radius of 15 mi. from Charing Cross as a centre. The ancient City, however, is only 1 sq.mi. in area. is of limited resident population but of great wealth and importance and has never been a part of the metropolitan police district. With this exception. the metropolitan police district embraces all of London and Middlesex counties and parts of Surrey. Essex, Kent and Hertford, the whole including several score municipal and county boroughs.

Headquarters of the metropolitan force are at New Scotland Yard in the borough of Westminster on the Thames embankment—close by the offices of the national government and the seat of empire in Whitehall. The police commissioner of the metropolis is appointed by the crown, with the home office occupying the position of responsible police authority in all metropolitan police matters. The home secretary exercises direct control over this critically important agency for law enforcement in the nation's capital.

The commissioner of the City of London police is chosen by the mayor and aldermen, while in other cities and boroughs having their own police establishments, the watch committee of the city or borough council appoints the chief constable in each instance. Each county constabulary is under the control of a standing joint committee consisting of specially designated members of the county council and justices of the peace (quarter sessions). This committee selects the chief constable; but in counties, cities and boroughs alike, the choice of a chief constable must be ratified by the home office.

The early county constabularies were created around 1840, primarily for the protection of rural areas, but many now are also charged with responsibility for policing cities and boroughs, some of them of considerable size. This process of consolidation was going on for many years and was speeded up greatly by the exigencies of World War II. Further absorption of 45 of the 47 noncounty borough forces followed application of the terms of the Police Act of 1946. Another trend toward integration is marked by the device of placing a single chief constable in command of two or more neighbouring forces.

Authorized strength of the metropolitan police in the latter 1950s was nearly 20.000 with the separately protected City of London adding nearly 1,000 to the area's quota. In addition county constabularies with an authorized strength of about 30,000 and city or borough forces totalling about 22,000 were responsible for policing almost 500 cities: boroughs and counties in England and Wales. The Scottish establishment consisted of county constabularies with a total authorized strength of about 3,200 and borough forces aggregating nearly 4,500 men.

Ratios of police to population are highest in England, where in the latter 1950s there were 1.66 police per thousand of population as against Scotland's 1.49 and 1.39 in Wales. Some of this disparity is caused by the varying ratios of urban and rural population, some of it by special influences affecting the gravity of the local police problem.

Although the British police system is deeply imbedded in local political institutions. the national government nevertheless maintains a certain degree of surveillance over the administration of even the smallest borough forces and county constabularies and extends financial and technical aid in various important ways. This represents an effort to introduce some degree of unity and coherence into a system that in most respects is wholly decentralized. Hence, the home secretary (for England and Wales) and the secretary of stnte for Scotland may enforce standards of efficiency in all police establishments. They also control the conditions of police employment (appointment, promotion, discipline. compensation, etc.) through widely ranging regulations. Such controls are made effective by the grant-in-aid annually made to each police establishment, totalling one-half of the net cost of each force, including pensions. With the various forces thereby made dependent in large degree upon the national exchequer, it is provided that the grants shall be made only to those meeting the required standards. Annual visitations by her majesty's inspectors of constabulary (four for the home office,one for the Scottish office) operate to enforce compliance.

The national government provides various central facilities. It operates seven forensic science laboratories, district recruiting offices, regional networks for wireless communication and eight training centres serving a number of neighbouring forces. It also bears a special relationship to the metropolitan police that springs from the unique position and character of that force. For example, the metropolitan police force through its Special Branch is charged with certain imperial and national duties not readily performed by any other existing body. It is responsible for the protection of the royal family; the ministers of government and distinguished foreign visitors; the regulation of traffic and maintenance of order in the vicinity of the houses of parliament; the guarding of government buildings and special precautions taken at state functions; and protection against political agitators and sabotage. A special contribution of £100,000 a year is made from the exchequer for these purposes.

The metropolitan police force performs a widely heralded and generally misunderstood function in investigating certain crimes committed outside the metropolitan area. For the most part these excursions are confined to cases of murder; and since they are authorized only upon the request of the local authorities directly concerned, their number in any one year is small. A new branch was formed in 1954 to co-operate on country crimes committed by London criminals. The metropolitan police force also operates the Criminal Record office, a national registry of crimes and criminals, and publishes the daily *Police Gazette* which carries details of persons wanted for crime, and of stolen property and is distributed without charge to both British and other police forces.

BIBLIOGRAPHY.—Brian Chapman. articles on French and European police in *Public Administration* (Spring 1951), *The Journal of Criminal Law, Criminology, and Police Sciences* (Nov.–Dec. 1953) and *The Manchester Guardian* (Aug. 25 and 27, 1955); Police College, Japan, *The Japanese Police* (Ryton-on-Dunsmore, Eng., 1954); Bruce Smith, *Police Systems in the United States* (New York, 1940, New York, Toronto, 1949); Sir John Moylan, *Scotland Yard* (London, 1934); J. M. Hart, *The British Police* (New York, London, 1951); Her Majesty's Inspectors of Constabulary, *Police; Counties and Boroughs, England and Wales* (London, annual reports); also *Reports* of Her Majesty's Inspector of Constabulary ior Scotland (Edinburgh, annual); Federal Bureau of Investigation, *Uniform Crime Reports for the Cnited States and Its Possessions* (Washington, D.C., semiannual).

(BR. S.; L. GU.)

POLICE COURTS, courts of summary jurisdiction held in London and certain large towns in England and Wales by specially appointed and salaried magistrates.

Police magistrates are appointed by the Crown. They must be practising barristers for seven years or stipendiary magistrates for some place in England or Wales. One police magistrate has the same powers as two justices.

In the Cnited States there are no so-called police courts in the Federal system of courts except in the District of Columbia. where the President appoints, subject to confirmation by the Senate. two judges of the police court. In the various States, police courts, the presiding official of which is either a judge or a magistrate. were created for many cities. They are elected by the voters, and try the violators of municipal ordinances.

POLICE POWER is a term used in U.S. constitutional law to describe the permissible scope of state legislation. In spite of its importance. police power is not mentioned in the U.S. constitution; the concept was created by the courts to reflect the conclusion that an approved law did not violate specific constitutional prohibitions —especially the 14th amendment's provision that no state may "deprive any person of life, liberty or property without due process of lam."

During the decades immediately preceding 1937, while the U.S. supreme court was forcefully using the due process clause to outlaw social and economic controls, such as minimum wage and maximum hour laws, an important step in the court's reasoning was a narron definition of the police power. The freedom of labour to bargain was thought of as a liberty protected under the due process clause; an invasion of this liberty could be justified only by a proper exercise of the police power. The critical point in the court's reasoning was the further assertion that the state's police power existed only for certain limited objectives which the court frequently described as the promotion of "health, safety and morals."

Under this formula much social and economic legislation could be outlawed. Limiting the hours of work might not directly affect health. except in unusual situations such as underground mines and smelters; through this approach the supreme court in 1905 invalidated New York's 60-hour maximum work week for bakers. The court similarly concluded that minimum wage legislation did not fit under any of the permitted headings of the police power. Thus in 1923, the court invalidated the establishment of minimum wages for women, observing: "It cannot be shown that well-paid women safeguard their morals more carefully than those who are poorly paid." Even in cases where the police power was said to extend to "health, safety, morals and welfare," the court's early decisions indicated that it was physical, rather than economic or social, welfare which fell within the permissible scope for legislation.

In 1937, notably first in a decision upholding a Washington state minimum wage law (R'est *Coast Hotel Co.* v. *Parrish,* 300 U.S. 379). the supreme court sharply altered its approach to allow wide latitude for social and economic legislation; in the course of this development the court virtually abandoned the police power concept as a means of limiting legislative power. For example, in the 1952 *Day-Brite* case upholding a state law which required that workers be paid for time spent going to the polls on election day, the court's opinion declared that the police power "is not confined to a narrow category" but "extends to all the great public needs." Although the validity of aesthetics as a goal of regulation was once in doubt, the court in 1954 sustained a program of urban development, declaring that the state may legislate to make the community "beautiful as uell as healthy"; the goals of legislation may be "spiritual as well as physical, aesthetic as well as monetary." While police power as a concept for limiting governmental objectives thus was virtually abandoned by the supreme court, state supreme courts in construing their own state constitutional provisions in many cases continued the earlier approach which requires that legislation be justified under distinct and traditional headings.

Police power has occasionally been invoked to sustain rather than to invalidate legislation. This has been true in dealing with laws which impair the value of property, *e.g.,* by shutting down a still on the advent of prohibition or by restricting the use of property through zoning; the court has sustained such legislation on the ground that effective exercise of the police power justified the restriction. But this reference to police power is only another way of saying that constitutional provisions for the protection of property, such as those of the 5th and 14th amendments, cannot have been intended to block the necessary processes of government even though some financial loss may result In similar manner, the police power has been invoked in deciding whether laws, such as those suspending mortgage obligations in times of economic depression, violate the constitutional prohibition against impairing the obligation of contracts. In all these cases, resolving the question whether public or private interest must yield has called for balancing delicate and elusive considerations applicable to each individual case; the general concept of police power, although often invoked, has not in reality supplied the specific materials for decisions.

See also AMERICAN LAW: *Public Law;* CONSTITUTION AND CONSTITUTIONAL LAW: United States.

See E. Freund, Police Power (1904); C. B. Swisher, *American* Constitutional *Development,* ch. 32, 33, 37, 2nd ed. (1954). (J. O. Ho.)

POLIDORO CALDARA DA CARAVAGGIO: see CARAVAGGIO, POLIDORO DA.

POLIGNAC, an ancient French family, which had its seat in the Cevennes near Puy-en-Velay (Haute Loire). It can be traced to the 9th century, but in 1421 the male line became extinct. The heiress married Guillaume, sire de Chalanqon (not to be confused with the barons of Chalanqon in Vivarais), who assumed the name and arms of Polignac.

The first historically important member was Cardinal MELCHIOR DE POLIGNAC (1661–1742), a younger son of Armand XVI, marquis de Polignac, who became a distinguished diplomatist. In 1695 he was sent as ambassador to Poland, where he brought about the election of the prince of Conti as successor to John Sobieski (1697). In 1712 he was sent as the plenipotentiary of Louis XIV to the Congress of Utrecht. During the regency he became involved in the Cellamare plot, and was sent to Flanders for three years. From 1725 to li32 he acted for France at the Vatican. In 1726 he received the archbishopric of Auch, and he died at Paris in 1742.

Prince JULES DE POLIGNAC (1780–1847), son of Count Jules (d. 1817). played a conspicuous part in the clerical and ultraroyalist reaction after the Revolution. Cnder the empire he was implicated in the conspiracy of Cadoudal and Pichegru (1804). and was imprisoned till 1813. After the restoration of the Bourbons he held various offices, received from the pope his title of "prince" in 1820, and in 1823 was made ambassador to the English court. On Aug. 8, 1823, he was called by Charles X to the ministry of foreign affairs. and in November became president of the council. His appointment was taken as symbolical of the king's intention to overthrow the constitution, and, with the other ministers, he nas held responsible for the policy which culminated in the issue of the Four Ordinances uhich were the immediate cause of the revolution of July 1830. On the outbreak of this he fled for his life, but was arrested at Granville and condemned to perpetual imprisonment. The sentence was commuted to one of exile by the amnesty of 1836. During his captivity he nrote *Considérations politiques* (1832). He spent some years in England. but was permitted to re-enter France on condition that he did not live in Paris. He died at St. Germain on March 29. 1847.

POLISH LANGUAGE, Polish, the mother tongue of probably 30.000.000 speakers, belongs to the western group of the Slavonic languages (*q.v.*). Its first written records consist of proper names in Latin documents of the 12th century, and extant manuscripts containing any considerable amount of connected Polish text go back no earlier than the 14th century. The modern literary language may be dated from the 16th century. when the ferment of Reformation, Renaissance and Counter-Reformation produced the first outstanding Polish writers, such as Mikołaj Rej, Jan Kochanowski. Piotr Skarga and others associated with the Golden Age of Polish literature. Under their cultivation, Polish developed with astonishing rapidity into the refined instrument of literary expression that it has since remained.

Foreign influences on Polish have been numerous, but (except for the macaronic aberrations of the late lith and early 18th centuries) have been easily absorbed without harm to the integrity of the language. The introduction of Christianity brought not only Latin, but also Czech, the language of the first missionaries, into living contact with Polish. As an already developed literary language. Czech continued to enjoy high prestige among the Poles as late as the 14th and 15th centuries. and there are still Polish words whose form betrays their Czech origin, such as *hańba* "disgrace," *brama* "gate," *władać* "to rule." The large medieval German immigration and settlement in Polish cities is reflected in an extensive layer of the vocabulary. such as *ratusz* "town hall," *burmistrz* "mayor," *malarz* "painter." *handel* "trade," *rachunek* "account." *gmach* "building," *szlachta* "nobility" and many others (compare German *Rathaus,* Biiugermeister, *Maler, Handel, Rechnung, Gemach, Geschlecht*). Italian (at the time of the Renaissance), French (in the 17th and 18th centuries) and English have supplemented the Polish vocabulary. In addition; special mention should be made of White Russian and Ukranian influences, particularly as they penetrated into Polish through the works of writers from the eastern borderlands.

Polish shares with other West Slavonic languages a number of notable phonological characteristics, such as: (1) fixed stress accent—in Polish, on the penultimate syllable of the word; (2) nonpalatalization of Common Slavonic (CS) velars in forms like kwiat, *gwiazda*—compare Czech *květ, hvězda* and contrast Russian *cvet, zvezdá;* (3) the development of CS *tj,* dj to hissing, sounds, as in *świeca, miedza* (<CS **světja, *medja*)—compare Low Sorbian *swěca, mjaza* and contrast Russian *svečá, mežá;* (4) š (spelled *sz*) resulting from the second palatalization of CS *x,* as in *wszystek,* wszak—contrast the hissing sibilant in Russian ves', *vsjákij;* (5) preservation of dental stops before *l,* as in *wiódł, mydło*—compare Czech *vedl, mýdlo* and contrast Russian vel, *mylo.*

More or less peculiar to Polish, particularly in contrast to Czech and Slovak, are such phenomena as: (1) nasal vowels (spelled *ę, ą*), indirectly continuing the nasal vowels of CS. as in *mięso, trząść*—contrast Czech *maso, třásti;* (2) dispalatalization of CS *e, ě, ŕ* to o, a, *ar* before nonpalatalized t, d, n, *s, z, r* and *ł* as in zona, *wiara, twardy*—contrast Czech *žena, víra, tvrdý;* (3) palatalization of consonants (indicated in the spelling by i following the consonant letter) before e from CS front *jer*—contrast, for example, Polish pies, *dzień* and Czech pes, den.

The dialects, whose difference cause no practical difficulties in understanding. are customarily grouped into a few major types, notably Great Polish and Pomeranian, Silesian, Little Polish and Mazovian. In addition, Cassubian has come to assume the role of a Polish dialect although, historically speaking, it is not. The dialect base of the literary language, which displays some features associated with Great Polish and others associated with Little Polish, is still a matter of dispute.

BIBLIOGRAPHY.—*Grammars:* H. Grappin, *Grammaire* de la langue *polonaise,* 2nd ed. (1949); T. Benni, J. Łoś, K. Nitsch, J. Rozwadowski, H. Ułaszyn, Granzatyka *języka* polskiego (1923); W. Doroszewski, *Podstawy gramatyki polskiej 1* (1952); St. Szober, *Gramatyka języka* polskiego, 4th ed. (1957). *Dictionaries:* K. Bulas and F. J. Whitfield, *Kościuszko Foundation* Dictionary *I,* English-Polish (1959); K. Bulas, L. L. Thomas and F. J. Whitfield, *Kościuszko* Foundation Dictionary *II,* Polish-English (1960); J. Stanislawski, English-Polish and Polish-English Dictionary (n.d.); S. B. Linde, Skownik *języka* polskiego, 2nd ed., 6 vol. (1854–60; repr. 1952); J. Karłowicz et *al., Słownik języka* polskiego, 8 vol. (1900–27; 1932); T. Lehr-Spławiński, Skownik jgzyka polskiego, 2 vol., A–N (n.d.); W. Doroszewski, St. Skorupka et *al., Słownik języka* polskiego *Polskiej Akademii Nauk* (1958 et seq.); Fr. Stawski, *Słownik etymologiczny języka* polskiego (1952 et *seq.*). History: J. Łoś, *Gramatyka* polska, 3 vol. (1922–27); T. Lehr-Spławinski, *Język polski: pochodzenie,* powstanie, *rozwój,* 2nd ed. (1951); Z. Stieber, *Rozwój fonologiczny języka* polskiego (1952); Z. Klemensiewicz, T. Lehr-Spławiński, St. Urbańczyk, Granzatyka *historyczna języka* polskiego (1955). Dialectology: St. Urbańczyk, *Zarys dialektologii polskiej* (1953); J. Karłowicz, *Słownik* gwar *polskich,* 6 vol. (1900–11). Polish in *the United* States: W. Doroszewski, *Język polski w Stanach Zjednoczonych* Anzeryki *Północnej* (1936). *Manuals:* M. Corbridge-Patkaniowska, Essentials *of* Polish *Grammar* (1944) and Teach *Yourself Polish* (1950); J. A. Teslar, *A* New Polish *Grammar,* 5th ed. (1917); Z. M. hrend, A Polish Phonetic Reader (1921).
(F. J. WD.)

POLISH LITERATURE. Although Poland's historical presence in Christian Europe dates from the 10th century. Polish literature was late in emerging. This was because of Poland's geographical remoteness from cultural centres and the difficulties that assailed the young state. frequently attacked from without by plundering invaders and weakened from within by division into small principalities; an additional factor was the foreign clergy.

THE MIDDLE AGES

Latin Remains. — Just as in other European countries, Latin was at the beginning the only literary language in Poland Early writings were confined to lives of saints such as the life of St. Wojciech or Voytech (Xdalbert), the first Polish martyr (d. 997), probably written by his brother, a Czech (a 12th-century version was undoubtedly already Polish). The 13th century brings two tales of the life of Stanisław of Szczepanów, uhose story bears a great similarity to that of Thomas à Becket. Ecclesiastics are also the authors (in Latin again) of the beginnings of historical writing which took the form of annals and chronicles. An anonymous author called Gallus, a Frenchman most probably, wrote a biography of King Bolesław III Wrymouth in the *chanson de geste* style brought up to 1113. Wincenty Kadłubek (1160–1223), an ecclesiastic who studied in Paris. wrote a chronicle with all the characteristics of an allegorical, devotional romance in a very artificial and florid style. The so-called *Chronicle of Great Poland* relates events up to 1271. The masterpiece among chronicles is the *Historia Polonica* written by Jan Dlugosz (*q.v.;* 1415–80). It is the first and. for centuries, the only attempt at a systematic and scholarly history of mediaeval Poland.

The 15th century produced a lay writer and the first man openly to criticize the church in the person of Jan Ostroróg (1436–1501), author of *Monumentum . . . pro Reipublicae ordinatione.* The first Polish lay poet, Stanislaw Ciolek (1382?–1437), wrote court poetry on a European pattern.

Polish Remains. — The vernacular was at first only admitted by the church in circumstances where Latin could not meet particular needs. It was used in prayers, sermons and songs The oldest Polish literary text is a song in honour of the Virgin Mary, the *Bogurodzica;* its archaic language is used with high artistic craftsmanship. Although it belongs to the category of church hymns, it may be presumed to be an original work, no Latin prototype ever having been found. The first copy dates from the 14th century but it was probably written much earlier.

The practice of preaching became established toward the end of the 13th century when the Polonization of the clergy made itself felt. The *Sermons of the Holy Cross,* the oldest specimen of Polish prose, odd scraps of six sermons, dates from the end of the 13th or the beginning of the 14th century.

The first translation of a psalter which has been preserved (the so-called *Psalter of Queen Jadwzga)* dates from the end of the 14th century and the text is in three languages Latin. German and Polish (the latter probably a copy of an earlier manuscript). Jędrzej of Jaszowice the chaplain of Queen Sofia. widow of King Władysław II Jagiello, made a thorough translation of the Bible in 1455, but only parts have been preserved. This again was based on an earlier, now lost, translation.

The natural supplement to those works were the Polish lives of saints, legends and apocrypha. *The Meditation on the Ltfe* of *Our Lord Jesus* appeared in manuscript form at the end of the 1 jth century. *Raj duszny* ("The Soul's Paradise," 1513), a prayer book by Biernat of Lublin. is the first book printed entirely in Polish

Toward the end of the 15th century devotional literature is supplemented by secular works. Song literature is represented by a song directed against "the Roman Antichrists" written by Jędrzej Gałka, a follower of Wycliffe and Huss. The highest literary standard was achieved in a work of morality poetry, the *Dialogue Between Master and Death,* satirical and grotesque.

Mediaeval literature was slow in disappearing in Poland and some of its characteristics lived on well into the 16th century. Marcin Bielski (1495–1575), although a Proteslant in creed, was one of the representatives of late mediaevalism. He was :he author of the *Kronika uszystkiego Swiata* ("Chronicle of the World," 1551), the first book on general history in Polish.

This period shows no original characteristics: its literature is but a peripheral part of the western European Christian literature. It produced no outstanding work of universal appeal and it lacked certain genres (*i e.,* chivalrous poetry). After a very slow and difficult start, there was a sudden leap forward at the time of Casimir III the Great. a catching-up with the rest of Europe. It was rnarked less by literary works than by the appearance of a greater number of thinkers and men of learning such as Paweł Włodkowic (d. 1435).

RENAISSANCE

The Renaissance reached Poland comparatively late, lasted for a shorter period than in other countries but flourished abundantly; hence the name "golden age" given to it. This blossoming was caused by several factors such as external security, constitutional consolidation and the disturbance caused by the Reformation. All this occurred because of close contact with the west, above all with Italy whence came the inspiration of two generations of poets, the first continuing to write in Latin, the second using both Latin and Polish.

The First Generation of Humanists. — The humanists made their appearance at a time when the lingering echoes of mediaevalism still resounded. Among them were Andrzej Krzycki (1482–1537), chancellor, bishop and primate, author of witty, satirical, sometimes frivolous epigrams and courtly panegyrics as well as of touchingly sincere religious poems and of political verse; and Jan Flachsbinder, known as Joannes Dantiscus (1485–1548), a courtier, diplomat, author of incidental verse, love and panegyrical poetry, who gained laurels in Vienna for his political and moral epistles. The dominating figure of this group was Klemens of Januszkowo (Janicius, 1516–43), the son of a peasant. student at the university of Padua, poet laureate and the first true poet in Poland. His tender elegies, in the manner of Tibullus and Ovid, bear the mark of his personality, full of deep emotion and melancholy.

On the Border Line of Two Epochs: **Rej.**—Between the two generations of Renaissance humanists looms the massive personality of Mikołaj Rej of Nagłowice (1505–68). A self-educated man of extreme vitality and of the greatest literary force, he reflected the clash of two ethical ideals, the mediaeval and the Renaissance. He is the first truly original writer in Polish and the first widely read writer of his time; hence his right to the title of "the father of Polish literature." He wrote numerous works in verse and a large collection of satirical epigrams called *Figliki* ("Trifles," 1574). But Rej is above all a prose writer with an extremely rich, vivid, expressive and individual style, his most representative works being his *Postilla* (1557), a collection of sermons written from the Calvinist point of view, and the *Żywot człowieka poczciwego* ("Life of an Honest Man." 1568). This narrative of an average nobleman's life contains an account of customs and conditions in 16th-century Poland, unique of its kind.

Kochanowski and the Second Generation of Poets. — Jan Kochanowski (1530–84) is the leading personality of this generation and of the whole period. The son of a country squire, he studied in Padua. He met Ronsard in Paris and became acquainted with his works written in French. Kochanowski wrote in Latin to the end of his life, but his importance lies in his numerous works in Polish. He was the first in Poland to attempt heroic-satirical poetry; he wrote the first Polish classical drama on a subject taken from the *Iliad, Odprawa posłów greckich* ("The Dismissal of the Greek Envoys," 1578). Best of all, however, were his lyrical works. His translation of the *Psalterz Dawidów* (1578) shows a happy blend of sensitivity and mastery of poetic form as well as the painstaking care of an accomplished philologist. The *Fraszki* ("Trifles"). of which he wrote about 300, are his most typically Renaissance works. displaying a vigorous joy of life with epigrammatic brevity and dramatic precision. The posthumous *Pieśni* ("Songs," 1 j86) in their great variety include love songs, patriotic songs and festive and meditative songs. The crowning work of Kochanowski, the first Polish masterpiece which can be put alongside the great European works, are the *Treny* ("Laments," 1580), the outcome of a crisis through which he passed after the death of his infant daughter and of his recovery of spiritual harmony. Kochanowski ranked as a classic already during his lifetime; he exercised an influence unrivaled until Mickiewicz.

Among poets in Kochanowski's circle Szymon Szymonowic (1558–1629) should be mentioned. A burgher of Lwów, educated in Cracow and abroad, he published a collection of *Sielanki* ("Pastorals," 1614), introducing to Poland a new kind of poetry inspired by the classics but instilled with original life and colour.

Renaissance Prose.—The 16th century's prose ranks with the poetry of the age and sometimes even surpasses it in vitality and range. The first place among prose writers writing exclusively in Latin belongs to Andrzej Frycz Modrzewski (1503–72). In his *De Republica emendanda* (1551–54) he evolved a bold concept of a social and political system which reached out far beyond the accepted ideas of his own time; it was based on the Christian principle of the equality of men before God and before the law. Polish prose of the period is represented by three outstanding men: Stanisław Orzechowski (1513–66), Łukasz Górnicki (1527–1603) and Piotr Skarga (1536–1612). Orzechowski was a controversialist who commanded a keen and artistically sure range of vocabulary and imagery, hitherto unknown in Poland. Górnicki, in his free and original version of Baldassare Castiglione's *Il Cortegiano,* which he transplanted on Polish soil and adapted to Polish conditions (1566). created, in aristocratic prose, the ideal of the Renaissance man. Skarga. a militant Jesuit, the first representative of the Polish Counter Reformation, wrote *Żywoty Świętych* ("Life of Saints," 1579), the most popular among the didactic works of old Poland Skarga's masterpiece, unsurpassed by anything in Polish Renaissance prose. was the *Kazania sejmowe* ("Parliamentary Sermons." 1597). This treatise was written by a royalist who saw his country's salvation in the strengthening of royal authority, the curtailing of the rights of parliament and the rejection of the Reformation. His prose has an extraordinary fervour.

The 16th century left a great wealth of historical writings, though none of them may be compared with Dlugosz' work. It also witnessed the beginnings of polemical writing, a characteristic of Polish literature which flourished until the collapse of the old Polish state. The most outstanding representatives of this type of literature are Cardinal Stanislaw Hose (Stanislaus Hosius, *q.v.;* 1504–79), author of *Confessio fidei,* translated into almost every European language, and, among the anti-Catholics, Szymon Budny (c. 1535–*c.* 1596), a member of the Polish Brethren, who wrote in language of great beauty. There appeared many translations of the Bible published by Protestants and Catholics alike. The Catholic translation (1593) by Fr. Jakub Wujek (1540–97) is the Polish counterpart of the authorized (King James) version and an outstanding literary work.

Polish literature in this period reflected Poland's position as a great poner, the evolution of the nobility as a ruling class and the economic prosperity of the country. It became a national literature expressing a fully awakened collective awareness and the ethos of a people, its love of rural life, sense of stability and a moderate optimism. It radiated strongly to countries east of the Polish border and above all to Moscow. Rej's *Postilla* appeared both in Russian and in Lithuanian. The Moldavian poet Miron Costîn wrote in Polish. In the west the culture of the Polish Renaissance was represented by men of high repute such as Nicolaus Copernicus *(q v.).*

BAROQUE

In contrast with the Renaissance, the baroque appeared in Poland very early, almost at the same time as in Italy. In 1564 Poland accepted the resolutions of the Council of Trent and invited the Jesuits to settle in the country. The baroque style and the attitude of mind that accompanied it were congenial to the Polish spirit. The baroque period engendered very considerable literary output, in spite of almost incessant wars.

Baroque **Poetry.**—An early representative, a forerunner even, of the poetry of this period is Mikołaj Sęp-Szarzyński (1550–81), a contemporary of Kochanowski. He died in his prime and left only one volume, *Rytmy* (1601), erotics, epigrams, religious and chivalrous poetry akin to the English "metaphysical poets."

Polish baroque had a special preference for two literary forms, the bucolic and the satire. The first is represented by Samuel Twardowski (1600–61) and his mythological pastoral *Daphnis* (1638), written in flowing octaves. In the same group Szymon Zimorowic (1608–29), with *Roksolanki,* graceful, tuneful and subtly intricate in form, represented a fresh development of the love lyric. Foremost among the satirists is Krzysztof Opalinski (1610–56), a haughty Polish magnate. His satires in blank verse are violently Juvenalian, keenly satirical and pessimistic.

A remarkable development of lyrical poetry produced two contrasting literary tenors. The first was a sort of rustic poetry of the gentry, praising country life and showing a markedly religious, though not very profound, attitude toward life; the second produced a poetry of extravagant conceits in the *seicento* manner. The first is represented by Wespazjan Kochowski (1633–1700), soldier and country squire; his *Psalmodia Polska* (1695) was written under the impact of John Sobieski's victory over the Turks at Vienna. In rhythmical, poetic and biblical prose, it is an outstanding work. The other contrasting line of baroque lyrics is represented at its best by Jan Andrzej Morsztyn (1613–93), a court dignitary and an able diplomat deeply read in Italian and French poetry. His *Psyche* is a free paraphrase of Giambattista Marino's work; he translated Corneille's *Cid* (1661) for the royal theatre. His court lyrics, mostly love poems of refined style and intricate form. achieved the peak of literary artistry in the baroque lyric. The palm for other forms of baroque poetry goes to Maciej Kazimierz Sarbiewski (1595–1640), a Jesuit and a poet laureate, for his Latin writings. His *Lyricorum libri* (1625) went through 36 editions in the 17th century and as many in later times. It was internationally known, particularly in England.

Heroic epics mere the ambition of the age. Torquato Tasso's *Gerusalemme liberata,* the classical example in this field. was brilliantly translated by Piotr Kochanowski (1566–1620) and inspired attempts at historic epic writing. Wacław Potocki (1625–96), a versatile and prolific writer. produced *Wojna chocimska* ("The War of Chocim"), a verse chronicle of great poetic vigour. Potocki practised all literary genres. including the short story and the novel in verse form.

Baroque Prose.—The prose of the period does not rise to the level of Renaissance prose or to that of the poetry of its own time. Memoirs are among the best writings of the age. This rich domain is best represented by two works: the first by Stanislaw Zółkiewski (1547–1620), *Początek i progres wojny moskiewskiej* ("The Beginning and the Progress of the Muscovite War," 1612). Żółkiewski's style is impressive in its monumental simplicity. Altogether different are the *Pamiętniki* ("Memoirs") of Jan Chryzostom Pasek *(c.* 1630–1701), a country squire whose writing displays spontaneity, liveliness and humour. Andrzej Maksymilian Fredro (1620–79) in his *Przysłowia* ("Proverbs." 1658), a collection of aphorisms. displayed keen understanding of human nature and reactionary political views. Stanisław Herakliusz Lubomirski (1636–1702), one of the most enlightened men of the time, in his *De vanitate consiliorum,* draws nihilistic conclusions from meditations on political systems.

Decadence and Indications of Change.—The age of baroque stretched into the middle of the 18th century. Its last stage, called after the two kings the "Saxon period." shows signs of decadence. also of the emergence of a nem classical style. The period was dominated by the personality of Stanisław Konarski (1700–73) whose writings forecast the coming changes. Konarski was a member of the Patres Scholarum Piarum, an advocate of 17th-century French classical poetry, a reformer of schools. of literary style *(De emendandis eloquentiae vitiis,* 1741) and of the decadent political system It li-as not until mid-20th century that this period nas fully appreciated. With the many contradictions it bore. it had produced an abundance of works and was an original contribution to the European baroque.

ENLIGHTENMENT

Close contact with western Europe, especially with France and to a lesser extent with England, for the first time in Polish history, characterizes the period of the Enlightenment. Certain ideas and tendencies of the second half of the 18th century coincided with the peculiar situation of Poland. The country, exhausted by the wars of the preceding century. burdened with a corrupt political system, was menaced by aggressive neighbours. Literature at this period is imbued with a desire to improve and reform, to strengthen the state against collapse and, at the least, to save Poland's national culture.

Drama. — The earliest significant event was the inauguration in 1765, on the king's initiative, of the first public theatre. Foremost among a line of playwrights inspired by Molière was Franciszek Zablocki (1750–1821), from 1779 the chief provider of stage plays. He practised the art of Polonizing foreign comedy plots successfully. instilling them with a Polish atmosphere and often a perfect poetical rendering. He wrote about 60 plays. Some, like *Fircyk* w *zalotach* ("The Dandy's Courtship." 1781), still delight modern audiences.

The comedies of Aleksander Fredro (1793–1876) are the crowning achievement in drama. Written toward the end of the period. their appearance coincided with the birth of romanticism in Poland. In them the influence of Molière and the more recent one of Carlo Goldoni were apparent.

Prose. — The writing of the age of Enlightenment was mainly didactic. Periodicals were important, above all the Monitor (first issue 1763). The most representative writers are Stanisław Staszic (1755–1826) and Hugo Kołłataj (Kollontaj) (1750–1812). Staszic, in his Przestrogi dla *Polski* ("Warning to Poland," 1790), voiced the need of moderate political and social reforms. Kołłataj placed his talent at the service of the Reform party both as a politician and as a writer. He advocated the "mild revolution" and was one of the authors of the constitution of May 3, 1791. His works attain the high standard of French 18th-century prose.

Two Principal Trends in Poetry. — Earliest of the poets of this period was Bishop Adam Naruszewicz (1733–96). His works are representative of the transition from baroque to classicism. He also won a place among the prose writers of the epoch with his important *Historia* narodu polskiego ("History of the Polish Nation." 7 vol., 1780–86). After Długosz, this was the second scholarly treatment of the subject. The central figure of the period was Ignacy Krasicki (1735–1801), prince-bishop of Warmia, truly European and modern in his writings. The latter include two comic-heroic poems, Satyry (1779) and Bajki i przy*powieści* ("Fables and Moral Tales," 1779). His Fables, epigrammatic in style, gems of conciseness and precision, are Krasicki's masterpiece outstanding among the poems of the age. Krasicki worked also as a novelist. His most important novel is *Doświadczyńskiego przypadki* ("The Adventures of Mr. Dośtviadczynski," 1776), the first Polish novel in the modern sense. Stanislaw Trembecki (1735–1812) equals Krasicki in clarity and is his superior in expressiveness of language. He wrote fables in the manner of La Fontaine, Anacreontics in the French manner as well as solemn odes and epistles.

The second trend in poetry is represented by a group of lyric writers whose rationalism is balanced or even outweighed by their sentimentality. The principal and most popular figure among them was Franciszek Karpinski (1741–182j). His love songs and pastorals, together with his religious songs, are still sung.

These two opposing trends were to outlast the partitions of Poland (1772–95). Classicism still lingered on. with its centre in Warsaw, gradually becoming formal and spiritless. The other trend was toward an expression of feeling. Its most, representative personality was Jan Paweł Woronicz (17j7–1829). His *Hymn* do Boga ("Hymn to God") strikes a note of religious and political prophecy which was later to become the creed of Polish Nessianism; this and others of his works brought the first indications of a tendency to idealize the past of the lost independent state.

From the spirit of Enlightenment sprouted a new and widespread cultural movement whose most imposing work was the *Słownik języka* polskiego ("Dictionary of the Polish Language," 6 vol., 1807–14) by Bogumił Linde (1771–1847). The personality which bridges the gap between the two eras. before and after the partitions, is that of Julian Ursyn (Ursin) Niemcewicz (*q.v.;* 1757–1841), the first Polish writer thoroughly acquainted with English literature. He was the first to write original *dumy* (ballads) under the influence of James Macpherson's *Ossian* and Thomas Percy; his *Śpiewy* historyczne ("Historical Songs," 1816) are a collection of historical ballads of a commonplace style but of great popular appeal. His Jan *z Tęczyna* (1825) is the first Polish romance in Sir Walter Scott's style.

The literature of the period of Enlightenment re-established a close contact with the west and, at the same time, became the mouthpiece of national awareness. Although mainly didactic in character, it reached high artistic standards and introduced hitherto unknown genres; Krasicki's Fables remains a work of lasting appeal. Although it was a literature of a community undergoing a severe crisis, it exercised an unmistakable influence on neighbouring countries (Krasicki on Russian, Czech and even Rumanian writers).

ROMANTICISM

The romantic movement began in Poland a quarter of a century later than in England and Germany, but it lasted longer than in any other European country. It coincided with a tragic moment in Poland's history, the loss of independence and the instinctive search for new sources of strength. Romanticism was to become one of them. It developed eventually into a distinct phenomenon, the most remarkable in Polish literature.

Romantic Poetry. — The publication in 1822–23 of two volumes of Poezje ("Poems") by Adam Mickiewicz (*q.v.;* 1798–1855) became a literary event of major importance. Mickiewicz was to become the leader of the romantic movement. The only author whose works do not show the influence of Mickiewicz was Antoni Malczeski (1793–1826), author of Maria, the first romantic tale in Byronic vein. The collapse of the national insurrection in 1831 drove the cultural élite of Poland into exile to France. This was the beginning of an experiment unique of its kind; the entire literature was born and shaped far from the mother country. The four greatest poets of the era, Mickiewicz, Słowacki, Krasinski and Norwid, were all refugees and all wrote in exile.

Juliusz Słowacki (1809–49), a romantic in the truest sense of the term, soon became Mickiewicz' rival. However. full recognition of his genius came long after his death. He began by writing poetical novels in the manner of Byron as well as excellent lyrical poems. As a counterpart to Mickiewicz' Dziady ("Forefathers") he published *Kordian* (1834), a drama of conspiracy and romantic spirit. The same applies to Anhelli (1838), again a counterpart to Mickietvicz' Ksipgi *pielgrzymstwa* ("Books of Pilgrimage"). Słowacki knew how to instill traditional forms with a new aesthetic content. *W* Szwajcarii ("In Switzerland." 1839) is a transformed pastoral. exalted to an unprecedented degree of subtlety; Ojciec *zadżumionych* ("The Father of the Plague-Stricken") discovered entirely new possibilities for the romantic poetical narrative. Much of his work comprises dramas written without experience of the stage and without the slightest hope of seeing them produced in a theatre. Nevertheless, these made Słowacki one of the greatest Polish dramatists. These plays show in turn his connection with the French romantic drama (Maria *Stuart, Mazepa*); with Shakespeare, whose work provided an experience intensely felt by Słowacki (*Balladyna,* a ballad in dramatic form with the charm of a fairy tale, and *Horsztyński,* which may be called the Polish *Hamlet*); with the antique tragedies (Lilla *Weneda,* the drama of a dying nation); and with Pedro Calderon (*Książę niezłomny,* a creative paraphrase of El *Principe* constante). The crowning effort of his dramatic ambition was the unfinished *Samuel Zborowski,* a bold transposition of historical and earthly events onto the cosmic plane. The last years of Słowacki's life were devoted to a poem of great length which he left unfinished — Krdl Duch ("The Spirit King," 1849). It is a lyrical and symbolic epic about the fate of a people! presented as the experience of a series of incarnations of the spirit of the nation.

Zygmunt Krasinski (1812–59) when 23 years of age published anonymously (as he did all his other works) *Nie-boska komedia* ("The Undivine Comedy," 1835). This play, making use of short, concentrated scenes (foreshadowing expressionism), presented, for the first time in Europe, the struggle of two social classes, two opposing outlooks and two civilizations. *Irydion* (1836), his second play, is a parable of Poland's fate, presented in the guise of a conflict between the Greeks and the Romans. The notion of Poland as the "Christ among the nations," a concept shared by most romantic writers and called Polish Messianism, is the subject of *Przedświt* ("The Dawn," 1843), a visionary poem.

The three poets—Mickiewicz, Slowacki and Krasihski — were very soon calied *wieszcz,* a term corresponding to the Latin *vates* ("national bard"). The genius of Cyprian Norwid (1821–83) was recognized only half a century later. He belonged to the second generation of Polish romantic poets, joined the writers in exile only in 1846 and became one of the most tragic figures among the refugees. During his lifetime he was completely misjudged and obscure. This lack of recognition resulted from the duality of his attitude. He accepted some of the romantic ideas while sharply criticizing others. He was an antirevolutionary and he opposed the Messianic delusion. Few of his works were published during his lifetime. Most of them appeared only in the 20th century, and an important collection of his lyrics, the *Vade mecum,* was published as late as 1953 in London. His life, his personality, his use of poetical language and the intellectual saturation of his poems are reminiscent of Gerard Manley Hopkins. His aesthetic ideas would place him among the Pre-Raphaelites; he foreshadowed symbolism in literature by inventing "free verse."

The lesser romantic *émigrés* formed the so-called Ukrainian school (the Ukraine played in Polish romanticism a role similar to that of Scotland in English literature). Bohdan Zaleski (1802–86) belonged to this group; his tuneful, playful poems, full of movement and light, owed a great deal to folk songs. Seweryn Goszczyhski (1801–76), a radical, conspirator and revolutionary and a romanticist of horror, wrote *Zamek Kaniowski* ("Kaniów Castle," 1828), a tale in verse with a distinct social bias.

Romantic Prose. — Prose writers in exile were outnumbered by poets. Among the novelists mention should be made of Zygmunt Milkowski (pen name T. T. Jez; 1824–1915), a writer with a very wide range of subjects which included folklore and the history of Balkan countries. The novel of the time is outshone by intellectual prose writing. Here the first place is taken by Joachim Lelewel (*q.v.;* 1786–1861), the most representative of the romantic historians.

Literary criticism is represented by Maurycy Mochnacki (1804–34), the first to outline the significance of the new romantic poetry and its national importance.

Writers in Poland. — Apart from Wincenty Pol (1807–72), representing the older generation, popular and superficial in his prolific writing of patriotic verses, a new generation of romantic poets emerged. Their activity was limited to closed, provincial circles which came into being because of the partitions. In Warsaw a large group of young, exuberant poets called the Warsaw Boheme was formed, but its activities were restricted by political pressure. The only noteworthy and more freely developed talent in this group was Teofil Lenartowicz (1822–93), who sang the praise of the countryside and the peasants of central Poland. In Poznań, under Prussian domination, in a traditionally unpoetical region, Ryszard Berwinski (1819–79) put in a meteoric appearance as a poet; he represented an extreme social radicalism. Kornel Ujejski (1823–97) lived in Lwów and is the author of *Skargi Jeremiego* ("The Lamentations of Jeremiah," 1847), a collection of elegies written under the impact of the tragic bloodshed during the peasant riots against the Galician landowners.

The situation of prose writers at home was the reverse of those in exile. Henryk Rzewuski (1791–1866), a genuine artist, belonged spiritually to the previous century; he wrote *Pamiątki Seweryna Soplicy* ("The Memoirs of Seweryn Soplica," 1839), a series of narratives on 18th-century themes evoking the atmosphere of the Polish baroque. Toward the end of the romantic period the first signs of a realistic tendency may be discerned. It is represented by the abundant output of Józef Korzeniowski (1797–1863). More important than his dramas, his folklore play *Karpaccy Gdrale* ("The Carpathian Highlanders," 1843) and his social comedies are his novels *Spekulant* (1846) and *Kollokacja* (1847), portraying the world of impoverished gentry in a remote countryside.

The dominating figure among the prose writers of the period is Józef Ignacy Kraszewski (*q.v.;* 1812–87), a giant of literary prolificacy (he published about 500 volumes of fiction, history, criticism, etc.). His most daring enterprise was a series of historical novels, covering the whole of Polish history from prehistoric times.

Romanticism made a deep mark, particularly as it appeared in a period in which literature played an exceptional role, not found in any other country or at any other time. It was not only the voice of the nation's awakened consciousness but its greatest asset, "a dominion over men's minds" which replaced government in the normal sense of the term. Polish romanticism, though oppressed by the realization of its special mission, produced works of the highest value and so far unsurpassed. They reached the homeland where they were prohibited and their possession and reading punished. Abroad they often provoked lively reactions. It may suffice to mention Mickiewicz' influence on Félicité de Lamennais and on the Slavonic literatures and George Sand's opinion when she compared Mickiewicz with Goethe and Byron. This exalted artistic estimation stood the test of time, though the practical implications of Polish romantic literature led to the disastrous insurrection of 1863.

POSITIVISM

This name was given to literature of the period which followed the year 1863. Polish positivism was a mood of practical thinking and action, a trend which expressed the rationalist reaction against romanticism and the domination of literature over life. "Work from the foundations" was the new realistic slogan. This meant the renunciation of armed resistance and the concentration of all energies on the preservation of the ideological and cultural assets of the nation.

Prose Works. — The natural consequence of this new outlook was the predominance of journalistic prose over poetry. Aleksander Swigtochowski (1849–1938) was a typical positivist commentator. He had a lucid and critical mind and he did not hesitate to draw radical conclusions from his beliefs. Together with the rest of the positivist Warsaw school of which he was the leader, he voiced democratic, anticlerical and antiaristocratic views.

Even historical prose of the time often had a polemical character. This was especially striking in Cracow, the second centre of Polish positivism. There a more conservative variety of the movement was represented by the so-called Cracow historical school. Michal Bobrzynski (1849–1935), its leading personality, was the author of the *Dzieje Polski* ("History of Poland," 1879) expounding the thesis that Poland's downfall was caused by its own shortcomings, by the absence of strong royal authority and by resulting anarchy.

Bolesław Prus (real name Aleksander Glowacki; 1847–1912) was both an essayist and a novelist. He represented positivism in its most noble and humanitarian form. He worked all his life as a journalist, ranks high among Polish short-story writers and is one of the most brilliant Polish novelists. *Lalka* ("The Doll," 1890) is the most outstanding novel of the time. It is an accomplished and vivid picture of Warsaw of Prus's time, with an intricate plot, presenting a large collection of characters drawn from every stratum of the community. The *Faraon* (1897) is an ambitious evocation of ancient Egypt. Eliza Orzeszkowa (*q.v.;* 1842–1910) was a woman writer of journalistic temperament who wrote on topics ranging from women's suffrage and the problems of general education to the Jewish question. The books of Henryk Sienkiewicz (*q.v.;* 1846–1916), the winner of the 1905 Nobel prize, were positivist in their aim of "lifting up the hearts" but in their subject matter they went back to the golden age and the baroque.

Toward the end of the period the somewhat tendentious didactic realism of Orzeszkowa and the idealizing realism of Sienkiewicz were supplanted by a more objective naturalism. Its principal promoter was Antoni Sygietynski (1850–1923), a shrewd and knowledgeable critic. Adolf Dygasinski (1839–1902) applied naturalist theories to his novels about animals and to his portrayals of peasant life. The most outstanding personality of this trend was Gabriela Zapolska (1860–1921), who with her many novels and plays belongs partly to the subsequent period. She ranks among the best of European playwrights of her period.

Poetry. — During this period there were only two poets of importance. Adam Asnyk (1838–97), a reflective lyricist of limited power and imagination, and Maria Konopnicka (1842–1910), a lyrical and emotional poetess who expressed her sympathy with the poor.

The period of positivism lasted barely a quarter of a century. In spite of its mainly utilitarian and defensive character it produced, particularly in the novel, works of great artistic value that thanks to Sienkiewicz became known throughout the world.

YOUNG POLAND

This movement is similar to those in western European countries. It denotes a large number of phenomena held together only by a general opposition to positivism. The dominating tone of this epoch was the return to the expression of feelings and to imaginative writing, hence its other name of neoromanticism. It aimed at freeing the arts from utilitarianism, hence a certain affinity with French naturalism and symbolism. Among the pioneers of the movement were Antoni Lange (1861–1929) and Zenon Przesmycki (1861–1944). Following in the steps of Sygietyhski they established again a close contact between Polish and foreign literature, particularly poetry. Both made translations from various languages; both furthered their aim by publishing critical essays. Przesmycki's greatest achievement was the spiritual "exhumation" of Norwid.

Poets. — The great lyricist of the time was Kazimierz Tetmajer (1865–1940). The first two series of his *Poems* (1891, 1894) met with a success as widespread as those of Mickiewicz' in the previous century. The main characteristics of Tetmajer's lyrics are his passionate yet very tender erotism, his nostalgia, disillusionment and pessimism put into an expressive, purposeful and concise form. But he also harboured a deep admiration for greatness and heroism which he expressed in a series of short stories entitled *Na skalnym Podhalu* ("Tales of the Tatras," 5 vol., 1903–10). A man who made his appearance earlier than Tetmajer but became known rather later was Jan Kasprowicz (1860–1926). He forsook didactic, naturalistic, revolutionary and antireligious poetry for lyrical writing of great inspiration in which he contemplated problems of life and death. The crowning work of his lyrical plays and collected poems was the volume *Ginącemu światu* ("To the Dying World," 1902). His *Księga ubogich* ("Book of the Poor," 1916) testifies to his inner harmony and his reconciliation with God and is remarkable for its moving simplicity. Close to Kasprowicz the entirely different talent of Leopold Staff (1878–1957) emerged. In this neoromantic period he is a representative of the classical trend. The dominant trait of his work is his capacity for compressing diverse and profound problems into precise and expressive poetic formulas. Beginning in 1901 with his volume of poems *Sny o potgdze* ("Dreams of Power"), Staff is a poet of extraordinarily long-lived creative force.

Novelists. — The most forceful personality among the prose writers was Stanislaw Przybyszewski (1868–1927). His early works were written in German. After his arrival in Cracow in 1898 he took charge of the periodical *Życie* ("Life"). There he revealed himself as a radical advocate of "art for art's sake" and an inspired prophet of modernism. By mid-20th century his works were outmoded. Of far more lasting value were the books of other prose writers of this age. The foremost personality according to the general opinion was Stefan (Stephen) Zeromski (*q.v.;* 1864–1925). As a result of his passionate interest in social and national problems his role was that of the "nation's conscience." His prose, both in short stories and in novels, displays certain affinities with naturalism, but his deep, sometimes overflowing lyricism, his impressionability and the archaic style of some of his works make him undoubtedly a representative of the neoromantic school. Wladyslaw Reymont (*q.v.;* 1868–1925) wrote novels and short stories dealing with everyday life, oscillating between naturalism and impressionism. His monumental epic, *Chłopi* ("The Peasants." 4 vol., 1904–09), was translated into every European language and he was awarded the Nobel prize in 1924. Just as *Chłopi* satisfied the craving for primitive, instinctive strength, so the novels and short stories of Wacław Sieroszewski (1860–1945) were an answer to the desire to escape mentally into exotic lands. Aesthetic escapism was represented by Wacław Berent (1873–1940).

Drama: **Wyspiański.**—Stanisław Wyspiahski (1869–1907) is supreme in the whole Young Poland movement. Painter, draftsman and designer of stained glass and typographer, he is next to Slowacki the greatest Polish dramatist. He created experimental scenic visions such as only a dramatist endowed with a great gift for the plastic arts and a vivid musical imagination could produce. He foreshadowed many of the revolutionary ideas of Edward Gordon Craig and was the true "artist of the theatre" *avant la lettre.* In his choice of subjects Wyspiahski turned to the problems of the romantic period, to Poland's past and present. He also took themes from Greek history. In two of his plays, *Wesele* ('(The Wedding," 1901) and *Wyzwolenie* ("The Deliverance," 1903), Wyspiański reached the peak of his inventiveness of artistic form and found the loftiest expression of his ideas. In the first, on the foundations of the primitive folk theatre, he created a visionary drama which he used as a vehicle for scathing criticism of the problems of his age. In the second he condemned romanticism and demanded a Poland of political reality, not one of poetical dreams. Thus Wyspiahski became the poet of the Poland that was to be reborn ten years after his death.

Close contact with western European literatures is characteristic of this period. The new generation of writers turned back to the Polish romantics, especially to Slowacki and the newly discovered Norwid, hence its Promethean tone not encountered in other literatures of the time.

RESTORED INDEPENDENCE

Normal conditions of existence, for which poets and prose writers had been fighting for more than a century, decisively affected the literary output and brought a change in its character.

Poetry. — For nearly the whole of the first decade, poetry predominated. A periodical called *Zdrój* appeared in Poznah which displayed certain connections with German expressionism. During the first stage of his career Józef Wittlin (1896–) was a member of this group. He is author of the stirring *Hymns* (1920), depicting the horrors of war, and of *Sdl ziemi* ("The Salt of the Earth." 1935), a novel portraying war experiences through the eyes of a humble man.

In Warsaw several young poets of different leanings formed a group called Skamander. This group had no general program, but was held together rather by the enthusiasm of its members arising out of the new situation. It introduced, however, new thematic, atmospheric and formal elements. The group was headed by Julian Tuwim (1894–1954), a lyricist of unusual emotional power as well as of extreme linguistic sensitivity. Kazimierz Wierzynski (1894–) gave the most striking expression to the intoxicating joy of the new life. His *Laur olimpijski* ("Olympic Laurels") sang the praise of sport, health and physical beauty. The poetry of Jan Lechon (1899–) treats of intellectual and national literary subjects rendered in a balanced classicist form. Antoni Slonimski (1899–) is yet another poet of that group, of a discursive and rhetorical temperament. Jarosław Iwaszkiewicz (1894–) showed himself to be an excellent prose writer. Among the sympathizers of the Skamander were Maria Pawlikowska-Jasnorzewska (1895–1945), the greatest poetess Poland had so far produced, with an exceptional gift for concentration, precision, control and objectivity in her emotional dispositions; Kazimiera Iłłakowiczówna (1892–), another poetess with a note of fantasy and mysteriousness in her poems; Stanisław Balinski (1898–), who strikes the romantic note of egotism and exoticism; and Władysław Broniewski (1898–1962), the poet of social revolution.

There were two other groups, equal in brilliance to the Skamander. Czartak, with an antiurban bent and a strong inclination toward country life and folklore, was headed by Emil Zegadlowicz (1888–1941), a poet, playwright and prose writer of great versatility but with a deplorable facility of writing. The Vanguard followed the steps of modern revolutionary trends in poetry which sprang up in France, Italy and Spain. This group contributed few really accomplished works, but it had a widespread influence upon the regeneration of poetical technique. Julian Przyboś (1901–), an exponent of this group, ranks among the best poets after World War II.

Prose. — Prose writing reached ascendancy in the second decade of independence. The works of Zofia Nalkowska (1885–1955) in their first period belonged to the Young Poland age and were a revelation of the feminine psyche. After World War I she turned to other themes, striving for objectivity in her narration and simplicity in literary technique. Ferdynand Goetel (1890–) came into the limelight after World War I, writing on his experiences in Russia during the Revolution (*Kar-Chat*), which he took up again in his novel *Z dnia na dzień* ("From Day to Day"). Zofia Kossak-Szczucka (1890–) began with the story of her experiences on the eastern border of Poland (*Poioga* ["The Blaze"], 1922) but later turned to historical novels. After World War II she lived in exile. Maria Kuncewiczowa (1897–) also continued writing in exile. She is the author of *Cudzoziemka* ("The Foreigner," 1935). The foremost personality among the prose writers of this period was Juliusz Kaden-Bandrowski (1885–1944). In his maturity he evolved a specific style of his own, a sort of realistic expressionism marked by a certain brutality. In this style he wrote the novel *Czarne skrzydła* ("Black Wings," 1921), set in the coal-mining areas, and the political satire *Mateusz Bigda* (1933).

The second decade brought several *romans-fleuves*. The most remarkable were written by women. The first was *Noce i dnie* ("Nights and Days") by Maria Dąbrowska (1892–). followed by *Krauzowie i inni* ("The Krauzes and Others") by Herminia Naglerowa (1892–). Both paint a vivid panorama of the life in central and eastern Poland in the second half of the 19th century.

Drama. — This literary genre was the weakest during this period. Włodzimierz Perzynski (1878–1930), a novelist who contributed realistic comedies, and Karol Hubert Rostworowski (1877–1938) with his poetical dramas both belong to the previous epoch. Toward the end of his career Rostworowski began writing plays in prose on social and moral problems in modern settings which at times attained the monumental grandeur of antique tragedies. Jerzy Szaniawski (1887–) was the third dramatist; he tried to give new meaning to the symbolist-lyrical drama.

The years of restored independence were a period of a rich and versatile literature which fully reflected the life of a free nation. It maintained a lively contact with western literature. Many translations from foreign languages, including English, were a proof of this interest.

COMMUNIST DOMINATION

Poland's subjugation to the U.S.S.R. inevitably produced a Polish literature in exile in addition to the one at home.

At Home. — During the first five years after World War II works were published in Poland that had been written secretly during the war. In general they represent the final stages of trends that developed during the country's political independence. The most striking are novels: *Mury Jerycha* ("The Walls of Jericho") by Tadeusz Breza (1905–); *Popidt i diament* ("Ashes and Diamonds") by Jerzy Andrzejewski (1909–); a novel of epic character, *Bolestaw Chrobry*, by Antoni Golubiew (1907–); and plays written by the adherent of Christian Personalism Jerzy Zawieyski (1906–).

The five years which followed bear the mark of the so-called social realism. This vague theory signifies in fact the subordination of literature to political directives and to Communist party control. No genuinely valuable work appeared during this time. The following may be considered above average: *Między wojnami* ("Between the Wars"), a trilogy by Kazimierz Brandys (1916–); and *Pamiqtka z Celulozy* ("A Souvenir of Cellulose") by Igor Newerly. The prevailing official doctrine exerted an even more disastrous effect on poetry. A partial deviation from the general rule may be noted in the works of Mieczysław Jastrun (1905–) and the prematurely deceased Konstanty Gałczyński (1905–45), whose poem *Niobe* is the only work of value to be born of the compromise between the doctrine of social realism and free poetical invention.

In Exile. — Literature in exile struggled against great odds. It was a literature of a political community dispersed all over the world. Among writers in exile were lyricists from the old Skamander group—Wierzyński, Lechon and Balinski, whose thematic and formal range had widened. From the circle close to the prewar avant-garde group there were three poets—Józef Lobodowski (1909–), whose work has been creatively enriched by Spanish and Spanish-Arabic lyric forms, Marian Czuchnowski (1909–) and Czeslaw Milosz (1911–). The two last are prose writers as well (Milosz won the Prix Littéraire Européen in 1953 for his novel *The Conquest of Power).*

Prose works were to a large extent dedicated to memoirs of the years spent in Soviet prisons and forced labour camps. Foremost among these from the literary point of view are *Between the Hammer and the Sickle* by Waclaw Grubinski (1883–) and *A World Apart* (1951) by Gustaw Herling-Grudzinski (1919–). Herminia Naglerowa's novel *The Case of Jdzej Most* is an artistic, strictly objective projection of the author's personal experiences in a Soviet prison. Novelettes by Czesław Straszewicz (1904–) and short stories in a picaresque style by Janusz Kowalewski (1910–) are an original contribution to postwar prose. They mark a reaction by the younger generation of writers against romantic pathos and the same may be said of *Transatlantyk* by Witold Gombrowicz (1904–), a satirical half novel, half memoir. Jerzy Pietrkiewicz (1916–), author of the *Knotted Cord* (1953), a novel written in English, is also a poet, playwright and historian of literature.

The essay occupies an important place and is represented by a number of writers such as Jerzy Stempowski (1894–), Tymon Terlecki (1905–). Wiktor Weintraub (1908–) and Stefania Zahorska (1896–). Mention should be made of the brilliant and passionate Zygmunt Nowakowski (1891–), columnist, novelist and playwright.

BIBLIOGRAPHY.—In Polish: G. Korbut, *Literatura polska* (1929–31), a general bibliographic compendium; addenda, contributed since 1951 by Maria Danilemicz in *The Year's Works in Modern Language Studies* (Cambridge); A. Brueckner, *Dzieje literatury polskiej w zarysie*, 2 vol., 3rd ed. (1921); K. Czachowski, *Obraz współczesnej literatury polskiej, 1884–1933*, 3 vol. (1934–36); M. Kridl, *Literatura polska na tle rozwoju kultury* (1945); J. Krzyianowski, *Historia literatury polskiej od średniowiecza do XIX w.* (1953).

In foreign languages: Marina Bersamo Begey, "Letteratura Polacca," *Le Lettere*, vol. ii (1944); B. Chlebowski, *La Littérature polonaise au XIXe siècle* (1933); R. Dyboski, *Modern Polish Literature* (1923), *Periods of Polish Literary History* (1924); J Kleiner, *Die Polnische Literatur* (1929); J. Krzyianomski, *Polish Romantic Literature* (1930); W. Lednicki, *Life and Culture of Poland* (1944); *The Sovietization of Culture in Poland* (1953); T. M. Filip and M. A Michael, *A Polish Anthology* (1944), a useful introduction to poetry and poetic prose; E. E. Ledbetter (comp.), *Polish Literature in English Translation* (1932). (T T. J. T.)

POLISH SUCCESSION WAR (1733–35), the name given to a war which arose out of the competition for the throne of Poland between the elector August of Saxony, son of August II (the Strong), and Stanislaus Leszcynski. the king of Poland installed 30 years before by Charles XII of Sweden and displaced by August the Strong when Charles's projects collapsed. The claims of Stanislaus were supported by France, Spain and Sardinia. those of the Saxon prince by Russia and the empire, the local quarrel being made the pretext for the settlement of minor outstanding claims of the great powers among themselves. The war was therefore a typical 18th-century "war with a limited object," in which no one but the cabinets and the professional armies were concerned. It was fought on two theatres, the Rhine and Italy. The Rhine campaigns were entirely unimportant, and are remembered only for the last appearance in the field of Prince Eugène and Marshal Berwick — the latter was killed at the siege of Philippsburg — and the baptism of fire of the young crown prince of Russia, afterward Frederick the Great. In Italy, however, there were three hard-fought — though indecisive — battles, Parma (June 29, 1734), Luzzara (Sept. 19, 1734) and Bitonto (May 25, 1735), the first and last won by the Austrians. the second by the French and their allies. In Poland itself Stanislaus, elected king in Sept. 1733, was soon expelled by a Russian army and was afterward besieged in Danzig by the Russians and Saxons (Oct. 1734–June 1735).

POLITIAN (1454–1494). Angelo Ambrogini, known in literary annals as Angelo Poliziano or Politianus from his birthplace, was born at Montepulciano in Tuscany on July 14, 1454. His father, Benedetto, a jurist of good family and distinguished ability, was murdered by political antagonists for adopting the cause of Piero de' Medici in Montepulciano; this circumstance gave his eldest son, Angelo, a claim on the family of Medici. At the age of ten the boy came to study at Florence, where he learned Latin under Cristoforo Landino and Greek under Xrgyropulos and Andronicos Kallistos. From Marsilio Ficino he imbibed the rudiments of philosophy. His genius for scholarship and poetry was early manifested. At 13 years of age he began to circulate Latin letters; at 17 he sent forth essays in Greek versification; at 18 he published an edition of Catullus. In 1470 he won for himself the title of *Homericus juvenis* by translating four books of the *Iliad* into Latin hexameters. Lorenzo de' Medici, who was then the autocrat of Florence and the chief patron of learning in Italy, took Poliziano into his household. made him the tutor of his children and secured him a distinguished post in the University of Florence. Before he reached the age of 30. Poliziano expounded the humanities with almost unexampled lustre even for that epoch of brilliant professors. Among his pupils could be numbered the chief students of Europe, the men who were destined to carry to their homes the *spolia opima* of Italian culture. Not to mention Italians. it will suffice to record the names of the German Reuchlin, the English Grocyn and Linacre, and the Portuguese Tessiras.

Poliziano published the notes of his courses on Ovid, Statius, the younger Pliny. Quintilian and the writers of Augustan histories. He also undertook a recension of the text of the *Pandects* of Justinian, which formed the subject of one of his courses; and this recension, though it does not rank high in the scale of juristic erudition. gave an impulse to the scholarly criticism of the Roman code. His versions of Epictetus. Herodian. Hippocrates, Galen, Plutarch's *Eroticus* and Plato's *Charmides* delighted contemporaries by a certain limpid fluency of Latin style and grace of manner which distinguished him also as an original writer. Of these learned labours the most universally acceptable to the public of that time were a series of discursive essays on philology and criticism, first published in 1489 under the title of *Miscellanea.* They had an immediate. a lasting and a wide renown, encouraging the scholars of the next century and a half to throw their occasional discoveries in the field of scholarship into a form at once so attractive and so instructive. Poliziano was not, however. contented with these simply professorial and scholastic compositions. Nature had endowed him with literary and poetic gifts of the highest order. These he devoted to the composition of Latin and Greek verses. which count among the best of those produced by men of modern times in rivalry with ancient authors. The *Manto,* in which he pronounced a panegyric of Virgil; the *Ambra,* which contains a beautiful idyllic sketch of Tuscan landscape. and a studied eulogy of Homer; the *Rusticus,* which celebrated the pleasures of country life in no frigid or scholastic spirit; and the *Nutricia,* which was intended to serve as a general ,introduction to the study of ancient and modern poetry — these are the masterpieces of Poliziano in Latin verse, displaying an authenticity of inspiration, a sincerity of feeling and a command of metrical resources which mark them out as original productions of poetic genius rather than as merely professorial lucubrations. Exception may be taken to their style: when compared with the best work of the Augustan or even of the silver age. But what renders them note orthy to the student of modern humanistic literature is that they are in no sense imitative or conventional. but that they convey the genuine thoughts and emotions of a born poet in Latin diction and in metre moulded to suit the characteristics of the singer's temperament.

Poliziano's principal Italian works are the stanzas called *La Giostra,* written upon Giuliano de' Medici's victory in a tournament; the *Orfeo,* a lyrical drama performed at Mantua with musical accompaniment; and a collection of fugitive pieces, reproducing various forms of Tuscan popular poetry. *La Giostra* had no plan, and remained imperfect; but it demonstrated the capacities of the octave stanza for rich, harmonious and sonorous metrical effect. The *Orfeo* is a slight piece of work, thrown off at a heat, yet abounding in unpremeditated lyrical beauties. and containing in itself the germ both of the pastoral play and of the opera. The Tuscan songs are distinguished by a "roseate fluency." an exquisite charm of half romantic, half humorous abandonment to fancy, which mark them out as improvisations of genius. It may be added that in all these departments of Italian composition Poliziano showed how the taste and learning of a classical scholar could be engrafted on the stock of the vernacular, and how the highest perfection of artistic form might be attained in Italian without a sacrifice of native spontaneity .and natural flow of language.

Beyond the sphere of pure scholarship and pure literature Poliziano did not venture. He was present, indeed, at the attack made by the Pazzi conspirators on the persons of Lorenzo and Giuliano de' Medici, and wrote an interesting account of its partial success. He also contributed a curious document on the death of Lorenzo de' Medici. Otherwise, his uneventful life was passed as a house friend of the Medici, as the idol of the learned world and as a simple man of letters to whom (with truly Tuscan devotion to the Saturnian country) rural pleasures were always acceptable. He was never married; and his morals incurred suspicion, to which his own Greek verses lend a plausible colouring.

Poliziano died, half brokenhearted by the loss of his friend and patron Lorenzo de' Medici. on Sept. 24. 1494.

See F. O. Mencken (Leipzig, 1736) ; Jac. Mahly, *Angelus Politianus* (Leipzig, 1864) ; Carducci's ed. of the Italian poems (Florence. Barbera, 1863); Del Lungo's ed. of the Italian prose works and Latin and Greek poems (Florence, Barbera, 1867) ; the Opera *omnia* (Basle, 1554) ; Greswell, *Life of Politian* (1805) ; Roscoe, *Lorenzo* de' *Medici,* 10th ed. (1851) ; J. Addington Symonds, *Renaissance in Italy* (1875–86) ; and translations from Poliziano's poems in Symonds's *Sketches and Studies in Italy* (1879). (J. A. S. ; X.)

POLITICAL PHILOSOPHY. The traditional problems of political philosophy have been the nature and the justification of political obligation and authority. There are here two essentially different sets of questions. First, there are the questions how men came together under governments and what were the motives which originally influenced them to do this and which still prevail to keep them obedient to government orders. These are questions of fact and they are properly studied by social historians, sociologists and psychologists; but before sociology and psychology were established as independent sciences: many political philosophers included speculations on these historical and psychological topics in their works. The second question is that of the ethical justification of obedience to government; or, if we look at it from the point of view of the rulers, that of the moral basis of their authority. This question is the proper concern of political philosophy. In this article some representative answers to it are considered.

Force. — One answer is that there is no ethical justification for government. Rulers govern because they have the power and consequently they govern in their own interest., Subjects obey because they cannot help it: they are the tools of the rulers. Greek sophists, of whom Thrasymachus in Plato's *Republic* is an example, first gave this answer, but it is still alive, for it was the view of the 19th-century anarchists and is still the official Marxist doctrine. "The State is nothing more than a committee for the administration of the affairs of the ruling class" (*Communist* Manifesto); and "With the disappearance of classes the State too will disappear" (Friedrich Engels). How far this is a complete answer will depend on the merits of the alternative answers which follow.

The Organic Theory.—The state has been likened to an organism, the citizens to its organs: "We are members one of another." As an eye is good when it best serves the organism as a whole, so the good citizen is he whose whole life is dominated by the ideal of state service. If he fails to perform his civil functions he should be liquidated ("If thine eye offend thee, cut it out . . ."). The government is the brain of the state, the organ whose function is the control of the other organs in the interest of the whole body.

The difficulties in this theory are these. First, it tends to assume that actual states are ideal, that their governments do control the citizens in the interest of the whole. Secondly, it assumes that there is something correctly described as "the interest of the whole state," to which individual interests can be sacrificed. But there is no such thing: the interests of some can be sacrificed to the interests of others: but the good of the state must be analyzed without remainder into the goods of individual men (as must public health or social welfare). Thirdly. this theory assumes that the state is the only form of association, as was the Greek city-state in the time of Plato and Aristotle when the theory first appeared. But the scriptural quotations cited above stressed the unity and organic character not of the state but of the church. Nowadays, with the vast multiplication of associations, it is impossible for one type of association, the political, to claim the complete self-sufficiency, the overriding authority and the undivided loyalty which the organic theory of the state requires.

The General Will.--On this view it was argued that a moral rule, to be moral, must be self-imposed, and the problem of political authority thus became that of self-government. At first sight this leads straight to democracy as the only legitimate form of government. We have an obligation to obey laws only if we ourselves have made them. But in Jean Jacques Rousseau, who originated this theory, the argument took a different direction, in which it was further developed by Hegel and his followers (*e.g.*, Bernard Bosanquet, The Philosophical Theory of the State). My real good must be distinguished from what at the moment I actually want. My permanent aim, if I am reasonable, is my real good, though my passing desires may thwart and impede it. This distinction between ends or aims is then carried over as a distinction between two selves within me, my rational, true. permanent, higher self and my lower, fluctuating, impulsive, desiring self. When a law compels me to abstain from murder or blackmail it expresses my higher against my lower self. Thus when I obey the law, I am obeying my own real will, the law is self-imposed, and I am "forced to be free" (Rousseau). Since "the good" is the same for all rational men, the real selves of all will be identical. and the state can be said to have (or be) a single will. the general will. There is thus attributed to the state a unity of a type higher even than that of an organism. the unity of a self. In Hegel and his successors this led to a kind of deification of the state as "the march of God upon earth" (Hegel) and as the sole source of moral right and the sole centre of human devotion.

Parallel objections to those against the organic theory are valid here. U'hat is called "the will of the state" is in fact the will of the government, and governments are just as capable as individuals of making irrational decisions based on desire or short-term interest. A state decision is in any sense my responsibility only if I have had some actual share in bringing it about. Much of morality and much of human value is no concern of the state at all. Finally it may be objected that, even if all this theory were literally defensible, what is said of the state could be said of any other association: trade unions, colleges, churches and athletic clubs would have (or be) general wills too.

Pluralism.——From this last criticism there emerged a theory called pluralism in contrast with the "monistic" theory of Rousseau and the Hegelians with their single supreme association. The pluralists varied in their attitude to the state. Some of them found no rational function for the state to perform (except making wars). There they joined hands with the Marxists, who were pluralists so far as they substituted for the state a complex of voluntary associations. Others held that there were certain functions which the state should perform, but these gave it no supremacy over other associations, no monopoly of loyalty, no right to stand as the sole source of morality and no claim to obedience beyond the affairs which were its special charge.

The Liberal View.—These theories have now few defenders; the living issues in politics are to be sought elsewhere. They are here considered under labels which are not used with any suggestion that they correspond to the lines between political parties. The views here considered are distinguished by the divergence between their basic principles and between the elements in politics on which they lay most stress. We have seen how the pluralists asked what was the function of government, what purposes the state in particular among all other associations was alone or best fitted to achieve. This question is the way in which the problem has been seen by the English tradition from Hobbes through Locke and J. S. Mill; and it is on the whole characteristic of British and American thought to look at government in this practical and utilitarian light.

First, government is needed to provide security of life, as Hobbes insisted. No individual is strong enough to guarantee his own security unaided. No voluntary association is sufficiently inclusive or wields the sort of weapons needed to keep violence at bay. But security of life is not all that men need. Security of other interests (especially property. said Locke) and security from all kinds of damage by blackmail, arson, rape, assault, etc. (this was Mill's view) require government action. This is the field of criminal law. The Communist says that the state will wither away at the establishment of a classless society; but Marx and Engels nowhere explain what is to be done about crimes of violence. Lenin does face this problem in one place; he says:

> We are not utopians, and do not in the least deny the possibility and inevitability of excesses on the part of individual persons, or the need to suppress such excesses. But, in the first place, no special machine, no special apparatus of suppression is needed ior this; this will be done by the armed people itself, as simply and as readily as any crowd of civilized people, even in modern society, interferes to put a stop to a scuffle or to prevent a woman from being assaulted (V. I. Lenin, The State and Revolution, ch. 5, sec. 2. in Lenin, Selected *Works*, vol. ii, pt. i, pp. 293–294, Lawrence and Wishart, London, 1951).

But crowds do not part combatants and men do not violate women when there is a crowd standing by. Lenin's recipe is lynch law, and lynch law is notoriously incapable of dealing with most crimes or of dealing justly with those which it does assail. Here then is a clear case for government action.

Secondly, government is required to settle disputes which are not amenable to direct compromise or agreed settlement. This is the province of civil law. If government were to wither away, the victory in every dispute would go to the stronger or to the possessor. Things would be little better if a voluntary society undertook to adjudicate. for some disputants would not fall under its authority, nor could it enforce its awards.

These two functions of protection and of settlement of disputes exhausted the functions of the state as seen by the classic English tradition. Here the work of government is essentially negative: its force is applied only against bad men or against the side in a dispute which has the weaker case; and its only duty to the good and peaceable citizen is to leave him alone, except to the extent that it must tax him and perhaps enlist his services as juryman or soldier to enable it to perform its protective and arbitral functions.

The Socialist View.—English and American governments up to the middle of the 19th century restricted themselves to those minimal negative protective functions. But they performed two jobs which were the seeds of a more positive doctrine of state action. The state protected men's rights from invasion by other men. But there was one right for which it did more than that. On the Hobbes-Locke view. the state's concern with the right to life was to prevent other men at home or abroad from endangering my life. But what if my life is endangered by starvation (not because an ogre has shut me in a dungeon but because I cannot work or cannot find work to do)?

On the strict liberal or protective view, governments should agree with Arthur Hugh Clough:

> Thou shalt not kill, but need'st not strive
> Officiously to keep alive.

But in fact government did so strive, through poor relief and casual wards. Over no other right did government assume this paternal care, but this is obviously the thin end of a very thick wedge. The "right to work" was originally taken to mean the right to do whatever work I can find (and to stop doing it) without interference; and this was how the right was interpreted and protected by English law. But what of the unemployed? Unemployment pay ensured their right to life, not their right to work. It is only since the state undertook the provision of schemes of work and adopted a full-employment policy that the supply of work has been accepted as a government responsibility.

The first seed in fact grew into the welfare state. Kot only life, but education, health and pensions have become government responsibilities. It might be thought that there can be no limit to this extension, and the phrase welfare state encourages this idea. But even its strongest supporters would not propose state-guaranteed supplies of tobacco, cosmetics, television sets or theatre seats. "To each according to his needs"—not his wants—is the socialist slogan: the state should ensure the supply of those things from which. it is thought, no human being should be debarred by accident of birth or wealth or dwelling place. The welfare state really appeals to a principle of justice. not of welfare—to the view that is is unfair that some men should be deprived of things without which life is not worth living (health, education, work) because they cannot afford them.

Though the welfare state is not usually extended to supply luxuries there is sometimes invoked another principle, in addition to that of justice. which would work in that direction. It is the principle of equality—not merely equality of opportunity (which. the principle of justice achieves) but an equality more fundamental still. It is thought wrong that some people should have automobiles. television sets or vacations which others cannot have. On this principle the aim of state education is not merely to provide educational opportunities for those who cannot afford them but to equalize education for all. The aim of taxation is not merely to raise money for necessary and justifiable services but to redistribute and to equalize incomes. It is held to give a child an unfair advantage not only if other children have no education but also if he has parents who can afford to send him to a better school or if he has the ability to pass examinations earlier than other children.

The second seed of a theory much wider than the negative liberal one to be found in 19th-century government was the postal service. For here was the idea that a certain service was required which could not be effectively supplied to all who needed it unless it was supplied by government. This seed has grown into the program of nationalization. This program too has tended to operate on a distinction between needs and wants. There are some services which every citizen in a civilized community has a right to enjoy: roads; drainage; and a clean water supply. All of these used to be supplied by individual enterprise or by private persons or companies working for profit. But this meant that many poor people or people living in remote areas could not have these services or had to pay a prohibitive price for them. But the list has grown to include railways. gas and electricity, where it is more doubtful whether these are needs to which all men have an equal right and which must therefore be state-supplied. We noticed above how the principle of justice was supplemented and in places supplanted by the principle of equality. Here too another basic principle has come in to promote the development of state services: the principle that no man's labour should be exploited for the profit of another man, or. put the other way round, that no man should enjoy income unearned by his own efforts. On this principle there are no limits to nationalization as an ideal. since whenever any industry is nationalized the employment of labour for profit is correspondingly diminished; it ceases to matter whether services nationalized are necessary for civilized existence or whether the nationalization benefits the workers or the public.

The Conservative View.—In opposition to the liberal and socialist principles. it has been objected that they overemphasize human reason. No citizen regards his state in this cool, calculating way as an association existing to do certain jobs for him. "The state ought not to be considered as a partnership agreement in a trade . . . to be taken up for a little temporary interest or to be dissolved on the fancy of the parties" (Edmund Burke). To regard the moral claims of one's country in this light is like doing one's best for one's friends or one's children solely from a lively expectation of favours to come. Around these centres—country, family, friends—gather a loyalty and a devotion, traditions of fellowship and service which mere utility can never explain or exhaust.

Nor is reason an adequate guide for the rulers either: no human individual or committee can be trusted to change a society or to plan its future. The garnered uisdom of centuries expressed in custom, tradition, laws and constitutions, the slow process of unconscious change, adapted perhaps empirically here and there to some immediate problem—these form a better guide than the blue books and blueprints of the planners. The conservative tradition respects the individual. not the abstract identical individuals of liberal theory, the bearers of universal rights, but the individual in his rich variety It would rather have things done in an illogical. confused and piecemeal way, provided that this allowed individual variety and individual enterprise. than in an efficient. streamlined way through uniform leveling and dragooning. It sees state provision and state management in human terms. State or "free" education means education at the taxpayer's expense. It will not deny occasional justice to the Robin Hood ethic of robbing rich Peter to pay poor Paul, but it will require strong justification for it in each case. It sees state control as control by politicians and civil servants. Such control, the conservative would say, may on occasion be justified but there is no such inherent merit in it as to justify rejoicing in its every advance, as the nationalizers do.

Politics and Morals.—The aim of the preceding sections has been to show how political ideals rest on certain moral principles or judgments of value. To work out these connections is the task of political philosophy. But it may be doubted whether it is the task of political philosophy to decide between these principles or the systems erected upon them. Here political thinking is driven back on a fundamental issue in ethics. Some would hold that moral values are subjective: each man must make his own decision between them; none of them can be rationally defended against its rivals. If so, political philosophy cannot claim to do as it once did. to lay down the best kind of state or the best laws.

Analysis.—Developments since the middle of the 19th century have thus tended to diminish the function of political philosophy. Factual questions have been removed from it and handed over to sociology and to psychology. Its noniactual arguments have been driven back into ethics, and ethical principles in their turn have been removed from the field of rational discussion. By the middle of the 20th century, however, philosophical movements were showing a great positive interest in linguistic analysis. and here, it would seem, there was another remaining field for political philosophy. The analysis of language about politics, of such terms as government. sovereignty, law, rights and punishment. remained to be achieved.

Bibliography.—T. H. Green, *Lectures on the Principles of Political Obligation* (1895), reprinted from *Philosophical Works*, vol. ii (1885); B. Bosanquet, *The Philosophical Theory oj the State* (1899); *L.* T. Hobhouse, *The Metaphysical Theory of the State* (1918); G. *D.* H. Cole, *Social Theory* (1920); *T*. D. Weldon, *States and Morals* (1946); J. D. Mabbott, *The State and the Citizen* (1948). (J. D. M.)

POLITIS, NIKOLAOS SOKRATES (1872–1942), Greek jurist and diplomat, a brilliant champion of the peaceful settlement of disputes and of disarmament, was born at Corfu on Feb. 7, 1872. After holding professorships in the faculty of law at Aix-en-Provence, at Poitiers and at Paris, he was in 1914 summoned by Eleutherios Venizelos to reorganize the Greek ministry of foreign affairs, of which he became director-general. Appointed minister of foreign affairs in 1916, he went to the peace conference of 1919 as the delegate of Greece. In the League of Nations, where he was also the Greek delegate, he wrote the report on the Geneva protocol (1924). As vice-president of the Disarmament conference, he drew up the definition of the aggressor there propounded. His lucid, powerful and eloquent speeches put him in the first rank of the delegates to the League.

Politis published a number of books of jurisprudence, including *La Justice internationale* (1924) and *Les Nouvelles Tendances du droit international* (1927; Eng. trans., *New Aspects of International Law*, 1928). These showed him to be at once a thinker of far-reaching interests and a passionate believer in the future of international law. The foundation of the Academy of International Law at The Hague was largely the result of his efforts. In 1937 he was made president of the Institute of International Law. He died at Cannes, France, on March 4, 1942. (CH. D. V.)

POLK, JAMES KNOX (1795–1849), 11th president of the United States, was born in Mecklenburg county, N.C., on Nov. 2, 1795. At the age of 11 he accompanied his family to Tennessee, settling in a-hat is now Maury county. In his childhood formal schooling was impossible because of ill health, but at the age of 20 he successfully passed the entrance requirements for the second-year class of the University of North Carolina. As an undergraduate his record was "correct, punctual, and industrious." As a graduating senior in 1818 he was the Latin salutatorian of his class—the pre-eminent scholar in both the classics and mathematics.

With this academic background he began to read law, in the office of Felix Grundy in Nashville, Tenn., to associate with leading public figures in the state and to make political speeches. In 1820 he was admitted to the bar. Since he was a confirmed Democrat and an unfailing supporter of Andrew Jackson, and since his style of political oratory became so popular that he was characterized as the "Napoleon of the stump," his political career was assured. With him in his rapid rise to political power was his wife, Sarah Childress Polk (1803–1891), whom he married Jan. 1, 1824, during his service in the state house of representatives (1823–25). Mrs. Polk's home was Murfreesboro, Tenn., the temporary state capital. The social prominence of her family and her personal charm a-ere distinct assets for a politically ambitious lawyer. As an official hostess she won the admiration and esteem of the leading figures of the day. For 25 years she was her husband's close companion in state and national politics. In the long period of her childless widowhood she maintained Polk Place in Nashville as a shrine.

James K. Polk was by nature a student of government, by experience a legislator and by force of circumstance an administrator. He was not an easy man to know or to like. Boon companions did not relish his austerity. Associates tolerated but did not approve his inflexible living standards. He had many acquaintances, but very few friends. One friend was Andrew Jackson, who encouraged and advanced Polk and whose influence carried him from the Tennessee house of representatives to the U.S. house of representatives, where he served from 1825 to 1839. From 1835 to 1839 he was speaker of the house. In that service in Washington Polk acquired a reputation as a constant, undeviating supporter of Jacksonian principles. In 1839 he left the house to become governor of Tennessee. Two defeats for a second term (1841, 1843) by small majorities convinced him that to strengthen his party he should return to Washington in some capacity.

Polk's nomination for president on the Democratic ticket in 1844 was unsought by him, for the party had more prominent sons in Martin Van Buren, Lewis Cass and James Buchanan. However, they could not reconcile their differences and a compromise candidate had to be found; since the campaign was to be run on issues and not on personalities, it was decided Polk would do, and the wheel horse of the party as a vice-presidential candidate became the dark horse of the national convention at Baltimore. He was young and he was a party man from the west, and his experience as a legislator, it was thought, would make possible the realization of legislative and executive co-operation and understanding in the functioning of the national government. As a legislator he had taken a number of personal positions of significance in his later career. In his maiden speech in the house of representatives he had advocated a constitutional amendment for the popular election of the president. Later he opposed an appropriation for the Panamá mission because it might lead to war with Spain. In a committee report he stressed the constitutional requirement that public revenue should be reduced to the requirements of the public services. As a member of the ways and means committee he opposed the bank of the United States. While speaker of the house he decided many procedural questions and was usually sustained on appeal by majorities composed of the leaders of both parties. He was a party man and his party feeling was intense, but his integrity was unquestioned. He knew the rights and privileges of the house and he also knew its responsibilities.

Polk was nominated on the ninth ballot of the convention on May 27, 1844, won a 65-vote plurality of the electoral college on Nov. 12, 1844, and was inaugurated president, March 4, 1845. Campaigner Polk surprised the country by taking a positive stand on two burning issues of the day. While other candidates hedged on Texas, he demanded annexation. While other candidates evaded the Oregon problem he openly advocated a drastic change in policy in the boundary dispute with Great Britain. His election was close, but it was decisive—a popular plurality of 38,175 and 170 electoral votes against 105 for Henry Clay.

President Polk not yet 50 years of age was the youngest successful candidate up to that time. He entered the presidency a comparatively young man, full of vigour, and with an expressed zeal to serve his country to the best of his ability. He left the presidency four years later exhausted and enfeebled by the efforts he had made. In office he demonstrated not only skill in the selection of his official advisers but also in the control of these able and competent men. He mas the responsible head of an administration composed of James Buchanan of Pennsylvania, secretary of state; Robert J. Walker of Mississippi, secretary of the treasury; William L. Marcy of New York, secretary of war; George Bancroft of Massachusetts and later John Y. Mason of Virginia, secretary of the navy; John Y. Mason, then Nathan Clifford of Maine and later Isaac Toucey of Connecticut, attorney general; and Cave Johnson of Tennessee, postmaster general. In his formal relations with congress his legislative experience served him well. When his party was united, he yielded to the wishes of congress. When he disagreed with congressional policy and made an issue of it. he fortified his position with recognized precedent and established practice. His formal disapprovals (two message vetoes and one pocket veto) were questioned, but the two returned measures after formal reconsideration failed to command the necessary two-thirds majority for repassage. The house bill on appropriations for rivers and harbours after two days of debate failed repassage, Aug. 4, 1846, by a vote of 96 to 91. The senate bill on the French spoliation claims after a short debate, failed to proper repassage, Aug. 10, 1846, by a vote of 27 to 15. This was during a decade of strong partisanship in congress wherein Polk's predecessor, John Tyler, suffered a repassage of one of his six vetoed measures and Franklin Pierce in his short administration saw five of his nine vetoed measures repassed.

The administration of James K. Polk was marked by territorial gains. The annexation of Texas as a state of the union was concluded—resulting in a two-year war with Mexico. As a consequence of that war the southwest and far west (California), by conquest and by purchase, became part of the U.S. domain. During this period the northwest boundary became fixed by treaty, and the continental United States emerged a recognized reality. Additional achievements included a treaty with New Granada (Colombia) clearing up the problem of right of way for U.S. citizens across the Isthmus of Panama; establishment of a warehouse system which provided for the temporary retention of undistributed imports; and the passage of the Tariffact of 1846. As these helped foreign trade, so the re-enactment of the independent treasury system helped in the solution of domestic financial problems. The expansion of the country westward caused the creation of a new agency, the department of the interior.

The Polk administration should also be credited with the establishment of the U.S. naval academy and the authorization of the Smithsonian institution.

Polk's influence over his congresses may be gauged from the results of the recommendations of four annual messages and ten significant special messages to one or both houses. His control of legislative policy in bitterly partisan congresses must be judged in terms of results, not oratory or parliamentary delay. He recommended with a high degree of success: settlement of a trade dispute with Great Britain; an increase in C.S. armed forces; war with Mexico; peace mith Great Britain over Oregon, making available finances to expedite peace conclusions; collection and usage of Mexican revenues; organization of the Oregon Territory: peace with Mexico providing for limited conquest; removal of tariff restrictions; and a revised treasury system. As an executive he refused information desired by Congress, incompatible mith the public interest. recognized a new French revolutionary government and proclaimed the validity of the Monroe doctrine. These pronouncements were recognized by succeeding presidents.

The diary kept by Polk during his term of office stressed the presidential burden. Day after day, week after week, he recounted in his diary his experiences with the hosts of office seekers who infested Washington and who occupied so much of his public time. Again and again there was evident a note of despair in his writings. He knew from personal experience what an evil an unlimited executive patronage can become. Nevertheless, he felt powerless to change its obligations and too conscientious to avoid its duties. At the close of his term. March 4, 1849, Polk retired to his home in Nashville. where he died on June 15, 1849.

The office of chief executive under Polk was well filled. He maintained it with dignity, with integrity and with a sense of extraordinary duty. His great influence over congress was due to the justness of his policies and the persistence of his efforts in having the members see the questions not as interests of district or section but as matters of national welfare. It was his sturdy character and unblemished reputation that gave weight to his counsels and strengthened his pleas. History may not rate James K. Polk as one of the greatest of U.S. presidents, but for the accomplishments of his short time in office he cannot be rated among the least influential.

BIBLIOGRAPHY.—The following references are highly selective as to source material and to availability: M. M. Quaiie (ed.), *The Diary of James K. Polk, 1845–1849* (1910), an almost complete printing of the manuscript material and a revelation of the mind of a president; E. I. McCormac, *James K. Polk: a Political Biography* (1922); C. G. Sellers, *James K. Polk, Jacksonian, 1795–1843* (1957). (G. C. Ro.)

POLK, LEONIDAS (1806–1864), U.S. general. was born at Raleigh. N.C.. on April 10. 1806. He was educated at West Point, but resigned his army commission six months after graduation to enter the Virginia Theological seminary. In 1831 he took orders in the Protestant Episcopal Church. In 1838 he became missionary bishop of the southwest. and in 1841 he was consecrated bishop of Louisiana. At the outbreak of the American Civil War in 1861, he accepted a commission in the Confederate army and no longer exercised his episcopal authority. His rank in the hierarchy and the universal respect in which he was held in the south, rather than his early military education, caused him to be appointed to the important rank of major general. He fortified the post of Columbus. Ky., the foremost line of defense on the Mississippi, against which Brig. Gen. U. S. Grant directed the offensive reconnaissance of Belmont in the autumn. In the following spring, Polk commanded a corps at Shiloh. In Oct. 1862 he was promoted to lieutenant general. and commanded one of the three corps of the army of Tennessee under Bragg and afterward was in charge of the department of Alabama, Mississippi and East Louisiana. He was killed near Pine Mountain! Ga., on June 14, 1864.

POLKA, a lively dance in 2/4 time of Bohemian origin, characterized by three quick steps and a hop. Introduced in Paris about 1843. it became an extraordinary craze in the ballroom and on the stage, sweeping rapidly across Europe and the United States. Frequently introduced in ballets; such as F. Ashton's *Façade,* it has also retained considerable popularity as a social dance.

(LN. ME.)

POLLACK (Pollachius *virens*), a fish distinguished from others of the cod genus by the long pointed snout, and the prominent lower jaw without a barbel; the colour is greenish, with yellow markings. It ranges from Norway to the Mediterranean, but is most abundant southward; it prefers rocky ground, and is piscivorous. It attains a weight of over 20 lb.

POLLAIUOLO, the name of two Florentine brothers, Antonio, who was a sculptor, painter, engraver and goldsmith, and Piero, who was a painter and sculptor.

ANTONIO POLLAIUOLO (*c.* 1430–1498) was trained by his father as a goldsmith, and his most outstanding work in this field is the base for the silver reliquary of St. Giovanni (1457–59, now in the Opera del Duomo, Florence). Yet his chief claim to fame rests on his works in bronze, such as a lively small group of "Hercules and Antaeus" (Bargello, Florence), which once belonged to the Medici. Called to Rome in 1484, he executed aith the assistance of his brother the lavish bronze tombs of Pope Sixtus IV (now in the SS. Grotte of St. Peter's) and of Innocent VIII (St. Peter's). The latter, with the enthroned figure of the pope giving his blessing. had a considerable influence on later papal tombs. It seems that Antonio learned the technique of painting from his brother and completed a number of pictures in collaboration with him, among them the altarpiece in the chapel of the cardinal of Portugal in S. Miniato, Florence, and the "Rfartyrdom of St. Sebastian" (National gallery, London). Antonio's chief interest was the human figure in motion; he is supposed to have been one of the first artists to concern himself aith dissection and anatomical studies. Hence his engraving "Battle of the Nudes" as well as his drawings took for his and later generations the place of pattern books. He died in Rome on Feb 4, 1498.

PIERO POLLAIUOLO (1443–1496), born in Florence in 1443, was probably a pupil of Alessio Baldovinetti. He painted six of the "Virtues" for the Mercanzia of Florence (1469–70, Uffizi, Florence). His principal work, "Coronation of the Virgin," was painted for S. Agostino, S. Gimignano (now in the cathedral). He died in Rome in 1496.

BIBLIOGRAPHY.—Maud Cruttwell, *Antonio Pollaiuolo* (1907); Attilio Sabatini, *Antonio e Piero Pollaiolo* (1944); L. D. Ettlinger, "Pollaiuolo's Tom'b of Pope Sixtus IV" in *Journal of the Warburg and Courtauld Institutes,* vol. xvi (1953). (L. D. ER.)

POLLARD, ALBERT FREDERICK (1869–1948), English historian and editor, was born at Ryde on Dec. 16, 1869, and educated at Jesus college, Oxford. He was elected a fellow of All Souls college, Oxford, in 1898. From 1893 to 1901 he was assistant editor of the Dictionary *of National* Biography. From 1903 to 1931 he held professorial chairs of English history and constitutional history in the University of London. He was founder and first chairman of the Institute of Historical Research. He died Aug. 3, 1948, at Milford-on-Sea, Hampshire.

His publications include Thomas Cranmer and the English Reformation (1898; new ed., 1926); Henry VIII (1902); Factors in Modern *History* (1907; new ed., 1926); Evolution of Parliament (1920); Factors in American History (1925).

POLLEN ANALYSIS (PALYNOLOGY) is the science of the investigation of materials by their content of pollen grains (*q.v.*) or spores. In its widest sense it embraces investigations of honey, of allergies caused by wind-borne pollen and of the natural classification of the higher plants. Nonetheless it mainly concerns the reconstruction of former vegetation by systematic analysis of the pollen and spore content of geological deposits. Pollen is shed in vast amounts from the vegetation (tens of thousands of grains per square centimetre each year), and if it falls into accumulating deposits, such as those of lakes or peat bogs, the grains are incorporated in vast numbers. Their walls resist decay, and the grains can be recovered by suitable mechanical and chemical treatments from the muds, clays or peats containing them. Since pollen grains exhibit a very wide range of size, shape and wall pattern, and have distinctive numbers and disposition of pores and furrows, it is possible to recognize under high magnifications of the microscope the family, the genus or, in some instances, the species of plant to which a given grain belongs.

The proportions of different grains in any sample reflect the composition of the vegetation when the sample was deposited; thus. the quantitative changes in the pollen types in a series of samples through a deposit reveal the vegetational changes of the region throughout the formation of the deposit. In northwestern Europe, where the method has been most fully developed, pollen analyses have revealed a remarkably consistent picture of vegetational history for the period since the ice sheets began their final retreat. Open park tundra was replaced by birch woodland and then by pine forest and hazel scrub; these gave way to a phase of mixed oak forest, and finally beech. hornbeam and spruce expanded their range considerably. These changes in floristic composition were climatically controlled, and parallel developments were reflected widely in a system of pollen zones which can be employed as an approximate climatic and time scale. Pollen analysis of deposits containing archaeological objects (or even of adhering mud) allows an approximate dating to be made, and the method is applied similarly to geological features such as solifluction deposits. raised beaches and submerged forests.

Pollen analysis has been applied with great success to the study of interglacial and even older deposits and to the characterization of the stages of disforestation of Europe by Neolithic and succeeding groups of agriculturalists.

BIBLIOGRAPHY.—K. Faegri and J. Iversen, *Text-book of Modern Pollen Analysis* (1950); *H.* Godmin, "Pollen Analysis: An Outline of the Problems and Potentialities of the Method," *New Phytol.,* 33:278–305, 325–358 (1934), *The History of the British Flora* (1956). (HA. *G.*)

POLLEN GRAINS. In the biology of the plant, pollen grains are the structures that produce the male sex cell (sperm), which in turn effects bisexual reproduction by union with the female sex cell (egg). In the evolution of higher plants pollen grains are derived from asexual reproductive structures called spores, and in certain groups of plants, both living and fossil, the distinction between pollen and spore is arbitrary since they both perform a similar function in reproduction. The term pollen is usually restricted, however, to the male reproductive structure of seed-bearing plants, including the gymnosperms—conifers! cycads, ginkgo. etc.—and the angiosperms—all the flowering plants. Genetically the pollen grain is a minute plant. the cells of which bear one-half the chromosome number (the haploid number) found in the parent plant (which has diploid cells). Botanically the pollen grain is the male counterpart of the haploid female embryo sac in the ovule, the potential seed.

Transfer of pollen is carried out by wind, water, insects and other agents. After a pollen grain has made contact with the female reproductive structure—the moist stigma of the pistil—it sends out a pollen tube, which travels down through the pistil and into the ovary, where the ovules are. The pollen tube works into the ovule and fertilizes the egg cell within the embryo sac. After fertilization the ovule begins to develop into a seed. For further details on pollination see POLLINATION.

The role of pollen grains in the reproduction of plants mas known empirically to several ancient cultures. The earliest is perhaps that of the Assyrians, who employed hand pollination to ensure full yields of date palm fruits. Since pollen grains are minute in size—although produced in prodigious numbers in some plants and therefore visible as a dust—knowledge of their structure and details of their biologic function awaited the discovery of the microscope. The early microscopists Nehemiah Grew and Marcello Malpighi studied and drew pollen grains.

Because of their remarkably symmetrical structure and surface patterns pollen grains are readily recognizable in the microscope. The structure of the wall of a pollen grain is oftentimes so characteristic that in some cases species may be identified by pollen grains alone. On the other hand there are cases in which pollen grains of very like structure occur in quite unrelated plant families.

Because of their high resistance to decay. their widespread dispersal by wind and water and their abundant production by plants. pollen grains are very common constituents of geologic sediments. both recent and ancient. In view of these features pollen grains have provided much information on the origin and geologic history of terrestrial plant life (see POLLEN ANALYSIS).

Pollen is produced in such quantities that it comprises a significant component of the air-borne constituents of the earth's atmosphere, especially in areas over continents. The proteinaceous substance in many pollen grains (viz., ragweed and many grasses) induces an allergic reaction commonly known as hay fever (*q.v.*).

BIBLIOGRAPHY.—G. Erdtman, *Pollen Morphology and Plant Taxonomy* (1952) and *An Introduction to Pollen Analysis (1943)*; *K.* Faegri and J. Iversen, *Textbook of Modern Pollen Analysis* (1950); *R.* P. Wodehouse, *Pollen Grains* (1935). (*EL. S.* B.)

POLLENTIA, an ancient town of Liguria, It., 10 mi. N. of Augusta Bagiennorum, on the left bank of the Tanarus. Its position on the road from Augusta Taurinorum to the coast at Vada Sabatia, at the point of divergence of a road to Hasta (Asti) gave it military importance. Decimus Brutus managed to occupy it an hour before Mark Antony in 43 B.C.; and it was there that Stilicho on March 29, 403, fought the battle with Alaric which, though undecided, led the Goths to evacuate Italy. Considerable remains of ancient buildings survived.

POLLINATION, a botanical term for the transference of pollen, the dustlike powder produced by the stamen of seed plants, to the stigma (the receptive surface) of the ovary of the flower. (See also FLOWER; POLLEN GRAINS.) Pollination brings about the fertilization of the ovules in the ovary and their subsequent development into seeds. As the pollen-bearing parts of the stamens are rarely in contact with the stigma at the time when both of these are ripe, usually wind or insects, though sometimes other agencies such as water or birds, bring the pollen to the stigma. The great variety in the form, colour and scent of flowers was developed in relation to the particular agency of insects. Apart from the mechanism of pollination we can distinguish two types—self-pollination (autogamy) in which pollen is transferred from the stamen to the stigma of the same flower; and cross-pollination (allogamy) in which pollen is transferred to the stigma of another flower on the same plant (geitonogamy) or to the flower of another plant of the same species (xenogamy). Occasionally hybridization is possible, the pollen of one plant bringing about fertilization of the ovary of the flower of another species.

Cross-Pollination.—Cross-pollination is the only possible method in the case of unisexual flowers because these flowers have only stamens or pistils, not both. In hermaphrodites. *i.e.,* in flowers bearing both stamens and pistils: either self-pollination or cross-pollination can occur. It is interesting to note, however, that many flowers have special arrangements to ensure that the pollinating mechanism, whatever it may be, causes cross-pollination and not self-pollination. One of the commonest methods to achieve this is a separation in time of the sexes—the stamens burst and shed their pollen either before or after the stigma is receptive. This separation in time—and it may apply to the separate male and female flowers on the same plant—is known as dichogamy. When the stamens ripen first it is known as protandry, the more common case; while when the stigma is ready first. it is known as protogyny. Protandry is very common in insect-pollinated (entomophilous) flowers; as in nearly all members of the Compositae (*q.v.*) and Umbelliferae, many Labiatae (such as dead nettle [*Lamium*] and *Salvia*), the Caryophyllaceae, the large willow herb (*Epilobium* angustifolium), etc. Protogyny is found in the horse chestnut (Aesculus), the autumn crocus (*Colchicum*), many Araceae, and in wind-pollinated anemophilous flowers such as plantain (Plantago), meadow rue (Thalictrum) and many grasses. though here separation in time is very short and many are self-pollinated, such as wheat, barley and oats.

Another structural feature which is a bar to self-pollination is heterostyly. It is seen at its simplest and clearest in the primrose. About half the population of this plant has flowers with long styles which bring the stigmas to the mouth of the corollas as little "pinheads." The stamens lie halfway down the tubes. In the other half the style is short and the stamens form a "thrumhead" at the mouth of the corolla. Visiting bees transfer pollen from one type of flower to the other. An equal balance of the population is maintained by a special genetic system. Species of *Linum, Oxalis* and *Lythrum salicaria* (loosestrife) are other examples.

The most complete bar to self-fertilization is self-sterility, which is known to be widespread. This condition is brought about by failure of the pollen tube to grow properly on styles of the same plant, though it can do so on styles of most other plants of the species.

Cross-pollination gives two distinct results, one short-term and the other long-term. It tends to give more and better seed and more vigorous progeny—a result well known in the production of outbred maize. The long-term effect is on the process of evolution. Crossing maintains and replenishes the pool of mutations, patent and latent, on which natural selection acts. Crossing also brings about new combinations of mutations. It has a major effect on the rate at which species can evolve.

INSECT POLLINATION (ENTOMOPHILY)

The special characteristics of entomophilous flowers are the attractive colour of the floral envelope, the presence of scent and of nectar, and of pollen which is not powdery but sticky and is present in comparatively small quantities. The entomophilous is the most common type of pollination in flowering plants, and special floral conformations and irregularities adapted to insect visitors are characteristic of the higher families of flowering plants, as will be seen below. The evolution of flowers and of insects must have gone hand in hand; such groups as Lepidoptera (butterflies and moths) and Hymenoptera (bees, wasps, etc.) could not have existed without the more elaborate and honey-bearing flowers. The plants with such elaborate flowers are cross-pollinated only by insects with highly specialized organs for sucking nectar and gathering pollen.

Types of Insects.—Five classes of insects visit flowers. The Hemiptera (bugs) are unimportant. The Coleoptera (beetles) are frequent visitors, eating pollen and licking nectar with short tongues. The Diptera (flies) are important and varied visitors; many have only short tongues but some, *e.g.,* the hoverflies, are moderately long-tongued and suck concealed nectar. The Hymenoptera (bees, wasps, etc.) include the most important flower visitors. Many bees have long tongues and can manipulate complex floral mechanisms. The Lepidoptera (butterflies and moths) are also important visitors. They include the longest-tongued insects which alone can reach the most deeply concealed nectar.

Classes of Flowers.—The entomophilous flowers were divided by H. Müller into nine classes based on the structure of the flower and its relation to particular insects.

1. Class A, flowers with exposed nectar: in this class come most Cmbelliferae. many Saxifragaceae, the bedstraws (*Galium*), ivy (Hedera), and such trees as maple. elder and lime. The flowers are wide open and usually small and the visitors are mostly short-tongued.

2. Class XB, flowers with partially concealed nectar: in this class fall the buttercups (*Ranunculus*), the Cruciferae, the strawberry (*Fragaria*) and the willows (Salix). The nectar is protected and concealed by the position of the stamens, by the development of hairs or scales, or by the flower being partially tubular.

3. Class B, flowers with fully concealed nectar: in this class are the flowers of many Carophyllaceae (such as *Gypsophila*), Geranium, Polemonium, blackberry (*Rubus*), eyebright (*Euphrasin*), mint (Mentha), heather (*Calluna*). In these the nectar may be concealed by the stamens, by the calyx, by the receptacle becoming hollowed or by the petals being united to form a sympetalous corolla. The insect visitors are the smaller bees and a few of the longer-tongued flies.

4. Class B' is an extension of Class B and includes the flowers of the Compositae, most Dipsaceae and some Campanulaceae, in which the flowers have the same length of tube, etc., as Class B, but are aggregated into. an inflorescence.

5. Class F, lepidoptera flowers: this includes those flowers in which the floral tube is so deepened that in many cases only Lepidoptera can reach the nectar. The alpine moss campion (Silene *acaulis*), for example, is adapted to butterflies, while the bladder campion (Silene *inflata*) is adapted to moths and emits a scent at night.

6. Class H, bee flowers, are those which are visited mostly by long-tongued bees, the depth of the tube being 6 mm. to 15 mm. The flowers are also often markedly zygomorphic, providing a landing place for the bee.

7. and 8. The D and K classes of flowers include those adapted to small insects; they are pollinated by flies, beetles and small bees.

Lastly, there is (9) Class Po, pollen flowers. These provide no nectar. but abundant pollen for which the flower is visited, mainly by bees; examples: Clematis, meadowsweet (Spiraea), rockrose (Helianthemum), dog rose (Rose *canina*), poppy (Papaver).

Food, Colour and Scent.—The insect visits the flower for nectar or pollen. Nectar is produced by special glands, the nectaries, which may occur on any of the floral organs. In many flowers it collects at the bottom of the corolla tube or in a special spur. It is a solution of the sugars glucose, fructose and sucrose at a concentration of 8% to 70%. Pollen is rich in proteins and oil.

It seems obvious that scent and brightness must be the guides for the visiting insect. Whether the insect perceives colour as such or only brightness was long in doubt, as were the details of its reactions. Exact knowledge dates from the work of K. von Frisch begun in 1914. He studied the special senses of the honeybee, a domestic animal that lends itself to controlled experiment. The bees of a hive can be trained to visit a piece of blue paper with a watch glass of sugar water on it. They continue to visit the paper for a time after the sugar is removed. This fixation is the basis of the bee's habit of mass visits to one type of flower in nature. Moreover, the bee can pick out the blue paper from a series of graded grays, some of which must have the same brightness. It perceives blue colour as such. It also perceives white and yellow; but it cannot distinguish red from green, dark gray or black. It is significant that, where insect pollination is predominant. flowers show white, yellow, purple and blue colours, but very rarely red.

By other similar experiments, Frisch showed that bees can distinguish between scents in very much the same way as man can. The sense of scent is used by scout bees to inform their fellows in the hive of the kind of flower available for mass visiting. This extraordinary proceeding and the subject of the bee "language" lies in the domain of insect physiology.

F. Knoll carried out similar studies on other insects in the field as well as in the laboratory. He came to the conclusion that colour is the important "distant" signal for the bee and that scent is a "near" signal which aids in the final selection of a flower. He studied the behaviour of one of the long-tongued flies, the bee fly (*Bombylius fuliginosus*), as it visited the flowers of the grape hyacinth (*Muscari* racemosum) in Dalmatia. It flew from one spike to another, fixed to this one flower. It would dip to a piece of blue paper placed between the plants, and could pick out blue from surrounding grays. It also visited yellow flowers. If a spike of flowers was covered by a clear inverted test tube the fly would approach and circle the tube but would not try the opening from which the strong scent welled out. Its sense of smell seems to be deficient.

In another group the hummingbird hawk moth (Macroglossum stellatarum) also visits the grape hyacinth, perceiving its blue colour. At close quarters it is able to find the mouth of the corolla by perceiving the pattern of white petal tips on the blue ground. Here is a distant reaction to blue and a near reaction to white circle on blue ground. The same insect flies from a distance to the yellow flowers of the toadflax, perceives at close quarters a pattern of orange blotch on yellow and is enabled to probe the narrow entrance to the deep spur with great speed and accuracy, and while in flight. Such colour patterns are frequent in flowers; *e.g.,* the dark streaks on pansy petals and the orange eye on blue ground of the forget-me-not. They are called honey guides. Their recognition is responsible for the accuracy with which insects probe sources of concealed nectar. The hawk moth has a deficient sense of smell, but it is certain the night-flying moths perceive odours. J. H. Fabre showed that they can react to flower scents at a distance of more than 100 yd. Some flies and beetles react to stinks like that of rotten meat. Such odours are given off by the clubs of many aroids and the flowers of some asclepiads. The colour of these is often a dull red, In the case of the South European Arum *nigrum* (a close relation of Arum maculatum, the lords-and-ladies) Knoll showed that the insects reacted to the smell and not to the lurid colour. In this curious plant the small flies and beetles slide down the slippery hood and are trapped among the ripe female flowers for a day. On the following morning they are able to crawl out through the male flowers then shedding their pollen.

The Form of the Flower and Floral Mechanisms.—The form and size of the flower and the degree of concealment of nectar determine the kind of insect visitor. With long-tongued, clever insects, the structure of the flower often imposes a particular course of visit which favours cross-pollination. There is very great variety of detail and the variety of structure gives the elegant range of floral form.

In the flowers of Class A the visits of small insects are haphazard. The small flowers of the hedge parsley (*Anthriscus sylvestris*) are showy in the massed umbel. The nectar is freely exposed on lobed nectarial disks in the centre of the corolla. Small flies and beetles lick the nectar and transfer pollen at random. But the stamens are withered before the stigmas are ripe and cross-pollination is favoured.

The buttercup (*Ranunculus* acris) is an example of the more advanced flowers of Class AB. There is a nectary at the base of each petal and it is covered by a little scale. There is no definite manner of visit, but larger flies and small bees tend to settle on the centre of the flower where they touch the stigmas first. Willows (Salix spp.) are the earliest mass source of nectar in the spring and are much visited by bees. The flowers are small and simple but are so close-set in their catkins that small insects cannot reach the nectar. They are dioecious; *i.e.*, with staminate and pistillate flowers on different plants.

In Classes B, B', F and K are found the most elaborate examples of floral structure and the closest relation of this to insect visit. Some idea of the range is given in the following examples.

Sage.—Such a plant as the sage (*Salvia* pratensis) has a typical bumblebee flower. The bee alights on the platform formed by the lower lip of the sympetalous corolla and pushes its head down the tube to reach the nectar at the bottom. Each of the two stamens is of special shape; the connective is very large and two-armed, and is hinged to the short filament. The longer arm bears a half anther while the short arm is sterile. the whole stamen having a lever mechanism. The bee. in probing for the honey, comes in contact with the short arm of the lever and in pressing this down brings the half anther at the end of the longer arm down upon its back where the pollen becomes deposited. The flower is protandrous and in a later stage the style elongates and is brought into the same position as occupied by the back of the bee when in contact with the anther.

Papilionaceous Types.—The Leguminosae show a very interesting series of pollination mechanisms. In this familiar type of flower, to which the pea and gorse belong, the essential parts of the flower are enclosed in the keel. The nectar is secreted by the inner sides of the lower part of the staminal tube; one of the ten stamens is usually free and at its base are two openings leading to the nectar. The nectar is thus not only carefully concealed but is also at a considerable depth. Cleverness and length of proboscis are thus required so that, as might be expected, these flowers are bee flowers. An insect visiting the flower alights on the wings, thus depresses them and, as they are joined to the keel, this is depressed also. The stigma and stamens are thus forced out, the stigma usually first so that it has the chance of brushing off pollen from the underside of the bee and thus being cross-pollinated.

There are four different types. (1) Flowers in which the stamens and stigma return within the keel so that repeated visits are possible; examples are the clovers. melilot and laburnum. (2) Flowers that are explosive, since the style and stamens are confined under tension in the keel and when it is depressed they are released with suddenness, thus scattering pollen on the undersurface of the bee. Only one insect visit is thus effective. Examples are broom (Genista), gorse (Ulex), lucerne (Medicago). (3) Flowers which display a piston mechanism—the pollen is shed early and the heads of the five outer stamens act as a piston so that the weight of the bee on the keel squeezes a narrow ribbon of pollen through the pore at the apex of the keel. A further pressure causes a protrusion of the stigma which is thus brought in contact with the bee. Examples are lupin (Lupinus), restharrow (*Ononis*) and bird's-foot trefoil (Lotus *corniculatus*). (4) Flowers which show a brush mechanism, for the pollen is again shed early and the style, which is provided with a brush of hairs, sweeps the pollen in small portions out of the tip of the keel. An example is the bean (Vicia faba).

Orchids—The orchids show many and complicated adaptations to pollination by insects. A great impetus to their study was given by the publication in 1862 of Charles Darwin's monograph on the various pollination mechanisms exhibited by this group. As is well known, in this flower there is generally only one stamen, which is two-lobed, and the pollen is in the form of two-stalked masses, the pollinia, which the insect carries away stuck to its head. As the insect flies away, the pollinia, if not already properly oriented, execute such a movement as brings them into position to touch the sticky stigma of the next flower that is visited. There are, honever. a great many variations in the details of this process. Nectar is not usually secreted by the orchid flower, hut to obtain a sweet juice the insect has to pierce a special tissue, usually that of the labellum (the posterior petal), which is often spurlike.

Honeysuckle.—The honeysuckle (Lonicera *periclymenum*) is a moth flower. It is pale in colour and becomes highly scented in the evening. Probably the scent is here the distant guide and the pale colour, showing up in half light, acts at close quarters. The tube is so long that it can be plumbed only by moths, which suck in flight. Stamens and style project from the mouth of the corolla. On the first evening of opening the style is folded down on the lower lip and only the stamens are touched. On the second evening the stamens are withered and empty and the style stands out, exposing the stigma.

BIRD POLLINATION (ORNITHOPHILY)

Pollination by insects is the basic type in flowering plants but there has gradually accumulated a great deal of evidence that pollination by birds is widespread throughout the tropics and in some warm temperate regions, such as western Australia and parts of South America. In Brazil one-third of the families investigated were found to include ornithophilous species. The birds concerned are mostly hummingbirds and honey birds, creatures that may be no larger than a bumblebee. They suck nectar through a closed bill with the tongue as a piston. They usually suck in flight and are rough visitors, not exact and clever like the bees. They require large quantities of liquid. They have little sense of smell. Their colour sense differs from that of the bee in that they distinguish reds, yellows and greens but not blues. Corresponding to these characters of the bird are distinctive characters in the flowers frequented.

The most notable is the frequency of brilliant reds. Of 160 South American species known to be bird pollinated. 134 or 84% were red. Garish colour contrasts are frequent. The bird-of-paradise flower (Strelitzia *reginae*) is blue and yellow. appearing to the eye of the bird as a pattern of black and yellow. The flowers of Billbergia are pink and green. The stamens and styles stand clear of the corolla and resist rough treatment by their stiffness. The flowers have no landing platform, spurs or such features. When birds perch they usually do so on bracts or other strong structures near the flower. In the Chilean *Puja* the tip of the inflorescence forms a rigid, flowerless perch. The flowers have no scent. but nectar is very abundant, even welling from the mouth of the corolla.

These features may be seen in some plants commonly grown in European greenhouses and gardens. Strelitzia is prized as a greenhouse plant for its brilliant colour display. The garden fuchsia

(*Fuchsia magellanica*) has flowers of crimson and blue. Style and stamens are stiff and project far out of the corolla. The nectar is so abundant that it can be shaken from the flower in drops. Even more interesting is *Salviu splendens*, the scarlet sage, extensively used as a bedding plant. It may be contrasted with the culinary sage described above. Apart from the colour it can be seen that the hooded petal and the broad landing stage are absent and that stamens and style are no longer enclosed but protrude from the corolla. It is a fine example of the way a flower fitted for bird pollination has evolved from the insect-pollinated type. There can be no doubt that ornithophily is a later development than entomophily and that the bird flower has evolved from insect-pollinated ancestors.

POLLINATION BY OTHER ANIMALS

Among the bats a group of vampires in the new world and a group of flying dogs in the old world have evolved suctorial tongues and feed on nectar. They act as pollinators. The bat is night flying. clings to the flowers with its claws and is a rough visitor. Bat-pollinated flowers tend to stand away from the stems or to hang in free bunches: they are a dirty white in colour and have a peculiar smell. Details of visits by quick-flying nocturnal animals are naturally hard to come by. But that the activity of bats is considerable is shown by the fact that. in Java alone, 31 species of plants have been identified as bat pollinated.

In Australia about a dozen species of small marsupials—the honey mice—are nectar feeders and pollinate the flowers of species of *Eucalyptus, Protea* and other trees.

Various other animals: including snails: have been observed transferring pollen.

POLLINATION BY WIND (ANEMOPHILY)

The conifers. more primitive than the flowering plants, are all wind pollinated. The pollen is not transferred to a stigma, for these are naked-seeded plants. The ovule is exposed and the pollen is caught in a drop of liquid exuded from the micropylar opening of the integument. There is an enormous wastage of pollen drifting in air currents, and very great quantities are produced. A male yew shaken in February fills the air with "yew smoke." Lakes in the vicinity of pine woods may have their surface covered with a yellow film. The pollen is very light. and powdery. in contrast to the sticky pollen of insect flowers. In the conifers male and female organs are always in separate cones and sometimes on separate trees.

There are many wind-pollinated flowering plants. They, too, produce light. powdery pollen in large quantities—as any sufferer from hay fever knows. The corolla is either little developed and green. or absent. There is neither scent nor nectar. Attractive characters are wanting. The lack of corolla is a positive advantage as it allows the free exposure of stamens and stigmas. The flowers stand well above surrounding foliage in the grasses, and appear before the leaves in such trees as the hazel and elm. The stigmas are often large and feathery, or covered with hairs acting as pollen traps. The individual stamen in the plantain and grasses, and the whole inflorescence in the hazel, is easily shaken, so that the pollen is readily dispersed when the air is in motion. Protogyny occurs, as in the plantain, and protandry, as in the grasses. Stamens and carpels occur in separate catkins in hazel, oak and beech.

The salad burnet (*Poterium sanguisorba*) in the Rosaceae and the meadow rues (*Thalictrum* spp.) in the Ranunculaceae are examples of wind-pollinated flowers in families normally insect-pollinated. There is no doubt that these and others like them do not show a primitive condition but were evolved from insect-pollinated ancestors. The great group of wind-pollinated plants which includes the grasses, sedges and rushes may also exhibit a derived condition. There is evidence to suggest that the most specialized family. the grasses! evolved through sedgelike and rushlike ancestors from showy-flowered plants of the lily type. The other great group of wind-pollinated plants. which comprises many forest trees such as the oak. birch. hazel and alder. offers a more diffcult problem. It Is possible that they are primitive types which have retained a primitive pollinating mechanism.

Pollination by the agency of water currents is very rare: an example is the grass wrack (*Zostera marina*).

SELF-POLLINATION (AUTOGAMY)

Self-pollination frequently takes place at the end of the life of a flower, ensuring fertilization if cross-pollination failed. It is often brought about by movements of the stamens or style. It is well seen in the Compositae where the branches of the style curl back and bring the stigmas into contact with their own pollen. There is great variety of detail in other flowers.

Some flowers never open and are said to be cleistogamous. They are small and budlike and petals are reduced or absent. The wood sorrel (*Oxalis acetosella*) and the sweet violet (*Viola odorata*) are examples.

APPLICATIONS

The fig is pollinated by a small wasp which passes from male to female inflorescences. The two are borne on separate trees and the male fig, which bears no fruit, is called a goat fig or caprifig. It was known in Greece in the time of Aristotle that goat figs must be planted near the fruiting trees, or branches placed in their crowns: the practice is known as caprification and still goes on. When the Smyrna fig was introduced into California at the end of the 19th century the goat fig and its wasps had to be brought in as well. The date is another Mediterranean fruit tree which was artificially pollinated from time immemorial by hanging male inflorescences among the female. The peach, when grown in the greenhouse, is usually pollinated by hand, using a brush or hare's foot; so is the melon. In the orchard it is often an advantage to make sure of adequate pollination by having beehives among the trees. Red clover can be pollinated only by bumblebees with their heavy bodies and very long tongues. The crop was a failure when first introduced into New Zealand, but succeeded when the bee was successfully established.

Artificial pollination is essential in all breeding work. When crosses are made it is usual to remove the stamens before they are ripe and to enclose the flower or inflorescence in a paper bag to avoid chance pollination. The most suitable technique must be worked out for each plant and an intimate knowledge of the development of the flower is required. When growing crops for seed production it is necessary to make sure that crossing with other varieties, and consequent impurity in the seed stock, does not occur. The cereals give little trouble in this respect, for they are almost entirely self-pollinated. With other crops—such as brassicas and beets—this is not so. Plots must be isolated by distance, by hedges or otherwise. Exact knowledge of pollination agencies is the basis of such precautions, and may even show precautions to be unnecessary.

BIBLIOGRAPHY.—The standard work is P. Knuth, *Handbook of Flower Pollination,* trans. by J. R. Ainsworth Davis, 3 vol. (1906–09), which includes an account of the work of such pioneers as C. K. Sprengel, C. Darwin and H. Müller. General accounts are in A. Kerner von Marilaun and F. W. Oliver, *The Natural History of Plants* (1894, 1895); M. Skene, *Biology of Flowering Plants,* 4th imp. rev. (1947), with reference to newer work. Accounts are given in most textbooks of botany. On the sense reactions of insects the main works are K. von Frisch, *Der Farbensinn und Formensinn der Biene* (1914), *Über den Geruchsinn der Biene* (1919); F. Knoll, "Insekten und Blumen," *Abh. zool.-bot. Ges.,* vol. xii (1921–26). A short account in English is K. von Frisch, *Bees, Their Vision, Chemical Senses and Language* (1950). Ornithophilous flowers are described by O. Sargent, "Fragments of the Flower Biology of Westralian Plants," *Ann. Bot.,* vol. xxxii (1918). For self-sterility consult D. Lewis, "Incompatibility in Flowering Plants," *Biol. Rev.,* vol. xxiv (1949). (V. H. B.; M. SE.)

POLLIO, GAIUS ASINIUS (76 B.C.–A.D. 4 or 5). Roman orator, poet and historian whose contemporary history, although lost. provided much of the material for Appian and Plutarch. Born into a leading Marrucine family—his grandfather had been an Italian general in the Social War—Pollio moved in the literary circle of Catullus and entered public life in 56 by supporting the policy of Lentulus Spinther (*q.v.*). In 54 he impeached unsuccessfully the tribune C. Cato, incurring Pompey's displeasure. In the Civil War he joined Caesar at the Rubicon and campaigned in Africa with Curio and (49–45) in Greece, Africa and Spain with Caesar, for whom he held a praetorian command in Spain against Sextus Pompey (44). On Caesar's death he followed Antony, for whom he governed Transpadane Gaul. There he was friendly with Virgil and in distributing land to veterans saved the poet's property from confiscation. He stood aloof from Fulvia, Antony's wife, and L. Antonius in the Perusine War, but held his army firmly in Antony's interests, and shared in the negotiations leading to the pact of Brundisium between Antony and Octavian in 40. In that year he was consul, and Virgil addressed his Fourth Eclogue to him. In 39 Pollio subdued the Parthini, an Illyrian people, and celebrated a triumph (Oct. 25). From the booty he built the first public library in Rome, in the Atrium Libertatis, which he restored. With full honours he then retired from public life. Unwilling to join Antony in the east, hoping for nothing from Octavian, he took no part in the Actium campaign (31) and subsequently maintained a position of republican dignity and independence. He gave hospitality to the rhetorician Timagenes, when the latter was in disgrace with Augustus. This was the main period of his activity as an advocate, and he devoted himself to the support of literature, organizing public recitations. He died in his villa at Tusculum.

Pollio was a distinguished orator, combining, according to Tacitus and Seneca, careful composition and dry Atticist elegance in strict presentation of his argument. His style displeased Ciceronian critics such as Quintilian and his speeches are lost. As a poet he was accepted by Catullus, Helvius Cinna and Virgil and wrote tragedies, which Virgil and Horace praised, but he ceased to write serious verse when he turned to history shortly after 35. His *Historiae* covered the period from 60 probably to 42 (hardly as late as 35 or 31), that is, from the First Triumvirate to Philippi —the period in which the Roman republic fell. To this contemporary work ("a work full of perilous hazard"), Pollio brought personal experience, independent judgment and a sober style that aided historical analysis. Pollio may be ranked with Sallust and Tacitus. A stern critic of men and style, he corrected Caesar, attacked Cicero, praised Brutus, and reprimanded Sallust for archaism and Livy for *Patavinitas* (probably "provincialism"). Above all, he defended Roman *libertas* under the *principatus* of Augustus. His three letters to Cicero (Ad *Cam.* x, 31–33) bring him closer to the reader than any other work.

BIBLIOGRAPHY.—For references to Pollio in classical literature see *Oratorum Romanorum fragmenta*, ed. by H. Malcovati, 2nd ed., pp. 516–518 (1955); *Historicorum Romanorunz reliquiae*, ed. *by H.* Peters, vol. ii, pp. 67–70, pp. lxxxiii–lxxxxvii (1906). *See* also R. Syme, *The Roman Revolution,* p. 5, 91 (1939), and *Tacitus,* p. 136 (1958); E. D. Pierce, A *Roman Man of Letters* (1922); J. André, La *vie et l'oeuvre d'Asinius Pollion,* with bibliography (1949); E. Gabba, *Appiano* (1956). (A. H. McD.)

POLLOCK, the name of a great English legal family. The best-known members are:

SIR JONATHAN FREDERICK POLLOCK (1783–1870), chief baron of the exchequer. was born on Sept. 23, 1783, in London, the son of David Pollock, saddler, of Charing Cross. He was educated at St. Paul's and Trinity college, Cambridge, and was called to the bar in 1807. He took silk in 1827, and in 1831 became member of parliament for Huntingdon. In 1834 he became attorney general and was knighted. His party lost office in 1835, but he was again attorney general from 1841 until in 1844 he succeeded Lord Abinger as chief baron of the exchequer. In 1866 he retired with a baronetcy, and on Aug. 22, 1870, he died at Hatton, Middlesex.

See Lord Hanworth (grandson of the chief baron), *Lord Chief Baron Pollock* (1929); Sir F. Pollock, 2nd Bart., *Personal Remembrances* (1887).

SIR FREDERICK POLLOCK (1845–1937), 3rd Bart., a grandson of the chief baron, and a notable author, was born in London on Dec. 10, 1845. He was educated at Eton and Trinity college, Cambridge, where he became a fellow in 1868. He was called to the bar by Lincoln's Inn in 1871 and for several years he practised, though with little success. After holding various teaching posts, from 1883 to 1903 he was Corpus professor of jurisprudence at Oxford. In 1885 he played a leading part in founding the *Law Quarterly Review,* the distinguished learned legal periodical of the common-law world, which he edited for the first 34 years. He also edited the *Law Reports* from 1895 to 1935. In 1911 he was made a privy councilor and in 1914 judge of the admiralty court of the Cinque Ports, an office with only nominal duties. In 1920 he became one of the first of the few academic lawyers to be made a king's counsel. He died in London on Jan. 18, 1937.

Sir Frederick Pollock's *Principles of Contract* was in many ways the first of the modern textbooks with a critical, analytical and learned approach, concentrating on principles rather than details. For over half a century his writings, especially in the *Law Qziarterly Review,* exerted an influence on the development of English law that was unprecedented for an academic lawyer. Yet Pollock was no mere lawyer; he was a true scholar who was widely read in many tongues, both in lam and other subjects, especially philosophy. Although somewhat reserved in his manner, he could be an effective speaker; and he was kindness itself to the serious student. Much of his remarkable personal and intellectual friendship of over 60 years with Justice Oliver Wendell Holmes, Jr., is revealed by their correspondence, published in 1941 and edited by M. de W. Howe.

Sir Frederick Pollock's works include *Principles of Contract* (1876; 13th ed., 1950); *Digest of the Law of Partnership* (1877; 15th ed., 1952); *The Law of Torts* (1887; 15th ed., 1951); *Possession in the Common Law,* with R. S. Wright (1888); *The History of English Law Before the Time of Edward I,* 2 vol., with F. W. Maitland (1895; 2nd. ed., 1898); *Spinoza, His Life and Philosophy* (1880; 2nd. ed. reissued with additions, 1912).

See Law Quarterly Review, vol. 53, pp. 151–206 (1937). (R. E. MY.)

POLLOCK, JACKSON (1912–1956), U.S. abstract painter, one of the founders of a loose movement called Abstract Expressionism or Action painting in the U.S. and *tachisrne* in France, was born at Cody, Wyo., on Jan. 28, 1912. After a period of realism after the style of Thomas Hart Benton, Pollock's first paintings in the new style, in 1943, mingled energetic linear invention and a subconscious imagery derived from Surrealism. His later work was entirely abstract, characterized by an intense activism of surface and by the interweaving of whipped lines. After 1947, Pollock employed aluminum paint and commercial enamels, dripping and spattering them over the canvas surface. This radical technical innovation brought him unfavourable publicity, but also helped identify him in the minds of many young American artists as the most revolutionary artist of an older generation of innovators. Pollock died at East Hampton, L.I., N.Y., on Aug. 11, 1956. Abstract Expressionism became one of the dominating international tendencies after the close of World War II. Its aesthetic principle is based upon free and expressive handling and unarranged, chance pictorial effects, which seem to arise spontaneously under the brush stroke. (S. HU.)

POLLS, PUBLIC OPINION: *see* PUBLIC OPINION.

POLL TAX. A tax of a uniform amount levied on each individual; a tax of so much per head (middle English *polle,* "a head"). By mid-20th century this tax had long been abandoned by most countries and nas not an important revenue raiser in any tax system in the world.

The most famous poll tax in English history is the one levied in 1380. which led to the revolt of the peasants under Wat Tyler in 1381, but the first instance was in 1377, when a tax of a groat a head was voted by both clergy and laity. In 1379 the tax was again levied, but on a graduated scale. John of Gaunt, duke of Lancaster, paid ten marks, and the scale descended from him to the peasants. nho paid one groat each, every person over 16 years of age being liable. In 1380 the tax was also graduated, but less steeply. For years after the rising of 1381 money was raised in this way only from aliens, but in 1513 a general poll tax was imposed. This produced only about £50,000, instead of £160.000 as was expected, but a poll tax levied in 1641 resulted in a revenue of about 1400,600. During the reign of Charles II, money was obtained in this way on several occasions. For years after 1688 poll taxes were a favourite means of raising money for the prosecution of the war with France.

Although a few U.S. states at mid-20th century still levied the tax for revenue purposes only. most discussion of the tax centred around its use as a voting prerequisite in the southern states. Ten southern states made the poll tax a voting prerequisite between 1889 and 1902; an 11th, Georgia, had enacted the requirement many years earlier. In its origins the tax is associated with the agrarian unrest of the 1880s and 1890s, which culminated in the rise of the Populist party in the west and the south. The Populists, a low-income farmers' party, gave the Democrats the only serious competition they had experienced since the end of Reconstruction. The intensity of competition led both parties to bring the Negro back into politics and to compete for his vote. Once the Populists were defeated the Democrats amended their state constitutions or drafted new ones to include various disfranchising devices. The poll tax was one of these. Its purpose was to disfranchise Negroes and possibly also to weaken politically the poor whites who had made up the backbone of the Populist party.

After 1920 the poll tax was abolished by state action in North Carolina, Louisiana, Florida, Georgia, South Carolina and Tennessee. Constitutional amendments to wipe out the tax were submitted to the voters in Arkansas, Virginia and Texas, but failed to pass. The tax still prevailed in these states as well as in Alabama and Mississippi at mid-century; the rate ranged from $1 to $2 per year. In Texas and Arkansas, failure to pay merely disfranchised a person for that year only and did not create an obligation which must be paid in subsequent years if he wished to vote. In Virginia and Mississippi the tax was in some degree cumulative, and in Alabama it was possible to run up a bill of as much as $36 in delinquent poll taxes which would have to be paid in order to vote. (D. S. S.; X.)

POLLUCITE, a rare mineral consisting of hydrated cesium aluminum silicate, is the richest source of cesium, the oxide being present to the extent of 30% to 36%. Cesium, together with rubidium, is important in the manufacture of photoelectric cells, scintillation counters and optical instruments and devices. Pollucite occurs sparingly, associated with the mineral petalite (*q.v.*) in cavities in the granite of Elba. and with beryl in pegmatite dikes at Andover and Hebron, Me.. and in the pegmatite mines of the Black hills, S.D. It also is found in Brazil, South-West Africa and the Union of South Africa.

The composition of pollucite is $CsAlSi_2O_6.H_2O$. It is closely related to the mineral leucite, $KAlSi_2O_6$. It crystallizes in the cubic system. is colourless and transparent and has a vitreous lustre. There is no distinct cleavage and the fracture is conchoidal, so that the mineral closely resembles quartz. The hardness is 6.5 and the specific gravity 2 90. See also CESIUM.

(L. S. RL.; X.)

POLLUX, JULIUS (2nd century A.D.) Greek scholar and rhetorician of Naucratis in Egypt, was the author of an *Onomasticon*, a Greek thesaurus of terms. The emperor Commodus appointed him to a chair of rhetoric in Athens. The *Onomasticon,* his only surviving work, is in ten books. It is incomplete, having undergone abridgment and interpolation in antiquity. The work contains rhetorical material (*e.g.,* collections of synonyms and compounds) and technical terms pertaining to a wide variety of subjects, as well as citations from literature. The material on music and the theatre is of special interest. Editions include that by W. Dindorf (1824) and by E. Bethe in the Teubner *Lexicographi* Graeci, 3 vol. (1900–37). (G. DO.)

POLLUX, in astronomy, the brightest star of the zodiacal constellation Gemini (*q.v.*). This reddish first magnitude star and the slightly less bright blue star Castor mark the heads of the celestial Twins, whose feet are in the Milky Way across from Orion. Pollux is distant 35 light-years and is intrinsically 33 times as luminous as the sun. The Twin stars are not far from overhead in the early evenings of early spring for observers in middle northern latitudes. (R. H. BR.)

POLO, MARCO (c. 1254–1324), Venetian traveller, was grandson of Andrea Polo of San Felice, and son of Nicolo Polo. The three Polos were presumably "noble," for Marco the traveller is officially so styled (*nobilis vir*). The three sons of Andrea Polo were engaged in commerce; the eldest suggests, by his will, a long business partnership with Nicolo and Maffeo.

About 1260, Nicolo with his wife and Maffeo were at Constantinople. The two brothers were led in their trading operations to the Crimea, and eventually to Bukhara. where they joined some envoys returning from a mission from Kublai Khan, with whom they journeyed to Cathay. It was the first time that the khan had met Europeans and he was delighted with the Venetian brothers. whom he sent back to the pope, with letters requesting the despatch of a body of educated men to instruct his people in Christianity and the liberal arts. On arriving at Acre in April 1269, they learned that no new pope had been appointed after Clement IV's death in 1268, and they returned to Venice.

The brothers resolved after two years to start again for the east. taking with them Nicolo's son Marco. They had letters authenticating their delay; but. hearing of the papal election soon after their start, they returned to execute Kublai's mission. The new pope. however, could supply but two Dominicans, who soon turned back.

Leaving Acre about Nov. 1271, Polo's book indicates that the party proceeded to Hormuz (Hurmuz) at the mouth of the Persian gulf, with the purpose of going on to China by sea; but that, abandoning their plans, they returned northward through Persia. Traversing Kerman and Khurasan, they went on to Balkh and Badakshan and ascended the upper Oxus through Wakhan to the plateau of Pamir (a name first heard in Marco's book). Crossing the Pamir, the travellers descended upon Kashgar, Yarkand and Khotan (Khutan). These are regions which remained almost absolutely closed to western knowledge till after 1860. From Khotan they passed on to the vicinity of Lop-Nor. Thence the desert of Gobi was crossed to Tangut, the region at the extreme northwest of China, within and without the Wall. In his account of the Gobi, or desert of Lop, as he calls it, Polo describes the waste, strikingly reproducing the description of the superstitious terrors of Suan T'sang, who crossed the desert 600 years earlier.

Early in 1275 the Venetians were cordially received by the Great Khan at Shangtu, and Marco made rapid progress. The "young bachelor" studied the languages of the Khan's subjects and soon entered the public service. On his public missions he travelled through Shansi, Shensi, and Szechuen provinces, and the wild country on the borders of Tibet, to the province of Yunnan, called by the Mongols Karajang, and northern Burma (Mien), Marco, during his stay at court, had observed the khan's interest in strange countries, and his disgust at the stupidity of envoys and commissioners who could tell of nothing but their official business. He made notes on facts likely to interest Kublai, which, on his return, he related He encountered many semi-civilized and barbarous tribes, many of which interested Kublai greatly.

Marco rose rapidly in favour and was often employed on distant missions as well as in domestic administration; he held for three years the government of Tangchow; on another occasion he visited Kangchow, the capital of Tangut, just within the Great Wall, and perhaps Karakorum on the north of the Gobi, the former residence of the Great Khans: also Ciampa, or southern Cochin-China; and perhaps, once more, on a separate mission to the southern states of India. We are not informed whether his father and uncle shared in such employments, though they rendered great service to the khan, in forwarding the capture of Siang-yang (on the Han river) during the war against southern China, by the construction of powerful artillery engines—a story, however, perplexed by chronological difficulties.

The Polos had become rich, and after their exile they began to dread what might follow Kublai's death. The khan, however, was deaf to suggestions of departure and the opportunity only came by chance. Arghun, khan of Persia, a grand-nephew of Kublai, lost in 1286 his favourite wife. Her dying injunction was that her place should be filled only by a lady of her own Mongol tribe. Ambassadors were despatched to the court of Peking to obtain one. The lady Cocacin (Kukachin), a maiden of seventeen, was chosen. The overland road from Peking to Tabriz was then imperilled by war, and Arghun's envoys proposed to return by sea Having met the Venetians, and bring eager to profit by their experience. they begged the khan to send the Franks in their company. He fitted out the party nobly for the voyage, sending friendly messages to the potentates of Christendom, including the pope, and the kings of France, Spain and England. They sailed from *Zaiton* or Amoy harbour in Fukien (probably the modern Changchow), then one of the chief Chinese havens for foreign trade, in 1292. The voyage involved long detention on the coast of Sumatra, and in south India, and two years or more passed before they arrived in Persia. Two of the three envoys and most of their suite died by the way; but the three Venetians survived all perils, and so did the young lady, who had come to look on them with filial regard. Arghun Khan had died before they left China; his brother reigned in his stead; and his son Ghazan married the lady. The Polos went on by Tabriz, Trebizond, Constantinople and Negropont to Venice, arriving about the end of 1295.

The first biographer of Marco Polo was John Baptist Ramusio, who wrote more than two centuries after the traveller's death. We need not hesitate to accept as a genuine tradition the substance of his story of the Polos' arrival at their family mansion in St. John Chrysostom parish in worn and outlandish garb, of the scornful denial of their identity, and the stratagem by which they secured acknowledgment from Venetian society.

We next hear of Marco Polo in a militant capacity. Jealousies had been growing between Venice and Genoa throughout the 13th century. In 1298 the Genoese prepared to strike at their rivals on their own ground, and a powerful fleet under Lamba Doria made for the Adriatic. Venice equipped a larger fleet under Andrea Dandolo. The crew of a Venetian galley at this time amounted to 250 men, under a *comito* or master. On one of the galleys of Dandolo's fleet Marco Polo served as *sopracomito* or gentleman commander. The hostile fleets met before Curzola Island on Sept. 6, and engaged next morning. The battle ended in victory for Genoa, and Marco Polo was taken there as a prisoner. The captivity lasted less than a year, and Marco returned to Venice in July or August 1299.

His captivity was the immediate cause of his *Book.* Up to this time he had related his experiences among his friends; and from these stories he had acquired the nickname of *Marco Millioni.* Yet he had written nothing. The narratives not only of Marco Polo but of other famous mediaeval travellers seem to have been extorted from them by pressure, and written down by other hands. In the prison of Genoa Marco Polo met Rusticiano or Rustichello of Pisa, also a captive of the Genoese, who was a respectable literary hack; he wrote down Marco's experiences at his dictation.

We learn little of Marco Polo's history after this captivity; at his death he left a wife, Donata, and three daughters, Fantina, Bellela and Moreta. One last glimpse of the traveller is gathered from his will. On Jan. g, 1324, he sent for a priest and notary to make his testament, and died the same day. He was buried, according to his wish, in the Church of St. Lorenzo. The archives of Venice have yielded a few traces of our traveller. Besides his own will just alluded to, there are the wills of his uncles, Marco and Maffeo; a few legal documents connected with the house property in St. John Chrysostom, and two or three entries in the record of the Maggior Consiglio. We have mentioned the sobriquet of Marco Millioni. Ramusio tells us that he had himself noted the use of this name in the public books of the commonwealth, and this statement has been verified in an entry in the books of the great council (dated April 10, 1305), which records as one of the securities in a certain case the "Nobilis vir Marchus Paulo Milion." It is alleged that long after the traveller's death there was always in the Venetian masques one individual who assumed the character of Marco Millioni, and told Munchausen-like stories to divert the vulgar. There is also a record (March 9. 1311) of the judgment of the court of requests *(Curia Petitionum)* upon a suit brought by the "Nobilis vir hlarcus Polo" against Paulo Girardo, who had been an agent of his. Another document is a catalogue of curiosities and valuables in the house of Marino Faliero, which mentions several objects that Marco Polo had given to one of the Faliero family. The most tangible record of Polo's memory in Venice is a portion of the Ca' Polo—the mansion where the three travellers, after their long absence, were denied entrance. The court in which it stands was known in Ramusio's time as the *Corte del millioni,* and now is called Corte Sabbionera. That which remains of the ancient edifice is a passage with a decorated 13th century archway.

No genuine portrait of Marco Polo exists. There is a medallion portrait dated 1761 on the wall of the Sala dello Scudo in the ducal palace. The oldest professed portrait is one in the gallery of Monsignor Badia at Rome, which is inscribed *Marcus Polus venetus totius orbis et Indie peregrator primus.* It is a good picture, but of the 16th century. The Europeans at Canton have absurdly attached the name of Marco Polo to a figure in a Buddhist temple there containing a gallery of "Arhans" or Buddhist saints, and popularly known as the "temple of the five hundred gods." The Venetian municipality obtained a copy of this on the occasion of the geographical congress at Venice in 1881.

Polo was the first traveller to trace a route across the whole longitude of Asia, describing kingdoms which he had seen; the first to speak of the court at Peking; the first to reveal China in its wealth and vastness, and to tell of the nations on its borders; the first to tell more of Tibet than its name, to speak of Burma, Laos, Siam, Cochin-China, Japan, Java, Sumatra; the Nicobar and Andaman Islands, Ceylon, India, but as a country seen and partially explored; the first in mediaeval times to give any distinct account of the empire of Abyssinia, and of the island of Sokotra, and to mention Zanzibar and Madagascar; while he carries us also to the remotely opposite region of Siberia and the Arctic shores, to speak of dog sledges, white bears and reindeer-riding Tunguses.

Within the traveller's own lifetime, we find the earliest examples of the practical and truly scientific coast charts (*Portolani*), based upon the experience of pilots, mariners. merchants, etc. In two of the most famous of the 14th century Portolani, we trace Marco Polo's influence—in the *Laurentian* or *Medicean Portolano* of 1351 (at Florence), and in the *Catalan Atlas* of 1375 (now at Paris). Both represent a very advanced stage of mediaeval knowledge, a careful attempt to represent the known world on the basis of collected fact, and a disregard for theological or pseudo-scientific theory; in the *Catalan Atlas,* as regards central and further Asia, and partially as regards India. Marco Polo's book is the basis of the map. His names are often much perverted, and it is not always easy to understand the view that the compiler took of his itineraries. Still we have Cathay placed in the true position of China, as a great empire filling the south-east of Asia. The trans-Gangetic peninsula is absent, but India proper is for the first time represented with a fair approximation to correct form and position. The map of Fra Mauro (1459) gives a much less accurate idea of Asia than the *Carta catalana.* Columbus possessed a copy of the Latin version of Polo's book made by Pipino, and on many pages of this there are manuscript notes in the admiral's handwriting, testifying to the influence of the work of the Venetian merchant upon the discoverer of the new world.

When. in the 16th century, attempts were made to combine new and old knowledge, the results were unhappy. The earliest of such combinations tried to realize Columbus' ideas regarding the identity of his discoveries with the great khan's dominions; but even after America had vindicated its independent existence, and the new knowledge of the Portuguese had named China where the Catalan map had spoken of Cathay, the latter country, with the whole of Polo's nomenclature, was shunted to the north, forming a separate system. Henceforward the influence of Polo's work on maps was simply injurious; and when to his names was added a sprinkling of Ptolemy's, as was usual throughout the 16th century, the result was a hotchpotch conveying no approximation to facts.

As to the alleged introduction of important inventions into Europe by Polo—although the striking resemblance of early European block books to those of China seem clearly to indicate the derivation of the art from that country, there is no reason for connecting this introduction (any more than that of gunpowder or the mariner's compass) with the name of Marco. In the 14th century not only were missions of the Roman church established in eastern China, but a regular overland trade was carried on between Italy and China. Many a traveller other than Marco Polo might have brought home the block books, and some might have witnessed the process of making them. This is the less to be ascribed to Polo, because he so curiously omits to speak of the process of printing, when, in describing the block-printed paper money of China, his subject seems absolutely to challenge a description of the art.

The book indited by Rusticiano is in two parts. The first, or prologue, as it is termed, is unfortunately the only part which consists of actual personal narrative. It relates the circumstances which led the two elder Polos to the khan's court, together with those of their second journey (when accompanied by Marco), and of the return to the west by the Indian seas and Persia. The second part consists of a series of chapters of unequal length and unsystematic structure, descriptive of the different states and provinces of Asia (certain African islands and regions included), with occasional notices of their sights and products, of curious manners and remarkable events, and especially regarding the Emperor Kublai, his court, wars and administration. A series of chapters near the close treats of sundry wars that took place between various branches of the house of Jenghiz in the latter half of the 13th century. There is now no doubt that the original was written in French. A manuscript in rude and peculiar French, belonging to the National Library of Paris (Fonds, Fr., 1116), which was printed by the Société de géographie in 1824, is evidently either the original or a close transcript. It shows characteristics of the unrevised product of dictation which would necessarily have disappeared in a translation or revised copy. Eighty-five mss. of the book are known, and their texts exhibit considerable differences. For a discussion of these see the authorities quoted in the bibliography.

We know from Gilles Mallet's catalogue of the books collected in the Louvre by Charles V, dating *c.* 1370–75, that five copies of Marco Polo's work were then in the collection; but on the other hand. the 202 known mss. and the numerous early printed editions of "Mandeville," with his lying wonders, indicate a much greater popularity. Dante, who lived 23 years after the book was dictated, never alludes to Polo; nor can any trace of Polo be discovered in the book of his contemporary, Marino Sanudo the Elder, though he is well acquainted with the work of Hayton the Armenian. Mandeville himself, who plundered right and left, hardly ever plunders Polo. The only literary works we know of the 14th century which show acquaintance with Polo's book or achievements are Pipino's *Chronicle,* Villani's *Florentine History,* Pietro d'Abano's *Conciliator,* the *Chronicle* of John of Ypres, and the poetical romance of *Baudouin de Sebouro.*

BIBLIOGRAPHY.—Sir Henry Yule's edition, which in its final shape, as revised and augmented by Henri Cordier (. . . *Marco Polo* . . . London, 1903), is the most complete storehouse of Polo learning in existence, embodying the labours of all the best students of the subject, and giving the essence of such works as those of Major P. Molesworth Sykes *(Ten Thousand Miles in Persia,* etc.) so far as these touch Marco Polo; the Archimandrite Palladius Katharov's "Elucidations of Marco Polo" from vol. x of the *Journal* of the North China branch of the Royal Asiatic society (1876), pp. 1–54; F. von Richthofen, *Letters to Shanghai Chamber of Commerce;* E. C. Baber, *Travels . . . in Western China;* G. Phillips, *Identity of . . . Zaitun with Changchau in T'oung Pao* (Oct. 1890), and other studies in *T'oung Pao* (Dec. 1895 and July 1896). There are in all 10 French editions of Polo as well as 4 Latin editions, 27 Italian, 9 German, 4 Spanish, 1 Portuguese, 12 English, 2 Russian, 1 Dutch, 1 Bohemian (Czech), 1 Danish and 1 Swedish. *See* also E. Bretschneider, *Mediaeval Researches from Eastern Asiatic Sources,* i, 239, 167; ii, 8, 71, 81–84, 184; Léon Cahun, *Introduction à l'histoire de l'Asie,* 339, 386; C. Raymond Beazley, *Dawn of Modern Geography,* iii, 15–160, 545–547, 554, 556–563; R. Allulli, *Marco Polo* (1923). *(H. Y.;* X.)

POLO, the most ancient game with stick and ball, takes its name from the Tibetan *pulu,* "a ball." The earliest records of polo are Persian; there is evidence that it was played in the time of King Darius. From Persia it spread to Constantinople, and eastward through Turkistan to Tibet, China and Japan, and from Tibet to Gilgit and Chitral. It was imported to Manipur from China. Polo also flourished in India throughout the Mogul dynasty. Then for 200 years its records in India proper cease, though the game continued to be played in Chitral, Gilgit, Little Tibet and Manipur.

In 1859 the first Europeans' polo club was formed and the first rules of the game drawn up at Silchar in Cachar near Manipur. The Calcutta Polo club was formed in the early 1860s. In 1869 the 10th Hussars started to play polo in England after reading an account of the game in India.

In 1871 the first recorded match took place on Hounslow heath between the 9th Lancers and the 10th Hussars, with eight players a side; in 1873 the numbers were reduced to five and in 1882 to four. The Hurlingham Polo club was founded in 1874 and the first code of rules was drawn up. Two other famous London clubs, Ranelagh and Roehampton, were started in 1896 and 1902 respectively.

The Game.—Polo is played with four players on each side, on exactly the same principles as hockey or association football. The ball is light, made of willow or bamboo root, not more than $3\frac{1}{4}$ in. in diameter and weighing between $4\frac{1}{4}$ and $4\frac{3}{4}$ oz. The stick is made of cane, with a narrow wooden head set on it at a slight angle, and is from 48 to 52 in. long.

A full-sized polo ground should not exceed 300 yd. in length by 200 yd. in width, if unboarded; and 300 yd. in length by 160 yd. in width, if boarded. The goals are not less than 250 yd. apart, and each goal is 8 yd. wide. A match lasts about an hour, divided into periods of play known as chukkers; intervals between periods, when ponies are changed, are of three minutes with five minutes at half time. Ends are changed every time a goal is scored.

Two umpires are required in a first-class match and in an important tournament a referee at the side of the ground decides disputes if the umpires disagree.

Tournaments are organized according to a system of handicapping which is world-wide. Handicapping committees rate all players during a season between ten and no goals and teams of specified totals (*e.g.,* 12 or 20 goals) are made up.

Development of Modern Polo.—Before 1881, when John Watson laid the foundation of modern polo, the method of play was for one man on each side to be the goalkeeper, and for the others to play forward and to hit the ball when and how they could. Watson introduced the backhand stroke, and placed his men at forward (no. 1 and 2) halfback (no. 3) and back (no. 4). He also taught them to combine and hit to each other. But he taught the game on rather rigid lines.

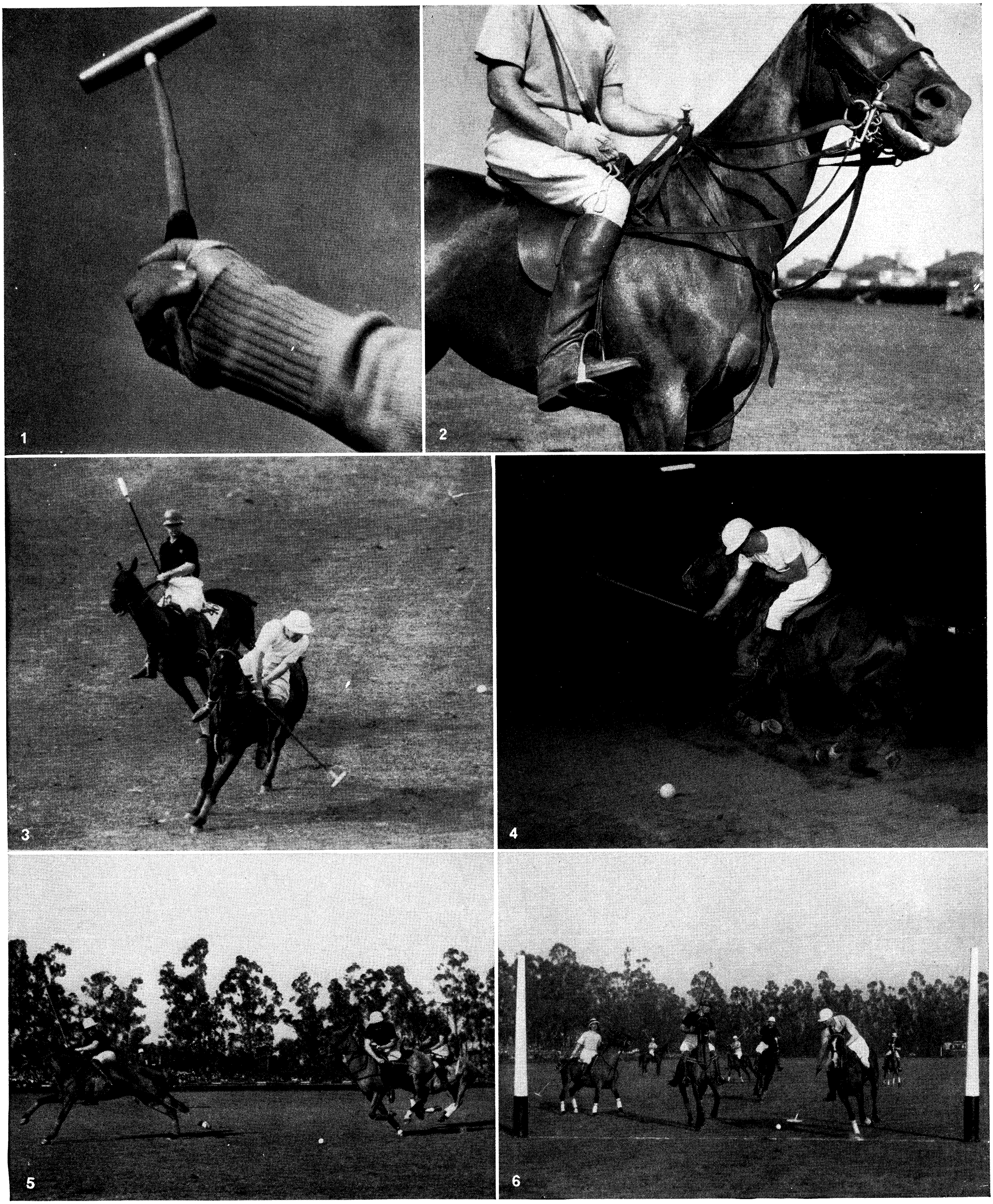
Then the brothers J., A. E. and A. Peat demonstrated how to play the game more scientifically, with such success that they won the Champion cup at Hurlingham eight times. Then came the era of the Freebooters', Rugby, Old Cantab and Roehampton teams, and of the various good regimental teams.

English polo suffered a shock in 1909 when the U.S. team known as "the big four" beat England easily for the Westchester cup. The U.S. had never adopted the English offside rule; they consequently developed a much faster and more elastic game. They met the ball on all possible occasions and hit under their ponies' necks instead of hitting backhanders from the side of the ground. They had developed the science of the attack, galloped faster and were much more accurate goal hitters. Their handicap system, dating from 1891, brought on young players quickly.

In 1910 the Hurlingham club, profiting by the lessons learned from the U.S. in 1909, made two important alterations in their rules. Offside was abolished and handicapping was introduced.

World War I gave a serious setback to English polo. The cost of the game increased enormously. Pony wastage in the war had been heavy, and speeding up the game meant that better ponies were needed; the big thoroughbred trained pony was in great demand, and its price rose considerably. It was contended by some that the quality of polo deteriorated because the size of the ponies made accurate hitting more difficult and the training less thorough. In spite of this polo flourished up to World War II. Programs were organized so that there were tournaments for all classes of players every week. The number of periods played in a match was reduced from eight to six throughout the British empire after World War I.

In India polo playing began gradually to decline. India finally



PHOTOGRAPHS, (1-3, 5) ACME, (4) PUBLIX PICTORIAL SERVICE, (6) INTERNATIONAL

TECHNIQUE AND PLAYS IN POLO

1. A thong attached to the haft of the mallet is wound tightly around the player's wrist to insure against loss of the mallet during play. The ball is hit with the side, not the head, of the mallet

2. Proper arrangement of the bridle reins on a polo pony. A martingale passed between the pony's forelegs and fastened to the girth under the belly gives the rider added control over his mount

3. Player making a backhand save. The ball is at the far right

4. Strobo-flash photograph of beginning of the swing in a backhand save

5. The player at the left is racing forward to receive a pass from his teammate (right) who is being pressed from behind by an opponent

6. Making a goal

ceased to be the training ground for British polo players in 1947.

The U.S. was at the height of its power between World Wars I and II, and all four members of its team in the Westchester cup of 1939 held handicaps of 10 goals. Argentina, with a unique pony power, were in the same class and in 1936 won the polo match at the Olympic games. Polo in the British empire was stronger than ever.

After World War II it looked as if polo in England was finished. In London, Ranelagh was derelict. The celebrated international ground at Hurlingham and the no. 2 ground were forcibly acquired by the London County council. Roehampton maintained one ground which was only available for a fortnight in the summer. In any case the cost of keeping ponies in London made a revival impossible. But the remnants of the prewar players were determined to carry on. The small Ham club was the first to start. Then Viscount Cowdray began a great revival with the Cowdray Park Polo club. Other old clubs revived and new ones started. A coronation tournament was organized in 1953; the U.S., Argentina, Spain and Chile brought teams. A feature of postwar polo was the large crowd of spectators that attended weekend polo at some clubs.

In 1949 the County Polo association was amalgamated with the Hurlingham Polo association, to which the associations of the following countries were affiliated and had representatives on the council — Ireland, India, Pakistan, South Africa, Egypt, New Zealand. Australia, Kenya, Nigeria, Malaya, Malta and Jamaica. In South Africa polo developed enormously after World War II. Argentina had become the leading polo-playing country. High-class polo had also developed rapidly in Mexico and in Chile, Colombia, and in other parts of South America.

Breeding of Polo Ponies. — The breeding of polo ponies is supervised in England by the National Pony society which maintains a stud book for all kinds of riding ponies and holds an annual show when prizes and medals are given for polo pony classes. Before World War I English- and Irish-bred ponies predominated, though there was a steady influx of Argentine ponies beginning in the '90s.

In India the small country-bred and Arab ponies held sway till the height increase to 14.1 and 14.2 brought in the Australian ponies in large numbers, and New Zealand produced some of high-class quality.

Polo Championships. — The two most important trophies for polo are the Hurlingham Champion cup, inaugurated in 1876, and the Westchester cup, an international contest between Great Britain and the United States. The first Westchester meeting took place in 1886.

Other important events in the London polo season before World War II were the matches for the Ranelagh open cup, started in 1897, the Coronation cup, 1911, and the Roehampton open cup, 1914.

Important events in India were the Indian Cavalry tournament (founded 1883), the Indian Infantry tournament (1884), the Indian Interregimental tournament (1877), the Indian Polo associations championship cup (1900) and the Prince of Wales cup (1921). The first Interregimental tournament at Hurlingham was held in 1878. (J. R. C. G.)

United States. — Attack has always been stressed in play in the U.S. In 1888 what came to be regarded as perhaps the most important legislative contribution to the sport was introduced with the first handicapping of players. Until that time, the game had been virtually monopolized by the better players and H. L. Herbert conceived the idea of the handicap to make possible a wider spread of play. The handicap, low at the start of a player's career, increases with his ability. Thus the beginners are able to play with the more experienced players on a far more even footing. Only the international matches and the open tournaments are played without handicap.

In a game the handicaps of all four players are totalled and the team handicaps compared. One team (unless the totals are even) receives the difference in total handicap. The handicapping system almost immediately resulted in new tournaments and new clubs.

Ten goals was the highest rating ever given to a player as of the mid-1950s. This was held in the U.S. game at varying times by Foxhall P. Keene, John E. Cowdin, Thomas Hitchcock, R. L. Agassiz. J. M. Waterbury, Jr., Lawrence Waterbury, Harry P. Whitney, Louis E. Stoddard, J. Watson Webb, Malcolm Stevenson, Devereux Milburn, Thomas Hitchcock, Jr., Cecil Smith. Elmer Boeseke, Stewart Iglehart, Michael Phipps and Robert Skene.

After the U.S. won its first victory in the Westchester cup international series with England in 1909, the rules were assimilated. The U.S. adopted the English rule permitting the hooking of mallets, and the English abandoned the outside rules and adopted the handicap system. At the close of World War I in 1918, all efforts at limiting the size of ponies were abandoned.

At first the U.S. teams played with native horses, mainly found in the southwest and descended, in part, from the Spanish barb left by those who penetrated that part of the United States in its early history. Later, though Texas and Wyoming produced many polo horses, the thoroughbred was much in demand, with English and Irish blood prominent in a certain line of mounts. The ponies of Argentina later became most popular, but thereafter, Texan mounts regained their popularity.

Although the number of international contests declined, there were more polo players in the United States in the 1950s than ever before. The reduction in the cost of playing was considered the reason for the increase. A new section of the sport, arena polo, a combination of outdoor and indoor polo, proved popular with both players and fans. (R. F. K.; G. E. Cn.)

Bibliography.—R. Weir and J. M. Brown, *Riding and Polo*, Badminton Library, rev. by T. F. Dale, new ed. (1905); J. M. Brown, *Polo* (1895); G. J. Younghusband, *Polo in India (1890)*; *Tournament Polo (1897)*; T. F. Dale, *The Game of Polo (1897)*; T. B. Drybrough, *Polo*, 2nd ed. (1906); E. D. Miller, *Modern Polo*, 6th ed. (1930); W. Buckmaster, *Hints on Polo Combination (1910)*; W. C. Forbes, *As to Polo* (1920); W. B. Devereux, *Position and Team Play in Polo (1914)*; "Marco" (Earl Mountbatten of Burma), *An Introduction to Polo*, 3rd ed. (1950); Hurlingham Club, *Laws and Bye-Laws of Polo (1912 et seq.)*; National Pony Society, *The Polo Pony Society Stud Book (1894 et seq.)*; *The Polo Monthly* (London, 1909–39); *Baily's Magazine of Sports and Pastimes (1889–1926)*; annual publications of the Hurlingham Polo association, the American Polo association and the Indian Polo association. (J. R. C. G.)

POLOCK, MOSES (1817–1903), U.S. publisher and bibliophile, is chiefly remembered as the first rare-book dealer to devote himself solely to Americana. Born in Philadelphia, Pa., on May 14, 1817, he was apprenticed to the firm of McCarty and Davis, an old Philadelphia house of bookdealers and publishers. Polock succeeded to the ownership of the firm in 1851 and from 1853 the business was conducted under his name. The store was frequented by well-known literary figures of the time.

Notable among his publications was the first collected edition of the works of Charles Brockden Brown (*q.v.*), earliest U.S. novelist, which appeared in 1857. He was also responsible for the first U.S. collection of children's literature; he specialized in books on Benjamin Franklin and George Washington. He became an authority on the early history of Philadelphia and Pennsylvania. Polock died on Aug. 16, 1903.

See W. Brotherhead, *Forty Years Among the Old Booksellers of Philadelphia (1891)*; A. S. W. Rosenbach, *Books and Bidders (1927)*.

POLONAISE, a dignified ceremonial dance, in $\frac{3}{4}$ time. It frequently served, from the 17th to 19th centuries, to open court balls and other royal functions. Originally a folk dance or warriors' triumphal march, it was adopted by the Polish nobility as a formal march as early as 1573. In its aristocratic form the dancers, in couples, walked around the ballroom in stately procession, with slightly accented steps.

As a musical form, the polonaise was occasionally employed by Luduig van Beethoven, Wolfgang Mozart and George Frederick Handel, and was highly developed by Frédéric Chopin. The polonaise has been introduced in opera (Modest Mussorgsky's Boris *Godounoff*) and ballet (Peter Tschaikovsky's *The* Sleeping Beauty). (Ln. Me.)

POLONIUM (see also Radioactivity, Natural). A radioactive element; symbol Po; atomic number 84.

Historical. — This element was discovered in 1898 by Pierre and Marie Curie. Having found that the radioactivity of uranium and thorium minerals was much greater than could be predicted by the content of uranium and thorium. they undertook to extract the substance responsible for this anomaly from a uranium mineral. Joachimsthal pitchblende. Since the only known property of this hypothetical substance was its radioactivity. Pierre and Marie Curie developed a new experimental method which has remained the basis of all radioactive chemistry. They carried out separations of the various substances in the mineral and measured the radioactivity of each portion. They quickly found that the activity became concentrated, partly with the alkaline earths and partly with the sulphides precipitated from acid solution. They were soon able to confirm the existence of two new radioelements: one a higher homologue of barium — radium; the other a homologue of tellurium. to which they gave the name polonium in honour of Marie Curie's birthplace. Poland.

Polonium was the first element to be discovered by the radiochemical method.

Since then the term polonium has been used in a more general sense and fills the 84th place in Dmitri Mendeléyev's table. allotted to the numerous isotopes listed below. Some of these isotopes are members of the natural radioactive families. (Their individual symbols are given in parenthesis). The others are artificial radioelements.

Isotope	*Period*	*Manner of Disintegration*
Po^{206}	9 days	K (90%), α (10%)
Po^{207}	5.7 hr.	K (about 100%), a (0.01%)
Po^{208}	about 3 yr.	α
Po^{209}	very long (?)	–
Po^{210} (RaF)	140 days	α
Po^{211} (AcC′)	5×10^{-3} sec.	α
Po^{212} (ThC′)	3×10^{-7} sec.	α
Po^{213}	4.4×10^{-6} sec.	α
Po^{214} (RaC′)	1.5×10^{-4} sec.	a
Po^{215} (AcA)	1.8×10^{-3} sec.	β (about 5.10^{-4}%), α (about 100%)
Po^{216} (Th.4)	0.158 sec.	β (about 0.014%), a (about 100%)
Po^{217} (not discovered)		
Po^{218} (RaA)	3.05 min.	β (0.04%), α (about 100%)

The radioelement discovered by Pierre and Marie Curie is the principal isotope: Po^{210}.

Natural Occurrence and Preparation. — Polonium is found in much smaller amounts than radium in minerals containing uranium. About 2,900 kg. of uranium element are in radioactive equilibrium with 1 g. of radium and 0.224 mg. of polonium (1 curie). It can therefore be estimated that the polonium content of a Joachimsthal pitchblende containing **65%** of uranium is about 0.05 mg. in 1,000 kg. of the mineral.

The half life of polonium is long enough to enable it to be extracted directly from uranium minerals. This process has been used but is of little practical value. It is usually extracted either from radio-lead, which is a by-product of the extraction of radium from uranium minerals, or from radium D, obtained by washing old radium tubes which contain the long-lived active deposit: radium D+E+F (I. Curie), or it can be extracted from old preparations of radium salts (E. Rona).

The extraction of polonium from solutions of radium D, as well as the preparation of strong sources (up to about one to two millicuries/cm.^{2}) of this radioelement is usually carried out by electrochemical deposition on Ag or Ni from a weak solution of acetic, nitric or hydrochloric acid. On Ag, Po is deposited free from RaE and RaD; on Ni, from hot solution, Po and RaE are deposited almost free from RaD (W. Marckwald, I. Curie, O. Erbacher and K. Philipp).

Strong sources can be obtained by volatilizing polonium at red heat in a quartz tube in a current of nitrogen or argon and collecting it on a cooled metallic surface (E. Rona and E. Schmidt, I. Curie and F. Joliot).

Finally, element number **84** can be produced artificially by transmutation of atoms of lead or bismuth (J. J. Livingood; D. G. Hurst, R. Latham and W. B. Lewis; D. H. Templeton, J. J. Howland and I. Perlman).

In certain nuclear reactions it is formed directly:

Pb^{204}	(α,2n)	Po^{206}
Pb^{206}	(α,3n)	Po^{207}
Pb^{207}	(α,3n)	Po^{208}
Pb^{208}	(α,2n)	Po^{210}
Bi^{209}	(p,2n)	Po^{208}
Bi^{209}	(d,an)	Po^{208}
Bi^{209}	(d,n)	Po^{210}

In others, Bi^{210}(RaE) is formed intermediately:

Bi^{209}	(n,γ)	Bi^{210}
Bi^{209}	(d,p)	Bi^{210}
Pb^{208}	(α,pn)	Bi^{210}

and $Bi^{210}\xrightarrow{\beta}Po^{210}$.

Properties and Radioactivity. — In 1910 Marie Curie and A. Debierne, using about 0.1 mg. of Po mixed with a few milligrams of other metals. studied the spark spectrum of this material and observed several lines attributable to polonium. the most intense of which was at 4,170.5 A.U. In 1930 A. Czapek pointed out the existence of a line at 2,450.0 Å.U. B. Karlik and H Petterson confirmed this and have drawn attention to a line at **2,558**12 **Å.U.**

The coefficient of diffusion of polonium at ordinary temperature in Al, Fe, Ni, Cu, Ag, Au and Pb is low, about 10^{-14} cm.^{2}/day according to E. Rona and E. Schmidt. In gold and platinum at 470° it is about 10^{-9} cm.^{2}/day (L. Wertenstein and H. Dobrowolska).

According to P. Bonet-Maury, the rate of volatilization in *vacuo* of Po deposited on Ni is measurable at 108° C. and, on heating for 5 min. at 350° C., 90% of the polonium atoms are liberated. From Pt, volatilization does not begin until about 350°. According to Rona it begins from Au at a slightly lower temperature and from Pd only at about 500°–560° C. The vaporization temperature of Po increases with the age of the product. It also varies with the method of preparation of the sources and the gaseous atmosphere into which volatilization is carried out.

Since polonium belongs to the radioactive family uranium-radium and is formed by the disintegration of radium E, an isotope of bismuth, it is sometimes called radium F (RaF).

It disintegrates in its turn with the emission of a-rays to give radium G, an inactive isotope of lead (Pb^{206}). The disintegration period (half life) of polonium is **140** days.

$$\mathrm{Ra}\xrightarrow[\alpha]{}\mathrm{Rn}\xrightarrow[\alpha]{}\mathrm{RaA}\xrightarrow[\alpha]{}\mathrm{RaB}\xrightarrow[\beta]{}\mathrm{RaC}\begin{cases}\xrightarrow{\alpha}\underset{1.32\ \mathrm{min.}}{\mathrm{RaC''}}\xrightarrow{\beta}\\ \xrightarrow{\beta}\mathrm{RaC'}\xrightarrow{\alpha}\end{cases}\mathrm{RaD}\xrightarrow[\beta]{}\mathrm{RaE}\xrightarrow[\beta]{}\mathrm{Po(RaF)}\xrightarrow[\alpha]{}\mathrm{RaG\,(Pb)}$$

Period =	1,590 years	3.82 days	3.05 min.	26.8 min.	19.7 min.	1.5×10^{-4} sec.	22 years	5 days	140 days	stable

The range of the a-rays from polonium has been determined with great accuracy by Irène Joliot-Curie and is **3.87** cm. in air at 15° C. and 760 mm. of Hg. In the gelatin of usual photographic plates it is about 27μ and in aluminum, 22μ. During its passage through air each of the a-particles emitted gives rise to 152,000 pairs of ions. It is calculated that the amount of polonium corresponding to a saturation current of 1 E.S.U. in an ionization chamber utilizing all the ions produced in a solid angle of 2π is equal to 1.67×10^{-10} g. A current of 1,350 E.S.U. represents 1 millicurie of polonium. This a-radiation. which does not seem to be of uniform (kinetic) energy, is accompanied by γ-radiation of weak intensity (about one quantum of 0.773 Mev for 10^5 α-particles) and a secondary β-radiation. According to A. Sanielevici the hourly heat output of 1 E.S U. of polonium, equivalent to the kinetic energy of the a-rays and the recoil RaG atoms is equal to 20.24×10^{-6} cal.

M. Curie and A. Debierne have been able to make a direct determination of the Avogadro number by measuring the volume of helium corresponding to a known number of a-particles emitted by a source of polonium.

The radiation from polonium can bring about the decomposition of water, the ozonization of air, the marking of photographic plates and the coloration of glass or quartz. It exerts a toxic effect on living organisms. A rabbit injected with 500 E S U. of Po wasted considerably and died a few days afterward (A. Lacassagne, J. Lattès and J. Lavedan).

Polonium is often used in radioactivity as a source of a-radiation free from penetrating rays. I. Curie and F. Joliot discovered artificial radioactivity in 1934 by bombarding aluminum, boron and magnesium with a-rays from polonium. A deposit of polonium on beryllium forms a natural source of neutrons which are produced by the nuclear reaction:

$${}^{9}_{4}\mathrm{Be}+{}^{4}_{2}\alpha={}^{12}_{6}\mathrm{C}+{}^{1}_{0}\mathrm{n}$$

and $$^{9}_{4}\text{Be}+^{4}_{2}\alpha=3\,^{4}_{2}\alpha+^{1}_{0}\text{n}.$$

The chemical and electrochemical properties of polonium were determined by radiochemical methods using very small amounts of the order of 10^{-11} to 10^{-6} g. of Po^{210}(RaF).

Polonium in 0.1–0.5 normal solutions of nitric, hydrochloric or acetic acid is deposited spontaneously on Ag, Te, Bi, Ni and on the less noble metals (Marckwald and others).

By the action of an electric current it can be collected from acid solution on the cathode, probably in the metallic state, and on the anode as the peroxide (F. Paneth and G. Hevesy). Similarly, deposits on the cathode and the anode can be obtained from sufficiently alkaline soda solution (M. Haissinsky).

The critical deposition potential of Po in acid solution, for concentrations in the region of 10^{-8} to 10^{-10} normal, has been determined by the decomposition potential method devised by Hevesy and Paneth and considerably improved by F. Joliot. Assuming that Nernst's electrochemical law is applicable when extrapolating to normal potential, as shown by the experiments carried out by Haissinsky with solutions of Bi and its isotopes RaE and ThC, it is found for the electrode Po/Po^{++++} with respect to the hydrogen electrode that:

$$E_h^o\ (Po/Po^{++++}) = +0.77 \text{ v. at } 18° \text{ C.}$$

Polonium is situated, then, between Ag and Te in the normal potential series.

F. Joliot has shown that the cathode deposition potential is lowered if electrolysis is carried out in acid solution in the presence of different reducing agents.

Chemical Properties.—Chemically, polonium being the higher homologue of tellurium and next to bismuth in the periodic table is allied to both these elements.

The following properties of polonium are in common with those of tellurium and bismuth: hydrolysis of its compounds in aqueous solution near the neutral point with the formation of an insoluble hydroxide; precipitation of a sulphide insoluble in dilute acid (P. and M. Curie), reduction to the metallic state by hypophosphorus and hydrosulphurous acid, $TiCl_3$ in hydrochloric acid solution and by hydrazine and formaldehyde in soda solution (M. Guillot and Haissinsky).

Polonium resembles tellurium in its amphoteric character. It can, in effect, act as a cation in acid solution but also gives a volatile hydride PoH_2 (Paneth) and a sodium polonide $PoNa_2$ (V. Khlopin and A. Samartseva). Polonium hydroxide $(O{=}Po{=}[OH]_2)$ is equally amphoteric and dissolves in concentrated sodium hydroxide to give a polonite Na_2PoO_3, analogous to the tellurites (J. Escher-Desrivières). As with tellurium, polonium is precipitated in the metallic state from hydrochloric acid solution by $SnCl_2$ (Marckwald). Finally, according to M. Guillot, it forms polonium hexachlorides isomorphous with similar salts of Te, Pb, Sn, Pt $([M^{IV}Cl_6][NH_4]_2)$ and is then, in that case, quadrivalent and hexa-co-ordinated.

On the other hand, contrary to tellurium, polonium is not precipitated from acid solution by hydrazine and SO_2. It resembles bismuth in the insolubility of its sulphide in ammonium sulphide in alkaline solution (M. Curie) and the insolubility of its pyrogallate in weakly acid solution (Haissinsky). Furthermore, M. Guillot has obtained mixed crystals of dithiocarbamates of polonium and the trivalent metals Bi^{+++} and Co^{+++}. This worker explains the analogies between Po and Bi by supposing that certain reducing agents convert polonium to the trivalent state, which is in agreement with the existence of two cathode deposition potentials. The co-ordination index of the ion Po^{+++} in the complex should be the same as Po^{++++} and equal to 6. Under certain conditions it forms an oxychloride soluble in anhydrous ethyl alcohol, acetone and dioxane (G. Bouissières).

An acetylacetonate of polonium is known (M. Servigne), also a polonium methyl (V. Khlopin and A. Samartseva) and a polonium carbonyl (I. Curie and M. Lecoin).

Summarizing, chemical and electrochemical work has led to polonium's being attributed positive valencies 6, 4, 3 and negative valency 2.

Dosage.—A thin layer of polonium is prepared when measuring the ionization produced by its α-radiation. If it is mixed with other salts, it must be extracted by electrochemical deposition on silver or nickel foil (1 E.S.U. equals 1.67×10^{-10} g. of Po). The magnitude of the activity of a source can be readily judged by the luminosity produced in the dark on a screen of zinc sulphide placed in front of it.

Glossary of Technical Symbols Used in This Article

Ra	Radium	Te	Tellurium
Ac	Actinium	Bi	Bismuth
Th	Thorium	Pb	Lead
&	Silver	Sn	Tin
Ni	Nickel	Co	Cobalt
Pt	Platinum	$TiCl_3$	Titanous chloride
Al	Aluminum	$SnCl_2$	Stannous chloride
Fe	Iron	SO_2	Sulphur dioxide
Cu	Copper	μ	Micron ($=10^{-3}$ mm.)
Pd	Palladium	E.S.U.	Electrostatic unit
Hg	Mercury	Mev	Million electron volts

Bibliography.—Marie Curie, *Traité dc radioactivité* (1935); Irene Joliot-Curie, *Radioéléments naturels* (1946); M. Haissinsky, *Le Polonium* (1937). (I. J.-CE.; G. Bs.)

POLONNARUWA, a ruined city and ancient capital of Ceylon. It first became a royal residence in A.D. 368, when the lake of Topawewa was formed, and succeeded Anuradhapura as the capital in the middle of the 8th century. The principal ruins date chiefly from the time of Prakrama Bahu (A.D. 1153–86). The most imposing pile remaining is the Jetawanarama temple, a building 170 ft. in length, with walls about 80 ft. high and 12 ft. thick. The city is now entirely deserted, and, as in the case of Anuradhapura, its ruins have only recently been rescued from the jungle.

POLOTSK, a town of the Belorussian S.S.R., U.S.S.R., at the confluence of the Polota and Dvina, in 55° 29' N., 28° 49' E. Pop. (1956 est.) 38,100. It is on a railway junction and has saw-milling and timber industries and a flour mill. Its position between central Russia and the west made it a storm centre, and little of the ancient town remains; both the upper castle, which had seven towers, and the lower one are in ruins and its 12th-century cathedral fell in ruins in the 18th century.

Polotesk or Poltesk is mentioned in 862 as one of the towns given by the Scandinavian Rurik to his men. In 980 it had a prince of its own, Ragvald (Rogvolod or Rognvald), whose daughter is the subject of many legends. It remained an independent principality until the 12th century, resisting the repeated attacks of the princes of Kiev; those of Pskov, Lithuania, and the Livonian knights, however, proved more effective; and Polotsk fell under Lithuanian rule in 1320. About 1385 its independence was destroyed by the Lithuanian prince Vitovt. It was five times besieged by Moscow in 1500–18 and was taken by Ivan the Terrible in 1563. Recaptured by Stephen Bathory, king of Poland, 16 years later, it became Polish by the treaty of 1582. It was then a large and populous city and carried on an active commerce. Pestilences and conflagrations were its ruin; the plague of 1566 wrought great havoc among its inhabitants, and that of 1600 destroyed 15,000. The castles, the town and its walls were burned in 1607 and 1642. The Russians continued their attacks, burning and plundering the town, and twice, in 1633 and 1705, taking possession of it for a few years. It was not definitely annexed to Russia until 1772, after the first dismemberment of Poland. In 1812 its inhabitants resisted the French invasion, and the town was partially destroyed.

POLTAVA, a town in the Ukrainian S.S.R., Union of Soviet Socialist Republics, on the right bank of the Vorskla river, in 49° 36' N., 34° 35' E. Pop. (1959) 141,000.

It is the centre of an agricultural district in which grains, sugar beets, tobacco, vines and orchard fruits are grown. Leather is the chief manufacture, and there is an annual fair for the sale of skins, leather and leather goods. Other industries include smelting, stocking manufacture, distilling and brewing. The town is on the railway and is a grain-collecting centre. The Russian annals mention Poltava in 1174 under the name of Ltava. In 1430 it was given, together with Glinsk, to the Tatar prince Leksada by Gedimin, prince of Lithuania. Under the Cossack chief, Bogdan Chmielnicki, it was the chief town of the Poltava "regiment."

Peter the Great defeated Charles XII of Sweden in the neighbourhood of Poltava in 1709.

POLTERGEIST: see Psychical Research.

POLTORATSK: see Ashkhabad.

POLTROT, JEAN DE (*c.* 1537–1563), sieur de Méré or Mérey, a nobleman of Angoumois, who murdered Francis, duke of Guise. He had lived some time in Spain, and his knowledge of Spanish, together with his swarthy complexion, which earned him the nickname of the "Espagnolet," procured him employment as a spy in the wars against Spain. Becoming a fanatical Huguenot, he determined to kill the duke of Guise and gained admission as a deserter to the camp of the Catholics who were besieging Orléans. On Feb. 18, 1563, he hid by the side of a road along which he knew the duke would pass, fired a pistol at him and fled. He was captured the next day, tried, tortured and sentenced to be drawn and quartered. On March 18, 1563, he underwent a frightful punishment. The horses not being able to drag off his limbs, he was hacked to pieces with cutlasses. He had made several contradictory declarations regarding the complicity of Admiral Gaspard de Coligny, but his accusations seem to have had no foundation.

BIBLIOGRAPHY.—*Mémoires* du prince de Condk (1743); T. A. D'Aubigné, *Histoire* universelle, ed. by A. de Ruble, *Soc.* de l'histoire de France (1886); A. de Ruble, *L'Assassinat* du *duc François* de Lorraine (1897).

POLYAENUS (2nd century A.D.), a Macedonian living in Rome as a rhetorician and pleader, was the author of a work entitled Strategica (or Strategemata) which he dedicated to the emperors Marcus Aurelius and Lucius Verus on the outbreak of the Parthian War (162–165). This work, still extant, is a historical collection of stratagems and maxims of strategy written in Greek and strung together in the form of anecdotes; it includes also examples of wisdom, courage and cunning from civil and political life. Comprising eight books (parts of the sixth and seventh are lost) it originally contained 900 anecdotes, of which 833 are extant. Despite its many errors of judgment and fact, its contents have some historical value. Evidently highly esteemed by the Roman emperors, it was handed down by them as a sort of heirloom, and passed to Constantinople, being diligently studied by Leo VI who himself wrote a work on tactics. It was also used by Stobaeus and in the Suda lexicon.

See for the text, E. Wölfflin and I. Melber (eds.) in the Teubner series, 2nd ed. (1887); Eng trans. by R. Shepherd (1793).

POLYANDRY, the system under which a woman is married to several men at the same time (Gr. *polys*, "many" and *aner*, andros "man"). Polyandrous institutions include: (1) cases where children recognize more than one man as having the status of true father; (2) cases in which a woman bears legitimate children to several different fathers in succession; (3) cases where a legitimately married woman regularly cohabits with several men, none of whom rate as father to her children; and (4) cases where a single legitimate husband allows other men to have sexual access to his wife. It is debatable how far any of these varieties may properly be described as polyandrous marriage.

Type 1 occurs in Ceylon, parts of India and Tibet; the fathers in question are usually, but not always, full brothers (in the latter case called adelphic or fraternal polyandry). An unusual version was reported from the Lele of the Belgian Congo, where certain women are regarded as the common wife of all the men in the village. The child of such a woman is a "child of the village" and has a special exalted status. Type 2 is strictly polyandrous only if the successive fathers simultaneously have the status of husband, as seems to be the case among the Todas (south India) and among certain peoples of Northern Nigeria. Such cases may be hard to distinguish from those where each child is born of a different marriage separated from the last by a divorce. The classic example of type 3 is that of the Nayar of south India. Formerly every Nayar (Kair) girl, before attaining puberty, went through a form of marriage with a single husband designated by astrology. After three days the marriage was dissolved and the husband returned to his home. The wife then took lovers who had a recognized status but were not regarded as the legal fathers of her children. If she had several such lovers at one time they cohabited with her but did not reside with her. In this matrilineal society the initial marriage ceremony serves to make a woman's children legitimate, but these children belong to the matrilineage (taravad) of the mother; the social status of father is repudiated altogether. (See NAYAR.)

Polyandry of type 4 includes "wife lending," which may be simply an expression of hospitality and which serves a purpose among families liable to be separated over long periods, as among the Australian aborigines and the Eskimo. Type 4 also includes cicisbeism (male concubinage): the woman has only one legal husband and her children have only one legal father, but her lovers have a recognized and respectable status. Institutions of this kind have occurred sporadically throughout history: Caesar is a witness for the ancient Britons; Herman Melville for the Marquesas islanders; about 1716 it was fashionable at the court of Vienna. The distinction between cicisbeism, slavery and prostitution is not always easy to draw.

Why some societies should approve of polyandry and others not has not been satisfactorily explained. Some polyandrous peoples are said to have more men than women and their polyandry has sometimes been directly attributed to this fact, but the evidence on this point is unconvincing. Tibetan polyandry is alleged to check the increase of population in regions from which emigration is difficult,but since most adult Tibetan women bear children this can hardly be the case. The view that polyandry is designed to prevent the dispersal of family property has greater plausibility for some cases. Personal relations within polyandrous families are often markedly free from jealousy. The polyandry of the Nayar is linked historically not only with their matrilineal ideology but also with their military organization, which prevented the men from living the ordinary life of a husband and father of a family. Polyandry may coexist with monogamy and polygyny (*q.v.*).

See also MARRIAGE.

BIBLIOGRAPHY.—W. H. R. Rivers, The Todas (1906); E. Westermarck, The History of Human Marriage, vol. iii (bibl.), 5th ed. (1921); E. R. Leach, "Polyandry, Inheritance and the Definition oi Marriage," Man (1955); Mary Trew, "A form of Polyandry Among the Lele of the Kasai," Africa, xxi (1951); M. G. Smith, "Secondary Marriage in Northern Nigeria," Africa, xxiii (1953); E. Kathleen Gough, "Changing Kinship Usages . . . Among the Nayars of Malabar," J. Roy. Anthrop. *Inst.*, lxxxii (1952); H. T. Fischer, "Polyandry," Int. Arch. Ethnogr., xlvi (1932). (E. R. L.)

POLYANTHUS, a common name applied to several flowers. Although its spelling suggests a true genus, there is no genus by this name. The name (as well as polyantha) is often used as a specific name for plants that produce flowers in clusters. The polyanthus primrose is a hybrid of Primula elatior, P. veris and P. *vulgaris*. Polyanthus narcissus is one of many forms of *Narcissus* tazetta. The old polyanthus or polyanthus lily of Victorian days is the tuberose — Polianthes *tuberosa*. (R. M. C.)

POLYBIUS (*c.* 200–after 118 B.C.), the Greek historian of 3rd- and 2nd-century Rome, was born at Megalopolis in Arcadia; his father Lycortas was a distinguished Achaean statesman. The dates of his birth and death have to be inferred. His reference to measurements along the Via Domitia in Narbonese Gaul (iii, 39, 8) suggests that he was still alive in 118, when this road was constructed; if he died from a fall from his horse at the age of 82, as stated in the pseudo-Lucian's Macrobii, he was probably born about 200 B.C. This would fit Plutarch's description of him (in his Philopoemen) as a boy when he carried Philopoemen's ashes to burial in 182, and also the fact that when appointed ambassador to Egypt in 180 he was under the legal age, which was probably 30 (xxiv, 6, 5; xxix, 24, 6).

Polybius received the upbringing appropriate for a son of rich landowners. His youthful biography of Philopoemen reflected his admiration for the great Achaean leader; and an interest in military matters found expression in his lost book on Tactics (ix, 20, 4). He enjoyed riding and hunting, but his knowledge of literature was rather specialized (apart from the historians) and his acquaintance with philosophy superficial. Between 180, when the Egyptian embassy was canceled because of Ptolemy V's sudden death, and 170/169, when he was hipparch in the Achaean confederation, nothing is known of his career. But he then became involved in critical events. Encumbered by their war with Perseus of Macedonia, the Romans were watching for disloyalty in the Greek states. Although Polybius declared for open support of Rome and was sent with the cavalry to the consul Q. Marcius, Achaean help was rejected (xxviii, 12–13). After Perseus' defeat at Pydna (168 B.C.) Polybius was one of 1,000 eminent Achaeans who were deported to Rome at the instigation of the pro-Roman Callicrates, and detained in Italy without trial.

At Rome Polybius had the good fortune to attract the friendship of L. Aemilius Paulus' two sons Q. Fabius Maximus Aemilianus and P. Cornelius Scipio Aemilianus; he became the latter's mentor and through his family's influence was allowed to remain in Rome when the other detainees were distributed into custody throughout Italy (xxxi, 23, 5). It is probable that Polybius accompanied Scipio to Spain in 151, went with him to Africa (where he saw the Numidian king Masinissa) and crossed the Alps in Hannibal's footsteps on his way back to Italy (iii, 48, 12). In 150, through Scipio's influence and Cato's acquiescence, the 300 surviving internees were allowed to return home (xxxv, 6). Shortly afterward Polybius joined Scipio at Carthage and was present at its siege and destruction in 146; and it is likely that he then undertook a voyage of exploration in the Atlantic as related in Pliny's *Naturalis historia*. Meanwhile hostilities had broken out between Achaea and Rome, and Polybius was in Corinth shortly after its destruction (146). He devoted himself to securing as favourable a settlement as possible for his countrymen, and to re-establishing order (xxxix, 5); and as the geographer Pausanias states, Achaean gratitude found expression in the erection of statues in his honour at Tegea, Pallantiurn, Mantineia, Lycosura—where the inscription declared that "Greece would never have come to grief, had she obeyed Polybius in all things, and having come to grief, she found succour through him alone"—and Megalopolis, where it was recorded that "he had roamed over all the earth and sea, had been the ally of the Romans, and had quenched their wrath against Greece." The inscribed base of a statue erected to him by Elis was discovered at Olympia in 1877; and in 1880 a relief shoning Polybius himself in idealized form was found at Clitor (reproduced in F. W. Walbank, Commentary, frontispiece; see bibliography) and above it a couplet recording that the city raised this most beautiful statue to Polybius, son of Lycortas, in recognition of his noble deeds. Of Polybius' life after 146 little is known. At some date he visited Alexandria and Sardis (xxi. 38, 7). He is known to have discussed political problems with Scipio and Panaetius of Rhodes. He wrote a history of the Numantine War, evidently after 133 B.C., and also a treatise on the habitability of the equatorial region; but when he composed the latter is unknown.

Scope of the History.—The history on ahich his reputation rests consisted of 40 books, the last being indices. Books i–v are extant. For the rest there are excerpts in the collection of passages from Greek historians assembled for Constantine Porphyrogenitus in the 10th century, rediscovered and published by various editors from the 16th to the 19th centuries; excerpts from books i–xvi and xviii, first published at Basel in 1549; and citations and extracts in numerous authors writing between the 1st and 6th centuries A.D., and from the Suda lexicon and that of Stephanus of Byzantium.

Polybius' original purpose was to narrate the history of the 53 years (220–168 B.C.)—from Hannibal's Spanish campaign to the battle of Pydna—during which Rome had made itself master of the world. Books i–ii form an introduction covering Roman history from the crossing into Sicily against the Carthaginians in 264 and including events in various other parts of the world (especially Achaea) between 264 and 220. In book iii, 4, Polybius sketches a modified plan, proposing to add an account of how the Romans exercised their supremacy down to the destruction of Carthage in 146. These events of 168–146 were related in books xxx–xxxix. Probably Polybius conceived his revision after 146, having by this date completed his narrative down to the end of the Second Punic War. At least books i–vi seem to have been published by about 150; there is no information as to when the rest of the work, including the revised plan in book iii, appeared.

Conception of History.—"All historians," according to Polybius (i, 1, 2), "have insisted that the soundest education and training for political activity is the study of history, and that the surest and indeed the only way to learn how to bear bravely the vicissitudes of fortune is to recall the disasters of others." Practical experience and fortitude in facing calamity are the rewards of studying history, and are stressed repeatedly throughout the aork History is essentially didactic. Pleasure is not to be nholly excluded; but the scale comes donn sharply on the side of profit. To be really profitable history must deal with political and military matters; and this is *pragmatike* Izistoria, in contrast to other sorts of history (ix, 1–2)—genealogies and mythical stories, appealing to the casual reader, and accounts of colonies, foundations of cities and ties of kindred, nhich attract the man with antiquarian interests. Its nature is austere, though it may include contemporary developments in art and science, for instance the fire-signaling perfected by Polybius himself (x, 47). It stands in contrast to the sensationalism of many of his predecessors, who confuse history with tragedy. His remarks on Phylarchus are characteristic (ii, 56, 7 ff.): "In his anxiety to excite his readers' pity and secure their sympathy for what he is describing, he introduces women clinging to altars, their hair dishevelled and their breasts uncovered, and crowds of both sexes together with children and aged parents weeping and lamenting as they are led away to slavery. . . . A historian should not try to astonish his readers by such sensationalism, nor, like the tragic poets, seek after men's probable utterances and enumerate all the possible consequences of the events under consideration, but simply record what really happened and was said, however commonplace. For the object of history is the very opposite of that of tragedy. The tragic writer seeks by the most plausible language to thrill and charm the audience temporarily, the historian by real facts and real speeches to instruct and convince serious students for all time. There it is the probable that counts, even though it be false, the object being to beguile the spectator; here it is the truth, the object being to benefit the student."

This attack on Phylarchus is not isolated. Similar faults are castigated in other historians guilty of sensationalism (cf. ii, 16, 13–15; iii, 48, 8; vii, 7, 1–2; xv, 34, 1–36). Nor are these their only weaknesses. Many historians are prone to exaggeration—and that for a special reason. As writers of monographs whose subjects are simple and monotonous, they are driven "to magnify small matters, to touch up and elaborate brief statements and to transform incidents of no importance into momentous events and actions" (xxix, 12, 3). In contrast Polybius stresses the universal character of his own theme, which is to narrate "how and thanks to what kind of constitution the Romans in under 53 years have subjected nearly the whole inhabited world to their sole government—a thing unique in history" (i, 1, 5). Apart from a general preference for a comprehensive view of history, Polybius had a particular reason for adopting it at that point. "Hitherto the affairs of the a-orld had been as it were dispersed . . . ; since this date (220 B C.) history has formed an organic whole, and the affairs of Italy and Africa have been interlinked with those of Greece and Asia. all tending towards one end" (i, 3, 3–4). Indeed, only universal history is capable of adequately treating Rome's rise to world power—the historian's synoptic view matches the organic character of history itself: "What gives my work its peculiar quality, and is nowadays most remarkable, is this. Tyche (Fortune) having guided almost all the world's affairs in one direction and having inclined them to one and the same goal, so the historian must bring under one conspectus for his readers the operations by which she has accomplished her general purpose. For it was chiefly this consideration, coupled with the fact that none of my contemporaries has attempted a general history, which incited and encouraged me to undertake my task" (i, 4, 1–2).

The role here allotted to Tyche is somewhat unusual. For clearly the value of history as a source of practical lessons is diminished if cause and effect are at the mercy of an incalculable and capricious power. Usually, although Polybius uses Tyche to cover a variety of phenomena ranging from pure chance to something very like a purposeful providence, much of the apparent inconsistency springs from his use of purely verbal elaboration or the careless adoption of current Hellenistic terminology, which habitually made Tyche a goddess. Here, however, Tyche seems to be a real directive power, which raised Rome to world dominion—because Rome deserved it. Normally Polybius lays great emphasis on causality, and his distinction (iii, 6) between the causes of an event (aitiai) and its immediate origins (*archai*) is useful up to a point, though it is more mechanical than that of Thucydides, and allows nothing for the dialectical character of real historical situations. An important place in Polybius' work is occupied by his study of the Roman constitution and army and the early history of the city in book vi. His analysis of the mixed constitution, which had enabled Rome to avoid the cycle of change and deterioration to which simple constitutional forms were liable, is full of problems, but it has exercised widespread influence from Cicero's De *republica* down to Machiavelli and Montesquieu.

Sources of **Information.**—Polybius defines the historian's task as the study and collation of documents, acquaintance with relevant geographical features and, finally, political experience (xii. 25e); of these the last two are the most essential. Polybius practised what he preached; he possessed good political and military experience and he traveled widely throughout the Mediterranean and beyond; as he explains, "I sustained the perils of journeys through Africa, Spain and Gaul and of voyages on the sea adjoining these lands on the outside, in order to correct the errors of my predecessors and make known those parts of the world also to the Greeks" (iii, 59, 7). He did not neglect written sources, however; indeed for his introductory books (i–ii), covering the period from 264 to 220, they were essential. His discussion of Aratus and Phylarchus, his sources for Greece, and of Fabius Pictor and Philinus, those for the First Punic War (i, 14–15; ii, 56. 2; iii, 26, 3–4), indicates his critical approach. For the main part of his history, from 220 onward, he consulted many writers, Greek and Roman; but following precedent he rarely names them. An exception is Zeno of Rhodes, whom he criticizes harshly (xvi, 14–19).

He had access to private sources, for instance Scipio Africanus' letter to Philip V of Macedonia, describing the capture in Spain in 209 B.C., of New Carthage (x, 9, 3) and that of Scipio Nasica to some Hellenistic king about the campaigns of the Third Macedonian War (xxix, 14, 3). He almost certainly consulted the Achaean record office (cf. xxii, 9, 10) and must have drawn on Roman records for such material as the treaty between Carthage and Philip V (vii, 9). That he had access to the Rhodian records has not been proved. His detailed figures for Hannibal's troop formations in Italy came from an inscription left by Hannibal, which he found in the temple of Juno on the Lacinian promontory (iii, 33, 18).

Polybius himself regarded oral sources as his most important, and questioning witnesses as the most vital part of a historian's task (xii, 4c, 2–5); indeed this is one reason why he chose to begin his main history at 220. Anything else would be "hearsay at one remove," a safe foundation for neither judgments nor statements (iv, 2, 3). Of the thousands whom he must have questioned few names can be isolated; but at Rome he had opportunities of meeting men from all parts, including internees, ambassadors and visitors.

His purpose was to ascertain the truth. "Truth is to history," he writes (i, 14, 6), "what eyesight is to the living creature"; and in the main Polybius achieves this standard. There are exceptions. His prejudice against Aetolia is easily detected and disallowed; and there is some rancour against Boeotia (xx, 5–7). But no serious charges can be leveled against his reliability; and he has stated his own position very frankly: "That historians should show partiality for their own country I would allow; but not that they should make statements about it that contradict the facts. There are enough errors of ignorance to which historians are liable and which a man may hardly avoid. But if we write falsely from intention—be it for country or for friends or for favour—what better are we than those who make their living by such means? . . . Readers should keep a watchful eye on this tendency, and historians themselves should be on their guard against it" (xvi, 14, 6–10).

Style and Qualities as a Historian.—Writing in the 1st century B.C. as a strict Atticist, Dionysius of Halicarnassus reckons Polybius among those who "have left behind them compositions which no one endures to read to the end"; that his successors shared this view of Polybius' style is confirmed by the failure of his works to survive except in an incomplete form. The infelicity of Polybius' Greek (which frequently reproduces the conventional phrases of the Hellenistic chancelleries familiar from contemporary inscriptions) lies in its awkward use of long and cumbersome circumlocutions, vague abstract nouns and pedantic repetitions. To the scholar his style is, however, no great obstacle; and though in his anxiety to improve his reader he moralizes and labours the obvious, the perennial interest and importance of his theme will always insure him a following among those who can enjoy a historian who is accurate, serious and sensible, understands the events of which he writes, and above all who asks the right questions.

BIBLIOGRAPHY.—*Editio princeps,* bk. i–v, *by* V. Opsopaeus *(1530)* (Latin trans. by N. Perotti, *1473);* later editions include F. Hultsch, 4 vol. (1870–92); T. Buttner-Wobst, Teubner series, 5 vol. (1889–1905); and J. L. Strachan-Davidson, *Selections From Polybius (1888).* Text with Eng. trans. by W. R. Paton, Loeb series, 6 vol. *(1922–27).* Eng. trans. by E. S. Shuckburgh, *Histories of Polybius,* 2 vol. *(1889). See* also R. von Scala, *Die Studien des Polybios (1890); O.* Cuntz, *Polybios und sein Werk (1902);* J. B. Bury, *Ancient Greek Historians* (1909); C. Wunderer, *Polybios (1927);* T. R. Glover, *Cambridge Ancient History,* vol. viii *(1930);* E. Mioni, *Polibio* (1949); K. Ziegler in Pauly-Wissowa, *Real-Encyclopädie,* vol. xxi. col. *1440–1378 (1952);* A. Mauersberger, *Lexicon Polybianum,* vol. 1 *(1956); F. W.* Walbank, *Historical Commentary on Polybius,* vol. 1 *(1957).* *(F. W. Wa.)*

POLYCARP *(c.* 69–*c.* 155), bishop of Smyrna and one of the Apostolic Fathers, derives much of his importance from the fact that he links together the apostolic age and that of nascent Catholicism. The sources from which we derive our knowledge of the life and activity of Polycarp are: (1) a few notices in the writings of Irenaeus, (2) the Epistle of Polycarp to the Church at Philippi, (3) the Epistle of Ignatius to Polycarp, (4) the Epistle of the Church at Smyrna to the Church at Philomelium, giving an account of the martyrdom of Polycarp. Since these authorities have all been more or less called in question and some of them entirely rejected by recent criticism, it is necessary to say a few words about each.

Sources.—I. The Statements of Irenaeus are found *(a)* in his *Adversus haereses,* iii. *3, 4, (b)* in the letter to Victor, where Irenaeus gives an account of Polycarp's visit to Rome, *(c)* in the letter to Florinus—a most important document which describes the intercourse between Irenaeus and Polycarp and Polycarp's relation with St. John. The genuineness of *(c)* is not uncontested, but it is generally accepted.

2. *The Epistle of Polycarp.*—Though Irenaeus states that Polycarp wrote many "letters to the neighbouring churches or to certain of the brethren" only one has been preserved, viz., the well-known letter to the Philippians. The epistle is largely involved in the Ignatian controversy (*see* IGNATIUS). The rehabilitation of the Ignatian letters in modern times has, however, practically destroyed the attack on the Epistles of Polycarp. The date of the epistle depends upon the date of the Ignatian letters and is now generally fixed between 112 and 118. The language in this letter is simple but powerful.

3. *The Epistle of Ignatius to Polycarp.*—This epistle has of course been subjected to the same criticism as has been directed against the other epistles of Ignatius *(see* IGNATIUS); the general criticism, may now be said to have been completely answered by the investigations of Zahn, Lightfoot and Harnack. Some modern scholars feel a difficulty about the peremptory tone which Ignatius adopts towards Polycarp. There was some force in this argument when the Ignatian Epistles were dated about 140, as in that case Polycarp would have been an old and venerable man at the time. But now that the date is put back to about 112 the difficulty vanishes, since Polycarp was not much over forty when he received the letter.

4. *The Letter of the Church at Smyrna* to the Philomelians is a most important document, because we derive from it all our information with regard to Polycarp's martyrdom. Eusebius has preserved the greater part of this epistle (iv. *15),* but we possess it entire with various concluding observations in several Greek mss., and also in a Latin translation. The epistle gives a minute description of the persecution in Smyrna, of the last days of Polycarp and of his trial and martyrdom; and as it contains many instructive details and professes to have been written not long after the events to which it refers, it has always been regarded as one of the most precious remains of the 2nd century. Certain recent critics, however, have questioned the authenticity of the narrative. The more moderate school of modern critics—*e.g.,* Lightfoot *(Ignatius and Polycarp,* 1589 *seq.),* Harnack (*Gesch. d. altchrist. Lit.* II. i. 341), and Krüger *(Early Christian Lit., 1897)—is* unanimous in regarding it as an authentic document, though it recognizes that here and there a few slight interpolations have been inserted. Besides these we have no other sources for the life of Polycarp.

Life.—Polycarp must have been born not later than the year 69, for on the day of his death (*c.* 155) he declared that he had served the Lord for eighty-six years (*Martyrium,* 9). Irenaeus tells us that in early life Polycarp "had been taught by apostles and lived in familiar intercourse with many that had seen Christ" (iii. 3, 4).

This testimony is expanded in the remarkable words which Irenaeus addressed to Florinus:

"I saw thee when I was still a boy (παῖς ἔτι ὤν) in Lower Asia in company with Polycarp . . . I can even now point out the place where the blessed Polycarp used to sit when he discoursed, and describe his goings out and his comings in, his manner of life and his personal appearance and the discourses which he delivered to the people, how he used to speak of his intercourse with John and with the rest of those who had seen the Lord, anrl how he would relate their words. And everything that he had heard from them about the Lord, about His miracles and about His teaching, Polycarp used to tell us as one who had received it from those who had seen the Word of Life with their own eyes, and all this in perfect harmony with the Scriptures. To these things I used to listen at the time, through the mercy of God vouchsafed to me, noting them down, not on paper but in my heart, and constantly by the grace of God I brood over my accurate recollections."

These words establish a chain of tradition (John-Polycarp-Irenaeus) which is without a parallel in early church history. Polycarp thus becomes the living link between the Apostolic age and the great writers who flourished at the end of the 2nd century. Recent criticism, however, has endeavoured to destroy the force of the words of Irenaeus. Harnack (*Chronologie,* i., 325–329), for instance, attacks this link at both ends. (*a*) The connection of Irenaeus and Polycarp, he argues, is very weak, because Irenaeus was only a boy (παῖς) at the time, and his recollections therefore carry very little weight. The fact, too, that he never shows any signs of having been influenced by Polycarp and never once quotes his writings is a further proof that the relation between them was slight. (b) The connection which Irenaeus tries to establish between Polycarp and John the apostle is probably due to a blunder. Irenaeus has confused John the apostle and John the presbyter. Polycarp was the disciple of the latter, not the former. In this second argument Harnack has the support of a considerable number of modern scholars who deny the Ephesian residence of John the apostle. But in spite of much modern criticism there seems to be no solid reason for rejecting the statements of Irenaeus and regarding Polycarp as the link between the Apostolic age and the first of the Catholic fathers.

Though Polycarp must have been bishop of Smyrna for nearly half a century we know next to nothing about his career. We get only an occasional glimpse of his activity, and the period between 115 and 155 is practically a blank. The only points of sure information which we possess relate to (1) his relations with Ignatius, (2) his protests against heresy, (3) his visit to Rome in the time of Anicetus, (4) his martyrdom.

His Relations with **Ignatius.**—Ignatius, while on his way to Rome to suffer martyrdom, halted at Smyrna and received a warm welcome from the church and its bishop. Upon reaching Troas he despatched two letters, one to the church at Smyrna, another addressed personally to Polycarp. In these letters Ignatius charged Polycarp to write to all the churches between Smyrna and Syria (since his hurried departure from Troas made it impossible for him to do so in person) urging them to send letters and delegates to the church at Antioch to congratulate it upon the cessation of the persecution and to establish it in the faith. The letters of Ignatius illustrate the commanding position which Polycarp had already attained in Asia. It was in the discharge of the task which had been laid upon him by Ignatius that Polycarp was brought into correspondence with the Philippians. The Church at Philippi wrote to Polycarp asking him to forward their letters to Antioch. Polycarp replied, promising to carry out their request and enclosing a number of the letters of Ignatius which he had in his possession.

Polycarp's Attack on Heresy.—All through his life Polycarp appears to have been an uncompromising opponent of heresy. We find him in his epistle (ch. vii) uttering a strong protest against certain false teachers (probably the followers of Cerinthus).

For every one who shall not confess that Jesus Christ is come in the flesh is antichrist; and whosoever shall not confess the testimony of the Cross is of the devil; and whosoever shall pervert the oracles of the Lord to his own lusts and say that there is neither resurrection nor judgment, that man is the first-born of Satan. Wherefore let us forsake their vain doing and their false teaching and turn unto the word which was delivered unto us from the beginning.

Polycarp lived to see the rise of the Marcionite and Valentinian sects and vigorously opposed them. Irenaeus tells us that on one occasion Marcion endeavoured to establish relations with him and accosted him with the words, "Recognize us." But Polycarp displayed the same uncompromising attitude which his master John had shown towards Cerinthus and answered, "I recognize you as the first-born of Satan." The steady progress of the heretical movement in spite of all opposition was a cause of deep sorrow to Polycarp, so that in the last years of his life the words were constantly on his lips, "Oh good God, to what times hast thou spared me, that I must suffer such things!"

Polycarp's Visit to Rome.—It is one of the most interesting and important events in the church history of the 2nd century that Polycarp, shortly before his death, when he was considerably over eighty years old, undertook a journey to Rome in order to visit the bishop Anicetus. Irenaeus, to whom we are indebted for this information (*Haer.* iii. 3, 4; *Epist. ad victorem, ap.* Euseb. v. 24), gives as the reason for the journey the fact that differences existed between Asia and Rome "with regard to certain things" and especially about the time of the Easter festival. Unfortunately all he says is that with regard to the certain things the two bishops speedily came to an understanding, while as to the time of Easter, each adhered to his own custom, without breaking off communion with the other. We learn further that Anicetus as a mark of special honour allowed Polycarp to celebrate the Eucharist in the church, and that many Marcionites and Valentinians were converted by him during his stay in Rome.

Polycarp's Martyrdom.—Not many months apparently after Polycarp's return from Rome a persecution broke out in Asia. A great festival was in progress at Smyrna. The proconsul Statius Quadratus was present on the occasion, and the asiarch Philip of Tralles was presiding over the games. Eleven Christians had been brought, mostly from Philadelphia, to be put to death. The appetite of the populace was inflamed by the spectacle of their martyrdom. A cry was raised, "Away with the atheists. Let search be made for Polycarp." Polycarp took refuge in a country farm. His hiding-place, however, was betrayed and he was arrested and brought back into the city. Attempts were made by the officials to induce him to recant, but without effect. When he came into the theatre, the proconsul urged him to "revile Christ," and promised, if he would consent to abjure his faith, that he would set him at liberty. To this appeal Polycarp made the memorable answer, "Eighty and six years have I served Him and He hath done me no wrong. How then can I speak evil of my King who saved me?" These words only intensified the fury of the mob. They clamoured for a lion to be let loose upon him there and then. The asiarch, however, refused, urging as an excuse that the games were over. When they next demanded that their victim should be burned, the proconsul did not interfere. Timber and faggots were hastily collected and Polycarp was placed upon the pyre. With calm dignity and unflinching courage he met his fate and crowned a noble life with an heroic death.

Eusebius in his *Chronicon* gives A.D. 166 as the date of Polycarp's death, and until the year 1867 this statement was never questioned. In that year appeared Waddington's *Mémoire sur la chronologie* de *la* vie *du rhéteur* Aelius *Aristide,* in which it was shown from a most acute combination of circumstances that the Quadratus whose name is mentioned in the *Martyrium* was proconsul of Asia in 155–156, and that consequently Polycarp was martyred on Feb. 23, 155. Waddington's conclusion has received overwhelming support amongst recent critics. His views have been accepted by (amongst many others) Renan (*Antéchrist,* 1873, p. 207), Hilgenfeld (*Zeitschr.* f. *wiss. Theol.,* 1874, p. 325), Gebhardt (*Zeitschr. f. hist. Theol.,* 1875, p. 356), Lipsius (*Jahrb.* f. *prot. Theol.,* 1883, p. 525), Harnack (*Chronologie,* i. 334–356), Zahn (*Zeitschr.* f. *wiss.* Theol., 1882, p. 227). Lightfoot (*Ignatius* and *Polycarp,* i. 629–702) and Randell (*Studia biblica,* 1885, i. 175). Against this array of scholars only the following names of importance can be quoted in support of the traditional view—Keim (*Aus dem Urchristentum,* p. 90), Wieseler (Die Christen-*verfolgungen* der *Caesaren,* 1878, p. 34) and Uhlhorn (Studia Biblica, 1890, ii., 105–156). The problem is too complex to admit of treatment here. There seems to be little doubt that the case for the earlier date has been proved.

The significance of Polycarp in the history of the Church is out of all proportion to our knowledge of the facts of his career. The violent attack of the Smyrnaean mob is an eloquent tribute to his influence in Asia. "This is the teacher of Asia," they shouted, "this is the father of the Christians: this is the destroyer of our gods: this is the man who has taught so many no longer to sacrifice and no longer to pray to the gods." And after the execution they refused to deliver up his bones to the Christians for burial on the ground that "the Christians would now forsake the Crucified and worship Polycarp." Polycarp was indeed, as Polycrates says, "one of the great luminaries" (*megala* stoikeia) of the time. It was in no small degree due to his staunch and unwavering leadership that the Church was saved from the peril of being overwhelmed by the rising tide of the pagan revival which swept over Asia during the first half of the 2nd century, and it was his unfaltering allegiance to the Apostolic faith that secured the defeat of the many forms of heresy which threatened to destroy the Church from within.

Polycarp had no creative genius. He was a "transmitter, not a maker." As Irenaeus says (iii. 3, 4), "Polycarp does not appear to have possessed qualifications for successfully conducting a controversial discussion with erroneous teachers . . . but he could not help feeling how unlike their speculations were to the doctrines which he had learned from the Apostles, and so he met with indignant reprobation their attempt to supersede Christ's gospel with fictions of their own devising." It is this that constitutes Polycarp's service to the Church, and no greater service has been rendered by any of its leaders in any age.

Bibliography.—J. B. Lightfoot, *Apostolic Fathers*, pt. ii. (2nd ed., 1889). Polycarp is dealt with in i. 417–459, 530–704; ii. 897–1086; G. Volkmar, *Epistula Polycarpi Smyrnaei genuina* (1885); *T*. Zahn, *Forschungen zur Geschichte des Kanons, &c.*, iv. 249, 279; J. M. Cotterill, "The Epistle of Polycarp to the Philippians," *Journ. of Philol.* (1891), xix., 241–285; Harnack, *Chronologie der altchristlichen Litteratur* (1897), and authorities quoted in the text. *See* also Apostolic Fathers. (H. T. A.; X.)

POLYCHAETA, a class of segmented, largely marine worms. The name refers to the serially arranged tufts of bristles at the sides of the body. Examples are *Nereis* and *Serpula*. *See* Annelida.

POLYCLITUS (Polycleitus), the name of two Greek sculptors of the school of Argos; the first belonging to the 5th century, the second to the earlier part of the 4th.

The elder, better known Polyclitus (fl. 5th century B.C.) was a contemporary of Phidias and in the opinion of the Greeks his equal. Whether he was a pupil of Ageladas is disputed; at least he carried on the Argive tradition. He made a figure of an Amazon for Ephesus which was regarded by later Greek writers as superior to the Amazon of Phidias made at the same time. His colossal Hera of gold and ivory which stood in the temple near Argos was considered as worthy to rank with the Zeus of Phidias. Balance, rhythm and the minute perfection of bodily form, which were the great merits of this sculptor, appealed especially to the Greeks of the jth century. Polyclitus worked mainly in bronze.

In regard to his chronology we have data in a papyrus published by B. P. Grenfell and A. S. Hunt containing lists of athletic victors. From this it appears that he made a statue of Cyniscus, a victorious athlete (464 or 460 B.C.), of Pythocles (452) and Aristion (452). He thus can scarcely have been born as late as 480 B.C. His statue of Hera is dated by Pliny to 420 B.C. His artistic activity must therefore have been long and prolific. His two great statues, ideal or heroic types rather than portraits, are the Diadumenus ("Man Tying on a Fillet") and the Doryphorus ("Spearbearer"), copies of both of which survive. The Doryphorus was known as "The Canon," because it embodied the correct proportions of ideal male form. The most complete copy is from Herculaneum. There are Roman copies in marble of the Diadumenus in London and New York, giving a good basic impression but only a general idea of the finish of Polyclitus' work in bronze. At Delos French excavators discovered a Diadumenus of more pleasing type and greater finish, a Hellenistic transformation of the Polyclitan type into a youthful Apollo. Among the bases of statues found at Olympia were three signed by Polyclitus, still bearing on their surface the marks of attachment of the feet of the statues. This gives us their pose, and critics such as A. Furtwängler identified several extant statues as copies of figures of boy athletes victorious at Olympia set up by Polyclitus. Among these the Westmacott athlete in the British museum is probably a copy of the "Cyniscus" mentioned above.

The Amazon of Polyclitus survives in many copies, among the best being the Lansdomne statue in the Metropolitan Museum of Art, New York. The masterpiece of Polyclitus, his Hera in gold and ivory, has totally disappeared, but coins of Argos give us the general type. A marble head in the British museum gives a Greco-Roman version of this type. treated in general terms.

The want of variety in the works of Polyclitus was brought as a reproach against him by certain ancient critics. Varro says that his statues were square and almost of one pattern. Excepting the statue of Hera, the work of his later years, he produced scarcely any notable statue of a deity. His field was narrowly limited; but in that field he was unsurpassed.

The younger Polyclitus (fl. 4th century B.C.) was of the same family as the elder. Sculptures by him have been difficult to identify among existing copies. Some bases bearing the name. however, are inscribed in characters of the 4th century, when the elder sculptor cannot have been alive. He was also an architect of note. His best-known buildings are the tholos (in ruins) and the theatre (now restored) of Epidaurus (360–330 B.C.).

Bibliography.—G. M. A. Richter, *The Sculpture and Sculptors of the Greeks*, 246 ff. (1950); G. Lippold. *Handbuch der Archäologie*, iii, 1, 162 ff. (1950); R. B. Bandinelli, *Policleto* (1938). (C. C. V.)

POLYCRATES, tyrant of Samos (c. 535–515 B.C.). Having won popularity by donations to poorer citizens, he took advantage of a festival of Hera, which was being celebrated outside the walls, to make himself master of the city (about 535 B.C.). After getting rid of his brothers Pantagnotus and Syloson, who had at first shared his power, he established a despotism which is of great importance in the history of the island. He equipped a fleet of 100 ships and so became master of the Aegean basin. This ascendancy he abused by numerous acts of piracy which made him notorious throughout Greece; but his real aim was the control of the archipelago and the mainland towns of Ionia. He maintained an alliance with Lygdamis of Naxos, and dedicated to Delos the island of Rheneia. He also defeated a coalition of two great naval powers of the Asiatic coast, Miletus and Lesbos. He made an alliance, probably commercial in object, with Amasis of Egypt. But the squadron he sent to Amasis' support against Cambyses of Persia, being composed of political opponents of Polycrates, suspected treachery and returned and attacked Polycrates. After a defeat by sea, Polycrates repelled an assault upon the walls, and subsequently withstood a siege by a joint armament of Spartans and Corinthians assembled to aid the rebels. He maintained his ascendancy until about 515, when Oroetes, the Persian governor of Lydia, who had been reproached for his failure to reduce Samos by force, lured him to the mainland and put him to death by crucifixion.

Beside the political and commercial pre-eminence which he conferred upon Samos, Polycrates adorned the city with public works on a large scale. He was also a patron of letters; he collected a library, and Anacreon lived at his court.

POLYCYTHEMIA VERA, a chronic disease of unknown cause usually affecting adults of northern European origin. The basic abnormality is overproduction of red cells, white cells and platelets by the marrow and to a lesser extent by other blood-forming tissues. The patient has a red-blue appearance and complains of dizziness and headaches due to the increase of red cells. Major causes of death and disability are hemorrhages and clots, especially in the skin, brain and gastrointestinal tract. These complications may be controlled by irradiation or radiomimetic drugs which depress the overactive blood-forming tissues. Irradiation of any type may be followed by acute leukemia (*q.v.*). Over the years, regardless of treatment. the spleen enlarges due to formation of a marrowlike tissue; the previously active marrow is replaced by scar tissue and bone. In this terminal "burnt-out" stage the overproduction of blood cells ceases. The patient develops weakness due to anemia: bleeding due to lack of platelets. malnourishment and infection. Treatment is then palliative. consisting of blood transfusions. (M. H. Bl.)

POLYDORUS, the name of two figures in Greek mythology.

1. Polydorus, youngest son of Priam and Laothoe (Homer, *Iliad* xxii, 46) or Hecuba (Euripides and later writers). In Homer, Polydorus is killed in battle by Achilles. Euripides (*Hecuba*) tells

how Priam sent Polydorus with great treasures to Polyrnestor, king of Thrace, who murdered the boy for the money and threw his body into the sea; the corpse was tragically discovered later by Hecuba. Virgil (Aeneid iii, 22 ff.) has Polymestor bury Polydorus, polluting Thracian soil against Aeneas' settlement.

2. Polydorus was the son of Cadmus, father of Labdacus and ancestor of Oedipus. (WM. S. A.)

POLYGALACEAE, a family of dicotyledonous herbs, shrubs and small trees, comprising 10 genera and about 700 species, not represented in New Zealand, Polynesia and the arctic zone, but otherwise cosmopolitan. In North America about 50 species are found, chiefly in the southern and western United States. Polygala *vulgaris* is the British milkwort (*q.v.*), and P. Senega, the Senega snakeroot, a North American medicinal plant.

POLYGLOTT or POLYGLOT, a book which contains side-by-side versions of the same text in several languages (Gr. *polys,* many, and glotta, tongue). The most important polyglotts are editions of the Bible, or its parts, in which the Hebrew and Greek originals are exhibited along with the great historical versions. The famous *Hexapla* of Origen (*q.v.*), in which the Old Testament Scriptures were written in parallel columns, probably suggested the later polyglotts, but though it gives six texts it is itself only in two languages. In the 16th and 17th centuries polyglotts became a favourite means of advancing the knowledge of eastern languages as well as the study of Scripture. See also BIBLE.

POLYGNOTUS (c 500–440 B.C.), Greek painter, son of Aglaophon, was a native of Thasos who soon moved to the Greek mainland and eventually acquired Athenian citizenship. His fame was based on large, monumental wall paintings in the severe style, admired by posterity but now totally lost. The following titles are mentioned by ancient writers: (1) Plataeae, entrance porch of the temple of Athena Areia: "Ulysses after the punishment of the suitors"; (2) Athens, Painted Hall ("Poikile"): "The taking of Ilium"; (3) Athens, Temple of the Dioscuri ("Anakeion"): "Wedding of the daughters of Leucippus"; (4) Athens, Acropolis ("Pinacotheca"): "Achilles in Scyrus"; (5) Same as no. 4: "Nausicaa"; (6) Delphi, Hall ("Lesche") of the Cnidians: "Departure of the Greeks from Ilium"; and (7) Same as no. 6: "Ulysses visiting Hades."

Pausanias left an account of the last two paintings (Paus. x, 25–31) from which, with occasional support of other sources, the following characteristics of Polygnotus' style are deduced. Figures approximating life-size were freely distributed within the composition, near the lower border and higher. In Greek painting of the first half of the 5th century B.C. this method represents an innovation, though precedents existed elsewhere, notably in Assyrian art. It constitutes a break with the ancient Greek principle of arranging figures on a single base line; Polygnotus replaced the horizontal base lines by irregular, mounting or descending terrain lines. Comparable representations can be found in contemporary vase paintings, perhaps under his influence. There was no unifying perspective in the modern sense: the individual figure remained the focus of interest even when several figures were grouped together. Stateliness was paired with subtlety of detail: delicate headdresses of women, transparent garments, mouths uith parted lips uncovering the teeth. Sharp foreshortenings were not lacking. Coloration consisted of four basic colours: black, white, red and ochre. None of the last named characteristics can be claimed for Polygnotus alone: he was merely the outstanding representative of the severe style in Greek monumental painting. The "ethos" which later critics, including Aristotle (Poetics, ch. 6), valued so highly in his work indicates a concept of character as an innate disposition, governing the actions and manifest in a person's outward bearing.

See Carl Weickert, "Studien zur Kunstgeschichte des 5. Jahrhunderts v. Chr. I., Polygnot," *Abhandlungen* der Deutsch. *Akademie* des *Wissenschaften,* vol. 1947, no. 8 (1950). (O. J. BL.)

POLYGONACEAE, the buckwheat family, a dicotyledonous family of about 40 genera and 800 species, consisting chiefly of herbs, although shrubs, vines and even trees occur. The stems are often swollen at the nodes (from whence comes the genus name *Polygonum,* referring to the many joints or knees). The leaves are alternate, usually simple and entire, and stipules at the base of the leaves usually form a highly characteristic sheathing growth (ocrea) around the stem. The flowers, often borne in clusters, are radially symmetrical, lacking petals, and usually small. The calyx generally consists of five or six separate or united sepals. These are usually green or white, but other colours such as rose and yellow also occur. The stamens vary in number from five to nine and the achenelike fruit is one-celled, one-seeded and usually three-carpellate and three-sided. The single seed is erect and attached at the base of the fruit. The flowers, usually bisexual, are wind- or insect-pollinated (depending on the genus), or sometimes self-pollinated. The family is so distinct from its nearest relatives that it is placed in a separate order. the Polygonales.

The apparently basic type of flower has six sepals (two whorls of three), nine stamens and three united carpels: such a flower is usual in Eriogonum. Although examples with the flower parts in fours occur, the usual variation is a reduction in number of one or all of the parts. Five sepals and five to eight stamens are frequent in *Polygonum;* two whorls of two (2 + 2) sepals and two united carpels characterize Oxyria.

The family occurs primarily in the northern hemisphere. As is true in many plant families, the geographic distribution of the genera often provides interesting problems. Polygonum (about 200 species) is widely distributed, whereas Rheum is strictly Asian, and *Muehlenbeckia* (15 species) is unusual because it is limited almost entirely to the southern hemisphere. Coccoloba, with 125 species, is confined to the American tropics and subtropics. Several small genera (*e.g.,* Gilmania, Hollisteria, Mucronea) are limited to California, while the one species of Koenigia, in addition to being circumboreal, is found also in the Himalayas and in Tierra del Fuego. Of the two species of *Brunnichia,* one occurs in the southeastern part of the United States, the other in west Africa.

The tribe Eriogoneae is strictly American and occurs almost entirely in the western portion of the United States. Besides several small genera, the tribe includes Chorizanthe (60 species) and *Eriogonum,* nearly 200 species. The tribe is unusual in lacking the ocreae so characteristic of the family.

To the Polygonaceae belong such wild plants as mountain sorrel (Oxyria digyna), smartweed and water pepper (several species of Polygonum), canaigre (*Rumex hymenosepalus;* see DOCK), whose root is a source of tanning material and dye, and California buckwheat (*Eriogonum* fasciculatum), an important bee plant in its native range.

Common weeds that belong to this family are knotweed (*q.v.*) or knotgrass (Polygonum aviculare); the vine, black bindweed (Polygonum convolvulus); and dock or sorrel (*qq.v.*) (several species of *Rumex*). In this last genus, the three inner sepals known as valves, enlarge and surround the fruit.

Among the important cultivated food plants in the family are buckwheat (*q.v.;* Fagopyrum esculentum) and rhubarb (*q.v.*) or pieplant (*Rheum rhaponticum*). Ornamentals include several old world species of *Polygonum* such as silver lace vine (P. auberti), coral vine (Antigonon) from Mexico and the sea-grape (Coccoloba uvifera) whose fleshy sepals form an edible berrylike structure. (G. J. G.)

POLYGONAL AND POLYHEDRAL NUMBERS: see FIGURATE NUMBERS.

POLYGONS. A polygonal line, also called a broken line, joining the point A, to the point A, is any finite set of points A_1, A„ . . . , *A,* and the segments A_1A_2, A_2A_3, . . . , $A_{n-1}A_n$. In this and the following definition of a polygon the phrase "a point A," means a point associated with the symbol *A,* and the phrase "a segment A_iA_j" means the segment whose ends are the points which are the associates of the symbols A, and A, respectively, associated with the symbol A_iA_j. A segment is the set of all points of any (straight) line which are between any two points of that line. Each of the latter points is called an end of the segment. A polygon is any finite set of points A_1A_2, . . . , A, and the segments A_1A_2, A_2A_3 . . . , A_{n-1} A„ A_nA_1. The points A, and segments A_iA_{i+1}, A_nA_1, $i = 1, 2, \ldots, n$, are called respectively the vertices and sides of the polygon; similarly for a polygonal line.

The terms polygonal line and polygon are used also with meanings which are different from, although closely related to, those given above. A polygon as defined may have one of two senses assigned to it so that the first end and the second end of each side is specified in such a way that the vertex A_i is either the first end of the side A_iA_{i-1} and the last end of the side $A_{i-1}A_i$, and if $i=1$, A, is the first end of A_1A_2, and the second end of A_nA_1, or vice versa. A polygon with such an assignment of a sense is called an *oriented* or a *sensed polygon*. In an obvious way an oriented polygonal line is defined. Thus two sensed polygons or polygonal lines are associated with each polygon or polygonal line. In the sequel the phrase the oriented (or sensed) side AB of a sensed polygon indicates that *A* is the first end of the oriented side ***AB*** of that oriented polygon, and B the second. Polygonal lines and polygons according to the first definition are referred to as *unoriented* or *unsensed polygonal lines* and *polygons* respectively. In formulating a third meaning of the terms polygonal line and polygon it should be emphasized that the elements involved in the above definition are points and segments associated with symbols so that an unoriented or oriented polygon is neither a set of points and segments nor a set of points. The word polygon also is used to signify either certain sets of points and segments or certain sets of points. The distinctions just pointed out although delicate are logically essential and even practically important. For the purpose of this article the single word "polygon" denotes any set of points which consists of the points which are the associates of the symbols $A_1, A_2, \ldots, A_n$ and the points which belong to the segments which are the associates of the symbols A_iA_{i+1}, $i=1, 2, \ldots, n$ and A_nA_1 of the first definition; *i.e.*, the definition of an unsensed polygon. Similarly in the case of a polygonal line.

The above definitions are of broad scope and define abstractions which are based on the phenomenon of the motion of a particle from point to point along intermediate rectilinear stretches. Important specializations of these ideas are the so-called *simple polygons* or polygonal lines according to any of the definitions given. A simple unoriented polygon is any unoriented polygon which is such that none of its vertices is an end of more than two of its sides and no side of the unoriented polygon contains a vertex or a point which belongs to another side of the unoriented polygon. The definitions of simple unoriented polygonal lines, simple oriented polygonal lines and polygons as well as those of simple polygons and polygonal lines in conformity with the third definition are apparent and consequently are not stated formally. Alternative definitions for the several concepts defined or indicated above may be given; for example a simple polygon may be defined as a finite set of points and segments such that *(a)* every point of the set is the end of two and only two segments of the set, *(b)* each end of every segment of the set is a point of the set, (c) no segment of the set contains a point of the set or a point of another segment of the set and (d) no (proper) subset of the given set satisfies (a), (b) and (c). It is easy to show that this definition is equivalent to the one indicated in introducing the third formulation of the idea of a polygon and it is valuable in that it admits of immediate generalization to the idea of a polyhedron in space.

Place of Polygons in Mathematics.— The theory of polygons as a special chapter in mathematics is chiefly concerned with the classification of unoriented and oriented polygons all of whose elements,—that is, vertices and sides,—are in the same plane. The corresponding question for space concerns polyhedrons and is taken up in the article on SOLIDS, GEOMETRIC. Polygons whose elements are not in one plane have not as yet formed the subject of any interesting theory. Such polygons, as well as plane polygons, however, serve as important aids, as in the study of continuous curves in general. This is largely because of the fact that any continuous arc contains the vertices of a polygonal line, the length of whose sides are all less than any preassigned positive number, and which is simple if the arc is simple. In particular, the length of an arc of a curve is defined by means of the lengths of the inscribed polygonal lines,—that is, polygonal lines which join the ends of the arc and whose vertices are on the arc and have an order which conforms to one of the two senses along the arc. In the geometry of the Euclidean plane, plane polygons,—that is, those having all of their points in one plane,—take on an added significance because of the fact that the Euclidean plane is separated into two regions by any simple polygon that is contained in it. This is a consequence of the basic fact that a line separates the Euclidean plane. Unless it is stated otherwise it is understood that in the following all configurations are in the Euclidean plane. A *region* is a set of points such that any point of the set is the centre of a circle which has only points of the set in its interior and such that the set is not composed of two sets having the latter property and also having no points in common. It follows easily that any two points of a region are joined by a simple polygonal line which is contained in the region. A precise statement of the important fact mentioned above is that if P is any simple plane polygon, then the plane is composed of P and two regions which have no points in common with each other or with P. One of these regions is of infinite extent and the other is not. A region such as the latter is referred to as a *polygonal region* and also as the *interior* of the polygon concerned and the latter is called the *boundary* of the polygonal region. Every circle which has a point of the boundary of the polygonal region as centre contains points of the region and any point which is such that any circle having it as centre contains points which belong to the region and also points which do not is a point of the boundary of the region. This property of the boundary of any polygonal region is used as the defining property of the boundary of a region in general. As a further consequence should be mentioned the fact that any polygonal region plus its boundary is composed of a finite number of triangles and their interiors, which have no points in common, and the vertices of the triangles are vertices of the bounding polygon. A region which is not a polygonal region is, however, approximated to by polygonal regions according to the following theorem: If Σ is any region, then there exists a sequence of polygonal regions $\Sigma_1, \Sigma_2, \Sigma_3, \cdots, \Sigma_n, \ldots$ such that *(a)* Σ_n and its boundary is contained in Σ and also in Σ_{n+1} for all (positive integral) values of n and (b) each point of Σ is contained in all but a finite number of the polygonal regions Σ_n. This theorem is easily proved by using as the polygonal regions regions which are composed of congruent squares which are formed by two sets of parallel lines, the lines of each set being equally spaced and intersecting orthogonally those of the other set. These acts indicate the importance of polygonal lines and polygons in the study of more general configurations.

THE THEORY OF PLANE POLYGONS

The Interior, Exterior and Peripheral Angles of a Plane **Polygon.**—We now proceed to the special theory of plane polygons. As remarked above, this theory concerns itself largely with unoriented and oriented polygons. In the case of a simple polygon the meaning of "an interior angle of a polygon" is immediate in virtue of the theorem concerning the separation of the plane by the polygon. This meaning leads to an interesting generalization in the case of an oriented polygon. In proceeding to this generalization and to related ideas it should be stated that all of the terms used are not defined with the mathematical completeness that would be possible with a greater allowance of space, but it has been aimed at least to indicate clearly the way to that completeness. Now it can be proved that if P is a simple oriented polygon and *A* any vertex of P then for the positive (counterclockwise) rotation of any side AB of P about its first end *A*, in accordance with the sense of P, which transforms the side ***AB*** into the other side of P having *A* as an end and which has a magnitude not exceeding 2π radians, then the points on the intermediate positions of AB which are within a certain distance of *A* are all in the interior of the polygon determined by P if the sense of P is the same as that of the rotation and all in the exterior in the contrary case. (Note that senses of oriented polygons are compared only in the case of simple oriented polygons.) Accordingly the *interior angle at any vertex* A_i of any oriented polygon P is defined as the positive angle (rotation) which has A_i as its vertex and whose initial side contains the side of P which has A_i

as its first end, say the side A_iA_{i+1}, whose terminal side contains the side with the ends A_i and A_{i-1}, if $i\neq 1$, and A_n if $i=1$, and whose magnitude does not exceed 2π. (See fig. 1.)

Further if A_i is any vertex of an oriented polygon P and the first end of the oriented side A_iA_{i+1} of P then there is a rotation about A_i of the half-line having A_i as its initial point and having the same direction as the oriented side $A_{i-1}A_i$ ($i-1\equiv n$ if $i=1$), that is the half-line of the line through A_{i-1} and A_i, which has A_i as its initial point and which does not contain A_{i-1}, into the half-line which contains the side A_iA_{i+1} which has a magnitude greater than $-\pi$ and less than or equal to π and there is another such rotation which is positive and has a magnitude not exceeding 2π. The former angle (rotation) is called the *exterior angle* and the latter the *peripheral angle* of the oriented polygon P at the vertex A_i.

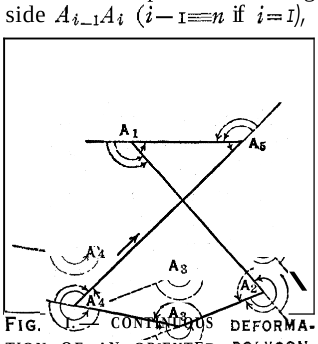


FIG. 1.— CONTINUOUS DEFORMATION OF AN ORIENTED POLYGON, WITH FIVE VERTICES

If α_i, β_i, γ_i are respectively the magnitudes of the interior, exterior and peripheral angles of the oriented polygon P at the vertex A_i then $\alpha_i+\beta_i=\pi$ and $\alpha_i+\gamma_i=\pi$ or 3π according as α_i is or is not less than π. If α_i is less than π then γ_i is and conversely. If the sum of all the β_i is set equal to $2a\pi$ and the sum of all the γ_i to $2a'\pi$ then a and a' are integers or zero as a simple consideration shows and $a'-a$ is the number of interior angles of P whose magnitudes are greater than or equal to π. If P' and P'' are two oriented polygons which differ only in orientation and if α_i', β_i', γ_i' and α_i'', β_i'', γ_i'' are respectively the magnitudes of the interior, exterior and peripheral angles of P' and P'' at the vertex A_i then $\alpha_i'+\alpha_i''=2\pi$, $\beta_i'+\beta_i''=0$ and $\gamma_i'+\gamma_i''=2\pi$. Hence the value of a for P'' is the negative of its value for P' while the value of a' for P'' is the number of vertices of P' (or P'') minus the value of a' for P'.

Classification of Plane Polygons.— In the classification of oriented polygons the numbers a and a' have been used to define the so-called types of such polygons. It is obvious how they may be used in the classification of unoriented polygons. There exist oriented polygons of any number n of vertices for which the value of a is any number whose absolute value does not exceed $\frac{1}{2}(n-1)$ except that for a triangle a cannot be zero. A more detailed scheme of classification is according to the values of a and $q=a'-a$. If all of the interior angles of an oriented polygon have magnitudes which do not exceed π then the polygon is called a *convex oriented polygon.* The unoriented polygon P is convex if and only if P with a sense assigned to it is convex. Both of these definitions are in conformity with the important notions of a *convex simple polygon* and a *convex polygonal region.* A *convex region* is a region such that all of the points of any segment whose ends belong to the region belong to the region also. A simple polygon is said to be convex if it is the boundary of a convex region, which is then a convex polygonal region. As theorems we have: A line which does not contain a side of a convex simple polygon contains not more than two points of the polygon and conversely. Also, no point of a convex simple polygon is on a particular one of the two sides of the line which contains any side of the polygon and conversely.

Another method of classification of unoriented and oriented polygons uses the notion of the continuous deformation of such polygons. Any one of two unoriented polygons with the vertices $A_1, A_2, \ldots, A_n$ and $B_1, B_2, \ldots, B_n$ respectively is deformable continuously into the other so that the vertex A_i corresponds to the vertex B_i and the side A_iA_{i+1} to the side B_iB_{i+1}. To obtain subclasses of unoriented polygons continuous deformations of such polygons, which satisfy any or all of the following conditions, are used: (1) no intermediate polygon of the deformation has two consecutive sides which lie in the same line and which have no points in common; (2) neither of two consecutive sides of any intermediate polygon of the deformation is contained in the other; and (3) no point is common to more than two sides of any intermediate polygon of the deformation. In the case of oriented polygons it is also required that sense be preserved by the deformation. Two oriented polygons that are transformable one into the other by a continuous deformation satisfying the first condition have the same value for a. If instead of the first condition the second is satisfied the oriented polygons have the same value for a'. If the deformation satisfies both the first and second conditions then the two oriented polygons are related so that if the magnitudes of one of two corresponding interior angles is less than π then the same is true of the other. Corresponding results for unoriented polygons follow easily. An interesting classification of unoriented polygons which satisfy the conditions on the intermediate polygons of the deformations satisfying all three conditions and which, in addition, have no vertex as the end of more than two sides and no side containing a vertex or a point belonging to more than two sides is that in which any unoriented polygon in one class is deformable into any other or into the symmetric image of any other in that class by a continuous deformation satisfying all three of the above conditions. For unoriented polygons of 4, 5 and 6 vertices there are respectively 3, 11 and 70 classes under this classification.

Non-metrical and Metrical Theories. Regular Polygons. Area of Polygons.— It should be pointed out that the above theory of the classification of unoriented and oriented polygons holds without essential modification in a more general plane than the Euclidean for only the order relations of the Euclidean plane are essential. Between this theory and the corresponding theory in the projective plane there are, because of the different kinds of linear order, some essential differences. but both theories are non-metrical. By making use of the metric properties of the Euclidean plane the consideration of regular polygons, oriented or not, becomes possible; also the question of the area of polygonal regions arises. An unoriented polygon is *regular* if any side is congruent to any other side and any angle of the polygon, *i.e.,* the figure consisting of a vertex and the two consecutive sides having that vertex as an end, congruent to any other "angle" of the polygon. The regular polygons are convex and there exists a circle circumscribed about and another inscribed in every regular polygon. Those regular polygons that are not simple also are called *star polygons.* If n points which are equally spaced on the circumference of a circle and numbered in order along that circumference are joined by segments so that the i-th point is joined to the $(i+d)$-th point, where d is a fixed positive integer, then the polygon resulting is a regular polygon for which the value of a, defined above, is d. Thus the number of "types" of regular polygons of n vertices is half of the number of positive integers which are less than and prime to n. Other kinds of regular polygons have been studied with particular reference to their classification along the lines explained above. For instance, there are the polygons which have the property that the figure composed of any vertex and the two sides of the polygon which have that vertex as an end is congruent to any other such figure and also the polygons which are such that the figure consisting of any side and two adjacent angles of the polygon is congruent to any other such figure. These polygons have an even number of vertices and a circle is circumscribable about any of those of the former kind and inscribable in any of those of the latter.

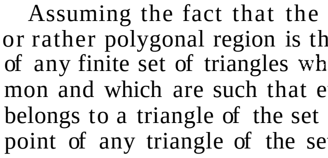


FIG. 2.— DEFORMATION OF A POLYGON OF FOUR VERTICES INTO THREE TYPES

Assuming the fact that the area of any plane simple polygon or rather polygonal region is the sum of the areas of the triangles of any finite set of triangles which have no interior points in common and which are such that every point of the polygonal region belongs to a triangle of the set or to the interior of one and every point of any triangle of the set or of the interior of any belongs to the polygonal region or its boundary the notion of the area of any plane unoriented or oriented polygon is approached. In the case of an unoriented or oriented polygon in general there is no region uniquely determined as in the case of simple polygons. In the following only the case of oriented polygons is considered for that essentially covers the case of unoriented polygons. If the area of a triangle according to the usual meaning is σ then the area of that triangle with a sense assigned to it is defined as σ or $-\sigma$ according as that sense is positive or negative; *i.e.*, the same or not the same as the counterclockwise sense along the circumference of a circle. Using the symbol $A_1A_2 \dots A_n$ to denote

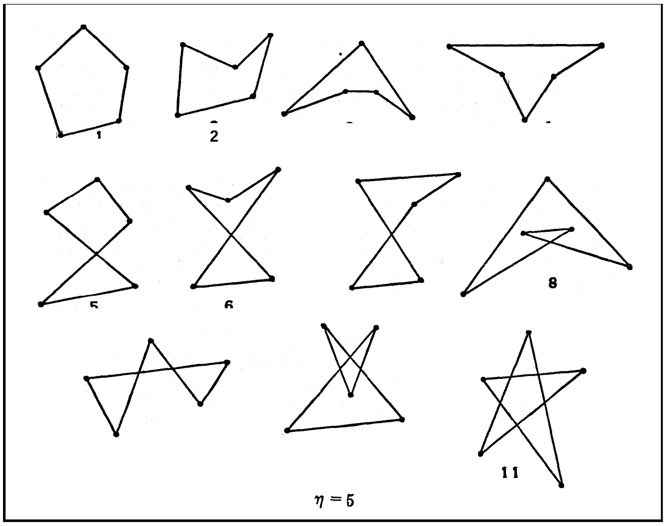


FIG. 3.— DEFORMATION OF A POLYGON OF FIVE VERTICES INTO 11 DIFFERENT TYPES

the oriented polygon with the vertices $A_1, A_2, \dots, A_n$ and the sensed sides A_iA_{i+1}, the area of the oriented polygon $A_1A_2 \dots A_n$ is defined as the sum of the areas of the oriented triangles $OA_1A_2, OA_2A_3, \dots, OA_nA_1$ where O is any point of the plane. It is, of course, proved that the value of the area thus defined does not depend on the position of O and that if $A_1A_2 \dots A_n$ is simple, this definition agrees with the area of a simple polygon according to the fundamental definition. An oriented polygon P determines a finite number of polygonal regions in its plane which have no points in common and whose boundaries are composed of points belonging to P. One and only one of these regions is of infinite extent. Now the following interesting facts pertain: let the regions, or cells, of finite extent be denoted respectively by $S_1, S_2, \dots, S_k$, and let the area of the cell S_i according to the fundamental definition of the area of a polygonal region be σ_i so that σ_i is a positive number; then there exists a set of numbers $c_1, c_2, \dots, c_k$ which are either integers or zero such that the area of the oriented polygon P is $c_1\sigma_1 + c_2\sigma_2 + \dots + c_k\sigma_k$. Further: c_i is the number of complete positive revolutions minus the number of complete negative revolutions made by the radius vector, having any point O of S_i as its initial point, as its terminal point describes once the oriented polygon P in the assigned sense. c_i is called the coefficient of the cell S_i. *See* TOPOLOGY, ALGEBRAIC.

BIBLIOGRAPHY.—M. Brückner, *Vielecke und Vielflache* (1900); H. Forder, *Foundations of Euclidean Geometry* (1927); E. Steinitz, *Encyklopaedie der mathematischen Wissenschaften*, Bd. iii (1922); O. Veblen and J. W. Young, *Projective Geometry*, vol. ii (1918); C. Wiener, *Über Vielecke und Vielflache* (1864). (G. A. P.; X.)

POLYGRAPH, a device for simultaneously measuring and recording various bodily functions such as heart-beat, blood pressure, respiration rate, etc. Because these functions tend to fluctuate abnormally when a person attempts to lie or deceive, the polygraph is used extensively in the investigation of crime. Used in this manner it is popularly called a lie detector (*see* INVESTIGATION, CRIMINAL: *Detection of Deception*).

POLYGYNY, the system under which a man is married to several women at the same time, a type of polygamy or plural marriage. Polygyny is nowhere the exclusive form of marriage, and among most peoples who permit it the large majority of men live in monogamy. It may be modified in a monogamous direction both from the social and the sexual point of view. Frequently one of the wives: generally the one first married, holds a higher position than the rest or is regarded as the principal wife. In some cases this position implies certain sexual privileges; but more often it is the custom for the husband to cohabit with wives in turn, or this is actually required of him. How far theory and practice coincide is moot—one may be for a time the favourite.

Primitive Societies.—Among preliterate peoples polygyny does not seem to be practised on a large scale by the hunters and food-collectors, except some Australian and Bushman tribes, nor by any incipient agriculturists. On the other hand, a considerable number of these hunting and slightly agricultural tribes—such as some of the South American Indians, the aboriginal tribes of the Malay peninsula, most of the Andaman Islanders, the Veddas of Ceylon, certain tribes in the Malay archipelago, most of the Negritos of the Philippine Islands and some at least of the central African pygmies—are represented as monogamous. Among more well-to-do hunters polygyny is more frequent, although in the majority of their tribes it is practised only occasionally; and exclusive monogamy is rare, though perhaps not unknown. Among pastoral peoples there seems to be none that can be regarded as strictly monogamous; and both among them and the higher agriculturists polygyny is undoubtedly more frequent than among the hunters and incipient agriculturists, although cases of regular monogamy are more frequent among the higher agriculturists than among the higher hunters. The cases in which polygyny is represented as general are comparatively much more numerous among African than non-African pastoral peoples and higher agriculturists. Polygyny is at its height in Africa, both in point of frequency and in number of wives. King Mtessa of Uganda and the king of Loango are said to have had 7,000 wives.

Ancient Civilizations.—Polygyny, or a sort of concubinage hardly distinguishable from genuine polygyny, is found among most peoples of archaic civilization. In China there were, besides the legal principal wife, so-called wives "by courtesy" or lawful concubines. In Japan concubinage of the Chinese type existed as a legal institution until 1880. In ancient Egypt polygyny seems to have been permitted but to have been unusual, except in the case of kings. The Babylonian code of Hammurabi assumed that marriage should be monogamous; yet "if a man has married a wife and a sickness has seized her," he might take a second wife; and if she remained childless he might take a concubine. Among the Hebrews a man could in any circumstances have a plurality of wives, and there was no difference in the legal status of different wives, nor was there any limit to the number of wives a man might take. In Arabia Mohammed ordained that a man's legal wives should be not more than four. Polygyny has been permitted among many of the Indo-European peoples—among ancient Slavs and Teutons, the ancient Irish and the Vedic Indians—though it seems to have been as a rule confined to kings or chiefs or nobles. None of the Hindu lawbooks restricts the number of wives a man is allowed to marry; yet some preference is often shown for monogamy, and most castes object to their members having more than one wife, except for some cogent reason. On the other hand, there can be little doubt that monogamy was the only recognized form of marriage in Greece; concubinage existed in Athens, but it was well distinguished from marriage, conferring no rights on the concubine. Roman marriage was strictly monogamous; liaisons between married men and mistresses were not uncommon, but such a relation was not considered lawful concubinage.

Modern Times.—Polygyny has been found even in Christian Europe. No obstacle was put in the way of its practice by kings in countries where it had occurred in the times of paganism. In the middle of the 6th century Diarmait, king of Ireland, had two queens and two concubines. Polygyny was frequently practised by the Merovingian kings. Charlemagne had two wives and many concubines; and one of his laws seems to imply that polygyny was not unknown even among priests. In later times Philip of Hesse and Frederick William II of Prussia contracted bigamous marriages with the sanction of the Lutheran clergy. In 1650, soon after the peace of Westphalia, when the population had been greatly reduced by the Thirty Years' War, the Frankish *Kreistag* at Niirnberg passed the resolution that thenceforth every man should be allowed to marry two women. The Anabaptists and the

Mormons once advocated polygyny with much religious fervour.

Causes.—One cause of polygyny can be an excess of marriageable women in certain age groups. But while the existence of available women makes polygyny possible. the direct cause of it is generally the man's desire to have more than one wife. There are various reasons for this desire. Among many of the simpler peoples the husband has to abstain from his wife during her pregnancy. or at least during the latter stage of it, and after childbirth until the child is weaned. which often means an abstinence lasting for a couple of years or more. Other contributing factors are the attraction of youth and beauty, the desire for many children—which is one of the principal causes of polygyny in the east—and the fact that polygyny may contribute to a man's material comfort or wealth, and thereby his social importance. But it should also be noted that the paying of a dowry, the amount of which is influenced by economic conditions, makes it possible for certain men to acquire several wives while others can acquire none at all.

See MARRIAGE; POLYANDRY; SOCIAL ANTHROPOLOGY; SORORATE; see also references under "Polygyny" in the Index volume.

BIBLIOGRAPHY.—L. T. Hobhouse, G. C. \%'heeler and M. Ginsberg, *The Material Culture and Social Institutions of the Simpler Peoples* (1915); Nobushige Hozumi, *Ancestor-Worship and Japanese Law* (1913); P. W. Joyce, *A Social History of Ireland*, vol. ii (1903); J. Jolly, *Recht und Sitte* (1896); L. Beauchet, *Histoire du droit privé de la République Athénienne*, vol. i (1897); T. Mommsen, *Römisches Strafrecht* (1899); E. Westermarck, *The History of Human Marriage*, vol. iii (1921); R. Briffault, *The Mothers*, vol. ii (1927); G. P. Murdock, *Social Structure* (1949). (E. W.; X.)

POLYMERIZATION, in chemistry, was originally considered to be any process in which two or more molecules of the same substance unite to give a molecule (polymer) with the same percentage composition as the original substance (monomer), but with a molecular weight which is an integral multiple of the original molecular weight. The special case that exists when the monomer and polymer are so easily interconvertible that their isolation and chemical distinction are difficult, is usually considered to be association (*q.v.*).

The term "polymerization" now applies when the monomer and polymer are easily distinguished; it applies also to preparations of some polymers which do not conform to the original definition (*see* below). Polymerization is the process by which plastics, resins and rubber are synthesized (see PLASTICS: RESINS; RUBBER: PRODUCTION AND MANUFACTURE). This article is concerned with the general principles of polymerization processes. and particularly with the much-studied. industrially important processes which produce polymers of high molecular weight (high polymers).

Addition Polymerization.— This process occurs when monomer units simply join together to form polymers. The process usually requires a double or triple bond in the structural formula of the monomer. Although a carbon-oxygen or carbon-nitrogen multiple bond will serve (see FORMALDEHYDE)! most examples involve carbon-carbon double bonds, particularly olefins with $>C=CH_2$ groups (see CHEMISTRY: Organic *Chemistry* for many terms used here). Some polymers contain only two or three monomer units (see TERPENES), some contain many, and some monomers yield more than one kind of polymer. Phosphonitrile chloride. $P\equiv NCl_2$, is an inorganic monomer yielding several addition polymers.

The polymerization of styrene (*q.v.*) illustrates addition polymerization. The monomer is a colourless, mobile liquid. On standing for several weeks at room temperature. for a few days at 100° C., or for a shorter time at higher temperatures, the liquid polymerizes, becoming first an increasingly viscous solution of polymer in monomer. and finally a clear, odourlcss, glassy solid. The polymer is a mixture of molecules of the formula $(C_6H_8)_n$, where n has a wide range of values and averages several thousand. When the monomer is warmed with 1% or less of an initiator such as benzoyl peroxide. $C_6H_5—CO—O—O—CO—C_6H_5$, a similar polymer is formed, but in minutes or hours instead of days or weeks. These processes are chain reactions, starting when styrene is activated thermally, or when the initiator decomposes, to give electrically neutral fragments of molecules. with free or unsaturated valences (free radicals with trivalent carbon atoms). Such a fragment, R —, adds easily to the double bond in the monomer

$$R - + H_2C = CH - C_6H_5 \rightarrow R - CH_2 - CH(C_6H_5) -$$

forming a larger radical with the free valence now on the styrene unit. This new free radical adds to another double bond, and so on, so that many monomer units become linked together in a linear (threadlike) polymer. Thousands of steps in a single reaction chain may occur in a second, the reaction ending when two radicals interact and mutually destroy their free valences.

Similar polymerizations are industrially important both with liquids (*e.g.*, vinyl acetate, acrylic esters, acrylonitrile) and with gases under pressure (*e.g.*, ethylene, butadiene and vinyl chloride). Such polymers have a wide range of physical properties (see PLASTICS; ETHYLENE; BUTADIENE). To avoid difficulties in handling large masses of hard or viscous polymer, large-scale polymerizations are frequently carried out in emulsion or suspension in water to produce synthetic latex or beads.

Initiators which do not produce free radicals may also be employed. Some metal halides (aluminum chloride or boron trifluoride), sulfuric acid, metal alkyls (from sodium, lithium or aluminum: see ORGANOMETALLIC COMPOUNDS) and strong bases (sodamide) also cause addition polymerization of some olefins. but here the growing chains are usually ion pairs. These initiators require anhydrous conditions since the polymer ions are destroyed by water. Although styrene and butadiene are polymerized by all the initiators mentioned, the choice of initiators for most monomers is limited.

Considerable heat is evolved when high polymers are formed, and the process can become violent. The driving force in the polymerization is the conversion of the double bond in each monomer to two single bonds in the polymer. In a sense, the strain in the double bond is thus relieved. However. in the polymer, the monomer units are crowded together and restricted in their motions. These restrictions become more important at increasing temperatures. and high polymers made from larger monomers begin to revert to monomer above 200° C. Polymers from smaller monomers hold together better, but at 300°–400° C. they also break up, yielding complex mixtures and rather little monomer.

When a mixture of two monomers is subjected to polymerization. the product may contain both monomers in each polymer molecule (*i.e.*, copolymerization of two monomers yields a copolymer), or it may contain only one kind of monomer in each polymer molecule, depending on the monomer and type of initiator. Many commercial polymers are actually copolymers. a wider range of properties being possible than with single monomers.

Two polymers may have atoms joined together in the same sequence. but still have different physical properties because of different spatial relations among the atoms (see STEREOCHEMISTRY: *The Stereochemistry* of Carbon). Lowering the temperature of polymerization for SBR synthetic rubber from 50° to about 5° C. has resulted in the improved "cold rubber." Natural rubber has been duplicated by polymerizing isoprene with specific organometallic catalysts. Similar catalysts have produced crystalline modifications of polystyrene and polypropylene which melt above 150° C.. instead of softening below 100°.

Condensation **Polymerization.**—This is the process of making products, commonly called polymers, with the formation of a small, easily removed molecule (often water) for each step in the process. For making high polymers, the general method is to choose a simple and clean organic reaction, to make it possible for this reaction to take place at each end of every molecule, and to force the reaction to completion by removing the water (or other volatile condensation product) from the reaction mixture. Reactions uhich give amides or esters are particularly useful. For example, a polyamide can be made either from an amino acid, $H_2N—(CH_2)_x—CO_2H$, or from an equimolecular mixture of a dibasic acid, $HO_2C—(CH_2)_y—CO_2H$, and a diamine. $H_2N—(CH_2)_z—NH_2$. Proteins are polyamides assembled from many amino acids in a very specific manner by enzymes. Starch and cellulose can be considered to be made similarly from glucose units. The condensation of a dihydroxysilane produces a silicone (*q.v.*) polymer. (See also AMIDES; ESTERS; PROTEINS; STARCH; CELLULOSE.)

For polymerization to occur, each molecule must contain two potential open ends and the monomer units must join end-to-end into linear polymers. Such polymers are usually soluble in suitable solvents, soften (reversibly) on heating, and are termed thermoplastic. However, if the monomers contain more than two sites of reaction (*e.g.*, butadiene, glycerol, phenol, tribasic acids), then netlike (cross-linked) instead of threadlike molecules result. When the networks grow large enough, they become equivalent to many linear polymer molecules joined together in a single network. At this stage, the polymers are insoluble and infusible and are termed thermosetting. See PLASTICS: Causes of *Resinification,* Synthetic Resin Plastics; RESINS: Synthetic Resins.

See C. E. H. Bawn, "New Kinds of Macromolecules," *Endeavour*, vol. 15, pp. 137–143 (1956); P. J. Flory, *Principles of Polymer Chemistry* (1953).
(FK. R. M.)

POLYMORPHISM. Many chemical substances, elements as well as compounds, crystallize in two or more distinct atomic arrangements which are differentiated by their X-ray diffraction patterns, outward crystal form, optical properties, energy content, volume, etc., and as such, are separate crystalline phases of the substance, according to the definition laid down by J. W. Gibbs (1876). The name "polymorphism" was applied to this property by E. Mitscherlich (1823), who discovered it in sodium phosphate and sulphur. Another term: "allotropy," attributable to J. Berzelius (1841), was proposed as a name for the supposed different conditions of the same element, both in the pure state and in compounds of which the element forms a part. Subsequent usage tended to confine the term to elements (W. Ostwald, 1893), and included such forms as gaseous oxygen and ozone, the mobile and viscous forms of sulphur, the different forms of phosphorus and the diamond and graphite forms of carbon. In the broadest sense, allotropy was applied by A. Smits (1911) to compounds in studies of "inner equilibria" prevailing therein between different molecular species. All cases of allotropy in the crystalline state are merely examples of polymorphism, and are best described as such. A polymorphic substance may be described as dimorphic, trimorphic, etc., according to the number of distinct crystalline forms.

Polymorphic substances may also be distinguished according to whether or not two given forms are reversibly transformable one into the other. When the transformation is reversible, the change is said to be enantiotropic; if it is found to be unidirectional only under all conditions investigated thus far, it is said to be monotropic. Two phases of one substance in equilibrium form a univariant system according to the phase rule; this means that if pressure and temperature are chosen as the external variables, the equilibrium temperature will depend upon the pressure, the composition being constant. The equilibrium temperature at constant pressure is known as the transition or inversion point. For example, rhombic sulphur is in equilibrium with monoclinic sulphur at 95.6° C., 1 atm., and at 129.9° C., 845 atm. The variation of the transition temperature with the pressure is expressed quantitatively by the Clapeyron equation in the form $dT/dp = T(v_{I}-v_{II})/L$ where T is the temperature on the Kelvin scale, p the pressure, L the latent heat absorbed and $v_{I}-v_{II}$ the difference in volume of the high- and low-temperature form, respectively, all per unit mass. dT/dp was measured for numerous enantiotropic transitions by G. Tammann, P. W. Bridgman and others. Since $v_{I}-v_{II}$ is usually small in comparison with L/T, high pressures are required to produce appreciable changes in the transition temperature; for sulphur in the above example, the average $dT/dp=0.034°$ per atmosphere. Other examples are: low to high quartz, 0.021; red to yellow HgI_2, 0.0016. Three phases of one substance in equilibrium form an invariant system; this means that the phases can coexist at some one constant pressure and temperature characteristic of the phases present. This invariant point is named the triple point. In polymorphism two of the phases must be different crystalline forms of the substance; the third phase may be another crystal form, or liquid or vapour. For sulphur the triple point rhombic-monoclinic-vapour is 95.6° C. (approx.), 0.00003 atm.; rhombic-monoclinic-liquid, 153.7° C., 1,400 atm. For water, which has seven crystalline phases, the triple point ice I—ice II—ice III is at −34.3° C., 2,100 atm. (see ICE).

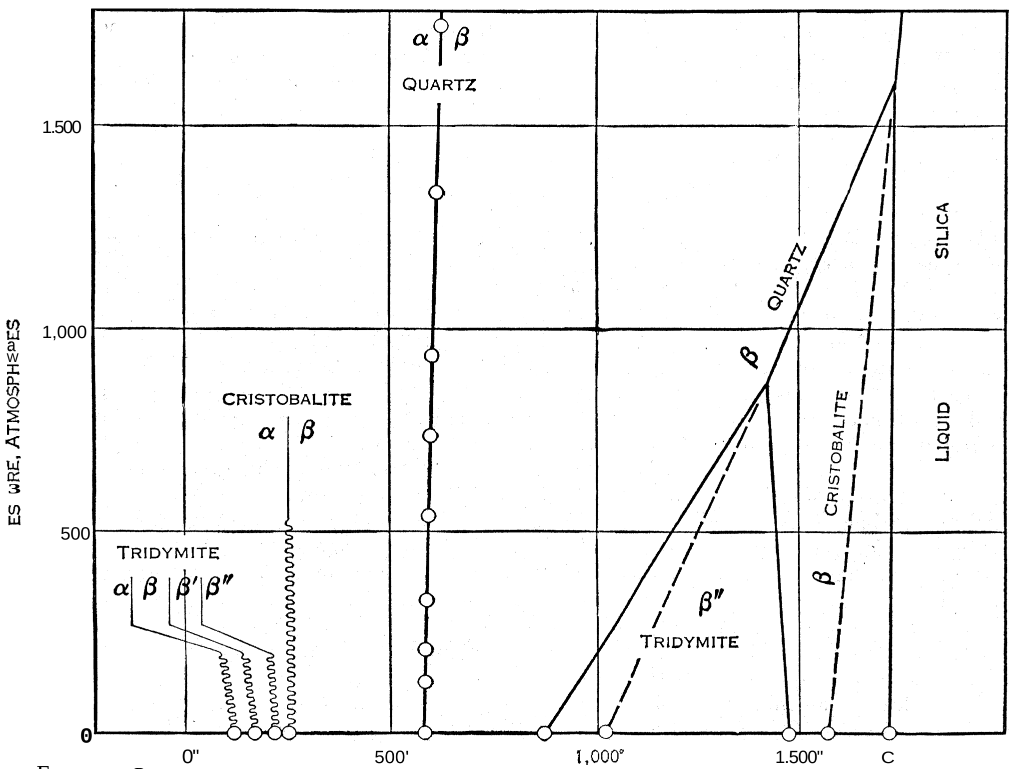


FIG. 1.— PRESSURE-TEMPERATURE PHASE DIAGRAM FOR SILICA. SOLID LINES REPRESENT TRANSITIONS OF PHASES STABLE IN THE RESPECTIVE ADJOINING REGIONS. BROKEN LINES REPRESENT TRANSITIONS OF METASTABLE PHASES. TRIDYMITE AND CRISTOBALITE IN THE REGION OF THEIR ALPHA-BETA TRANSITIONS ARE EACH METASTABLE WITH RESPECT TO ALPHA QUARTZ, WHICH IS HERE THE STABLE PHASE

A polymorphic substance, when mixed with one or more other substances and brought to equilibrium, may have its transition point changed. Both experimental evidence and deductions from the phase rule indicate that this occurs when the polymorph and the added substance form solid solution. If the polymorph crystallizes pure from the mixture or solution, the transition point remains unaltered. Thus, NH_4NO_3, which crystallizes pure from its aqueous solution, is found to invert at 32°, 84° and 125° C., whether alone or in the presence of its aqueous solution. KNO_3, on the other hand, forms solid solutions with NH_4NO_3, and equilibrium mixtures of the two invert at temperatures which depend on the composition of the system. Specifically, *e.g.*, 20% KNO_3 added to NH_4NO_3 lowers the 32° transition to near 0° C.

The enantiotropic transformations considered above are in many respects analogous to melting or freezing, with one important difference. In melting it is rarely observed that a crystal can be superheated above its melting point. although undercooling on freezing is common. Polymorphic transitions may be both superheated and undercooled; the aidth of the band of indifference (hysteresis band) varies from a few degrees for prompt transitions to unknonn values for very sluggish ones. Transitions in uhich only minor changes of crystal symmetry occur are often prompt, while those involving marked alterations of structure are usually more or less sluggish Both varieties of behaviour may be found in the same chemical substance, as in silica *(q v)*. *See* fig 1. The three main varieties of silica are quartz, tridymite and cristobalite. These differ considerably in their crystal structures, and are mutually transformed only with great difficulty. quartz to tridymite at 867° C and tridymite to cristobalite at 1,470° C., at the pressure of one atmosphere The sluggishness of these transformations is evidenced by the fact that these varieties of silica have been found in coexistence in certain volcanic rocks for geologic ages. On the other hand, there occur one or more relatively rapid transitions between high- and low-temperature forms of each of the main varieties, accompanied by only slight changes in crystal structures; namely, in quartz at 573° C., in tridymite at 118°, 163° and 230° C. and in cristobalite between 200° and 275° C. In the slow transformation of quartz to tridymite or to cristobalite, catastrophic changes in the structure occur which involve the breaking of Si-O-Si bonds. whereas only distortions of structure occur in the rapid transitions of the low- to high-temperature forms in quartz, tridymite or cristobalite.

The enantiotropic transformations may be contrasted with the monotropic transformations. for which no transition temperature had been found experimentally at mid-20th century. The classification is not particularly exact, inasmuch as it is usually based not on the knowledge of the actual stabilities of the phases but rather on empirical findings, usually at atmospheric pressure only. The tendency to transform may be held in abeyance by the same energy barriers that are responsible for the metastable existence of such enantiotropic forms as cristobalite at ordinary temperature. Many cases of monotropism at ordinary pressure occur among organic compounds, as in chloroacetic acid. which can crystallize in three different forms with melting points at 50.2°, 56.2" and 61.3° C., the two lower melting forms being unstable with respect to the highest melting form An instance of apparent monotropism is offered by calcium carbonate, which is found in nature as the stable calcite (*q.v.*) and as aragonite, which is unstable with respect to calcite at ordinary and higher temperatures. The transformation aragonite to calcite at these temperatures is truly unidirectional. A thermodynamic study of the stabilities of the two indicates. however, that belcw −60° C. aragonite becomes the stable form. At higher temperatures, the complex aragonite structure, although unstable, inverts only slowly to the simpler structure of calcite. Both aragonite and calcite have been found together in certain fossils. The influence of structure on transformability is shown even more strikingly in diamond and graphite, two forms of carbon (fig. 2). Diamond, the less stable torm,

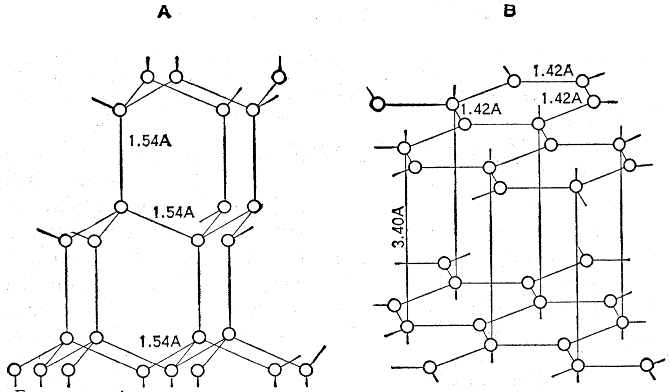


FIG 2 — ARRANGEMENT OF ATOMS IN THE LATTICE OF (A) DIAMOND, WITH (111) PLANE HORIZONTAL, AND (B) GRAPHITE. WHERE LINES LINK ATOMS OF SUCCESSIVE SHEETS WHICH ARE IN THE SAME VERTICAL COLUMNS. NOTE THE DIFFERENCES IN THE INTERATOMIC DISTANCES IN THE TWO TYPES OF CRYSTAL. SMALL CIRCLES INDICATE LOCATIONS OF CENTRES OF CARBON ATOMS, AND BEAR NO RELATION TO THEIR SIZE

has a very rigid cubic structure, with each carbon atom joined to four others by bonds of equal strength. whereas the rhombohedral graphite has one weak bond and three much stronger ones. These give it its layer lattice and lubricating properties. The two lattices have nearly the same energies of cohesion, about 170,000 cal. per mole, which differ by only joo cal. per mole; the difference is too small to provide the energy of activation for the necessary rearrangement in the strengths of the bonds, and there is no evident tendency to transform at ordinary temperatures. From measurements made at the national bureau of standards, it appears that high pressures and low temperatures increase the thermodynamic stability of diamond; very great pressures would. however: be required to produce artificial diamonds at temperatures high enough for the rate of transformation to become appreciable (much more than 50,000 atm. at 2,000° C.).

The occurrence of polymorphism and the formation of metastable modifications had not yet been satisfactorily explained in detail at mid-20th century. Qualitatively, the energy change in the transition of one form to another (*i.e.*, the heat of transition) is much smaller than the energy of formation of the individual lattices from the vapour. A number of atomic arrangements of nearly the same energy may be possible for a given substance, such that different lattices in turn become the more stable at different temperatures. The exact calculations are difficult, and only the lattice energies of the simplest crystals have been calculated. The various possible lattices of a substance may differ in the degree of order of arrangement of the atoms; the more symmetrical lattices, such as the cubic, may be considered as less highly ordered than the less symmetrical, such as the monoclinic or triclinic. It may be noted that the less highly ordered lattices tend to occur as stable phases at high temperatures where the disordering action of thermal vibrations is more violent. They often tend also to crystallize first from melts, from solutions or from the vapour, even though other forms may be more stable. Thus, KNO_3 crystallizes from solution in rhombohedra and only later inverts to the more complex orthorhombic stable form; silica almost invariably crystallizes from dry silicate melts as cubic cristobalite rather than as the more complex quartz. Such examples indicate the trend, but apparently there are many exceptions, and little can be said about cases where all the modifications have complex structures. The problem of polymorphism is further complicated by the occurrence of lattices with defects in the atomic arrangement. In the high-temperature forms of AgI, Ag_2S, Ag_2HgI_4 and certain related compounds, some or all of the metal ions are mobile in a still rigid anion lattice, whereas in the low-temperature forms of such substances all the ions are in ordered positions. In heating some alloys, an ordered arrangement of the metal atoms inverts to a random one (Cu_3Au, CuZn, AgZn), and in some other substances: certain radicals or whole molecules change from an ordered orientation to a random one (NH_4Cl, CH_4, NH_4NO_3, $NaNO_3$, HCl). A still further type of disordering is that suffered by quartz on changing from the low- to the high-temperature form, where bent Si-O-Si bonds are straightened. In such cases the final (abrupt) transition is often preceded by a gradual change in structure, volume: specific heat and other properties, extending over many degrees, as the temperature is raised.

Liquid crystals, turbid, viscous, structure possessing phases intermediate between true crystals and true liquids of some long-chain organic compounds. invert promptly to true crystals with a small heat of transition and a small volume change. About 250 examples are known.

Liquid phase transformations, as in sulphur or helium, may be mentioned as examples not of polymorphism but of allotropy in the broader sense. There is no sharp phase transition. but rather a gradual transformation evidenced by a change in physical properties of the liquid over a narrow range in temperature.

BIBLIOGRAPHY.—Introductory textbooks on physical chemistry ; P. W. Bridgman, *The Physics of High Pressures* (1931), "Recent Work in the Field of High Pressurcs," *Reviews of Modern Physics*, vol. 18, p. 1 (1946); R. C. Evans, *An Introduction to Crystal Chemistry* (1939); F. Seitz, *Modern Theory of Solids* (1940); J. C. Slater, *Introduction to Chemical Physics* (1939); A. F. Wells, *Structural*

Inorganic Chemistry (1945); A. Eucken, "Übergänge zwischen Ordnung und Unordnung in festen und flüssigen Phasen," *Z. Elektrochem.*, vol. 45, p. 1 (1939); A. Smits, *The Theory of Allotropy*, trans. by J. Smeath Thomas (1922); H. Jones, "The Properties of Liquid Helium," *Reports on Progress in Physics*, vol. vi, p. 280 (1939); *Discussion on Liquid Crystals*, Trans. Faraday Society, vol. 29 (1933); J. W. Mellor, *A Comprehensive Treatise on Inorganic and Theoretical Chemistry*, vol. 10, "Sulfur and Selenium," p. 23 (1930); tables of transitions in *Int. Crit. Tables*, vol. iv (1928); *Smithsonian Physical Tables* (1933); R. Smoluchowski (chairman of editorial committee), *Phase Transfornzations in Solids*, symposium held at Cornell university, hug. 23–26, 1948 (1931). (F. C. Kk.)

POLYNESIA, the islands scattered over the eastern Pacific ocean between 170° E., and 110° W. long., lying within the vast triangle formed by the Hamaiian Islands to the north, New Zealand to the south and Easter Island (Chile) to the east. Western Samoa, American Samoa (U.S.) and Tonga Islands (British) are located at the western base of this triangle and the Society Islands (French), with Tahiti the largest of the group, at the centre. Northeast of the Society Islands are the Marquesas Islands (French), and between them the Tuamotu archipelago (French) stretches eastward to the Mangareva (Gambier) Islands (French). The Cook Islands (New Zealand) lie to the west of the Society Islands and the Tubuai (Austral) Islands (French) to the south. (For the structure, geology, climate, flora and fauna, etc., see Pacific Islands.)

The Polynesian people. — The native inhabitants of Polynesia are a large-framed, soft-featured, brown people with black wavy hair and wide-open brown eyes, readily distinguishable from the small, fine featured, but also brown Micronesians north of the equator and to the west, and the small, dark, frizzly-haired Melanesians south of the equator and to the west. In bodily proportions, shape of the nose, thickness of lips and waviness of hair. they stand in contrast with the American Indians. Many Polynesians have streaks of blond hair and features akin to Caucasians. Therefore the racial classification of the Polynesians has been a difficult problem. They are compounded of elements observable around the Pacific and including the primitive Ainu of Japan, who have Caucasian traits. Some combination of these elements, producing the modern Polynesians, was isolated in a homeland from which they dispersed. The fact that a Polynesian population has not been found outside of Polynesia and some islands to the west settled by them raises the possibility that their formation took place within an island group of Polynesia itself, before dispersal. It would seem from their remarkable homogeneity that in their spread through the islands of Polynesia they encountered no other people different from themselves. This is not to say that all Polynesians look alike, but the same types reappear in the major island groups in much the same proportions.

If the racial classification and origin of the Polynesians is obscure this is not true of their languages. They speak dialects of Malayo-Polynesian, and islanders from one part of the region after short contact can readily converse with those from any other part. It is the close language affiliations with the islands to the west and the total absence of linkage with any American Indian language mhich has long convinced anthropologists of a western origin for the Polynesians. (*See* Polynesian Language.)

Origin of Domesticated Animals and Plants.—The pig, fowl and rat introduced by the Polynesians are of Malaysian origin, as well as nearly all of the introduced plants, such as taro, sugar cane and the breadfruit. A notable exception is the sweet potato, which botanists agree comes from South America.

American Indian **Influence.**—The presence of the sweet potato in Polynesia raises the question of what else may have been derived from America. It has been demonstrated that the balsa rafts such as were employed by the Incas of Peru could drift to Polynesia. Possibly one of these was responsible for the introduction of the sweet potato with a Peruvian Indian name. A number of cultural parallels between ancient Peru and eastern Polynesia may be the result of cultural diffusion from South America. Certain advocates of the theory of a basic American Indian origin for the Polynesians have selected details from myths and traditions, mhich, unfortunately, are too nebulous to be relied upon, and have seized upon cultural parallels from widely scattered parts of America and Polynesia for evidence. Most of this evidence will not bear careful scrutiny as demonstrating historical connections, but a residue cannot be lightly dismissed. People from the islands to the west, however, must have firmly established themselves first in Polynesia as far east as Easter Island, within 2,000 mi. of Peru; if this were not the case, language relationships would not be what they are. The argument that the islands of Polynesia could not be reached from the west because they lie in the face of prevailing winds and currents is untenable. For, if the hypothesis that they were reached from the west is not accepted, it is impossible to account for the presence at Easter Island of the Indonesian fowl and the China paper mulberry bush, imported to make bark cloth.

The Canoes and Their Origin. — The canoes of Polynesia are outrigger types. Ocean voyages were carried out in great double canoes based on the outrigger canoe, mhich is of Malayan origin in design and native terminology, and completely lacking in the Americas. It is a swift sailing, highly manoeuvrable, seaworthy craft, capable of sailing close to the wind, and was in the hands of bold and skilled navigators. Although the Indians on the west coast of the Americas had the advantage of winds and currents for reaching Polynesia, they also had the handicap of a vast and empty stretch of water before them, canoes inadequate for ocean voyages or clumsy rafts, and no foreknowledge of havens in the sea.

Date of **Arrival.**—Archaeologically, no clear traces in any part of Polynesia of a people possessing a culture radically different from the historical culture, which is so strongly western Oceanic in its affiliations, had come to light by the 1950s. The amount of local change in the language since the dispersal of the Polynesians to their present island homes indicates a separation of at least 1,000 years. A radiocarbon date of first settlement in the Hamaiian Islands is A.D. 1004. Indications are that the Hawaiian Islands were one of the last groups to be settled, that Tahiti received its first people about A.D. 200 and Samoa and Tonga to the west by at least 500 B.C.

Religion.—A Polynesian believed himself surrounded by gods who were personifications of nature, or presided over localities, or were spirits of men who had been experts in an art or a craft, or who were ancestor spirits. He sought their aid through offerings, prayers and auguries. Rites were performed at simple stone altars or open-air temples set with grotesque images. The worship of the greater gods was in the hands of an organized priesthood, serving the ruling chiefs. Some of these gods required human sacrifices.

Essential to religion and magic was the concept of *mana*, connoting supernatural pomer invested in gods and to varying degrees in some men. The chiefs, as descendants of the gods, possessed *mana*.

Social and Political Organization. — Kinship constituted the vital nucleus of the social organization, rather than locality. One family, by virtue of physical and mental prowess, rose to the ascendancy and remained in ruling power through maintaining the belief of descent from the creator gods. The head of this family was, normally, the eldest male and the ruling chief. His eldest surviving son succeeded him. All the land of the island or district under his jurisdiction was his. Over the people he had absolute power. The chief ruled through members of his family and trusted experts in a highly developed organization.

Economics. — Fishing and agriculture maintained the people. Their regular diet was supplemented by the flesh of dogs and fowls, and on special occasions by pork. In some of the islands human flesh was included at times. Taro was the favorite vegetable food and its cultivation, similar to that of rice, resulted in intricate irrigation systems. The sweet potato, bananas, breadfruit and sugar cane were grown around the houses. Goods and foods were exchanged through gifts. The chiefs received their taxes in the form of feathers, fine cloth, pigs, dogs and other valuables, which were redistributed among their followers.

Traditional Lore. — The Polynesians developed an unwritten literature consisting of myths, legends, traditions and poetry of vast extent and admirable quality. The creation myths, cast in chant form, conceive of the world evolving from darkness and chaos, through the mating of phenomena such as thunder and lightning until the earth and sky appear. Their union results in the birth of the gods, who separate their parents and thus emerge into the world of light. One of the gods marries a woman formed from sand and by her begets the first man.

Modern Polynesia.—All of Polynesia came under the dominance of foreign powers and outside contacts drastically altered the original life of the Polynesians. Modern Polynesians are nominally Christians and most of them have followed the ways of modern civilization. *See* also Easter Island; Hawaii; Pacific Islands; etc.; *see* also Index references under "Polynesia" in the Index volume. (K. P. E.)

POLYNESIAN LANGUAGE is spoken by fewer than 1,000,000 persons living among a group of Pacific islands which covers a larger segment of the globe than that encompassing the native speakers of any other single language. This one language has more than 60 closely related dialects and subdialects. but contrasts markedly with the many related Melanesian. Micronesian and Indonesian languages of the Austronesian (or Malayo-Polynesian) family of language, itself a member of the over-all Austric group. The Polynesian speech area is bounded by Kapingamarangi and Nukuoro Islands in the west through Hawaii to the north and New Zealand in the south through Easter Island to the east. The best known of the dialects include Hawaiian, New Zealand Maori, Samoan, Tongan, Tahitian, Niuean, Mangarevan and Tuamotuan.

Intensive exploration of the Pacific ocean by Capt. James Cook and his contemporaries of the last quarter of the 18th century accompanied a general awakening of interest in linguistic studies. The early discoverers collected vocabularies for both practical and scientific purposes. Following this period of discovery a world-wide expansion of Christian missionary activity and an accompanying need for translation of the Bible into native tongues led to a more systematic study of many of the Polynesian dialects. By the middle of the 19th century there were dictionaries, grammars and a full translation of the Bible for the most important island groups. Continuing interest in Polynesian history and culture has resulted in this language becoming one of the best known of the non-Indo-European languages from the standpoint of morphology and the techniques of translation.

Phonology.—Because of the paucity of consonants and the presence of at least ten meaningfully distinct vowel sounds, Polynesian is frequently termed a "vowel language," Each of the positional variant sounds /*a*/, /*e*/, /*i*/, /*o*/ and /*u*/ has about five recognizable variants of length in ordinary speech. For orthographic purposes these may be clustered together in two groups. distinguished by the use of the macron (¯) over the longer variants, as in New Zealand Maori *mata* "the face" and *mātā* "a heap." The many variant vowel lengths are patterned in relation to their linguistic environment, but exact rules of pronunciation have not been worked out. There are indications that the meaningful distinction between short and long vowels is a relatively recent phenomenon related to the loss of consonants uith or without the coalescence of two or more shorter vowels.

Considerable alternation exists between certain vowels, notably /*i*/ ⟷ /*u*/ and /*a*/ ⟷ /*e*/. This shift may be freely variable within one dialect, as Hawaiian *imu*⟷*umu* "earth-oven" Frequently it is fixed between dialects, as Rarotongan *nzeitaki* and Tahitian *maita'i* "excellent." but is never an established sound shift in the same sense that consonants are found to vary between dialects

A comparison of data from 50 dialects suggests the following reconstruction of the proto-Polynesian consonantal system:

	Bilabial	Labiodental	Alveolardental	Velar	Glottal
Continuant .	M	V	N	ŋ	
Stop . .	P		T	K	'
Fricative . .		F	S		H
Flap . . .			L/R*		

*Whether or not the sound was /L/ or /R/ or whether both existed as distinct meaningful sounds is not clear.

No modern dialect retains all of the original sounds, and there has been a marked tendency toward reduction in the number of consonants, especially in Eastern Polynesia. Only seven consonants appear to be present in Rurutuan, contrasting strongly with Tongan, the most conservative in the retention of consonants. Regular shift of consonants betneen dialects and the complete loss of certain consonants are characteristic of most dialects. Hence, the variations between dialects may be predicted and ancient or modern forms within one dialect may be derived with a fair degree of confidence. In Rarotongan when one finds that the term for proto-Polynesian (PPN) **ahi* "fire" is *a'i*, and that PPN **faka* the causative prefix is *'aka*, then it may be assumed that the term for PPN **tahi* "one" will be *ta'i*, as the shift from the PPS fricative to the glottal stop is obvious. Likewise, when it is determined that Rarotongan *taŋata* "person" and *tapu* "sacred, forbidden" are in Hawaiian *kanaka* and *kapu* then it may be predicted that Hawaiian *maka* "face" will be *mata* in Rarotongan.

In some cases the sound shift was only partially completed at the time of European arrival, as in Mangaian where the velar stop /*k*/ has shifted to the glottal stop /'/ only in certain words. In other cases there has been an irregular but complete loss of a sound, as in Hawaiian *'uala* and Mangaian *'uara* from PPN **kumara* "sweet potato." as well as in such words as PPN **tasi* "sea" which becomes *tai* in much of Polynesia.

There are no such distinctive voiced sounds as English /b/, /d/ and /g/, although in the past European recorders have misspelled terms such as *tapu* "forbidden" as *tabu*, and the island of *Porapora* as *Borabora*. Polynesians cannot distinguish between the English speaker's "bad" and "bat," "tab" and "tap." Other than the apparently mnemonic device of the controversial Easter Island "talking boards" there was no pre-European system of writing. Those English and French missionaries who developed the present Polynesian systems of writing attempted to use their own European orthography. In most cases they did not understand the significance of the distinction between short and long vowels and the importance of the glottal stop, hence these were not provided for in the alphabets. These omissions seriously affect the ability to read aloud or to translate from the literature in most areas other than New Zealand.

Many foreign words have been adapted by the various dialects. The sound changes involved bring the new words into conformance with the Polynesian sound system by shifting any voiced sounds to sibilants or stops and by adding vowels to closed syllables; hence English "broom" and "towel" become Tahitian *purumu* and *tauera*.

Morphology.—The seemingly inexhaustible vocabulary is derived from a relatively limited number of basic words. which are capable of being used individually or combined with other basic words and frequently also with a small number of prefixes and suffixes. These basic words are usually, but not invariably, disyllabic in nature. All syllables end in vowels although the initial sound may be consonant or vowel. Stress or "accent" varies between areas and appears to be absent from certain dialects, notably Tahitian; traditionally it is stated to be upon the penultimate syllable, with certain exceptions related to vowel length. The New Zealand Maori base word *tupu* "to grow" when combined with the causative prefix *whaka* becomes *whakatupu* "to cause to grow"; *turipona* "the knee joint" is derived from *turi* "the knee" and *pona* "a knot. joint"

Basic words and syllables are frequently duplicated to form diminutives, pluralatives, frequentatives, and other variants of the base. as *paki* "to pat," *pakipaki* "to pat frequently," *papaki* "to clap together"; or *manu* "a bird, small insect," *manumanu* "a very small insect." A few words are composed of a single sound or syllable, as New Zealand Maori *ā* "to compel, drive," *ki* "to be full."

Syntax.—Sentences are generally brief, and when spoken in full are composed of an initial predicative phrase followed by a subject, which may or may not be followed by one or more locative. directive or possessive phrases. The predication is the most significant part of the sentence and is spoken even when the nature of the situation permits the rest of the sentence to remain unsaid, as in Rarotongan E *kai!* E *kai ra!* "Eat! Eat on!"

Phrases are composed of one or more central "full words," usually (but not always) preceded and in some cases also followed by particles. Full words are those innumerable terms which have definable meanings within themselves. The very limited number of particles do not in themselves convey meaning, but serve only to place the predication or substantive as to identity, location and duration of the time. place or type of possession. A simple analogy would be to a brick wall, the bricks being similar to the full words of a sentence. the mortar similar to the particles which serve to bind the individual units into the whole structure. The Rarotongan base term *'aere* "to go" (without connotation of direction) and *au* "I ego" may be combined with particles as follows: *Kua 'aere au* "I went," *Ka 'aere au* "I shall go," *Tē 'aere nei au* "I am (in the process of) going."

Terms may be classified as full words or particles on the basis of specific meaning or function, but not individually as the traditional noun, verb and the like. A more useful classification relates to their use and position within the phrase or sentence. Many Polynesian full words may serve as predicative, substantive or the modifier of either. The initial full word of a phrase is invariably the most significant term with respect to meaning, and the words which may follow or the surrounding particles serve only to modify the basic concept. The first full word of the initial phrase of a sentence is the basis of the predication and the first full word of the second phrase is the subject, as *Kua tupu te taro* "The taro grew" and *Kua oti te tupu* "The growth stopped."

Polynesian predicatives lay greater stress upon the state of being than do English verbs and many of them must be preceded in translations by the phrase "was in the state of being." A particular source of confusion relates to the fact that a predicative may be either active or passive in nature as well as transitive or intransitive in any one of the four possible combinations. The full word involved may be modified by the passive suffix, one of a number of prefixes and by the intransitivizing particle. A secondary source of confusion relates to the sentence initial particle *E*, which is frequently mistranslated as equivalent to the English indefinite nominalizing particle "a, an," but in reality it is a predicative equational particle best translated as "is, am, was," as in Rarotongan *E taŋata tikai koe* "You are truly a man."

Polynesian full sentences may be analyzed as follows (particles are in small capitals, full words are italicized):

In Hawaiian

UA *ho'ohiu* 'IA / KA *moku* / I *luna* O KE *alahukinzoku*
predicative phrase / subject / locative phrase
The ship was liited (was liited the ship) on to (on top of) the marine railway.

In Tahitian

'UA *papa'i* HIA / TE *rata* / Ē *au*
predicative phrase / subject / agentive phrase
The letter was written (was written the letter) by me.

Semantics.—Studies utilizing the technique of glottochronology reveal that Polynesian is possibly the most changeless of languages known to scholars. During more than 2,000 years following the settlement of Polynesia about 90% of such basic vocabulary terms as "fish," "fire" and "water" have retained the same form as that of the proto-language. The recording and translation of Polynesian has been considerably hampered by the lack of adequate orthography, and many dictionaries give the false impression of lack of precision of terminology as a result of having entered meanings belonging to several orthographically separate words under a single form. Despite the conservatism and the preciseness of vocabulary meanings, Polynesian makes extensive and richly complex use of analogy and imagery in oratory, poetry and folk lore. Despite the lack of written language there was an elaborate oral literature, with great stress upon preciseness of memorization and usage. Feats of memory witnessed by early explorers and later by anthropologists seem little short of phenomenal. Much of the memorization involved ancient prayers, religious ceremonies, folk tales and legends, but the most significant of all (and still a vital force in court cases) was the recounting of genealogy and secret family chants. This type of knowledge was the sole patent to land rights and verbal knowledge ruled in the event of dispute.

Together with other Oceanic languages Polynesian utilizes a complex system of differentiating persons, with the individual distinguished from two persons as well as from a plurality, and the further differentiation of whether or not the person spoken to is included in the reference. Furthermore, the system of particles distinguishes persons and personified places or things from all others. All phenomena are divided into category of implicit and explicit connection when spoken of in the possessive sense, where for example one's blood kin are considered to be intimately a part of the speaker, hence are intrinsic, and one's wife is much less so and therefore explicitly "possessed."

Polynesian dialects, together with languages such as Javanese, utilize a form of courtesy reference or "chiefly language," as it is referred to in Samoa where its use is most elaborated. This separate vocabulary is used by commoners in addressing chiefs and their families and by the upper classes in discourse among themselves. The terms are frequently simple analogies, as when the chiefly women of Samoa are referred to as "flowers," but in other cases represent the retention of archaic terms. In central Polynesia a distinct vocabulary was also used for theological purposes by initiated priests, enabling them to perform ceremonies and render prayers not understood by noncommunicants. Learned aged men still are able to carry on conversations among themselves, to the bafflement of the younger generation.

BIBLIOGRAPHY.—Songs, tales, chants, genealogies have been preserved in the *Journal of the Polynesian Society*, Wellington, New Zealand; the *Memoirs* and *Bulletins* of the Bernice P. Bishop Museum, Honolulu, Hawaii; and in the *Bulletin de la Société des Etudes Océaniennes*, Papeete, Tahiti The most important dictionaries include C. M Churchward, *Tongan Dictionary* (1959); Herbert W Williams, *A Dictionary of the Maori Language*, 6th ed (1957); Mary Kawena Puki and S. H Elbert, *Hawaiian-English Dictionary* (1957); J. Frank Stimson with Donald Stanley Marshall, *A Dictionary of Some Tuamotuan Dialects of the Polynesian Language* (1960). (D. S. ML.)

POLYNOMIAL, in elementary algebra, an expression composed of two or more terms combined by operations of addition or subtraction. Thus $\frac{1}{2}a+7b+c$ and $2+a-\sqrt{(\frac{1}{2}xy)}+z^2$ are polynomials. A polynomial of two terms is called a binomial, and one of three terms is called a trinomial. An expression consisting of a single term is called a monomial.

The word polynomial is often used with a more technical meaning, particularly in higher mathematics, to characterize the manner of dependence of an expression on one or more quantities regarded for the time being as independent variables. Importance attaches then to the nature of the operations performed on the variables, rather than to the number of terms, and monomial expressions of suitable iorm are admitted as special cases. Under this interpretation, which will be adopted throughout the rest of the article, a polynomial in one variable is a sum of terms. each consisting, of a power of the variable multiplied by a coefficient independent of the variable, or, as an extreme case, a single such term; in a polynomial in several variables, each term contains a power of one of the variables or a product of powers of two or more of them. By a power in this connection is meant a power with exponent equal to a positive whole number or zero. The highest exponent that occurs, or, in the case of more than one variable, the highest value attained by the sum of the exponents in a single term, is the degree of the polynomial. Thus ax^2+bx+c is a polynomial of the second degree in x (if $a\neq 0$), and $x^5+3xy^2-8x^3y^4$ is a polynomial of the seventh degree in x and y. The latter is also said to be of the fifth degree in x, and of the fourth degree in y.

Having fundamentally a relative sense, the definition is applicable to charadterize the manner of dependence on quantities which may themselves be more or less complicated expressions of any iorm. Thus ax^2+bx+c, $a(1+\sqrt{x})^2+b(1+\sqrt{x})+c$, $a/x^2+b/x+c$, $a(\log x)^2+b\log x+c$ are polynomials with respect to x, $1+\sqrt{x}$, $1/x$, and $\log x$ respectively, though the last three are not polynomials with respect to x; and ax^4+bx^2+c, a polynomial in x, can also be regarded as a polynomial in x^2. The sum, difference, or product of two polynomials is a polynomial; their quotient in general is not. Polynomials and quotients of polynomials are known collectively as rational functions.

In elementary algebra, expressions coming under the more technical definition of polynomials are studied largely in connection with the equations formed by setting them equal to zero. If $f(x)$ denotes the polynomial

$$a_0x^n+a_1x^{n-1}+a_2x^{n-2}+\ldots+a_{n-1}x+a_n,$$

where $a_0\neq 0$, then the so-called "fundamental theorem of algebra" ensures the existence of a root r of the equation $f(x)=0$. The number r is a complex number. or as a special case a real number, and the fact that $f(r)=0$ implies that $(x-r)$ is a factor of $f(x)$. By a repetition of this argument one can show that $f(x)$ can be factored in the form

$$f(x)=a_0(x-r_1)(x-r_2)\ldots(x-r_n)$$

where the r_1 are the roots of $f(x)=0$. This factorization is uniquely determined. If the factor $(x-r)$ occurs exactly h times in the factorization then r is said to be a root of multiplicity h of the corresponding equation.

The resolution of a polynomial into linear factors makes essential use of the availability of all complex numbers as coefficients. If a more restricted system of coefficients is employed. such a factorization may not be possible. For example, x^2+1 is irreducible if real numbers only are allowed as coefficients. and x^3-x+2 is irreducible if rational numbers only are allowed. As these examples show, it is necessary in any discussion of factorization to specify the coefficient domain. If this domain is denoted as F it is customary to denote the system of all the polynomials in x with coefficients in F by $F[x]$, and more generally, the system of all polynomials in $x_1, x_2, \ldots x_m$ with coefficients in F by $F[x_1, x_2, \ldots x_m]$. If F is a field (*e.g.,* the set of all complex numbers. the set of all real numbers, the set of all rational numbers) then a polynomial belonging to $F[x]$ is called irreducible if it cannot be expressed as a product of polynomials in $F[x]$ of lower degree. Every polynomial in $F[x]$ which is not itself irreducible can be resolved into irreducible factors in this domain and apart from the order of the factors and from constant factors, can be so resolved in only one way. A similar definition of irreducibility can be used in the domain $F[x_1, x_2, \ldots x_m]$ and there, too, the unique factorization theorem holds. In a slightly modified form the theorem holds also for other polynomial domains. (*See,* for example. A. A. Albert's *Modern* Higher Algebra, 1937.)

It is an important fact in trigonometry that the cosine of n times an angle, where n is a whole number, can be expressed as a polynomial of the nth degree in terms of the cosine of the angle itself:

$$\cos 2x = 2\cos^2 x - 1,\ \cos 3x = 4\cos^3 x - 3\cos x,$$
$$\cos 4x = 8\cos^4 x - 8\cos^2 x + 1$$

The sine of nx can be expressed as the product of sin x by a polynomial of degree n − 1 in cos x; when n is odd. but not when n is even, it can also be expressed as a polynomial of the nth degree in sin x; *e.g.,*

$$\sin 2x = 2\sin x\cos x,\ \sin 3x = \sin x\,(4\cos^2 x - 1) = 3\sin x - 4\sin^3 x$$

The relation between algebra and trigonometry was emphasized by François Vieta (1540–1603), who contributed largely to the advancement of both branches.

Analytic geometry is largely concerned with the geometric interpretation of the equations obtained by setting polynomials in the co-ordinates equal to zero. In the plane, an equation of the first degree, of the typical form $Ax + By + C = 0$, represents a straight line; *i.e.,* if (x, y) are the rectangular co-ordinates of a point, all points whose co-ordinates satisfy the equation lie on a straight line, and all points of the line have co-ordinates satisfying the equation. The conic sections (*q.v.*)—ellipse, circle (which may be regarded as a special case of the ellipse). parabola, hyperbola (*qq.v.*), and certain "degenerate" forms (pairs of straight lines)—are represented by equations of the second degree, of the form

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$$

where in particular cases one or more of the coefficients may be equal to zero. René Descartes (*Géométrie,* 1637) and his contemporary, Pierre de Fermat, are regarded as the founders of analytic geometry (*q.v.*). The curves represented by equations of the third degree were systematically studied by Sir Isaac Newton (1704). In three dimensions, an equation of the first degree, $Ax + By + Cz + D = 0$, represents a plane, and one of the second degree a quadric surface—ellipsoid, sphere (a special case of the ellipsoid), hyperboloid (of one sheet or of two sheets), paraboloid (elliptic or hyperbolic). cone. cylinder (*qq.v.*), or, as a degenerate form, a pair of planes.

The study of curves and surfaces defined by polynomial equations of arbitrary degree constitutes the field of algebraic geometry. A fundamental concept in the modern development of this subject is that of a polynomial ideal, defined to be a set **I** of polynomials such that (1) the difference of any two polynomials that belong to **I** also belongs to I, and (2) the product of any polynomial in **I** by any polynomial belongs to **I**. If $u_1(x,y)$, $u_2(x,y)$, $\ldots u_r(x,y)$ are fixed polynomials then the totality of polynomials of the form

$$f_1(x,y)u_1(x,y) + f_2(x,y)u_2(x,y) + \ldots + f_r(x,y)u_r(x,y)$$

where the $f_1(x,y)$ range independently over the polynomial domain. is an ideal. The polynomials $u_1(x,y), \ldots u_r(x,y)$ are said to form a basis for this ideal. An important theorem due to David Hilbert (1890) asserts that any polynomial ideal has a finite basis.

The theory of the transformation of homoneneous polynomials, or *forms* (see ALGEBRAIC GEOMETRY; TENSOR ALGEBRA), by linear substitutions in the variables, and of the invariants and covariants associated with such transformation, is an important branch of algebra with numerous applications. For example, if x,y in the polynomial $ax^2 + bxy + cy^2$ are expressed, in terms of a new pair of variables u, v, by the relations

$$x = \alpha u + \beta v, \qquad y = \gamma u + \delta v$$

where $\alpha\delta - \beta\gamma = 1$, it is found that $ax^2 + bxy + cy^2$ is identically equal to an expression of the form $Au^2 + Buv + Cv^2$, in which $B^2 - 4AC = b^2 - 4ac$, a fact which is of fundamental significance in analytic geometry. More generally, for any values of α, β, γ, 6,

$$B^2 - 4AC = (\alpha\delta - \beta\gamma)^2\,(b^2 - 4ac)$$

The expression $b^2 - 4ac$, itself a polynomial in terms of the coefficients a, b, c, is called an invariant.

Polynomials in one variable are the simplest class of functions from the point of view of the calculus, because the rules for their differentiationand integration are simple, and are obtained immediately from the definitions of these processes. The result of differentiating or integrating a polynomial with respect to its independent variable is always a polynomial. In the modern theory of functions (see FUNCTION), any polynomial is a continuous and analytic function of its variables. If a function of a single complex variable z is analytic for every finite value of z, and becomes infinite when z, represented by a point in a plane, goes to infinity in an arbitrary manner, the function is necessarily a polynomial.

Applications.--Apart from their specific properties, polynomials are of fundamental importance from their use in the approximate representation of other functions. The standard functions of elementary analysis can be represented by power series (see SERIES), of the form

$$c_0 + c_1x + c_2x^2 + c_3x^3 + \ldots \text{ (Maclaurin's series)}$$

or, more generally,

$$c_0 + c_1(x - a) + c_2(x - a)^2 + c_3(x - a)^3 + \ldots \text{ (Taylor's series)}$$

which reduces to the preceding when $a = 0$: the sum of an infinite series is by definition the limit approached by the sum of a finite number of its terms, as the number of terms is taken larger and larger, and the sum of a finite number of terms of a power series is a polynomial. Representation by power series can be made the basis for a systematic treatment of analytic functions of a complex variable. Another important form of development in series, theoretically applicable with greater generality, proceeds in terms of the polynomials of Adrien Legendre (1752–1833) or Legendre's coefficients. These may be defined as the coefficients of successive powers of r in the power series for $(1 - 2xr + r^2)^{-\frac{1}{2}}$. One of their most striking properties is that the product of any two of them, integrated over the interval from −1 to +1, gives zero. Legendre polynomials have been found to be of great value in mathematical physics. especially in quantum mechanics. Approximations in terms of the polynomials of Gustave Hermite (1822–1901) are of importance in the theory of probability. Karl Weierstrass (1885) proved that an arbitrary continuous function can be uniformly approximated by a polynomial with any assigned degree of accuracy.

The ordinary process of simple interpolation (*q.v.*), is equivalent to the replacement of the tabulated function by a polynomial of the first degree, over the interval in which the interpolation is performed. Formulas for interpolation by means of higher differences depend for their derivation on the fitting of polynomials of higher degree to the tabulated values. Formulas of numerical

$x = 0$	$y = 3$		
		$\Delta y = 8$	
1	11		$\Delta^2 y = 2$
		10	
2	21		2
		12	
3	33		2
		14	
4	47		2
		16	
5	63		

integration or mechanical quadrature likewise depend on the fitting of polynomial approximations. In connection with the use of polynomials for interpolation. it is an important fact that, if the values of a polynomial of the nth degree are tabulated for equally spaced values of the variable, the nth differences are constant. Consider the preceding table of values of the polynomial $y = x^2 + 7x + 3$. The first column contains values of x, and the second. the corresponding values of y. The entries in the third column, obtained by subtracting each y from the following. are the first differences. The last column is made up of the differences of the first differences. which are called second differences, and in the present instance are all equal. It is clear that by means of this property the table could be continued further, without direct substitution in the original formula. *See* CALCULUS OF DIFFERENCES.

BIBLIOGRAPHY.—H. Weber, Lehrbuch der Algebra (1895); A. A. Markoff, Differenzenrechnung (Leipzig, 1896); G. Chrystal, Algebra (1898, 1901); M. Bôcher, Introduction to Higher Algebra (1907); D E. Smith, History of Mathematics (1923); W. Le R. Hart, College Algebra (1926); L. E. Dickson, Modern Algebraic Theories (1926); D. Jackson, The Theory of Approximation (1930); B. L. van der Waerden, *Moderne* Algebra (Berlin, 1940); A. A. Albert, Modern Higher Algebra (1937); G. Szego, Orthogonal Polynomials (1939); C. C. MacDuffee, An Introduction to Abstract Algebra (1940); G. Birkhoff and S. MacLane, A Survey of Modern Algebra (1941). (D. JA.; N. J.)

POLYP, in medicine, is a general term used to designate any growth projecting from the wall of a cavity lined with a mucous membrane. This growth may have a broad base, in which case it is called sessile; or it may have a long narrow neck, the characteristic of a pedunculated polyp. The surface of a polyp may be smooth, irregular or multilobular. The commonest locations of polyps in the human body are the nose. the bladder and the gastrointestinal tract, especially the rectum and colon. Symptoms of polyps depend upon their location and size. There may be no symptoms, or there may be symptoms resulting from pressure or from mechanical obstruction of all or part of a lumen, such as the nose or bowel; they may occasionally bleed. Usually polyps are simple, benign growths, but a small percentage may be either precursors to cancers or may actually contain cancers. It is for this reason that it is best, when possible, to remove all polyps and examine them microscopically to determine whether further treatment is necessary. (J. A. RR.)

POLYP, in zoology. is the name commonly applied to animals that bear tentacles and that are in some way attached to the substrate. In its broadest usage, the name applies to the individuals of such diverse animal phyla as the Bryozoa (Ectoprocta), the Endoprocta, the pterobranch Hemichordata and the sessile members of the Coelenterata. More strictly the term is ordinarily applied only to members of the latter group. The word itself seems to have come into English from the French word *poulpe* ("octopus"). Polyps are illustrated and discussed in the articles COELENTERATA, HYDROZOA, SCYPHOZOA, ANTHOZOA and SEA ANEMONE.

In the phylum Coelenterata the polyp represents one of the two body forms known in that group. the other being the medusa. Polyps are of columnar form in general and with few exceptions are attached to the substrate or burrow into it. The attached end may be called the base and is the aboral end. The free end of the polyp has a mouth at its centre and is surrounded by tentacles in most instances. The parasitic hydroid Hydrichthys, found on fish, and the minute hydralike polyp Protohydra are examples of exceptional polyps that have no tentacles. Another hydroid (Monobrachiurn) has a single tentacle on each polyp; *Proboscidactyla* (another hydroid) has two; while most polyps have many tentacles. Some large sea anemones have thousands of tentacles.

The polyp. in the different groups of coelenterates, is not only morphologically different in the different classes but represents different stages in the life history of those animals. For example, the polyps of the Hydrozoa. the hydroids, are morphologically quite simple. They usually have small numbers of tentacles, are of small size and have a coelenteron (the gut) that is a simple sac. These polyps are usually the immature. attached stages of medusae. representing the adult, sexually reproducing form. Within the Hydrozoa. however, not all polyps bud off free medusae. and many polyps are known that are themselves the sexually reproducing stage. In almost all instances where hydroid polyps represent sexual adults, it can be shown nonetheless that the gonads develop in association with structures that represent reductions of the medusa. Thus it seems to be a safe generalization that the polyp of the Hydrozoa represents an immature stage in the life history of the members of that class.

Much the same seems to be true for the class Scyphozoa. whose members are the large medusae or jellyfish of marine waters. The polyps here are simple, but the coelenteron is divided into four compartments by four projections or mesenteries that arise along the inner body wall. These polyps bud off the sexual medusae (the adults) much as in the Hydrozoa, and the polyps seem to represent only an attached immature stage in the life history of the group. In the Anthozoa, on the other hand, no medusae are known and the polyps represent the adult individuals. Here the polyps may grow to very large sizes, up to about three feet in diameter, and internally become very complex through the possession of many mesenteries which subdivide the coelenteron into many radially distributed compartments.

Polyps may occur as solitary individuals as in the fresh-water Hydra and many sea anemones, or they may occur as colonial aggregations. These colonies result from asexual reproduction by budding from the original polyp. Buds may arise apically, laterally or from stoloniferous growths from the basal region. Associated with colony formation, in many instances, especially among the marine hydroids, individual polyps in the colony assume different morphologies and have differing functions. Thus some individual polyps may be specialized for feeding (gastrozooids), for protection (tentaculozooids and dactylozooids) or for reproduction (gonozooids). Colonies possessing more than one type of polyp are said to be polymorphic; a good example is the common hydroid Hydractinia or *Podocoryne.* Another excellent example of a polymorphic colonial coelenterate is to be found in such organisms as the Portuguese man-of-war or any other of its relatives (Siphonophora). Commonly among these free-floating colonial hydroids, having a number of polymorphic polyps present, medusalike individuals may also occur that function as locomotory structures for the colony.

Polyps may occur as naked individuals or colonies, or they may have skeletons of various sorts. Among the hydroids, tough but flexible chitinous exoskeletons are common, and in many cases the polyp can contract completely within the surrounding skeletal cup. Skeletons of calcium carbonate or lime are also known among marine hydroids; the colonial polyps possessing these are called hydrocorals. The true corals, which are anthozoan polyps. also have skeletons of lime (see CORAL). The polyps here, as in the hydrocorals, live in cups on the surface of the limey skeleton and when disturbed contract into these protective structures. In the Anthozoa a number of colonial polyps are known, such as sea fans and sea pens, that have an axial, internal skeleton around which the colony grows.

Coelenterate polyps possess nematocysts (see COELENTERATA), and with the aid of these are able to capture other animals as food. Contact of a potential food organism, such as a small worm, mollusk or fish, with the tentacles of a polyp causes the nematocysts to discharge. Once a food item has been caught the tentacles bend toward the mouth and the mouth opens in preparation to receive the food. Primary digestion of the food takes place in the coelenteron, where strong protein-splitting enzymes break the food doun to minute particles. The cells lining the coelenteron then engulf these particles and final digestion takes place within the individual cells.

Polyps are for the most part restricted to marine habitats. In fresh water abundant Hydras are found and occasionally the minute polyps of the fresh-nater medusa, *Craspedacusta.* The only other coelenterate polyp seen in fresh water is the widely distributed colonial hydroid, *Cordylophora,* which, while commonest in brackish waters, does occasionally appear in lakes and reservoirs. In marine habitats coelenterate polyps are abundant nearly everynhere. The open ocean supports many different siphonophores, while along the shores of the world hydroids, anemones and corals flourish, the latter, however, being most conspicuous in tropical waters. Somewhat below the reach of the lowest tides occur veritable gardens of sea fans and sea pens, particularly in warm waters. while even at the greatest depths of the oceans anemones and hydroids may still be found. In fact, the tallest hydroid polyp known, *Branchiocerianthus*, is usually restricted to waters more than one-half mile deep, and the largest specimens recovered have been more than six feet long: See JELLYFISH; *see* also references under "Polyp" in the Index volume. (C. HA.)

POLYPHEMUS, the most famous of the Cyclopes, son of Poseidon and the nymph Thoosa. Odysseus, having been cast ashore on the coast of Sicily, fell into the hands of Polyphemus, who shut him up with 12 of his companions in his cave and blocked the entrance with an enormous rock. Odysseus at length succeeded in making the giant drunk, blinded him by plunging a burning stake into his eye while he lay asleep, and with six of his friends (the others having been devoured by Polyphemus) made his escape by clinging to the bellies of the sheep let out to pasture. *See* ACIS; CYCLOPS; ODYSSEUS.

POLYPODIUM, an inclusive genus of ferns containing about 600 species. widely distributed throughout the world, but specially developed in the tropics. Sometimes it is divided into ten or more "natural" genera. The name is derived from Gr. *polys*, "many," and *podion*, "a little foot," on account of the foot-like appearance of the rhizome and its branches. The species differ greatly in size and general appearance and in the character of the frond; the sori or groups of spore cases (sporangia) are borne on the back of the leaf, are globose and naked, that is, are not covered with a membrane (indusium). The common polypody (P, *vulgare*) of Europe. Asia and western North America is widely diffused in the British Isles, where it is found on walls, banks: trees, etc.; the creeping. densely scaly rootstock bears deeply pinnately cut fronds. the fertile ones bearing on the back the bright yellow naked groups of sporangia. It is also known as adder's foot, golden maidenhair and woodfern. There are a large number of varieties, differing chiefly in the form and division of the pinnae; var. *cambricum* (originally found in Wales) has the pinnae themselves deeply cut into narrow segments; var. *serratum* has the pinnae serrate. Besides the well-known polypody of eastern North America (P. *virginianum*), very similar to the foregoing, several other species occur in the southern and western states.

POLYPTYCH: *see* ALTARPIECE.

POLYTECHNIC. This term, common to many languages, is ordinarily used, by itself or nith the word "institute" or, more rarely. "school." to denote an educational establishment equipped to teach many subjects (Greek *polus*, "many"). but mainly if not exclusively scientific and technological studies and processes (*technē*, "art" or "craft"). It has also been used occasionally to describe other kinds of establishment designed to encourage interest in the arts and sciences, and in one instance at least has been applied to a large shop with many departments.

In general, a polytechnic institute offers instruction to students beyond school age, though it may include a secondary school organized as a separate department. But the exact significance of the name varies almost with every establishment or, as in England, group of establishments. In France. where it appears to have been first used, the name *école polytechnique* was applied in 1795 to the Ecole des Travaux Publics, founded a year previously in Paris by the National convention to advance scientific knowledge and in particular to train engineers for the army. The sobriquet, originating by way of protest against the almost exclusive devotion to literary and abstract studies then common to French places of higher education. became and remained the institution's official title; but the École Polytechnique stayed predominantly a school of military and civil engineering and therefore, strictly speaking, rather a monotechnic than a polytechnic. Similarly, the Faculté Polytechnique of Mons, Belg., is restricted to engineering studies, though the range is wide; and the same applies to the Polytekniske Laereanstalt at Copenhagen, Den. The Istituti Politecnici at Milan and Turin. It.. and the Polytechneion at Athens, Gr., have faculties of architecture as well as engineering. The famous Eidgenossische Technische Hochschule (Swiss Federal Institute of Technology), frequently referred to as the Zurich Polytechnikum, is as good an example of a polytechnic in the literal sense as can be found. It is organized in 12 schdols which include, in addition to civil, mechanical, electrical and agricultural engineering, subjects as varied as forestry and pharmacy; and there is also a department of optional subjects embracing literature, history, economics, politics and philosophy. All the foregoing institutions are either universities in their own right or hold university status. The location, character and status of educational establishments in Communist Europe were liable to change at a moment's notice, but at mid-20th century there were reported to be polytechnic institutes in Poland at Warsaw, Gdańsk, Gliwice, Lodz and Wroclaw (Breslau) and in Rumania at Bucharest, Jassy and Timişoara. Most if not all of these appear to have been degree-granting institutions and mainly if not entirely devoted to technological studies.

London.—In England the title "polytechnic" is almost restricted to the members of a group of educational institutions founded in London during the latter part of the 19th century with the dual purpose of providing vocational and other educational facilities for young working people and of promoting definite religious, social and civic ideals. These London polytechnics and their distinctive aims and organization derive from the initiative of Quintin Hogg (1845–1903), who as a young man of 19 shortly after leaving Eton college began a lifetime of evangelistic and educational pioneering by teaching street urchins to read. His first "classroom" was under the archways of the Adelphi on the north side of the Thames. In 1871 he opened a Youths' Christian institute in Castle street (moved to larger premises in Long Acre in 1878) for young shop assistants and artisans between the ages of 16 and 21. This he developed to provide, in addition to the optional Bible classes and other religious exercises which were the basis of his enterprise, a wide range of educational, social and athletic activities including, despite lack of support from employers and opposition from trade unions, classes for instruction in the building and other trades.

So successful nas he that by 1880 he mas looking for larger premises. As it happened, about this time there was offered for sale a building in Regent street called the Royal Polytechnic institution. It had been opened in 1838 to advance "practical science" and for many years enjoyed much popularity as a resort where the demonstration of scientific novelties nas pleasantly tinctured with entertainment. Hogg bought it, retained the name and reopened his institute there in Sept. 1882, with accommodation for 2,000 members. By the end of the winter session there had been 6,800 applications for membership. As he refused to increase the modest fees or to accept any subventions which involved compromise of the religious principles on which he based his work, Hogg for some years incurred heavy financial losses. But this did not deter him from continuing to build up the "Poly," as it soon came to be affectionately called, into a many-sided educational and social institution, providing instruction "in subjects ranging from the domestic arts to carriage-building, photography, and goldsmith's work" (Ethel M. Hogg. *Quintin Hogg, a Biography*, London, 1904) and offering its members reading rooms, library, gymnasium, billiard room. refectory. concerts. country excursions and a wide range of athletic activities Members were also encouraged to co-operate in the management of the Poly and in the maintenance of good discipline From the start women were admitted to classes, and in 1885 a separate institute was opened for them under the direction of Mrs. Hogg. In 1856 a school was started for boys and girls which gave special attention to manual, domestic and commercial subjects

The resounding success of the Regent Street polytechnic naturally suggested the foundation of other establishments on the same model, and happily funds became available. In 1878 a royal commission had been appointed to inquire into the parochial charities in the City of London; it was felt that because of the increase in their value and the decrease. or disappearance, of the kind of beneficiaries whom they were founded to aid, the total annual income was far greater than was needed to provide adequately for all the designated objects of these charities. The outcome of the commission's report was the City of London Parochial Charities act. 1883. This provided that the charities in 107 of the city parishes (that is, in all save five of the largest) should after seven years be administered by a corporate body to be called the Trustees of the London Parochial Charities. A scheme was drawn up by the charity commissioners whereby that part of the income from the consolidated charities which was allocated to secular purposes was to go toward the establishment and maintenance of "industrial" and recreative institutes similar to Hogg's polytechnic and Walter Besant's People's palace in the Mile End road, for the benefit of the poorer classes of the working population of London. The commissioners' offer of these funds was made conditional upon the raising by voluntary effort of an amount approximately equal to the capitalized value of the endowment. Local committees were set up, valuable sites were given by private benefactors, and subscriptions were received from livery companies, charities and individuals. A total sum of more than £500,000, including grants made by the charity commissioners and the Trustees of the London Parochial Charities, was raised for capital expenditure. As a result. betneen 1891 and 1896 six new polytechnics opened their doors. Chelsea (1895), Woolwich (1891), Borough (1892), Battersea (1894), Korthampton (in St. John street; 1896) and Northern (1896).

A seventh was planned in the scheme, but lack of local support. delay in securing possession of the site and the incidence of World War I prevented the North-Western from opening before 1929.

The Trustees of the London Parochial Charities, as conditions for making grants toward the maintenance of the polytechnics, "laid down as their principles that the institutions which benefited should give instruction in the principles of the arts and sciences which underlie crafts and in the application of such principles to particular trades, that they should be a supplement and not in substitution for the workshop or place of business, that they might give instruction suitable for intending emigrants and hold lectures and concerts, encourage gymnastics, drill, swimming, and other forms of bodily exercise, and institute clubs and societies, libraries, museums and reading rooms, that their educational facilities should be equally open to both sexes, that the fees should be small, and that drinking, smoking and gambling should be prohibited" (R. L. Archer. *Secondary Education* in *the XIX Century*, Cambridge University Press, 4th impression, 1937). Membership was restricted, except in special cases (not to exceed 5% of the total), to persons between the ages of 16 and 25.

Large as they were, the funds available from the London Parochial Charities trust were quite inadequate to maintain the great establishments to which they were committed. But aid was at hand from another source In 1893 the London county council, empowered under the Technical Instruction act. 1889, to make limited grants in aid of technical education and also having had funds placed at its disposal for the purpose by the Local Taxation (Customs and Excise) act. 1890, devoted a considerable portion of the latter to the development and sustenance of the polytechnics. Thereafter an increasing percentage of their revenue came from public funds. The Education act, 1902 (as applied to London by its act of 1903), by making the council responsible for all education in its area, tended to diminish distinctions between the grant-aided polytechnics and the wholly maintained technical institutes set up by the council. The Education act, 1921, which empowered the council (in common with the other local authorities) to promote social and physical well-being and to co-ordinate all forms of education within its area, continued the process of assimilation; and the Education act, 1944, by transforming these powers into statutory duties. advanced it still further. The distinction between a polytechnic and a major technical college in London became increasingly managerial rather than educational.

The London county council from the start endeavoured to secure that the educational facilities in the polytechnics and technical institutes should be so disposed as best to meet the particular needs of any given district; and the governing bodies of the polytechnics from time to time accepted suggestions to this end from the council involving important revisions of their educational programs. For example, facilities for more specialized technologies were concentrated at individual establishments. Thus Battersea has in addition to important departments of engineering and chemistry one of hotel training and domestic science: Chelsea a department of pharmacy and a school of art; and the Regent Street Polytechnic schools of architecture and commerce and a department of management studies. The Borough houses the National College of Heating, Ventilating, Refrigeration and Fan Engineering, established in 1948 to give technological education at the highest level to selected persons in these industries. Similarly, the Northampton houses the National College of Horology and Instrument Technology (established 1947); and the Northern. temporarily, the National College of Rubber Technology (established 1948).

The location of these national colleges was a tribute to the outstanding work previously done by the respective polytechnics in the technologies concerned. The Northern contains also a department of radio and musical instrument technology, and the Northampton one of furriery.

Five of the polytechnics—Battersea: Chelsea, Northampton, Northern and Woolwich—prepare students in some subjects for internal degree examinations of the University of London. These polytechnics are not organically linked with the university, but the faculties concerned have on their staffs members whom it accepts as "recognized teachers." This arrangement dates from the reconstitution of the university in 1902. (H. C. D.)

United States.—The term "polytechnic" as used in the United States generally refers to a postsecondary educational institution offering various curricula in technology, science and possibly agriculture. There is no essential difference between a polytechnic institute and an institute of technology. One characteristic which differentiates a polytechnic institute from a liberal arts college is that the curricula in the institutes have been designed to prepare students for positions in engineering, applied science and agriculture upon graduation. The occupational objectives of the institutes' courses of training are thus more clearly defined than is the case with the liberal arts colleges. In the institutes a student spends as much as three-fourths to four-fifths of his time on technical and professional studies in the field of his specialization, and the remainder of the time is devoted to English and the social sciences.

The term was first given prominence in the United States by Benjamin Franklin Greene, second president of Rensselaer Polytechnic institute, who in 1849 wrote a report to his board of trustees entitled *The True Idea of a Polytechnic Institute*. In this he summarized the progress of technical education in Europe and made recommendations concerning the reorganization of Rensselaer. He envisioned a "series of special schools for the training of Architects; Civil Engineers, Mining Engineers and other Scientific Technists—all united under a common organization." The curriculum of this school was to be divided into two parts: a preparatory school which students would enter at 10 to 12 years of age and which would include the studies necessary to matriculation; and the polytechnic institute proper. The institute curriculum was to be three years in length and consisted of courses in the general school and the technical schools. The general school embraced mathematics, English, pure science and philosophy. The technical schools contained the applied subjects common to all the engineering specialties, as well as the specific subjects required in architecture, civil engineering and mining engineering.

In addition to suggesting the subjects to be included in the curriculum, Greene also suggested the addition of other schools, emphasized the importance of general education and went into detail regarding the residences for faculty and students, buildings for instruction and museum collections of many kinds. His report had widespread influence on the later development of Rensselaer Polytechnic institute.

The 1950–51 *Education Directory* of the U.S. office of education listed 12 institutions of higher learning including "polytechnic" as an integral part of the name. These schools varied widely in the number and level of curricula offered, type of control and number of students enrolled. Alabama Polytechnic institute with more than 7.000 students, for instance, is probably more like a university than a strictly technical institution. Curricula are offered which lead to degrees in agriculture, architecture, chemistry, education, engineering, home economics, pharmacy, science and literature and veterinary medicine. Contrasted with this would be Wyomissing Polytechnic institute, with about 400 students and a limited number of two-year vocational-technical curricula. The offerings of other institutes range between these two extremes. One factor common to these institutions, however, is the occupational emphasis of the curricula to the end that their graduates will be equipped to periorm successiully in the fields for which they are being trained.

See Federal Security Agency, Office of Education, *Education Directory, Part 3, Higher Education (1950–51)*; *The True Idea oj a Polytechnic Institute; A Facsimile Reprint from the Report of Benjamin Franklin Greene, Director of Rensselaer Polytechnic Institute, 1846–1858 (1949).* (L. F. SH.)

POLYTONALITY, a comparatively recent addition to musical terminology, signifying the simultaneous employment of conflicting keys. *See* HARMONY; KEY.

POLYXENA, daughter of Priam and Hecuba. The shade of Achilles appeared to the returning Greeks in the Thracian Chersonese and demanded Polyxena, who was put to death on his tomb. As a prominent leader he claimed a prominent female prisoner for his share of the booty, as Agamemnon did Cassandra (*q.v.*). Hence. in Philostratus, Dictys and other late authors, the story of a romantic affection between Achilles and Polyxena.

POLYZOA (BRYOZOA), a group of tiny aquatic animals in which the individuals bud and remain attached to each other to form colonies that are sometimes plantlike. See BRYOZOA.

POMBAL, SEBASTIÃO JOSÉ DE CARVALHO E MELLO, MARQUESS OF (1699–1782), Portuguese statesman, was born at Soure near Pomba, on May 13, 1699. In 1739 he was sent as Portuguese ambassador to London, where he remained until 1745. He was then transferred to Vienna. In 1749 he took up the post of secretary of state for foreign affairs and war. He reorganized Portuguese education, finance, the army and the navy. He also built up new industries, promoted the development of Brazil and Macao and expelled the Jesuits. His ascendancy over the mind of King Joseph dates from the time of the great Lisbon earthquake (Nov. 1, 1755). In Sept. 1770 he was made marquess of Pombal. Soon after the death of King Joseph, in 1777, Pombal was dismissed from office and was only saved from impeachment by the death of the queen mother, Mariana Victoria. On Aug. 16 a royal decree forbade him to reside within 20 leagues of the court. He died on May 8, 1782.

POME, a fruit in which the fleshy outer portion is formed by the undiverged bases of sepals, petals and stamens which surround the ovary, together with the carpels in whole or in part; the type of fruit characteristic of the apple, pear, quince, haw and juneberry. (J. M. BL.)

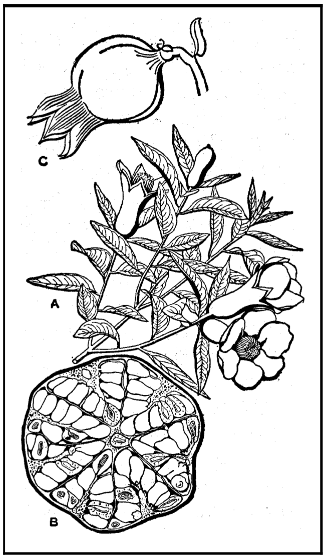
POMEGRANATE. Throughout the orient this fruit has since earliest times occupied a position of importance alongside the grape and the fig. It is produced by a bush or small tree, *Punica granatum,* only member of the family Punicaceae.

King Solomon possessed an orchard of pomegranates; and when the children of Israel, wandering in the wilderness, sighed for the abandoned comforts of Egypt, the cooling pomegranates were remembered longingly. Centuries later, the prophet Mohammed remarked sententiously: "Eat the pomegranate. for it purges the system of envy and hatred." It will thus be seen that this fruit is of exceptional interest because of its historic background. While the pomegranate is considered to be indigenous in Persia and perhaps neighbouring countries, its cultivation long ago encircled the Mediterranean and extended through Arabia. Afghanistan and India. There is something in the character of the juicy subacid pomegranate which makes it particularly agreeable to inhabitants of hot arid regions—which are precisely those in which it attains its greatest perfection.

The ancient Semitic name *rimmon* was adopted by the Arabs as *rumman,* from which the Portuguese in turn formed *romão* or *roman.* From the early Roman names *malum punicum* (apple of Carthage) and *granatum* have come the modern botanical binomial and the common name *granada,* used in Spanish-speaking countries.

The plant, which may attain 15 or 20 ft. in height, has elliptic to lanceolate bright green leaves about 3 in. long, and handsome axillary orange-red flowers borne toward the ends of the branchlets. The calyx is tubular, persistent, 5- to 7-lobed; the petals lanceolate, inserted between the calyx-lobes. The ovary is embedded in the calyx-tube and contains several locules in two series, one above the other.

The fruit is the size of an orange and often larger, obscurely six-sided, with a smooth leathery skin which ranges from brownish yellow to red in colour. Within it is divided into several cells, containing many thin transparent vesicles of reddish juicy pulp, each surrounding an angular elongated seed. A ripe pomegranate has a delightful subacid flavour.



POMEGRANATE (PUNICA GRANATUM), A. BRANCH WITH FLOWERS. B. TRANSVERSE SECTION THROUGH FRUIT SHOWING SEEDS, C. YOUNG FRUIT

Presumably the plant was introduced into the new world by the early Spanish colonists. It is commonly cultivated in gardens from the warmer parts of the United States to Chile. Small commercial plantings have been made in California. Though it will grow in a wide range of climates, good fruit is produced only where high temperatures and dry atmosphere accompany the ripening period. Deep, rather heavy loams are probably the best soils. Propagation is effected by seeds, cuttings and layers: the first-named can readily be grown, but choice varieties cannot be reproduced in this manner. Commercial propagation is by hardwood cuttings 10 to 12 in. long, which can be rooted in the open ground.

The varieties of the pomegranate are numerous. Ibn-al-Awam, a Moor who wrote in the 13th century, described some ten which were grown in southern Spain at that time. The three leading ones which have been cultivated commercially in the United States are Wonderful, Paper-Shell and Spanish Ruby. There are also dwarf forms which produce fruit of no value but are grown for their handsome scarlet flowers. (W. PO.)

POMFRET, JOHN (1667–1702), English poet, born at Luton, became rector of Maulden, Bedfordshire, in 1695, and of Millbrook in the same county in 1702. His poems were printed in Johnson's *English Poets* (1779, vol. xxi).

POMO. This group of American Indians, speaking Seven dialects of Hokan (*q.v.*) lineage, on Russian river and Clear lake, California, is noted for its basketry, which is perhaps the finest and most varied made on the continent. The general culture was central Californian as typified by the Maidu (*q.v.*).

POMONA, an old Italian goddess of fruit and gardens. Pomona had a special priest at Rome, the *flamen Pomonalis,* and a sacred grove near Ostia, called the Pomonal.

POMONA, a city of California, U.S., is located 30 mi. E. of Los Angeles (*q.v.*). A group of promoters purchased lands for town and agricultural development in 1875. The settlement, which the founders named Pomona for the Roman goddess of fruit, grew slowly until after 1880 when the sinking of deep wells provided a dependable source of irrigation water and made it the centre of a prosperous farming and fruit raising region. The southern California real estate boom of 1887 brought rapid growth; the town was incorporated in 1888 and the census of 1890 recorded a population of 3,634. Pomona remained the trading centre for a growing region which produced oranges, lemons and walnuts as well as deciduous fruits, field crops and livestock. The Southern Pacific, Santa Fe and Union Pacific railroads, which passed through or near it, gave a wide outlet for its crops. Pomona's agricultural character was recognized by the location of the extensive grounds of the Los Angeles County Fair there.

World War II and the years following brought major changes to Pomona. Its population, which had been 20,695 in 1930, grew to 67,157 in 1960. (For comparative population figures *see* table in CALIFORNIA: *Population.)* This was partly due to the expansion of Los Angeles which brought Pomona into commuting range of the city. It was even more the result of the industrialization of Pomona itself. There had been some manufacturing in Pomona since 1902, notably of water pumps necessary for the irrigation of the fruit groves. During and after the war, however, the number and size of industrial plants increased steadily. Naval ordnance, guided missiles, aircraft parts, pumps, paper products and tile were manufactured. Hundreds of acres of orange groves were replaced by single-family dwellings and citrus culture was no longer the prime activity of the region. The Kellogg-Voorhis campus of the California State Polytechnic college was established in 1938 just west of Pomona. The city has a council-administrator form of government, in effect since 1949. (J. H. K.)

POMONA or MAINLAND (the latter is the more correct name), the central and largest island of the Orkneys, Scot. Pop. (1951) 14,198. Area, including smaller adjacent islands, 201.6 sq.mi. It is irregularly shaped, and Kirkwall bay and Scapa Flow. cutting into the land on the north and south respectively, at one point reduce the width to less than 2 mi. The western coast is almost unbroken, but the eastern and southern shores are considerably indented. Ward hill (881 ft.) in the south is the highest peak in the island. There are numerous lakes, some of considerable size and most of them abounding in trout. Kirkwall (*q.v.*), the capital of the Orkneys, and Stromness (*q.v.*) are the only towns. Antiquities include Pictish *brochs,* chambered mounds and weems. or underground dwellings afterward roofed in. Northeast of Stromness, and within a mile of the standing stones of Stenness, lies the great barrow or chambered mound of Maeshowe. It is a blunted cone 300 ft. in circumference, and'at a distance of 90 ft. from its base is encircled by a moat. The ground plan shows that it was entered from the west by a passage, leading to a central apartment, the walls of which ended in a beehive roof. The barrow is variously ascribed to the Stone Age and to 10th-century Norsemen. The stone circles forming the Ring of Brogar and the Ring of Stenness, traditionally pagan temples, lie $4\frac{1}{2}$ mi. N E. of Stromness. The former stands on a raised circular platform of turf. surrounded by a moat and a grassy rampart. The ring originally comprised 60 stones. varying from 9 to 14 ft. in height. set up at intervals of 17 ft. Only 13 are now erect. The Ring of Stenness is of similar construction, and 150 yd. N. of it formerly stood the monolith called the Stone of Odin, pierced by a hole at the height of j ft., through which persons swearing a particularly binding oath clasped hands. At the bay of Skaill is the Neolithic village of Skara Brae (*q.v.*), where evidence has been found of more than one occupation, with perhaps hundreds of years between. On Marwick head stands the Kitchener memorial, erected to the memory of Lord Kitchener, drowned off Mainland in 1916. (*See* also ORKNEY ISLANDS.)

POMORZE (POMERANIA), a stretch of land extending from the lower Vistula on the east to the lower Oder on the west. The name is Slavonic and means "the country by the sea"; its Latinized form is Pomorania (later Pomerania), Pommern in German. Political developments contributed in extending the name west of the Oder as far as Stralsund with the island of Rügen (Rugia).

Physical Geography. — Pomorze is a flat country lying generally about 300 ft. above sea level, although its centre is traversed by a west-east range of morainic ridges rising in many places to 6jo ft., at some points over 975 ft. and at one, the Wiezyca hill (near Koscierzyna), to 1,066 ft. Off the west coast. which is irregular, lie the islands of Usedom (Uznam) and Wollin; the eastern coast is smooth in outline and is bordered with dunes and sandbanks. There are in Pomorze several small rivers, some of which flow north into the Baltic sea and some south into the Vistula or Notec rivers. The Leba, the Slupia and the Parseta are the most important among the former; the Brda, the Gwda and the Drawa among the latter.

The soil of Pomorze is for the most part thin and sandy. with patches of good land here and there. The principal crops are rye, oats and potatoes. Poland's ports are situated in Pomorze; in the chief ports of Gdansk (Danzig), Gdynia and Szczecin (Stettin) a shipbuilding industry is developing, while Kolobrzeg (Kolberg), Darlowo (Rugenwalde) and Ustka (Stolpmiinde) are mainly centres of fishing industry.

History. — In prehistoric times the southern coast of the Baltic seems to have been occupied by Celts, who made way for various tribes of Teutonic stock. These in turn were replaced, about the end of the jth century A.D., by Slavonic tribes. Pomorane or Pomorzanie settled between the Vistula and the Oder, while the Polabian Slavs — Lutycy (Veleti, Wilzen) and Obotryci (Obotriten) —were occupying the land between the Oder and the Elbe (Laba).

The whole of Pomorze was included in the territory of Mieszko I (d. 992), Poland's first historical ruler; so it was under King Boleslaw I the Brave (992–1025), who in the year 1000 founded a Polish bishopric at Kolobrzeg.

At that time there existed a local Slavonic dynasty that ruled over the whole of Pomorze and also in what was later known as Mecklenburg. Swiatobor or Svantibor, duke of Pomorze, who died in 1107, divided his land among his three sons: Boguslaw (Bogislaw or Bogislav) received the eastern part (Pomerania Ulterior, later known as Hinterpommern) with Gdansk; Warcislaw (Wratislaw) received the western part (Pomerania Citerior, or Vorpommern) with Wologoszcz (Wolgast); while Ratibor was the ruler of the central part with Szczecin.

Under King Boleslaw III, the Wry-Mouthed (1102–38), the dukes of Pomorze recognized the sovereignty of Poland. About 1125 eastern Pomorze was included in the Polish Kujawy diocese of Kruszwica. Later this episcopal see was transferred to Wloclawek. In 1140 a new bishopric for western and central Pomorze was created at Wollin, and about 1176 it was transferred to Kamien (Kammin), replacing that of Kolobrzeg.

In 1181 both western (Wolgast) and central (Stettin) Pomorze had to accept the protection of the German empire, and in 1225 the Wollin-Kamien diocese was transferred from the Polish archbishopric of Gniezno to the German archbishopric of Magdeburg. In the following five centuries these two parts of Pomorze were united under a single duke for two periods (1264–95 and 1478–1532) but generally remained separated under two branches of the same family. From the 13th century the country was opened to German immigrants, and this resulted in the Germanization of the towns and later of the nobility and of the countryside.

In 1294, on the death of Duke Mszczuj or Mestwin II, last duke of eastern Pomorze and stout opponent of the Germans, his land became an integral part of Poland. In 1308 it was conquered by the Teutonic order and reconquered by Poland in 1454, a reconquest recognized by the order in 1466.

Western and central Pomorze remained under the suzerainty of the German empire. In 1625 Boguslaw XIV once more united the duchies of Wolgast and Stettin. but he died without issue in 1637 and the whole dukedom passed to Brandenburg. At the peace of Westphalia in 1648 it was again divided with Sweden, which took its western part (Vorpommern), that is west of the Oder, with Stettin, leaving the remainder (Hinterpommern). as far as the frontiers of Poland, to Brandenburg. In 1720 Stettin and the southern part of Vorpommern, as far as the river Peene (Piana), was ceded to Brandenburg, but the northern part with Greifswald, Stralsund and Rügen remained Swedish until 1815.

In the meantime, Polish Pomorze was annexed by Brandenburg-Prussia in 1772 and renamed West Prussia. It was recovered by restored Poland in 1919 in somewhat smaller boundaries, and until 1939 constituted the province of Pomorze with chief town at Torun. Its area was 6,324 sq.mi. and in 1921 it had 939,000 inhabitants.

In 1815 Vorpommern and Hinterpommern were united in one Prussian province of Pommern with its chief town at Stettin. That province had an area of 11,663 sq.mi. and its population in 1926 was 1,897,166.

After 1945 almost the whole of historic Pomorze, except its section west of the Oder. became part of Poland. It was then divided into three provinces (*wojewodztwa*) of Gdansk, Bydgoszcz and Szczecin. On June 1. 1950, a fourth province of Koszalin (Koslin) was formed in the eastern part of that of Szczecin. The four provinces of Pomorze cover together an area of 24,098 sq.mi. Their total population in Feb. 1946 was 2,941,170, including 619,287

Germans. In 1955 it was estimated at 3,972,000, practically all Poles. (K. Sm.)

POMPADOUR, JEANNE ANTOINETTE POISSON LE NORMANT D'ÉTIOLES, Marquise de (1721–1764), mistress of Louis XV., was born in Paris on Dec. 29, 1721, and baptized as the legitimate daughter of François Poisson, an officer in the household of the duke of Orleans, and his wife, Madeleine de la Motte, in the church of St. Eustache; but she was educated at the charge of a wealthy financier and farmer-general of the revenues, Le Normant de Tournehem. He declared her "un morceau de roi," and specially educated her to be a king's mistress. This idea was confirmed in her childish mind by the prophecy of an old woman, whom in after days she pensioned for the correctness of her prediction. In 1741 she was married to a nephew of her protector and guardian, Le Normant d'Étioles, who was passionately in love with her, and she soon became a queen of fashion. The king met her at a ball given by the city to the dauphin in 1744, and he was immediately subjugated. She at once gave up her husband, and in 1745 was established at Versailles as "maitresse en titre." Louis XV. bought her the estate of Pompadour, from which she took her title of marquise (raised in 1752 to that of duchess).

She was hardly established firmly in power before she began to mix in politics. Knowing that the French people of that time were ruled by the literary kings of the time, she paid court to them, and tried to play the part of a Maecenas. Voltaire was her poet in chief, and the founder of the physiocrats, Quesnay, was her physician The command of the political situation passed entirely into her hands; she it was who brought Belle-Isle into office with his vigorous policy; she corresponded regularly with the generals of the armies in the field, as her letters to the Comte de Clermont prove; and she introduced the Abbé de Bernis into the ministry in order to effect a very great alteration of French politics in 1756. The continuous policy of France since the days of Richelieu had been to weaken the house of Austria by alliances in Germany; but Mme. de Pompadour changed this hereditary policy for the alliance with Austria which brought on the Seven Years' War, with all its disasters.

But it was to internal politics that this remarkable woman paid most attention. She made herself indispensable to Louis. She died on April 15, 1764, at the age of forty-tao.

See Capefigue, *Madame la marquise de Pompadour* (1858); *E.* and J. de Goncourt, *Les Maîtresses de Louis XV.*, vol. ii. (1860); and Campardon, *Madame de Pompadour et la cour de Louis XV. au milieu du dix-huitième siècle* (1867). Far more valuable are Malassis's two volumes of correspondence,*Correspondance de Madame de Pompadour avec son père M Poisson, et son frère M. de Vandières,* etc. (1878), and Bonhomme, *Madame de Pompadour, général d'arme'e* (1880), containing her letters to the Comte de Clermont. *See* also P. de Nolhac, *La Marquise de Pompadour* (1903).

POMPEII, an ancient town of Campania, Italy, near the river Sarnus, almost at the foot of Mt. Vesuvius. Its foundation was ascribed by Greek tradition to Heracles, in common with the neighbouring city of Herculaneum, but it was not a Greek colony. Strabo, in whose time it was a populous and flourishing place, tells us that it was first occupied by the Oscans, afterwards by the Tyrrhenians (*i.e.*, Etruscans), to whom it probably owes its rectangular ground plan, and Pelasgians, and lastly, by the Samnites. (See Campania.) No doubt, Pompeii shared the fate of the neighbouring cities, and afterwards passed in common with them under the yoke of Rome. But its name is only mentioned incidentally during the wars of the Romans with the Samnites and Campanians only when a Roman fleet landed near Pompeii in 309 B C. and made an unsuccessful marauding expedition up the river valley as far as Nuceria. At a later period, however, it took a prominent part in the Social War (91–89 B.C.), when it withstood a long siege by Sulla, and was one of the last cities of Campania that were reduced by the Roman arms. The inhabitants were admitted to the Roman franchise, but a military colony was settled in their territory in 80 B C by Sulla (*Colonia Cornelia* Veneria *Pompeianorum*), and the whole population was rapidly Romanized Before the close of the republic many Roman nobles acquired villas in the neighbourhood, among them Cicero, whose letters abound with allusions to his Pompeian villa. The same fashion continued under the empire, and during the first century of the Christian era, Pompeii had become a flourishing place with a considerable population. In A.D. 59 a tumult took place in the amphitheatre between the citizens and visitors from Nuceria. Many were killed and wounded on both sides. The Pompeians were punished for this violent outbreak by the prohibition of all theatrical exhibitions for ten years. A painting on the walls of one of the houses represents this event.

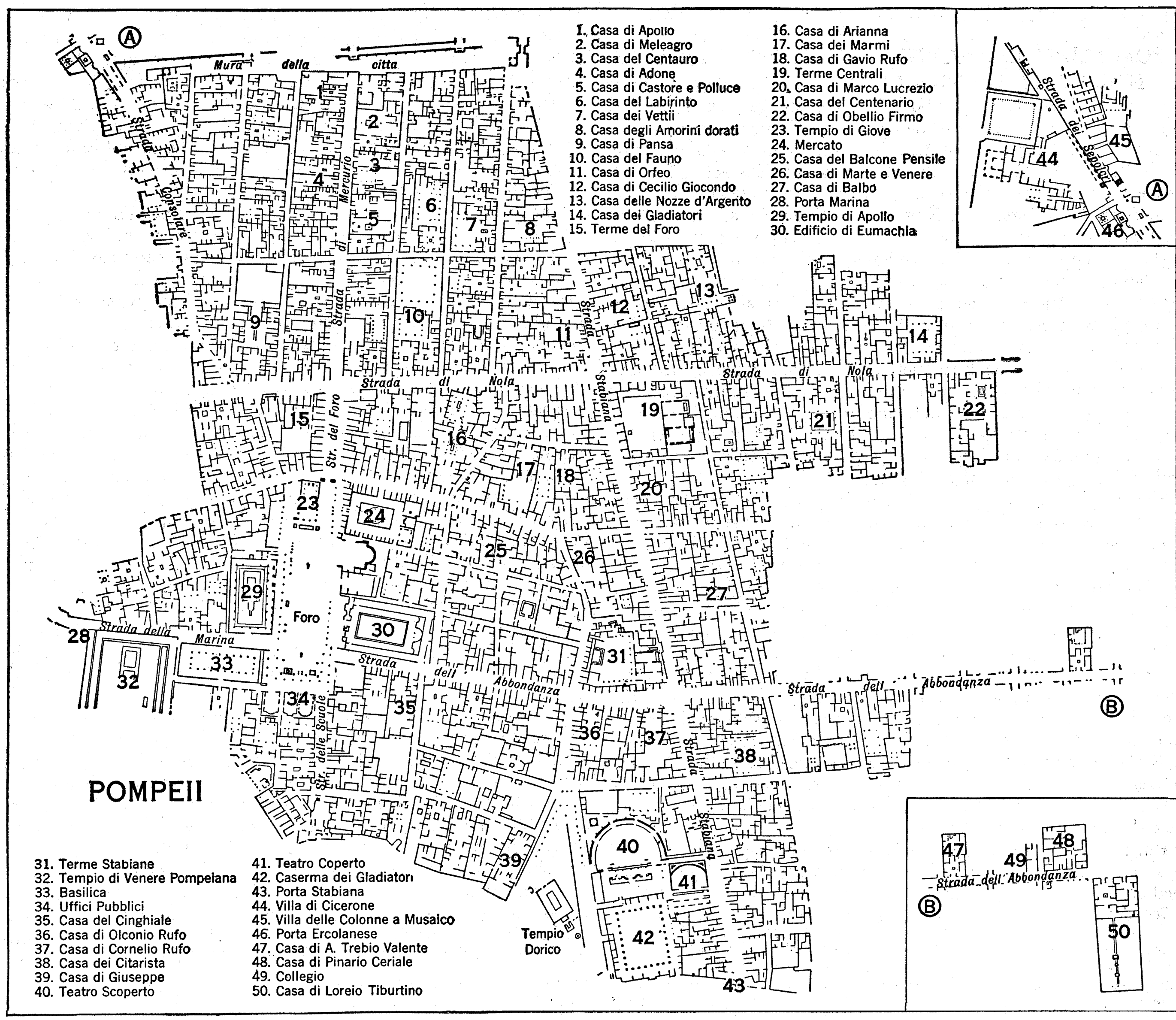
Four years afterwards (A.D. 63) an earthquake vented its force especially upon Pompeii, a large part of which, including most of the public buildings, was either destroyed or so seriously damaged as to require to be rebuilt. The inhabitants were still actively engaged in repairing and restoring it, when the whole city was overwhelmed by the great eruption of Vesuvius (*q.v.*), A.D. 79. Pompeii was merely covered with a bed of lighter substances, cinders, small stones and ashes, which fell in a dry state, while at Herculaneum the same substances, being drenched with water, hardened into a sort of tufa, which in places is 65 ft. deep. The whole of this superincumbent mass, attaining to an average thickness of from 18 to 20 ft., was the product of one eruption, though the materials may be divided generally into two distinct strata, the one consisting principally of cinders and small volcanic stones (called in Italian *lapilli*), and the other and uppermost layer of fine white ash, often consolidated by the action of water from above so as to take the moulds of objects contained in it (such as dead bodies, woodwork, etc), like clay or plaster of Paris. It was found impossible to rebuild the town, and its territory was joined to that of Nola. But the survivors returned to the spot, and by digging down and tunnelling were able to remove all the objects of value, even the marble facing slabs of the large buildings.

In the middle ages, however, the very site was forgotten. Ruins and inscriptions were found by the architect Domenico Fontana in making an underground aqueduct across the site in 1594–1600, but only in 1748 a more careful inspection of this channel revealed the fact that beneath there lay entombed ruins far more accessible than those of Herculaneum. Only in 1763 systematic excavations were begun; the work, which had received a vigorous stimulus during the period of the French government (1806–14), was prosecuted under the Bourbon kings (1815–61). Since 1861 it has been carried on under the Italian government on a system devised by G. Fiorelli, according to which the town is for convenience divided into 6 or 9 regions, which are subdivided into insulae (blocks), the gates, streets and houses being also named for convenience, though often incorrectly.

The town was situated on rising ground less than a mile from the foot of Vesuvius. This eminence is itself due to an outflow of lava from that mountain, during an eruption in prehistoric times, for we know that Vesuvius had been quiescent ever since the Greek settlements in this part of Italy.

The area occupied by the ancient city was of an irregular oval form, and about 2 m. in circumference. It was surrounded by a wall, which is still preserved for more than two-thirds of its extent, but no traces of this are found on the side towards the sea, and there is no doubt that on this side it had been already demolished in ancient times, so as to give room for the free extension of houses and other buildings in that direction. It consisted of two parallel stone walls with buttresses, about 15 ft. apart and 28 in thick, the intervening space being filled with earth, and there being an embankment on the inner side. These walls are strengthened at intervals by numerous towers, occupying the full width of the wall: They appear to have been added at a later period. probably that of the Social War. Similar evidences of the addition of subsequent defences are to be traced also in the case of the gates, of which five have been cleared, while at least one (and perhaps three) more are unexcavated.

The general plan of the town is very regular, the streets being generally straight, and crossing one another at right angles or nearly so. But exceptions are found in the south-west corner, where a small irregular group of streets represents the original Oscan settlement, and on the north-west in the street



FROM "GUIDA D'ITALIA DEL TOURING CLUB ITALIANO'

leading from the Porta Ercolanese (gate of Herculaneum) to the forum, which, though it must have been one of the principal thoroughfares in the city, was crooked and irregular, as well as very narrow, in places not exceeding 12 to 14 ft. in width. Another excention is to be found in the Strada Stabiana (Stabian Street) or Cardo, which, owing to the existence of a natural depression which affects also the line of the street just east of it, is not parallel to the other north and south streets. The other main streets are in some cases broader, but rarely exceed 20 ft. in width, and the broadest is about 32 ft., while the back streets running parallel to the main lines are only about 14 ft. (the standard width of a Roman highroad). They are uniformly paved with large polygonal blocks of hard basaltic lava, fitted very closely together, though now in many cases marked with deep ruts from the passage of vehicles in ancient times. They are also in all cases bordered by raised footways on both sides, paved in a similar manner; and for the convenience of foot-passengers, these are connected from place to place by stepping-stones raised above the level of the carriage-way. The careful investigation in recent years of the buildings in the eastern portion of the Strada dell' Abbondanza has shown that previous conceptions of the appearance of the exterior of the houses were entirely erroneous. The upper stories were diversified by balconies. open loggias, colonnades, etc., while the lower portions of the façades were painted, often with scenes of considerable interest. The streets were also diversified by fountains, small water-towers and shrines.

The first-mentioned of the two principal streets was crossed, a little before it reached the forum, by the street which led directly to the gate of Nola (Strada delle Terme, della Fortuna, and di Nola). Parallel to this last to the south is a street which runs from the Porta Marina through the forum, and then, with a slight turn, to the Sarno gate, thus traversing the whole area of the city from east to west (Via Marina, Strada dell' Abbondanza, Strada dei Diadumeni). These two east and west streets are the two decumani.

The population of Pompeii was mixed; both Oscan and Greek inscriptions are still found up to the last, and evidences of the presence of Jews are not lacking—such are a wall-painting, probably representing the Judgment of Solomon, and a scratched inscription on a wall, "Sodoma, Gomora." From the number of skeletons discovered, about 2,000 persons may have perished in the city itself in the eruption of A.D. 79.

The whole portion of the city which lies to the west of the Strada Stabiana, towards the forum and the sea, has been completely excavated. It is over one-half of the whole extent, and that the most important portion, inasmuch as it includes the forum, with the temples and public buildings adjacent to it, the thermae, theatres, etc. The greater part of that on the other side of the Strada Stabiana remains still unexplored, with the exception of the amphitheatre, a small space in its immediate neighbourhood and the buildings on each side of the Strada dell' Abbondanza and the Strada di Nola.

The forum at Pompeii was the centre of the life and movement of the city. Hence it was surrounded on all sides by public buildings or edifices of a commanding character. It was not, however, of large size. only 467 ft. in length by 126 in breadth (excluding the colonnades). The nature of its pavement, composed of broad flags of travertine, into which was let an inscription in large bronze letters, shows that it was only intended for foot-passengers. It was adorned with numerous statues. It was surrounded on three sides by a series of porticos supported on columns; and these porticos were originally surmounted by an upper storey, traces of the staircases leading to which still remain. Both this portico and the adjacent buildings were undergoing a process of restoration after the earthquake of 63, involving material changes in the original arrangements, which was still incomplete at the time of their final destruction. The north end of the forum, where alone the portico is wanting, is occupied in great part by the imposing temple of Jupiter, Juno and Minerva, or Capitolium. It was raised on a *podium* 10 ft. high, and had a portico with six Corinthian columns in front. This magnificent edifice had, however, been evidently overthrown by the earthquake of 63, and is in its present condition a mere ruin, the rebuilding of which had not been begun at the time of the eruption. On each side of it were two arches. affording an entrance into the forum, but capable of being closed by gates. On the east side of the forum were four public edifices. The first (from the north), is a *macellum* or meat-market, consisting of a rectangular court surrounded by a colonnade, with a twelve-sided roofed building (tholus) in the centre. On the south side were shops, and in the centre of the east side a chapel for the worship of the imperial house. Next to this comes the sanctuary of the Lares of the city, a square room with a large apse; and beyond this a small temple. Beyond this again, bounded on the south by the Strada dell' Abbondanza, is a large and spacious cloth-exchange, erected by a priestess named Eumachia. It is an open court, oblong, surrounded on all four sides by a colonnade; in front is a portico facing the forum, and on the other three sides there is a corridor behind the colonnade with windows opening on it. On the south side of the Strada dell' Abbondanza was the Comitium. At the south end of the forum are three halls side by side, similar in plan with a common façade —the central one, the curia or council chamber, the others the offices respectively of the duumvirs and aediles, the principal officials of the city; while the greater part of the west side is occupied by two large buildings—a basilica, which is the largest edifice in Pompeii, and the temple of Apollo, which presents its side to the forum. The former. a building of the 2nd cent. B.C., was an oblong edifice divided by columns into a central hall and a corridor running round all the four sides with a tribunal opposite the main entrance; and, unlike the usual basilicae, it had, instead of a clerestory, openings in the walls of the corridor through which light was admitted, it being almost as lofty as the nave. The temple was an extensive edifice, having a comparatively small *cella*, raised upon a podium, and standing in the midst of a wide space surrounded by a portico of columns, outside which again is a wall, bounding the sacred enclosure. Between this temple and the basilica the Via Marina leads off direct to the Porta Marina.

The remains of five other temples have been discovered. The most interesting, though the least perfect, is not only by far the most ancient edifice in Pompeii, but a true Greek temple (6th century B.C.). Unfortunately only the foundation and a few Doric capitals and other architectural fragments remain; they were coated with brightly painted stucco. The reverence attached to it in later periods is shown by its being left standing in the midst of a triangular space adjoining the great theatre, which is surrounded by a portico, so as to constitute a kind of forum (the so-called Foro Triangolare). Not far off, and to the north of the great theatre, stood a small temple, dedicated to Isis, rebuilt after the ruinous earthquake of 63. It is interesting as the only temple of Isis that has come down to us in a good state of preservation. The decorations were of somewhat gaudy stucco. The plan is curious, the internal arrangements being adapted for the performance of the peculiar rites of this deity. Close to this was the small temple of Zeus Milichius. The temple of the Fortune of Augustus (Fortuna Augusta), which stood north of the Forum, suffered very severely from the earthquake, but we learn from existing remains that its walls were covered with slabs of marble. and that the columns of the portico were of the same material. The fifth temple, that of Venus Pompeiana, to the west of the basilica, was in process of rebuilding at the time of the eruption. Before the earthquake of 63 it must have been the largest temple of the whole city. It was surrounded by a large colonnade, and the number of marble columns in the whole block has been reckoned at 296. Venus was the protectress of the young men of Pompeii, who had formed a society for gymnastics and other sports. They met in a hall (the Schola Iuventutis Pompeianae) in the Strada dell' Abbondanza.

All the temples above described, except that ascribed to Hercules, which was approached by steps on all four sides, agree in being raised on an elevated podium or basement—an arrangement usual with all similar buildings of Roman date. Among the other public buildings, the most conspicuous are the theatres, of which there were two, placed, as was usual in Greek towns, in close juxtaposition with one another. The largest of these, which was partly excavated in the side of the hill, was in great part cased with marble, with seats of the same material for about 5,000 spectators. It was erected in Roman times by two members of the same family, M. Holconius Rufus and M. Holconius Celer, both of whom held important municipal offices at Pompeii during the reign of Augustus. Their work was only a reconstruction of a more ancient edifice (probably 5th cent. B.C.), while its first alteration belongs to the "tufa" period, and three other periods in its history can be traced. The smaller theatre (for 1,500 spectators) was erected by two magistrates specially appointed for the purpose by the decuriones of the city, soon after the establishment of the Roman colony under Sulla. It was permanently covered.

Adjoining the theatres is a large rectangular enclosure, surrounded by a portico, at first the colonnade connected with the theatres, and converted, about the time of Nero, into the barracks of the gladiators. Remains of armour and weapons were found in some of the rooms, and in one, traces of the stocks used to confine insubordinate gladiators with three skeletons in them (63 were found in the whole building). The amphitheatre was erected by the same two magistrates who built the smaller theatre, C. Quinctius Valgus and M. Porcius when no permanent edifice of a similar kind had yet been erected in Rome itself, and is indeed the oldest structure of the kind known to us. It is in great part excavated in the surface of the hill, instead of the seats being raised on arches. Nor are its dimensions (460 by 345 ft.) such as to place it in the first rank, nor are there any underground chambers below the arena. The seating capacity was about 20,000 (for illustration see AMPHITHEATRE).

Among the more important public buildings of Pompeii were the public baths (thermae). Three different establishments of this character have been discovered, the first, the baths near the forum, though the smallest of the three, is in some respects the most complete and so well preserved that we trace without difficulty all the separate apartments described to us by Roman authors—the apodyterium, *frigidarium*, *tepidarium*, *caldarium*, and so on. (See BATHS.) The greater thermae (the so-called "Stabian" baths), which were originally built in the 2nd century B.C., and repaired about 80 B.C., are more extensive and combine a palaestra in the centre and other apartments for exercise or recreation. An inscription records the repair and restoration of the edifice after the earthquake of 63. These two establishments were inadequate to supply the wants of the inhabitants, and a third edifice, the so-called central baths, at the corner of the Strada Stabiana and the Strada di Nola, but on a still more extensive scale, intended for men only, was in course of construction in A.D. 79.

Far more interesting is the insight afforded us by the numerous private houses and shops into the ordinary life and habits of the population of an ancient town. The houses at Pompeii are generally low, rarely exceeding two storeys in height; the upper storey is generally of a slight construction, and occupied by small rooms, serving as garrets, or sleeping places for slaves. From the mode of destruction of the city these upper floors were in most cases crushed in and destroyed. The principal living rooms, as well as those intended for the reception of guests or clients, were all on the ground floor, the centre being formed by the *atrium*, or hall, which had an opening in the centre—the *compluvium*, so-called because the rain from the roofs was collected by it and fell into a basin (the *impluvium*). In the larger houses it was often surrounded with columns. Into this opened other rooms, the entrances to which, rarely protected by doors, were only closed by curtains. At the back was a garden. Later, under Greek influences, a peristyle with rooms took the place of the garden.

All the apartments and arrangements described by Vitruvius and other ancient writers may be readily traced in the houses of Pompeii, and in many instances these have for the first time enabled us to understand the technical terms and details transmitted to us by Latin authors. We must not, however, hastily assume that the examples thus preserved to us by a singular accident are to be taken as representing the style of building in all the Roman and Italian towns—in fact, the excavations at Ostia (*q.v.*) have shown us the contrary. We know from Cicero that Capua was remarkable for its broad streets and widespread buildings, and it is probable that the Campanian towns in general partook of the same character. At Pompeii indeed the streets were not wide, but they were straight and regular, and the houses of the better class occupied considerable spaces, presenting in this respect no doubt a striking contrast, not only with those of Rome itself, but with those of many other Italian towns, where the buildings would necessarily be huddled together from the circumstances of their position. Even at Pompeii itself, on the south side of the city, where the ground slopes somewhat steeply towards the sea, houses are found which consisted of three storeys or more, and with the inner walls painted black (with white designs on them) owing to the brilliancy of the light.

The excavations have provided examples of houses of every description, from the humble dwelling-place of the artisan or proletarian, with only three or four small rooms, to the stately mansions of Sallust, of the Faun, of the Golden Cupids, of the Silver Wedding, of the Vettii, of Pansa, etc.—the last of which is among the most regular in plan. But the general similarity in their plan and arrangement is very striking, and in all those that rise above a very humble class the leading divisions of the interior, the *atrium, tablinum, peristyle,* etc., may be traced with unfailing regularity. In all the more considerable houses in Pompeii the front, where it faces one of the principal streets, is occupied with shops, usually of small size, and without any communication with the interior of the mansion. In general the shop had a very small apartment behind it, and probably in most cases a sleeping chamber above it, reached by a staircase. The front of the shop was open to the street, but was capable of being closed with wooden shutters. Not only have the shops of silversmiths been recognized by the precious objects of that metal found in them, but large quantities of fruits of various kinds preserved in glass vessels, various descriptions of corn and pulse, loaves of bread, moulds for pastry, fishing-nets and many other objects too numerous to mention, have been found in such a condition as to be identified without difficulty. Inns and wine-shops appear to have been numerous; one of the latter we can see to have been a *thermopolium*, where hot drinks were sold. Bakers' shops are also frequent, though arrangements for grinding and baking appear to have formed part of every large family establishment. In other cases, however, these were on a larger scale, provided with numerous querns or hand-mills of the well-known form, evidently intended for public supply. Other establishments on a large scale were *fullonicae* (fullers' shops), where all the details of the business were illustrated by paintings still visible on the walls. Dyers' shops, a tannery and a shop where colours were ground and manufactured are of special interest, as is also the house of a surgeon, where numerous surgical instruments were found, some of them of a very ingenious and elaborate description, but all made of bronze. A blacksmith's shop was also found, with many tools that had been brought in for repair: here were discovered the remains of a *groma*, the instrument used by Roman land-surveyors, which has been successfully reconstructed (Della Corte in *Monumenti dei Lincei,* 1922). Another curious discovery was that of the abode of a sculptor, containing his tools, as well as blocks of marble and half-finished statues.

Of the numerous works of art discovered in the course of the excavations the statues and large works of sculpture, whether in marble or bronze, are inferior to those found at Herculaneum, but some of the bronze statuettes are of exquisite workmanship, while the profusion of ornamental works and objects in bronze and the elegance of their design, as well as the finished beauty of their execution, are such as to excite the utmost admiration—more especially when it is considered that these are the casual results of the examination of a second-rate provincial town, which had, further, been ransacked for valuables (as Herculaneum had not) after the eruption of 79. The same impression is produced in a still higher degree by the paintings with which the walls of the private houses, as well as those of the temples and other public buildings, are adorned, and which are not merely of a decorative character, but in many instances present us with elaborate compositions of figures, historical and mythological scenes, as well as representations of the ordinary life and manners of the people, which are full of interest to us, though often of inferior artistic execution. It has until lately been the practice to remove these to the museum at Naples; but the present tendency is to leave them (and even the movable objects found in the houses) *in situ* with all due precautions as to their preservation, which adds immensely to the interest of the houses; indeed, with the help of careful restoration, their original condition is in large measure reproduced. In some cases it has even been possible to recover the original arrangement of the garden beds, and to replant them accordingly, thus giving an appropriate framework to the statues, etc., with which the gardens were decorated, and which have been found *in situ.* The same character of elaborate decoration, guided almost uniformly by good taste and artistic feeling, is displayed in the mosaic pavements, which in all but the humbler class of houses frequently form the ornament of their floors. One of these, in the House of the Faun, well known as the battle of Alexander, presents us with the most striking specimen of artistic composition that has been preserved to us from antiquity.

The architecture of Pompeii presents in general a transitional character from the pure Greek style to that of the Roman Empire. The temples (as already observed) have always the Roman peculiarity of being raised on a *podium* of considerable elevation; and the same characteristic is found in most of the other public buildings. All the three orders of Greek architecture—the Doric, Ionic and Corinthian—are found freely employed in the various edifices of the city, but rarely in strict accordance with the rules of art in their proportions and details; while the private houses naturally exhibit still more deviation and irregularity. In many of these indeed we find varieties in the ornamentation, and even in such leading features as the capitals of the columns, which remind one rather of the vagaries of mediaeval architecture than of the strict rules of Vitruvius or the regularity of Greek edifices. One practice which is especially picvalent, so as to strike every casual visitor, and dates from the early years of the empire, is that of filling up the flutings of the columns for about one-third of their height with a thick coat of stucco, so as to give them the appearance of being smooth columns without flutings below. The architecture of Pompeii suffers from the inferior quality of the materials generally employed. No good building stone was at hand; and the public as well as private edifices were constructed either of volcanic tufa, or lava, or Sarno limestone, or brick (the latter only used for the corners of walls). In the private houses even the columns are mostly of brick, covered merely with a coat of stucco. Marble was sparingly employed.

These materials are used in several different styles of construction belonging to the six different periods which Mau traces in the architectural history of Pompeii.

1. That of the Doric temple in the Foro Triangolare (6th cen-

tury B.C.) and an old column built into a house in Region vi., Insula 5; also of the older parts of the city walls—date uncertain (Sarno limestone and grey tufa).

2. That of the limestone atriums (outer walls of the houses of ashlar-work of Sarno limestone, inner walls with framework of limestone blocks, filled in with small pieces of limestone). Date before 200 B.C.

3. Grey tufa period; ashlar masonry of tufa, coated with fine white stucco; rubble work of lava. The artistic character is still Greek, and the period coincides with the first (incrustation) style of mural decoration, which (coming from Asia Minor or Greece perhaps by way of Sicily) aimed at the imitation in stucco of the appearance of a wall veneered with coloured marbles. No wall paintings exist, but there are often fine floor mosaics. To this belong a number of private houses (*e.g.,* the House of the Faun), and the colonnade round the forum, the basilica, the temples of Apollo and Jupiter, the large theatre with the colonnades of the Foro Triangolare, and the barracks of the gladiators, the Stabian baths, the Palaestra, the exterior of the Porta Marina, and the interior of the other gates—all the public buildings indeed (except the Doric temple mentioned under [1], which do not belong to the time of the Roman colony). Date, end of 2nd century B.C.

4. The "quasi-reticulate" period—walling faced with masonry not yet quite so regular as *opus reticulaturn,* and with brick quoins, coinciding with the second period of decoration (the architectural, partly imitating marble like the first style, but without relief, and by colour only, and partly making use of architectural designs framing pictorial scenes, which are conceived as seen through openings). It is represented by the small theatre and the amphitheatre, the baths near the forum, the temple of Zeus Milichius, the Comitium and the original temple of Isis, but only a few private houses. This style probably owes much to Hellenistic theatrical decoration. Date, from 80 B.C. until nearly the end of the Republic.

5. The period from the last decades of the Republic to the earthquake of AD. 63. No homogeneous series of buildings—we find various styles of construction (quasi-reticulate, *opus reticulatum* of tufa with stone quoins, of the time of Augustus, *opus reticulaturn* with brick quoins or with mingled stone and brick quoins, a little later); and three styles of wall decoration fall within its limits: the later stage of the second, already mentioned, the third or ornate, with its freer use of ornament and its introduction of designs which suggest an Egyptian origin (originating in the time of Augustus), and the fourth or intricate, with a return to architectural forms, dating from about A.D. 50. Marble first appears as a building material in the temple of Fortuna Augusta (*c.* 3 B C.).

6. The period from the earthquake of A.D. 63 to the final destruction of the city, the buildings of which can easily be recognized. The only wholly new edifice of any importance is the central baths.

Outside the Porta Ercolanese, or gate leading to Herculaneum, is found a house of a different character from all the others, undoubtedly a large villa; its remains are of interest as aiding us in understanding the description of ancient authors, such as Vitruvius and Pliny, of the numerous appurtenances frequently annexed to houses of this description.

In the cellar of this villa were discovered no less than twenty skeletons, and fourteen in other parts of the house. Almost all the skeletons and remains of bodies found in the city were discovered in similar situations, in cellars or underground apartments—those who had sought refuge in flight having apparently for the most part escaped from destruction, or having perished under circumstances where their bodies were easily recovered by the survivors. It has been found possible in many cases to take casts of the bodies found.

An interesting farm-house (few examples have been so far discovered in Italy) is that at Boscoreale excavated in 1893–94, which contained the treasure of one hundred and three silvrr vases now in the Louvre. The villa of P. Fannius Synhistor, not far off, was excavated in 1900; it had fine wall paintings, which were exported, and sold by auction in Paris (some now in the Louvre, while others are in New York). (*See* F. Barnabei, *La Villa pompeiana di P. Fannio Sinistore;* Rome, 1901.) Another, closer to Pompeii, in the so-called Villa Item, contains remarkable life size frescoes representing scenes of initiation into the mysteries of Dionysus or of Orpheus.

The road leading towards Herculaneum is bordered on both sides for a considerable extent by tombs, in many instances monuments of considerable pretension, and of a highly ornamental character, which present in the highest degree the advantage common to all that remains of Pompeii, their perfect preservation.

There appears to have been in the same quarter a considerable suburb, outside the gate, extending on each side of the road towards Herculaneum, apparently much resembling those which are now fouad from thence to Naples. Other suburbs were situated at the harbour and at the saltworks (*salinae*).

No manuscripts have been discovered in Pompeii. Inscriptions have been found in considerable numbers, and give much information concerning the municipal arrangements of the town, as well as the construction of various edifices and other public works. The most interesting of these are such as are written in the Oscan dialect, which appears to have continued in official use down to the time when the Roman colony was introduced by Sulla. From that time the Latin language was the only one officially employed. Still more curious are the numerous writings painted upon the walls, which have generally a semi-public character, such as recommendations of candidates for municipal offices, advertisements, etc., and the scratched inscriptions (*graffiti*), which are generally the mere expression of individual impulse and feeling, frequently amatory, and not uncommonly conveyed in rude and imperfect verses. In one house also a whole box was found filled with written tablets—diptychs and triptychs—containing the record of the accounts of a banker named L. Caecilius Iucundus.

See A. Mau, *Pompeii: its Life and Art* (trans. by F. W. Kelsey, 2nd ed., New York and London, 1902; 2nd revised edition of the German original, *Pompeii in Leben und Kunst,* Leipzig, 1908) with *Anhang* (1913), with full references; and, for later excavations, *Notizie degli Scavi* and *Römische Mitteilungen, passim. A.* W. Van Buren in *Classical Journal* xv. (1919–20) 404–416, and *Companion to Pompeian Studies* (American Academy in Rome, 1927); W. Engelmann, *New Guide to Pompeii* (Leipzig, 1925); A. Ippel, *Pompeii,* ib. id ; T. Warscher, *Pompeii, ein Führer durch die Ruinen.* For the inscriptions on the tablets and on the walls, *Corpus inscriptionum latinarum,* vol. iv. For the paintings, *see* E. Pfuhl, *Masterpieces of Greek Drawing and Painting* (tr. J. D. Beasley, London 1926); M. Della Corte, *Case ed abitanti a Pompeii (Pompeii,* 1926). (E. H. B.; T. A.)

POMPEIUS, GNAEUS, surnamed STRABO (squint-eyed), Roman statesman, father of the triumvir. He was successively quaestor in Sardinia (103 B C.), praetor (94), propraetor in Sicily (93) and consul (89). He fought with success in the Social War, and was awarded a triumph for his services. Probably towards the end of the same year he brought forward the law (*lex Pompeia de Gallia transpadana*), which conferred upon the inhabitants of that region the privileges granted to the Latin colonies. During the civil war between Marius and Sulla he seems to have shown no desire to attach himself definitely to either side. He set out for Rome; the engagement which he fought before the Colline gate, although hotly contested, was indecisive. Soon afterwards he was killed by lightning (87).

See Plutarch, *Pompey, 1;* Appian, *Bell. civ.* i. 50, 52, 66–68, 80; Vell. Pat. ii. 21; Livy, *Epit.* 74–79; Florus iii. 18.

POMPEIUS, GNAEUS, surnamed MAGNUS (c. 75–45 B.C.), the elder son of the triumvir. In 49–48 B.C. during the civil war he commanded his father's fleet in the Adriatic. After the battle of Pharsalus he set out for Africa nith the remainder of the Pompeian party, but, meeting with little success, crossed over to Spain. Having been joined by his brother Sextus. he collected a considerable army, the numbers of which were increased by the Pompeians who fled from Africa after the battle of Thapsus (46). Caesar. who regarded him as a formidable opponent, set out against him in person. A battle took place at Munda (*q.v.*) on March 17, 45, in which the brothers were defeated. Gnaeus escaped, but mas soon (April 12) captured and put to death.

See *Bellum hispaniense,* 1–39; Lucan. *Pharsalia,* ix, 120; Dio Cassius, xliii, 28–40.

POMPEIUS, SEXTUS, surnamed MAGNUS (75–35 B.C.), the younger son of the triumvir. After his father's death he continued the struggle against the new rulers of the Roman empire. From Cyprus, where he had taken refuge, he made his way to Africa, and after the defeat of the Pompeians at Thapsus (46) crossed over to Spain. After Caesar's victory at Munda (45), he abandoned Corduba (Cordova), though for a time he held his ground in the south, and defeated Asinius Pollio, the governor of the province. In 43 he was proscribed by the triumvirate and put himself at the head of a fleet manned chiefly by slaves or proscribed persons, with which he made himself master of Sicily, and from thence ravaged the coasts of Italy. Rome was threatened with a famine, as the corn supplies from Egypt and Africa were cut off by his ships, and it was thought prudent to negotiate a peace with him at Misenum (39), which was to leave him in possession of Sicily, Sardinia and Achaea, provided he would allow Italy to be freely supplied with corn. But the arrangement could not be carried into effect, as Sextus renewed the war and gained some considerable successes at sea. However, in 36 his fleet was defeated and destroyed by Agrippa at Naulochus off the north coast of Sicily. After his defeat he fled to Mytilene, and from there to Asia Minor. In the attempt to make his way to Armenia he was taken prisoner by Antony's troops, and put to death at Miletus.

See Dio Cassius, xlvi.–xlix.; Appian, Bell. civ. iv. 84–117, v. 2–143; Vell. Pat. ii. 73–87; Plutarch, Antony; Livy, Epit. 123, 128, 129, 131; Cicero, *Philippica,* xiii., and many references in Letters to *Atticus.*

POMPEY, the common English form of Pompeius, the name of a Roman plebeian family.

POMPEIUS, GNAEUS (106–48 B.C.), the triumvir, the first of his family to assume the surname MAGNUS, was born on Sept. 30, in the same year as Cicero. When only 17 he fought together with his father in the Social War. He took the side of Sulla against Marius and Cinna, but for a time, in consequence of the success of the Marians, he kept in the background. On the return of Sulla from the Mithridatic War Pompey joined him with an army of three legions, which he had raised in Picenum. Thus early in life he connected himself with the cause of the aristocracy, and a decisive victory which he won in 83 over the Marian armies gained for him from Sulla the title of *imperator.* He followed up his successes in Italy by defeating the Marians in Sicily and Africa, and on his return to Rome in 81, though he was still merely an *eques* and not legally qualified to celebrate a triumph, he was allowed by general consent to enjoy this distinction, while Sulla greeted him with the surname of *magnus,* a title he always retained and handed down to his sons. Latterly, his relations with Sulla were somewhat strained; after Sulla's death he resisted the attempt of the consul M. Aemilius Lepidus to repeal the constitution. In conjunction with A. Lutatius Catulus, the other consul, he defeated Lepidus when he tried to march upon Rome, and drove him out of Italy (77). He retained his army, and jockeyed the senate into sending him to Spain *pro consule* (though he had as yet held no magistracy) to deal with Sertorius. Pompey was fighting in Spain from 76 to 71. After Sertorius had fallen a victim to assassination, Pompey easily defeated his successor Perperna and put an end to the war. On his way back he met and cut up a body of slaves, part of Spartacus' defeated forces, in flight northwards. He demanded a triumph, and permission to stand for the consulate.

The Consul.—The senate was inclined to grudge it, so he entered into a coalition with Crassus, and as both had armies at the gates, there was no more to be said. Pompey and Crassus were consuls together in 70, and that year saw the work of Sulla undone; the tribunate and censorship were restored, and the administration of justice was shared between the Senate, the equites, and the *tribuni aerarii.*

Pompey rose still higher in popularity, and on the motion of the tribune Aulus Gabinius in 67 he was entrusted with an extraordinary command over the greater part of the empire, specially for the extermination of piracy in the Mediterranean, by which the corn supplies of Rome were seriously endangered, while the high prices of provisions caused great distress. He was completely successful; the price of corn fell immediately on his appointment, and in 40 days the Mediterranean was cleared of the pirates. Next year, on the proposal of the tribune Manilius, his powers were still further extended, the care of all the provinces in the East being put under his control for three years together with the conduct of the war against Mithridates VI., who had recovered from the defeats he had sustained from Lucullus and regained his dominions. Both Caesar and Cicero supported the tribune's proposal, which was easily carried in spite of some opposition in the senate. Pompey was entirely successful. Mithridates was beaten and driven into the Crimea, and there was a generai settlemen. of affairs in the East. Syria and Palestine were annexed in 64 and 63. Tigranes of Armenia submitted and was confirmed as a vassal king, and an agreement was reached with Phraates of Syria whereby the Euphrates marked the boundary between them.

Pompey, now in his 45th year, returned to Italy in 61 to celebrate the most magnificent triumph which Rome had ever witnessed, as the conqueror of Spain, Africa and Asia.

Politics.—This triumph marked the turning-point in his career. As a soldier everything had gone well with him; as a politician he was a failure. He found a great change in public opinion, and the people indifferent to his achievements abroad. The senate had a unique chance to secure his support, but refused to ratify the arrangements he made in Asia or to provide money and lands for distribution amongst his veterans. In these circumstances he drew closer to Caesar on his return from Spain, and became reconciled to Crassus. The result was the first triumvirate. He was married to Caesar's daughter Iulia, and as yet the relations between the two had been friendly. Pompey was now in fact ruler of the greater part of the empire, while Caesar had only the two provinces of Gaul. But being no political tactician, Pompey made no use of this advantage, and all this time the balance of power was steadily turning in Caesar's direction. The senate and the aristocracy disliked and distrusted Pompey, but they felt that, should things come to the worst, they might still find in him a champion of their cause. Hence the joint rule of Pompey and Caesar was not unwillingly accepted, and anything like a rupture between the two was greatly dreaded as the sure beginning of anarchy throughout the Roman world. In 55 Pompey was consul again, in accordance with the arrangement with Caesar when the triumvirate was renewed at Luca in 56. As proconsul he should have left for his province, but ne remained in charge of the corn-supply, virtually master of Rome, and governed Spain by his *legati.* With the death of Pompey's wife Iulia (54) and of Crassus (53) the relations between him and Caesar became strained, and soon afterwards he drew closer to the conservative party and married into the house of Scipio. In 52, in the utter disorder that followed the death of Clodius. he was elected sole consul, carried through the trial of Milo, and started a programme of administrative and provincial legislation threatening Caesar's position.

Civil War.—The crisis arrived with the approaching end of Caesar's command at the end of 50. Pompey nearly compromised by accepting the Parthian command and leaving Rome, but Marcellus forced his hand, and civil war began. Pompey, wisely or unwisely, abandoned Italy. His cause, with that of the senate and' aristocracy, was finally ruined by his defeat by Julius Caesar in 48 in the neighbourhood of Pharsalus. That same year he fled with the hope of finding a safe refuge in Egypt, but was treacherously murdered by one of his old centurions as he was landing. He was five times married, and three of his children survived him—Gnaeus, Sextus, and a daughter Pompeia.

BIBLIOGRAPHY.—*Ancient:* Plutarch, *Pompey;* Dio Cassius; Appian; Velleius Paterculus; Caesar, *De bello civili;* Strabo xii., 555–560; Cicero, passim; Lucan, Pharsalia.

Modern: Histories of Rome in general (see ROME: Ancient History ad fin.); works quoted under CAESAR and CICERO. Also G. Boissier, Cicero and His Friends (Eng. trans., A. D. Jones, 1897); J. L. Strachan-Davidson's Cicero (1894); Warde Fowler's *Julius* Caesar (1892); C. W. Oman, Seven Roman Statesmen of the Later Republic (1902); notes in Tyrrell and Purser's Correspondence of Cicero.

POMPONAZZI, PIETRO (1462–1525), Italian philosopher, was born in Mantua on Sept. 16, 1462. He studied philosophy and medicine at Padua and taught philosophy in that university (1487–

1509, with interruptions), at Ferrara and finally at Bologna (1512–25), where he died on May 18, 1525. Thoroughly versed in Aristotle and his commentators, especially Averroes and St. Thomas, Pomponazzi was a leading representative of Renaissance Aristotelianism as it had developed at the Italian universities (*i.e.,* in conjunction with medicine rather than with theology) since the end of the 13th century. His questions and lectures on Aristotle are still for the most part unpublished 400 years after his death. His treatise on the immortality of the soul, *De immortalitate animae* (1516), was violently attacked but not officially condemned, and the author was allowed to defend his position in his *Apologia* (1518) and *Defensorium* (1519). He contended that the immortality of the individual soul cannot be demonstrated on the basis of Aristotle or of reason but must be accepted as an article of faith. In developing this view, he maintains that the end of human life consists in moral action and that virtue is its own reward, vice its own punishment. This moral virtue constitutes the peculiar dignity of man.

Pomponazzi's largest treatises, *De incantationibus* and *De fato,* were published posthumously (1556 and 1567). The former proposes a natural explanation of several reputedly miraculous phenomena. The latter defends the Stoic doctrine of fate against Alexander of Aphrodisias and adds a subtle philosophical discussion of predestination and free will.

BIBLIOGRAPHY.— *P. Pomponatii Mantuani tractatus . . . ntere peripatetici (1325); Opera (1367); Tractatus de immortalitate animae,* ed. by *W.* H. Hay *(1938)* and by *G.* Morra (1954); E. Cassirer *et al.* (eds.), *The Renaissance Philosophy of Man (1948); F.* Fiorentino, *Pietro Pomponazzi (1868); A. H.* Douglas, *The Philosophy and Psychology of Pietro Pomponazzi (1910); B.* Nardi, "Le Opere inedite del Pomponazzi," *Giornale critico della filosofia italiana* (1950 *et seq.);* P. O. Kristeller, "Two Unpublished Questions on the Soul of Pietro Pomponazzi," *Medievalia et humanistica,* vol. viii, pp. *76–101 (1955).*
(P. O. K.)

POMPOSA, an abbey of Emilia, Italy, in the province of Ferrara. 2 mi. from Codigoro. ahich is 30 mi. E. of Ferrara in the delta of the Po. The fine church, a nork of the 6th century, rebuilt in the llth, aith interesting sculptures and terra-cotta decorations on the façade and a splendid Romanesque. campanile 163 ft. high (1063), contains a good mosaic pavement (1036) and interesting frescoes of the 14th century—a "Last Judgment" of the school of Giotto, and others. There are also paintings in the refectory. The abbey was abandoned in 1650 because of malaria.

POMPTINE (PONTINE) **MARSHES,** an ill-drained area covering 300 sq mi. southeast of Rome and lying between Monti Lepini and a belt of coastal sand dunes. It nas apparently cultivated under the Volsci but later abandoned because of the prevalence of malaria. Attempts at drainage were made in Roman times, folloning the construction of the Via Appia in 312 B.C., and these were repeated at various times without much success. The draining was finally achieved under the Fascist government betneen 1930 and 1934. Previously, about one third of the land provided rough pasture for half-wild cattle and minter pasture for sheep brought down from the hills. There was also a little wheat cultivation by peasants who returned for a few days to harvest it. The rest of the land was covered with scrub. Some areas were under nater for most of the winter. A major canal nas made to carry drainage from the hills direct to the sea. and pumping stations were installed to drain the lowest lands.

Irrigation canals have made possible the cultivation of most of the area and healthful, well-planned towns. such as Littoria, Nettuno and Porto d'Anzio, have been established. Water supplies are drawn from wells. (T. HER.)

PONCA CITY, a city of Kay county, Okla., U.S., 90 mi. N E. of Oklahoma City. It was established in 1893. Prior to the opening of the historic Cherokee strip on Sept. 16 of that year (see OKLAHOMA. *History*). 2,300 $2 certificates were sold by a private group, entitling each holder to participate in forming the nea town and in acquiring a lot. More than 2,000 people gathered at the proposed site, and on Sept. 21 the drawing for lots was held and a provisional government nas organized by popular assembly.

The name is from the Ponca tribe of Indians, moved in 1879 to a reservation located south of the townsite. Although the name Ponca City had always been in popular use, the post-office name was Ponca until 1913. The city has a council-manager form of government, in effect since 1954.

Ponca City is an important petroleum centre; two large refineries have a combined daily capacity of more than 100,000 bbl. There is also an annual production of 75,000.000 lb. of carbon black. Other industries in the city process agricultural products; manufacture clothing, oil-drilling bits, farm equipment, ceramics, decorative wreaths and vacuum cleaners; and service diesel engines.

The city is the home of the famous "Pioneer Woman" statue and Pioneer Woman State park, presented to the people of Oklahoma by Gov. E. W. Marland, and is the location of the Pioneer Woman Historical museum.

For comparative population figures see table in OKLAHOMA: *Population.* (GE. H. S.)

PONCE, the largest and most important city on the southern coast of Puerto Rico and the second city in size and importance on the island. In 1960 the population of the city was 114,286 and of the municipal district 145,586. Ponce's official history dates from 1692 when a tonn council was established and a mayor appointed. In 1877, because of its growth and importance, the Spanish government elevated Ponce to the category of a city.

The warm, dry climate on the south coast is most agreeable. The average annual temperature is 79°, and the yearly rainfall is 36 in. Constant breezes coming off the mountains and from the Caribbean sea assure comfortable living. As Puerto Rico's principal shipping port on the Caribbean, Ponce trades with the islands of the Lesser Antilles, Colombia and Venezuela Extensive improvements of the excellent harbour were made under the direction of U.S. agencies. Cement, iron. shoes, candy, textiles and paper products are some of the more important industrial goods manufactured in Ponce. To the west on the coast is located a large oil refinery. To the east well-irrigated plains produce high-grade sugar cane. Five banking firms have offices in Ponce. There are four radio stations, two television stations and one daily newspaper.

Excellent highways connect the city with other coastal towns, and two well-kept paved roads lead up over the mountains to the interior and the north coast. The city is also connected with San Juan (*q.v.*) by regular commercial air service. Ponce's parks. plazas, public buildings and private residences are well-kept and attractive. In addition to first-class hotels, the city has an ultra-modern tourist hotel.

The Roman Catholic Church maintains the University of Santa Maria with facilities for over 3,000 students in the city.

(T. G. Ms.)

PONCE DE LEÓN, JUAN (*c.* 1460–1521), discoverer of Florida, was born in Servas, Spain, about 1460. He took part in the Moorish wars and then sailed for America with Columbus on his second voyage (1493). In 1509 he conquered Puerto Rico and was appointed governor. As soon as the island was under control and pacified he set out with three ships to search for the land of "Bimini," wherein, as the Indian legend told him, there was a fountain with waters of marvelous curative power. On Mar. 27, 1513, he discovered the mainland which he named Florida because the day was Easter Sunday *(Pascua Florida).* He landed north of the present site of St. Augustine on April 2 and on April 8 took possession in the name of the Spanish king. He afterward explored the coast southward to the cape and up the west shore of the peninsula to at least 27° 30' and perhaps to where the coast trended westward.

Ponce de León returned to Spain in 1514 and received an appointment from Ferdinand V as governor of "The Island of Florida." In 1521 he set out to conquer and colonize his possession, but the fierceness of the natives prevented his success.

In a sharp engagement Ponce de Leon was mortally wounded and his force driven to the ships. He died in Cuba in June 1521.

See F. A. Obcr, *Ponce de Ledn (1908);* Justin Windsor, *Narrative and Critical History of America,* vol. ii, chap. iv. *(1886);* "The Track of Ponce de Leon," *Amer. Geog. Soc. Bulletin, xlv.,* pp. 721–735 *(1913); Boletin histdrico de Puerto Rico, Año I;* pp. *118–161 (1914).*

PONCELET, JEAN VICTOR (1788–1867), French mathematician and engineer, one of the founders of modern synthetic geometry, was born at Metz on July 1, 1788. From 1808 to 1810 he attended the Bcole Polytechnique and afterward, until 1812, the *école d'application* at Metz. He then became lieutenant of engineers and took part in the Russian campaign during which he was taken prisoner and confined at Saratov, on the Volga, until 1814, when he returned to France. During his imprisonment he began his researches on projective geometry which led to his great treatise on that subject. This work, the *Traité des propriétés projectives des figures* (1822; 2nd ed., 2 vol., 1865–66), is occupied with the investigation of the projective properties of figures and entitles Poncelet to rank as one of the greatest of those who took part in the development of the new geometry of which G. Monge was the founder *(see* GEOMETRY: *History of Geometry).* Poncelet developed the principle of duality and discovered the circular points at infinity. From 1815 to 1825 .he was occupied with military engineering at Metz, and from 1825 to 1835 he was professor of mechanics at the *tcole d'application* there. In 1834 he became a member of the Académie; from 1838 to 1848 he was professor to the faculty of sciences at Paris and from 1848 to 1850 commandant of the Bcole Polytechnique, with the rank of ,general. He died at Paris on Dec. 22, 1867.

Poncelet's works include *Cours de me'chanique, appliquée aux Machines* (1826), and *Mémoire sur les roues hydrauliques à aubes courbes* (1826).

See Eric *T. Bell, Men of Mathematics* (1937). (O. OE.)

PONCHIELLI, AMILCARE (1834–1886), Italian musical composer, was born near Cremona on Sept, 1, 1834, and studied at the Milan conservatory. He attained his fame with *La Gioconda* (1876), written to a libretto founded by Arrigo Boito upon Victor Hugo's tragedy, *Angelo, Tyran de Padoue. La Gioconda* was followed by *Il Figliuol prodigo* (1880) and *Marion Delorme* (1885). He died at Milan on Jan. 17, 1886.

POND, JOHN *(c.* 1767–1836). English astronomer-royal, was born about 1767 in London. After leaving Trinity college, Cambridge, he settled at Westbury near Bristol, and began to determine star places with a fine altitude and azimuth circle of $2\frac{1}{2}$ ft. diameter by E. Troughton. His demonstration in 1806 *(Phil. Trans.* xcvi, 420) of a change of form in the Greenwich mural quadrant led to the introduction of astronomical circles at the Royal Observatory, and to his own appointment as its head. He was elected a fellow of the Royal Society on Feb. 26, 1807; he married and went to live in London in the same year, and in 1811 succeeded Nevil Maskelyne as astronomer-royal.

Under Pond the instrumental equipment at Greenwich was completely changed, and the number of assistants increased from one to six. The superior accuracy of his determinations was attested by S. C. Chandler's discussion of them in 1894, in the course of his researches into the variation of latitude *(Astron. Journ.* no. 313, 315). Pond received many academic honours. He published eight folio volumes of *Greenwich Observations,* translated S.-P. Laplace's *Système du monde* (in 2 vols. 8vo., 1809), and contributed 31 papers to scientific collections. His catalogue of 1,112 stars (1833) was of great value. He retired in 1835 and died at Blackheath on Sept. 7, 1836, and was buried beside Halley in the churchyard at Lee.

See *Mem. Roy. Astron. Soc.* x, 357; *Proc. Roy. Soc.* iii, 434; *Penny Cyclopaedia* (De Morgan); F. W. Bessel, *Pop. Vorlesungen,* p. 543; *Report Brit. Assoc.* i, 128, 136 (Airy); G. Airy's *Autobiography,* p. 127; *Observatory,* xiii, 204, xxii, 357; *Annual Biography and Obituary* (1837); R Grant, *Hist. of Phys. Astron.* p. 491; Royal Society's *Cat. Scient. Papers;* Maunder, *The Royal Observatory Greenwich.*

PONDICHERRY (Fr. *Pondichéry* from Tamil *puddu cheri,* "new village"); the name of a centrally administered state of India and of its capital, and of the chief settlement of former French India. On Nov. 1, 1954, on the basis of a vote of the elected representatives of French Indian municipalities, the administration of French India was transferred to the republic of India; central control was initiated through a chief commissioner with headquarters at Pondicherry; and on Jan. 6, 1955, the four settlements together were designated the state of Pondicherry. The distances from Pondicherry and relative locations of the isolated parts of the state are as follows: Karikal 70 mi. (Tanjore district, Madras); Mahé 285 mi. (Malabar dist., Madras); Yanoan 370 mi. (East Godavari dist., Andhra Pradesh). Total area 193 sq.mi.; total pop. (1955 est.) 330.688. Pondicherry territory itself (South Arcot district of Madras) has an area of 112 sq.mi. The town (pop., 1955 est., 62,716) is 122 mi. by rail (85 mi. direct) south-southwest of Madras city. Its roadstead is the best on the east coast.

Pondicherry was founded in 1683 by François Martin, on the site of a village given him by the governor of Gingee. In 1693 the Dutch took Pondicherry, but restored it, with the fortifications greatly improved, in 1697, at the peace of Ryswick. In 1761 it was taken by Col. Eyre Coote from the Comte de Lally. In 1763 it was restored to the French. In 1778 it was again taken, by Sir Hector Munro, and its fortifications destroyed. In 1783 it was retransferred to the French. and in 1793 recaptured by the English. The treaty of Amiens in 1802 restored it to the French, but it was retaken in 1803. In 1816 it was restored to the French.

(S. GL.)

PONDO, a Kafir people who have given their name to Pondoland, the country comprising much of the seaboard of Kaffraria, Cape province, immediately to the southwest of Natal.

PONDWEED, a popular name for *Potamogeton natans,* a cosmopolitan aquatic plant found in ponds, lakes and ditches, with broad, more or less oblong ovate, olive green, floating leaves. The name is also applied to other species of *Potamogeton,* one of the characteristic genera of lakes, ponds and streams all over the world but more abundant in temperate regions, embracing about 90 species. It is the principal genus of the family Potamogetonaceae and contains plants with slender branched stems and submerged and translucent, or floating and opaque, alternate or opposite leaves, often with membranous united stipules. The small flowers are borne above the water in axillary or terminal spikes; they have four stamens, which bear at the back four small herbaceous petallike structures and four free carpels, which ripen to form four small green fleshy fruits, each containing one seed within a hard inner coat; the seed contains a large hooked embryo. An allied genus, *Zannichellia,* occurring in fresh and brackish ditches and pools nearly throughout North America and in Great Britain, and also widely elsewhere in temperate and tropical regions, is known as horned pondweed, from the curved fruit.

FROM STRASSBURGER, "LEHRBUCH DER BOTANIK FUR HOCHSCHULEN" (GUSTAV FISCHER)
PONDWEED (POTAMOGETON NATANS), SHOWING FLOWERING STEM AND LEAVES

PONGEE, a plain weave fabric made of tussah or wild silk, originated with the Chinese in ancient times. Its sphere of usefulness has been broadened due chiefly to the increase in standard width from 18 to 36 or more inches, and the variety of colours extended. The Japanese buy from the Chinese the wild silk and work it up in their own plants.

Shantung, a variety of pongee, derives its name from the province which is the centre of the wild silk industry. It differs from true pongee in that the former must be a plain weave, while Shantung may include many types. even adding coloured threads for decoration. Because of the ease with which they can be laundered and their durability pongees are among the most practical of silks.

PONIARD, a dagger, particularly one of small size, used for stabbing at close quarters. The French word *poignard,* from which the English is a 16th-century adaptation, is formed from *poing,* fist, in which the weapon is grasped. *(See* DAGGER.)

PONIATOWSKI, the name of a Polish princely family of Italian origin, tracing descent from Giuseppe Torelli, who married about 1650 an heiress of the Lithuanian family of Poniatov, whose name he assumed.

STANISLAUS PONIATOWSKI (1677–1762), only belonged to the family by adoption, being the reputed son of Prince Sapieha and a Jewess. He was born at Dereczyn in Lithuania, and was adopted by Sapieha's intendant, Poniatowski. Attaching himself to the party of Stanislaus Leszczynski, he became major-general in the army of Charles XII of Sweden, who also employed him as diplomatic intermediary to the Sultan. He next became governor of the duchy of Zweibrücken, Bavaria. After the death of Charles XII in 1718 he visited Sweden; and was subsequently reconciled with Leszczynski's rival on the throne of Poland, Augustus II, who made him grand treasurer of Lithuania in 1724. On the death of Augustus II he tried to secure the reinstatement of Leszczynski, but presently gave his allegiance to Augustus III, by whom he was made governor of Cracow. He died at Ryki on Aug. 3, 1762.

His second son Stanislaus Augustus became king of Poland. *(See* STANISLACS II AUGUSTUS.) Of the other sons, Casimir (1721–80) was his brother's chancellor; Andrew (1735–73) became *Feldzeugmeister* in the Austrian service; Michael (1736–94) became archbishop of Gnesen and primate of Poland. Joseph Anthony (*q.v.*), Andrew's son. became one of Napoleon's marshals.

STANISLAUS PONIATOWSKI (1757–1833), son of Casimir, was grand treasurer of Lithuania, starost of Podolia and lieutenant-general of the royal army. In 1793 he settled in Vienna, and subsequently in Rome, where he made a magnificent collection of antique gems, subsequently sold. He died in Florence, Feb. 13, 1833, and the Polish and Austrian honours became extinct.

His natural, but recognized, son, JOSEPH MICHAEL XAVIER FRANCIS JOHN PONIATOWSKI (1816–1873), was born at Rome and in 1847 was naturalized as a Tuscan subject. He received the title of prince in Tuscany (1847) and in Austria (1850). He represented the court of Tuscany in Paris from 1848, and he was made a senator by Napoleon III., whom he followed to England in 1871. He also wrote numerous operas. He died on July 3, 1873. His son, Prince Stanislaus Augustus, married and settled in Paris. He was equerry to Napoleon III., and died in Jan. 1908.

PONIATOWSKI, JOSEPH ANTHONY (1763–1813), Polish prince and marshal of France, son of Andrew Poniatowski and the countess Theresa Kinsky, was born at Warsaw in 1763. He served with distinction in the imperial forces against the Turks in 1788, then becoming major-general and subsequently lieutenant general in the Polish army under his uncle, King Stanislaus. In 1789 he commanded the Ukrainian division; and after the proclamation of the constitution of May 3, 1791, was made commander-in-chief. Aided by Kosciuszko, he conducted the operations against Russia with much skill, but when the king acceded to the confederation of Targowica *(see* POLAND: *History),* at the same time guaranteeing the adhesion of the army, Poniatowski, and most of the other generals threw up their commissions and emigrated. During the Kosciuszko rising he again fought gallantly for his country under his former subordinate, and after the fall of the republic lived in retirement. After the evacuation of the Polish provinces by Prussia, Poniatowski became commander of the National Guard, and on the creation of the grand duchy of Warsaw he was nominated war minister.

During the war of 1809, he operated successfully against the Austrians. In Napoleon's campaign against Russia in 1812 Poniatowski commanded the fifth army corps; and after the disastrous retreat of the grand army remained faithful and formed a new Polish army of 13,000 men, with which he joined the emperor at Liitzen. In 1813 he guarded the passes of the Bohemian mountains and defended the left bank of the Elbe. As a reward for his brilliant services at Leipzig he was made a marshal of France and entrusted with the duty of covering the retreat of the army, in the course of which he perished, fighting heroically against overwhelming odds. His relics were conveyed to Poland and buried in Cracow Cathedral, where he lies by the side of Tadeusz Kosciuszko and Jan Sobieski. Poniatowski's *Mes souvenirs sur la campagne de 1792* (Lemberg, 1863) is of historical value.

See *Correspondence of Poniatowski* (ed. E. Raczynski, Posen, 1843); Bronislaw Dembinski, *Stanislaus Augustus and Prince Joseph Poniatowski in the light of their Correspondence* (Fr.; Lemberg, 1904); Szymon Askenazy, *Prince Joseph Poniatowski* (Pol.; Warsaw, 1905).

PONS, JEAN LOUIS (1761–1831), French astronomer, was born at Peyres (Hautes Alpes) on Dec. 24, 1761. He entered the Marseilles observatory in 1789, and in 1819 became the director of the new observatory at Marlia near Lucca, which he left in 1825 for the observatory of the museum at Florence. Here he died on Oct. 14, 1531. He spent his time searching for comets, of which he discovered a record number; some bear his name, *e.g.,* Pons-Winnecke's comet.

See M. R. A. Henrion, *Annuaire biographique,* i. 288 (1834); *Memoirs Roy. Astron. Soc.* v. 410; R. Wolf, *Geschichte der Astronomie,* p. 709; J. C. Poggendorff, *Biog. lit. Handwörterbuch.*

PONSARD, FRANÇOIS (1814–1867), French dramatist, was born at Vienne, Isbre, on June 1, 1814, and studied law. His translation of *Manfred* was published in 1837. His play *Lucrèce* was represented at the Théâtre Français on April 1, 1843. This date mprks a reaction against the romantic style of Dumas and Hugo. He received, in 1845, the Academy's prize for a tragedy "to oppose a dike to the waves of romanticism." Ponsard combined the liberty of the romantics with the sober style of earlier French drama. The success of his plays was aided by the impersonation of many of the principal rôles in them by Rachel. He followed up *Lucrèce* with *Agnès de Méranie* (1846), *Charlotte Corday* (1850), and others. *L'Honneur et l'argent*, one of his most successful plays, was acted in 1853, and he became an academician in 1855. In 1866 he obtained great success with *Le Lion Amoureux*, another play dealing with the revolutionary epoch. His *Galilée,* which excited great opposition in the clerical camp, was produced in 1867. He died in Paris on July 7, 1867.

His *Oeuvres complètes* were published in Paris (3 vols., 1865-76). *See* C. Latreille, *La Fin du théâtre romantique et François Ponsard d'après des documents inkdits* (1899).

PONSONBY OF SHULBREDE, ARTHUR AUGUSTUS WILLIAM HARRY PONSONBY, 1ST BARON (1871–1946), British author and politician, was born on Feb. 16, 1871, and educated at Eton and at Balliol college, Oxford. In 1894 he entered the diplomatic service, and after holding posts in Constantinople and Copenhagen, returned in 1902 to join the staff of the foreign office. In 1906 he became principal private secretary to Sir Henry Campbell-Bannerman, and in 1908 was elected Liberal M.P. for Stirling. He represented this constituency until 1918, and in 1922 was elected Labour member for the Brightside division of Sheffield, and held minor posts in the Labour governments of 1924 and 1929–31. He was raised to the peerage in 1930, and was leader of th'e opposition in the house of lords from 1931 to 1935. He died at Hindhead, Surry, March 24, 1946.

His works include *The Decline of Aristocracy* (1912); *Democracy and Diplomacy* (1915); *Wars and Treaties (1815–1914)* (1917); *Now is the Time* (1925); *Life Here and Now* (1936).

PONSONBY, English family. PONSONBY, JOHN (1713–1789), Irish politician, was born on March 29, 1713. In 1739 he entered the Irish parliament, where he became first commissioner of the revenue (1744), a privy councillor (1746), and in 1756 Speaker. Belonging to one of the great families which at this time monopolized the government of Ireland, Ponsonby was one of the principal "undertakers," men who controlled the whole of the king's business in Ireland, and he retained the chief authority until the marquess Townshend became lord-lieutenant in 1767. A struggle for supremacy between the Ponsonby faction and the party dependent on Townshend followed, which caused Ponsonby to resign the speakership in 1771. He died on Dec. 12, 1789. His wife was Elizabeth, daughter of William Cavendish, 3rd duke of Devonshire, a connection of advantage to the Ponsonbys.

Ponsonby's third son, GEORGE PONSONBY (1755–1817), lord chancellor of Ireland, was born on March 5, 1755, and educated at Trinity College, Cambridge. A barrister, he became a member of the Irish parliament in 1776 and was chancellor of the Irish exchequer in 1782, afterwards taking part in the debates on the question of Roman Catholic relief, and leading the opposition to the union of the parliaments Ponsonby represented Wicklow and then Tavistock in the united parliament; in 1806 he was lord chancellor of Ireland, and from 1808 to 1817 he was the official leader of the opposition in the House of Commons, He left an only daughter when he died in London on July 8,1817.

George Ponsonby's elder brother. WILLIAM BRABAZON PONSONBY, 1st Baron Ponsonby (1744–1806), was also a leading Whig politician, being a member of the Irish and, after 1800, of the British parliament In 1806, shortly before his death, he was created Baron Ponsonhy of Imokilly. On the death of his grandson, WILLIAM BRABAZON PONSONBY (1807–1866), the barony became extinct.

PONTA DELGADA, the capital of an administrative district, comprising the islands of St. Michael's and St. Mary in the Portuguese archipelago of the Azores. Pop. (1950) 22,706. Ponta Delgada is built on the south coast of St. Michael's. in 37° 40′ N. and 25° 36' W. Its mild climate and the fine scenery of its mountain background render it very attractive to visitors; it is the commercial centre and the most populous city of the archipelago. Great improvements in the harbour were effected after 1860 by the construction of a breakwater 2.800 ft. long.

PONT-À-MOUSSON, a town of northern France in the *département* of Meurthe-et-Moselle, 17 mi. N.N.W. of Nancy by rail. Pop. (1954) 10,872. Dating from the 9th or 10th century, Pont-à-Mousson constituted a lordship, which was made a marquisate in 1354. It was from 1572 to 1763 the seat of a well-known university. The Moselle, which is canalized, divides the town into two quarters, united by a 16th-century bridge. The church of St. Martin dates from the 13th, 14th and 15th centuries. The lower ecclesiastical seminary occupies the building of an old Premonstratensian convent.

PONTANO, GIOVANNI (JOVIANUS PONTANUS) (1422 or 1426–1503), Italian humanist whose voluminous and wide-ranging work illustrates the diversity of the Renaissance scene, was born at Cerreto, in Umbria, on May 7, 1422 or 1426. At about the age of 21 he went to Naples, where he spent the rest of his life. In 1471, on the death of the scholar Antonio Beccadelli (Panormita), he became head of the Neapolitan humanist academy, called after him Accademia Pontaniana. In 1461 he married Adriana Sassone, who bore him one son and three daughters and died in 1490. From 1486 until 1495 he was the effective political leader of the kingdom of Naples as adviser, military secretary and chancellor to the kings of the Aragonese dynasty. He died in Sept. 1503.

Pontano's extensive literary output, all in Latin, includes a historical work (De *bello Neapolitano*), philosophical treatises (*De prudentia, De* fortuna), an astrological poem (*Urania*), five dialogues dealing with such widely differing subjects as morals and religion, philology and literature (*Aegidius*, Actius, *Asinus, Antonius, Charon*) and many lyrics on love, nature, family life and scenes from Neapolitan life (*Lepidina*, *Amorum* libri, *Eridanus, Hendecasyllabi,* Dr *amore coniugali, Jambici, Tumuli*). His erudition embraced all fields of knowledge, but neither as a thinker nor ax a poet did he display a powerful personality. The importance of his work for the cultural and. even more, the social history of the Renaissance, lies not so much in its erotic originality as in the fact that it synthesizes and reproduces more completely perhaps than that of any other humanist the diverse elements of the period.

BIBLIOGRAPHY.—C. M. Tallarigo, *Giovanni Pontano e i suoi tempi (1873)*; M. Scherillo, "Il Rinascimento" in Le *origini e lo svolgimento della letteratura italiana,* parte i, pp. 76–122 (1926). (*G. P. G.*)

PONTARLIER, a frontier town of eastern France, 36 mi. S.E. of Besançon. Pop. (1954) 13,079. It is situated 2,750 ft. above sea level on the Doubs, about 4 mi. from the Swiss frontier, and forms an important strategic point at ,the mouth of the defile of La Cluse, one of the principal passes across the Jura. Pontarlier is the junction of railway lines to Neuchâtel, Lausanne, Lons-le-Saunier. Dôle and Besançon.

At Pontarlier the French army of the east made its last stand against the Prussians in 1871 before crossing the Swiss frontier. The distillation of herbs, largely grown for kirsch and other liqueurs. is the chief industry.

PONT AUDEMER, a town of northwestern France. in the *département* of Eure. 39 mi. N.W. of Evreux, on the railway to Honfleur. Pop. (1954) 6,380. The town owes its name to Audomar, a Frankish lord. who in the 7th or 8th century bridged the Risle there.

The church of St. Ouen, which has fine stained glass of the 16th century, combines the late Gothic and Renaissance styles; its choir is Romanesque. Manufacturing includes malleable metal founding, glue, leather goods and paper and cotton spinning. There is trade in flax, wool, grain, cattle, cider, paper, iron, wood and coal. The port has a length of more than one-half mile on the Risle, which is navigable for small vessels from this point to the Seine (10 mi.).

PONTCHARTRAIN, a lake in southern Louisiana, U.S., 40 mi. long and 25 mi. wide. with an area of 625 sq.mi. and a mean depth of from 10 to 16 ft. Lying due north of a bend of the Mississippi, it is in places only 5 mi. distant from the river. More a lagoon than a lake, since it connects eastward with the Gulf of Mexico by a narrow passage called the Rigolets, Pontchart-rain is brackish and teems with game fish. It was discovered by Sieur d'Iberville in 1699. New Orleans, founded on the Mississippi. now extends to the lake, on which there is a state park and many small resorts. Pontchartrain causeway. a 27-mi., multispan concrete bridge, crosses the lake north from New Orleans. (W. A. Ro.)

PONTE, JACOPO DA: *see* BASSANO, JACOPO.

PONTECORVO, a city of Lazio. Italy. in the province of Frosinone. about 48 mi. from Caserta. Pop. (1951) 5,207. The principality of Pontecorvo, once an independent state, belonged alternately to the Tomacelli and the abbots of Monte Cassino. Napoleon bestowed it on Bernadotte in 1806, and in 1810 it was incorporated with the French empire.

PONTÉCOULANT, LOUIS GUSTAVE LE DOULCET, COMTE DE (1764–1853), French politician, was born at Caen on Nov. 17, 1764. He entered the army in 1778. A moderate supporter of the revolution, he was returned to the convention for the department of Calvados in 1792 and became commissary with the army of the north. He attached himself to the party of the Gironde, and in Aug. 1793 was outlawed. He refused to defend his compatriot Charlotte Corday, who wrote him a letter of reproach on her way to the scaffold. He returned to the convention on March 8, 1795, and became its president in July; he was for several months a member of the council of public safety. He was elected to the council of 500, but was suspected of royalist leanings, and spent some time in retireinent before the consulate. Becoming senator in 1805, and count of the empire in 1808, he organized the national guard in Franche-Comté in 1811 and the defense of the northeastern frontier in 1813. He sat in the upper house under the restoration. He died in Paris on April 3, 1853.

PONTEFRACT, a market town and municipal borough in the West Riding of Yorkshire, Eng., 25 mi. S.S.W. of York and 13 mi. E.S.E. of Leeds by road; it is served by three railway stations. Pop. (1951) 23,185. Area 7.6 sq.mi. An ancient Brigantian settlement existed there, to be succeeded by the Saxon town of Kirkby; the name was changed to Pontefract at some date prior to 1140, when the death in the town of Archbishop Thurstan was recorded. The building of the famous castle was begun in 1069 by Ilbert de Lacy. After 240 years the much-altered castle and manor passed by marriage to Thomas, earl of Lancaster. Henry IV held his court there for many years after deposing Richard II, and within the castle dungeons Richard supposedly was murdered in 1400. There too, after Agincourt (1415), Charles, duke of Orléans, was imprisoned for over 20 years. In 1541 Henry VIII made a visit to the north with the object of pacifying the northern counties after the disturbances occasioned by the Pilgrimage of Grace, in the course of which the castle had been taken by Robert Aske. leader of the pilgrimage, in 1536. Elizabeth I also visited the castle and repaired the chapel. the remains of which can still be seen within the walls. During the civil wars the castle sustained three sieges. It was the last royalist stronghold to be reduced by Cromwell, who had it dismantled. Sufficient of its walls, towers and dungeons still remain to give some idea of its former grandeur.

The town was the site of several important monastic settlements, including the priory of St. John, which was later demolished upon the orders of Henry VIII. The material recovered from the demolition was used for the building of the New hall, about half a mile away, itself to be reduced to ruins (which may still be seen) during the course of the civil mar. In Southgate is an ancient hermitage and oratory cut from the solid rock and dating from 1396. The Butter cross in the market place was erected in 1734 by the widow of the Spaniard Solomon Dupier with whose collaboration Gibraltar had been taken by Adm. Sir George Rooke.

The church of All Saints', under the castle, dates from Norman times. Ruined in the civil war, it had its central portion repaired and it is still in use. The church of St. Giles, first mentioned in a charter of Henry I, became the parish church after the ruin of All Saints'.

There are several ancient almshouses; the earliest, that of St. Nicholas, having been founded before the Conquest. The old town hall (18th century) contains the original plaster cast from which was made the panel depicting the death of Lord Nelson, at the foot of the column in Trafalgar square, London. The King's school, whose foundation was confirmed by Edward VI in 1549, is now housed in modern buildings. Three miles away, at Ackworth, is the well known Society of Friends school, founded in 1778. Other principal buildings are the market hall, the courthouse, the barracks (of the York and Lancaster regiment), the assembly rooms and the municipal offices. There is a racecourse in the park.

The principal industries are those of liquorice confectionery, made from locally grown liquorice (the town being the home of the celebrated "Pomfret cakes," so named from the usual pronunciation of Pontefract), coal mining, furniture making. iron founding, tanning. textiles and engineering. The market rights are exercised under a charter granted by Roger de Lacy in 1194, while the first mayor was appointed pursuant to a charter of Richard III in 1484. From the end of the 13th century to the Reform act of 1832 Pontefract returned two members to parliament. In the mid-1950s the borough constituency of Pontefract, which includes Castleford and Featherstone urban districts. returned one member. The Pontefract court of quarter sessions has an unbroken history from 1640 to the present day, and the town gives its name to a bishop suffragan in the Wakefield diocese.

PONTEVEDRA, a maritime province of northwestern Spain. before 1833 a part of Galicia. Pop. (1950) 714.666; area 1,695 sq.mi., with a density of population 421.6 inhabitants per square mile. The surface is mountainous. The coast line is deeply indented; navigation is rendered difficult by fogs in summer and storms in winter. Large agricultural fairs are held in the chief towns, and there is export of cattle, hams. salt meat and fish, eggs, breadstuffs, leather and wine. Vigo is the chief port and there are harbours at Bayona, Carril, Marin, Villagarcia and elsewhere among the deep estuaries of the coast. At Tuy the Spanish and Portuguese railways meet.

PONTEVEDRA, the capital of the Spanish province of Pontevedra; on the Tuy-Corunna railway, and on the river Lerez, which here enters the Ria de Pontevedra, an inlet of the Atlantic. Pop. (1950) 41,828. The name of the town is derived from the ancient Roman bridge (pons *vetus*) of twelve arches, which spans the Lerez near its mouth. Pontevedra is mainly built of granite, and still partly enclosed by mediaeval fortifications. There is an active trade in grain, wine and fruit; cloth, hats, leather and pottery are manufactured.

PONTIAC (c. 1720–1769), famous chief of the Ottawa Indians and leader in the "Conspiracy of Pontiac" in 1763–64, was born about 1720, probably on the Maumee river, in what is now northwestern Ohio. His father was an Ottawa, and his mother an Ojibwa. By 1755 he had become a chief of the Ottawa and a leader of the loose confederacy of the Ottawa, Potawatomi and Ojibwa. As an ally of France, he possibly commanded the Ottawa in the defeat (1755) of Gen. Braddock. In 1760 he met Maj. Robert Rogers, then on his way to occupy Michilimackinac and other forts surrendered by the French, and agreed to let the English troops pass unmolested on condition that he should be treated with respect by the British. Like other Indians he soon realized the difference between French and English rule—that the Indians were no longer welcomed at the forts and that they would ultimately be deprived of their hunting grounds by encroaching English settlements. French hunters and traders encouraged Indian disaffection with vague promises of help from France; and in 1762 Pontiac enlisted the support of practically all the Indian tribes from Lake Superior to the lower Mississippi for a joint move to expel the British. He arranged for each tribe to attack the fort nearest to it in May 1763, and then to combine to wipe out the undefended settlements. Pontiac himself decided to capture Detroit, but his carefully laid plans for a surprise attack on May g were betrayed to the commanding officer, Maj. Gladwin, and he was forced to lay siege to the fort. The siege continued for five months, marked by desultory attacks and sorties. Schooners sent through Lake Erie with supplies and provisions were captured by the Indians, but Pontiac could not prevent reinforcements from Fort Niagara under Capt. Dalzell from reaching Detroit. However, when the besieged made a night attack on the Indian encampment, Pontiac, apprised of their coming, inflicted heavy losses on them at Bloody Run, July 31. The Indians were unused to making long sieges and, after a few months, several of the associated tribes made peace. With his own Ottawa, Pontiac continued to camp around Detroit until Oct. 30 when, hearing that no aid from the French could be expected owing to the signing of the peace treaty with the English, he withdrew to the Maumee river.

Pontiac's larger plan was more successful. Of the 12 fortified posts attacked by the Indians, all but four were captured; most of the garrisons were massacred; several relief expeditions were nearly annihilated, and the frontiers were desolated and plundered. Col. Bouquet, however, succeeded in defeating the Indians at Bushy Run, when on his way to relieve Forts Pitt and Ligonier, and in 1764, he led a second expedition into Ohio from Pennsylvania, and forced the Indian tribes to sue for peace and release their prisoners. Pontiac still hoped to arouse other tribes to continue the fight, but after another year he saw that the English were the real masters of the situation and, on behalf of the tribes lately banded in his league, he concluded a treaty of peace and amity with Sir William Johnson at Oswego, N.Y., July 25, 1766. Pontiac, laden with gifts from the enemy, returned to his home on the Maumee. He met his death in 1769 at the hands of an Illinois Indian bribed by an English trader to murder him at Cahokia (nearly opposite St. Louis). His death occasioned a bitter war among the Indians, and the Illinois group was all but annihilated by his avengers. Pontiac was one of the most remarkable men of the Indian race in American history, possessing a commanding energy and force of mind combined with subtlety and craft, and a power of organization.

BIBLIOGRAPHY.—*See* Francis Parkman, The Conspiracy of Pontiac (1851; 10th ed., 1905) ; Handbook of American Indians (Bureau of American Ethnology, vol. ii., 1910).

PONTIAC, the seat of Oakland county, Mich., U.S., 26 mi. N.W. of Detroit (*q.v.*) and within the Detroit metropolitan area, is an important automobile-manufacturing city in the midst of a resort region, with hundreds of lakes and numerous public parks Named for the famous Ottawa chief, Pontiac was settled in 1818 by the Pontiac company, organized in Detroit; the site was the intersection of the Clinton river and the Saginaw trail, which formed part of the Indian route from the Straits of Mackinac to northern Ohio. In the 19th century, Pontiac was the shopping centre for a prosperous agricultural area. It was chartered as a city in 1861; in 1877 its population of about 4,000 supported newspapers, banks, mercantile establishments, hotels, and blacksmiths, gunsmiths, mills, foundries and small factories.

Its river location made available water power essential to the rise of factories. Most important for its future were the wagon and carriage works, which, with the invention of the automobile, turned to production of cars and parts; in the 20th century, Pontiac's economy has depended largely upon the automobile industry. Pontiac has a commission-manager form of government, in effect since 1920. Pontiac State hospital is located in the city; nearby are the Cranbrook institutions (private schools, museum and art academy) and the Oakland branch of Michigan State university. The population of the city in 1960 was 82,233; for comparative population figures see table in MICHIGAN: Population.

(E. S. AD.)

PONTIANUS, pope from 230 to 235. He was exiled to Sardinia by the emperor Maximinus, and in consequence of this sentence resigned (Sept. 28, 235). He was succeeded by Anteros.

PONTIFEX. The collegium of the pontifices was the most important priesthood of ancient Rome, being specially charged with the administration of the *jus divinum; i e.,* that part of the civil law which regulated the relations of the community with the deities recognized by the state officially, together with a general superintendence of the worship of gens and family. The name is clearly derived from *pons* and *facere,* but whether this indicates any special connection with the sacred bridge over the Tiber (Pons Sublicius) cannot be determined. The college existed under the monarchy, when its members were probably three in number; they may be considered as legal advisers of the *rex* in all matters of religion. Under the republic they emerge into prominence under a *pontifex maximus,* who took over the king's duties as chief administrator of religious law, just as his chief sacrificial duties were taken by the *rex sacrorztm;* his dwelling was the *regia,* "the house of the king." During the republican period the number of pontifices increased. probably by multiples of three, until after Sulla (82 *B.c.)* they numbered 15; for the year 57 B.C. a complete list of them is given in Cicero *(Harusp. resp.,* 6, 12). Included in the collegium were also the *rex sacrorum,* the *flamines,* three assistant pontifices *(minores)* and the vestal virgins, who were all chosen by the *pontzfex maxımus.*

Vacancies in the body of pontifices were originally filled by cooptation; but from the second Punic war onward the *pontifex maximus* was chosen by a peculiar form of popular election, and in the last age of the republic this held good for all the members. They all held office for life.

The immense authority of the college centred in the *pontifex maximus,* the other pontifices forming his *consilium* or advising body. His functions were partly sacrificial or ritualistic, but these were the least important; the real power lay in the administration of the *jus divinum,* the chief departments of which may briefly be described as follows: (1) the regulation of all expiatory ceremonials needed as the result of pestilence, lightning, etc.; (2) the consecration of all temples and other sacred places and objects dedicated to the gods by the state through its magistrates; (3) the regulation of the calendar both astronomically and in detailed application to the public life of the state; (4) the administration of the law relating to burials and burying places, and the worship of the manes, or dead ancestors; (5) the superintendence of all marriages by *confarreatio; i.e.,* originally of all legal patrician marriages; (6) the administration of the law of adoption and of testamentary succession. They had also the care of the state archives and the lists of magistrates. and kept records of their own decisions *(commentarii)* and of the chief events *(annales).*

It is obvious that a priesthood with such functions and holding office for life must have been a great power in the state, and for the first three centuries of the republic it is probable that the *pontzfex maximus* was in fact its most powerful member. The office might be combined with a magistracy, and, though its powers were declaratory rather than executive, it may be described as quasi-magisterial. Under the later republic it was coveted chiefly for the great dignity of the position; Julius Caesar held it for the last 20 years of his life, and Augustus took it after the death of Lepidus in 12 B.C., after which it became inseparable from the office of the reigning emperor.

PONTOISE, a town of northern France, in the *dkpartement* of Seine-et-Oise, 18 mi. N.W. of Paris on the railway to Dieppe. Pop. (1954) 9,785. Pontoise existed in the time of the Gauls as *Briva Isarae* (Bridge of the Oise). It was destroyed by the Normans in the 9th century, united with Normandy in 1032 and acquired by Philip I in 1064. Capital of the French Vexin, it played a conspicuuus part in the wars between the French and the dukes of Normandy and in the Hundred Years' War. The English took it in 1419 and again in 1437. In 1441 Charles VII took it by storm after a three months' siege. After belonging to the count of Charolais down to the treaty of Conflans, it was given as a dowry to Jeanne of France when she was divorced by Louis XII. The *parlement* of Paris several times met in the town, and in 1561 the states-geneial convoked at Orléans removed thither after the death of Francis II. During the Fronde it offered a refuge to Louis XIV and Mazarin. Henry III made it an apanage for his brother the duke of Anjou. Later it passed to the duke of Conti. Down to the Revolution it remained a monastic town. Two churches alone remained in modern times: St. Maclou, a 12th-century church, restored in the 15th and 16th centuries, and containing a fine holy sepulchre of the 16th century; and Notre Dame, of the close of the 16th century, with the tomb of St. Gautier, abbot of Meulan in the 12th century. Trade is in grain and in flour ground by numerous water mills on the Viosne. Remains of the 12th-century Cistercian abbey of Le Val survived at Mériel, near Pontoise. Pontoise suffered damage during World War II.

PONTOPPIDAN, HENRIK (1857–1943), Danish writer whose novels and short stories present an unusually comprehensive picture of his country and his epoch, was born at Fredericia on July 24, 1857. His father was a clergyman, and it was partly in revolt against his environment that he began to study engineering in Copenhagen in 1873. In 1879 he broke off his studies and became for several years a teacher. His first collection of stories, *Staekkede Vinger,* was published in 1881, and thereafter he supported himself by writing, until 1900 partly as a journalist with various Copenhagen papers. In 1917 he shared the Nobel prize for literature with Karl Gjellerup. He died at Ordrup on Aug. 21, 1943.

Pontoppidan's output, mainly of novels and short stories, stretches over half a century and covers most aspects of Danish life and the social, political and religious problems of the period. As a poet he belonged to the naturalist school, though he showed a characteristically critical independence and an agile, dialectic, ironic mind. An individualist and an apostle of the cult of personality, he yet had strong ties with his nation and his compatriots, for whom he had great affection although he criticized them severely.

His first books were mainly descriptions of country-town life. *Landsbybilleder* (1883), *Fra Hytterne* (1887) and *Skyer* (1890) are all characterized by social indignation though also by ironic appreciation of the complacency and passivity of country people. The trilogy *Det forjaettede Land* (1891–95; Eng. trans., *Emanuel or Children of the Soil,* 1892, and *The Promised Land,* 1896) describes the religious controversies in country districts. The chief character is a pastor from Copenhagen, a dreamer who tries, unsuccessfully, to gain the confidence of the peasants. In the 1890s Pontoppidan wrote a number of short novels on psychological, aesthetic and moral problems (*e.g., Nattevagt,* 1894; *Den gamle Adam,* 1895; and *Højsang,* 1896). These were followed by a major work, the novel *Lykke-Per* (1898–1904), in which the chief character bears some resemblance to Pontoppidan himself. He is a clergyman's son who rebels against the puritanical atmosphere of his home and seeks his fortune in the capital as an engineer. But his religious background inhibits him and he loses interest in success and wealth, separates from his Jewish fiancée (who with her strength of will and pride probably represents Pontoppidan's ideal) and after an unsuccessful marriage ends his life in complete loneliness. The book's theme is the power of environment, and national tendencies toward daydreaming and fear of reality are condemned.

Deeper problems are touched on in the shorter novels *Borgmester Hoeck og Hustru* (1905) and *Den kongelige Gaest* (1908), after which follows a third great novel, *De Dødes Rige* (1912–16). This covers the first decade of the 20th century and shows dissatisfaction with political developments after the liberal victory of 1901, and anxiety for the future. It sounds a warning against the barrenness of the new era. Anxiety for the country's destiny also lies behind the bitter novel *Mands Himmerig* (1927), which describes neutral Denmark during World War I and attacks carefree materialism. The cold, aloof, epic style which Pontoppidan had developed during his career is also a feature of his last important work, the four volumes of memoirs which he published between 1933 and 1940 and which appeared in a collected and abridged version entitled *Undervejs til mig selv* (1943).

BIBLIOGRAPHY.—V. Andersen, *Henrik Pontoppidan* (1917); *P.* C. Andersen, *Henrik Pontoppidan, En Biografi og en Bibliografi* (1934); *C.* M Woel, *Henrik Pontoppidan,* 2 vol. (1945); Knut Ahnlund, *Henrik Pontoppidan* (1956). (S. *M* K)

PONTORMO, JACOPO DA (JACOPO CARRUCCI) (1494–1556), Italian painter, one of the leading representatives of the late Florentine school, was born at Pontormo, near Empoli, on Rlay 24, 1494, the son of Bartolommeo Carrucci, a painter. He was apprenticed to Leonardo da Vinci and afterward to Albertinelli and Piero di Cosimo. At the age of 18 he entered the workshop of Andrea del Sarto and was remarked as a young man of exceptional promise. One of his earliest works extant, painted in 1516, is the fresco in the vestibule of SS. Annunziata, Florence, representing the "Visitation." Two years later he completed the altarpiece in the Church of S. Michele Visdomini. From this early period of the master date three small pictures painted for the mansion of Piero Franceschi Borgherini of Florence. One of these, representing "Joseph and His Kindred in Egypt." is now in the National gallery, London. It was regarded by Vasari as Pontormo's best picture. The other two panels, also of the story of Joseph, are also in Great Britain. In 1521 he was employed on decorative work in the Medicean villa at Poggio a Caiano. He was then at the height of his powers, and a fresco painted in a large lunette with mythological figures may be regarded as one of his most successful achievements. He then took to imitating Diirer, whose engravings and woodcuts were circulating in Italy. In 1522 he executed at the Certosa di Val d'Erna a series of frescoes founded on the Passion subjects of the German master. Pontormo's last works were a series of frescoes for the Church of S. Lorenzo, Florence. He had by then come under the influence of Michelangelo's style. After working on these for 11 years he left themincomplete. He died in Florence on Jan. 2, 1556.

PONTRESINA, a village in the upper Engadine valley, canton Graubiinden, Switz., 5 mi. E. of St. Moritz. It is an important winter sport centre. At its station travelers change from a branch of the Rhaetic railway from Samaden onto the Bernina line going into Italy. Pop. (1960) 1.067, all Romansh-speaking.

PONTUS, an ancient region of northeastern Anatolia, bordering on the Euxine (Black sea) or Pontus Euxinus. The cradle of the Mithradatic kingdom of Pontus, it was at first called "Cappadocia toward the Pontus" or "Pontic [*i.e.,* Maritime] Cappadocia," the name Pontus being a later simplification.

At the eastern end of the central Anatolian plateau Pontic Cappadocia begins as a series of fertile plains within the arc of the river Halys (the modern Kizil Irmak) and stretches northward and eastward to comprise the catchment areas of the Iris (Yesil Irmak) and of the Thermodon, with the basin of the lower Halys, as well as a long and narrow strip of coastland beyond the mountains toward the Caucasus. The kingdom of Pontus, however, eventually included not only this area but also part of inland Paphlagonia and Armenia Minor and extended its coast line westward to the Bithynian frontier and eastward into Colchis.

The ethnic affinities of the indigenous Cappadocians, whom the Greeks called Leucosyri or White Syrians, are a matter for conjecture; so too are those of the Chalybes, the Tibareni, the Mosynoeci and the Macrones, barbarous tribes who were still inhabiting the mountains in Strabo's time (see ASIA MINOR for general indications of the racial type anterior to the Hittite invasion). The Chalybes, however, were credited with being the first workers of iron (Greek, *Chalyps*), and the mines of the eastern mountains provided much of the ancient world's supply of that metal. The Milesian Greeks established colonies on the coast at Sinope (Turkish, Sinop) and at Amisus (Samsun) in the 7th century B.C.; and Cotyora, Cerasus and Trapezus (Trebizond) were colonized from Sinope. Trapezus exported iron from the hinterland; Sinope was an entrepôt for this trade and for the grain sent from the opposite shores of the Euxine. Inland, the great temples of Ma at Comana, of Men at Ameria and of Anahita at Zela were major centres of native settlement. Something of the conditions prevailing in the country at the end of the 5th century B.C. can be gathered from Xenophon's Anabasis.

Little is known of the early kings. The emergence of the region as a political unit of international importance dates from the end of the 4th century B.C., when Mithradates I Ctistes (*Ctistes,* the Founder), taking advantage of the situation created by the Wars of the Diadochi, established a new kingdom there. The capital was at first at Amasya (Amasia) on the Iris, where the rock-cut tombs of four of the new kings have been recognized; later it was transferred to Sinope. The dynasty reached the zenith of its power in Mithradates VI Eupator, later called the Great, whose sovereignty embraced not only a large Anatolian state but also the Greek colonies in what is now the Ukraine and the Crimea and who at one time came near to subduing Greece proper. For an account of these kings and of Pompey's conquest of Pontus for the Romans in 66 B.C., when the king was driven from his country at the end of the Third Mithradatic War, see MITHRADATES. Under Pompey's settlement the Ora Pontica or western part of the seaboard, from a point east of Heracleia (Eregli) to Amisus, was attached to Bithynia to form the province of Bithynia and Pontus; and the eastern part of the coast as far as Trapezus, with most of the hinterland, was assigned to the Galatians.

See the *Cambridge Ancient History,* vol. ix, ch. v, with bibliography (1932); W. M. Ramsay, *Historical Geography of Asia Minor* (1890); J. G. C. Anderson, E. and F. Cumont and H. Grégoire, *Studia pontica,* 3 numbers (1903–10). Strabo, one of the principal ancient authorities, was born at Amasya.

PONTYPOOL, an urban district in the Pontypool parliamentary division of Monmouthshire, Wales, 9 mi. N. of Newport by road. Pop. (1961) 39,879. Area 24.9 sq.mi. It is on the right bank of the Afon Llwyd, a tributary of the Usk, which divides the mountainous industrial country to the west from the low agricultural land to the east. Its growth is due to its situation on the eastern edge of the great south Wales coal field. The first ironworks were put up in 1577 by Edmond Brode, a partner of Richard Hanbury, whose family has played a big part in its iron industry. Pontypool Park house, built by Maj. John Hanbury in the 17th century, is now a convent school and the park is public property. Pontypool was the pioneer in sheet rolling and tin-plating and it became famous for wire, cast-iron gates, etc. Specially lacquered decorated ironware was known in the 18th century as Pontypool japan.

The old forges have given place to huge steelworks, a nylon yarn factory and other industries.

PONTYPRIDD, an urban district in the Pontypridd parliamentary division of Glamorganshire, Wales, situated on the Taff at its junction with the Rhondda and on the Glamorganshire canal, 12 mi. N.W. from Cardiff. Pop. (1961) 35,536. Area 12.7 sq.mi. It receives its name from a remarkable one-arch bridge spanning the Taff, erected in 1756. It was a village until the opening of the Taff Vale railway in 1840 and it owes its progress chiefly to the development of the coal areas of the Taff-Rhondda valleys. Pontypridd became the railway junction for the Merthyr, Aberdare and Rhondda valleys and a big centre for the inhabitants of these valleys. Though industrial it is also a residential town and in the centre is the Unysangharad park, subscribed by the public in 1923. Two miles away is the Treforest trading estate, with 70 factories in 1955.

PONY, a horse of a small breed (see HORSE).

PONY EXPRESS, the name applied in U.S. history to a system for providing fast mail service between St. Joseph, Mo., and Sacramento, Calif., from April 1860 to Oct. 1861. The pony express was established by the freighting and stagecoach firm of Russell, Majors and Waddell. Expert riders chosen from boys and small men rode fleet horses in relays. They carried half-ounce letters bearing a $5 pony express stamp and a 10 cent U.S. stamp. A specially designed square of leather, called a mochila, was thrown over the saddle, with a hole for the saddle horn and a slit for the cantle. The letters were carried in four sole-leather boxes attached to the corners of the mochila. The goal of ten-day service between St. Joseph and Sacramento was sometimes achieved.

The route at the outset covered 1,838 mi. and included 157 stations from 7 to 20 mi. apart. "Home stations" were located at intervals of 75 to 100 mi. Each rider changed horses from six to eight times on his scheduled ride from one home station to another. After a rest period he carried the mail in the other direction.

The route followed in general the Oregon-California trail and passed through Ft. Kearney, Julesburg, Ft. Laramie, South pass, Ft. Bridger, Salt Lake City and Carson City. Indians burned stations, killed employees and otherwise disrupted service in the summer of 1860 during the Paiute War.

Among the best-known pony express riders were William ("Buffalo Bill") Cody and "Pony Bob" Haslam. Joseph A. Slade was a hard-driving division superintendent. Russell. Majors and Waddell had introduced the pony express in the hope of winning a mail contract that would save their tottering transportation empire from bankruptcy. In this they failed. Sensational though it was, the pony express was a financial failure when completion of the transcontinental telegraph line in Oct. 1861 ended all need for it.

See Raymond *W.* and Mary L. Settle, *Saddles* and *Spurs* (1955); Arthur Chapman, *The* Pony *Express* (1932). (T. A. LN.)

PONZA (anc. PONTIA), the principal of a small group of islands belonging to Italy. Pop. (1959 est.) 5,105 (commune). The group is of volcanic origin, and includes Palmarola (anc Palmaria), Zannone (Sinonia), Ventotene (Pandateria) and Santo Stefano. It is about 20 mi. S. of Monte Circeo and 70 mi. W. of Naples. There is regular communication with Naples by steamer, and in summer with Gaeta.

The islands rise to a height of about 70 ft. above sea level. Ventotene has a convict prison, and the islands were a place of banishment in ancient times. Under fascism, Ponza became again a place of banishment for Italians opposed to Mussolini, among them General Bencivenga.

POOL: see BILLIARDS.

POOLE, REGINALD STUART (1832–1895), English archaeologist and orientalist, was born in London on Jan. 27, 1832, the son of Edward Poole and his wife née Sophia Lane. Poole acquired his taste for antiquities during a stay (1842–49) with his uncle, R. S. Poole, in Cairo. In 1852 he became an assistant in the British museum, and was assigned to the department of coins and medals, of which in 1870 he became keeper. In 1882 he helped to found the Egypt Exploration fund and in 1884 the Society of English Medallists. He retired in 1893 and died on Feb. 8, 1895.

His elder brother, EDWARD STANLEY POOLE (1830–1867), who was chief clerk in the science and art department at South Kensington, was an Arabic scholar, whose early death cut short a promising career. His two sons, Stanley Lane-Poole and Reginald Lane-Poole (1857–1939), keeper of the archives at Oxford (1909–27), lecturer in diplomatic and author of various historical works, carried on the family tradition of scholarship.

POOLE, WILLIAM FREDERICK (1821–1894), U.S. bibliographer, was a pioneer in U.S. periodical indexing and library administration. He was born in Salem, Mass., Dec. 24, 1821. As a student at Yale he became librarian of a literary society; his An Alphabetical Index to Subjects Treated in the Reviews and Other Periodicals, to Which No Indexes Have Been Published (1848) appeared a year before his graduation. A second edition of what became Poole's Index to Periodical Literature (1887–1908) appeared in 1853. Poole was an assistant in the library of the Boston Athenaeum in 1851; was librarian of the Boston Mercantile Library association (1852–56); of the Boston Athenaeum (1856–69); served two years as a library consultant; was librarian at the Cincinnati Public library, which he organized (1871–73); of the Chicago Public library (1874–87), building it to the largest circulation in the U.S.; and organized the reference library of the Newberry library, Chicago, where he remained until his death, March 1, 1894, in Evanston, Ill. History was his avocation and he published widely, especially in the *North* American Review.

POOLE, a municipal and parliamentary borough and county, holiday resort and seaport in Dorsetshire, Eng., 24 mi. E. of Dorchester by road. Pop. (1961) 88,088. Area 24.4 sq.mi. excluding 3.5 sq.mi. of tidal water and foreshore. The name alludes to the remarkable situation of the old town on a peninsula between the almost landlocked Holes bay and the tidal waterway (7 mi. by $4\frac{1}{2}$ mi.) to the north of Purbeck known as Poole harbour. A bridge to Hamworthy crosses the entry to Holes bay; on the east Poole includes Parkstone and Branksome and extends to Bournemouth. It is a great yachting centre and its good sands have gained it popularity as a holiday resort. The southeast coast is formed by chalk cliffs scored by several of the chines characteristic of those parts. Largest of the islands in Poole harbour is Brownsea (a bird sanctuary) where in 1907 was held the experimental camp from which sprang the Boy Scout movement. There is an old-established pottery, and other industries include boatbuilding, chemicals, agricultural implements and engineering. Coal, timber, oil and general merchandise are imported; exports include clay and tar. Poole, not mentioned until after the Domesday survey, was granted its charter in 1248. It is uncertain when the burgesses obtained their town at the fee-farm rent of £8 13*s*. 4*d*. mentioned in 1312. In 1372 they obtained assize of bread and ale and right to hold courts of the lord of the manor. Elizabeth I made it a separate county in 1569.

POOLS, IN INDUSTRY. Rival manufacturers or traders who, while still ostensibly in competition with each other, either allocate among themselves by agreement the amount or proportion of business each shall do, or agree as to who shall put in the lowest tender for a contract, frequently set up, as a part of their agreement machinery, a pooling system. One type is that adopted by those associations of manufacturers in the same industry which allot to each member a percentage of the output of the whole group and require that each member who exceeds his quota shall pay an appropriate sum into a pool and that each member who does not reach his quota shall receive an appropriate sum from it. In associations concerned with work for which tenders are asked, three kinds of pooling are known. In one the tenders prepared by members of the group are confidentially examined by the secretary of the association and a percentage added to each, to be subsequently paid by the successful tenderer into a pool and divided among the rest. In another a uniform tender price is decided upon which all shall quote on the understanding that the firm receiving the contract shall pay an agreed percentage into the pool. In another the tenderers are informed of the order in which the sums quoted run, from highest to lowest, in order that the lowest tenderer may hold out for his price; in which case also the successful tenderer pays an agreed percentage of his contract into a pool. Another arrangement is the profit pooling agreement in which the future profits of two or more businesses are for a specified period paid into a common fund and divided out in agreed proportions. (See also COMPETITION, ECONOMIC; MONOPOLY; TRADE ORGANIZATION.) (J. H.)

Finance and Commerce.—A pool on the stock exchange would work in some such way as follows, although the actual details naturally vary:

1. Its members would consist of the holders of a certain share, and while the pool organizers would not attempt to bring in every shareholder, the members of the pool would between them have to hold a substantial block of the total shares issued for the formation of the pool to be worth while.

2. The pool members would authorize the pool organizers to sell their shares on their behalf and would agree not to sell them themselves.

3. The pool organizers would agree not to sell these shares at less than a certain price. Thus the first third of the shares in the pool might be sold at a minimum of 21*s*., the next third at 22*s*. and the remainder at 23*s*. 6d. The proceeds of the sale as effected, less the charge for the pool's expenses, would be paid over to the pool members in proportion to the shares each held.

4. After six months from its date of formation, the pool would break up, and any shares still unsold would be retransferred to the members. to deal with as best they could.

The whole object of a pool is to control and regulate the supply of a certain share to the market. For a pool to be effective, it must have a big holding of the share, or it will be faced with competitive selling from outsiders and will be unable to obtain its minimum price.

If a new issue meets with an immediately unfavourable reception so that the bulk of it has to be taken up by the underwriters, it often happens that the underwriters form a pool.

A commercial pool in a commodity would work in very much the same way; it might be a buyer's pool—as the U.S. rubber pool—or a seller's pool, such as the Canadian wheat pool. a great nonprofit, co-operative marketing association in Canada. In either case, the buying and selling is done by the pool for its members, who agree to operate only through the pool. The object is to obtain by combined effort a reasonable price. (N. E. C.)

United States.—Pools among railway companies became widely prevalent throughout the United States between 1870 and 1887 and aroused so much opposition on the part of the public that the Interstate Commerce act was passed in 1887 making them illegal as regards interstate traffic. The act was not altogether successful, for division of traffic, especially in the shipping of cotton, fruit and grain, persisted without the usual pooling machinery being in evidence. Such agreements, however, being nonenforceable, were seldom of long duration. The wisdom of the Interstate Commerce act has been often called into question, and recommendations favouring legalization under government supervision have been made both in presidential messages and in the reports of the Interstate Commerce commission itself. A decision of the supreme court in 1911 making contracts not illegal unless in "unreasonable restraint of trade" eased the situation somewhat, while the modern tendency toward combination also tends to eliminate the conditions which cause pooling arrangements to be made.

POONA (PUNE), a city and district of Bombay state, India. The city is at the confluence of the Mutha and Mula rivers, 1.850 ft. above sea level and 119 mi. S.E. from Bombay. Pop. (1961) 721,134. It was the centre of the Maratha empire for more than 100 years and the monsoon capital of the Bombay presidency under British rule. The old government house at Ganeshkhind is now the home of the university (founded 1948).

The cantonments of Poona (pop., 1951, 59,011) and Kirkee or Khadki (pop., 1951, 48,552) adjoin the Poona city area. Kirkee contains a large ammunition factory. In the city of Poona itself and in the adjoining cantonments are a number of places of historical association; *e.g.,* the remains of the famous Shaniwarwada palace of the Peshwas and the Aga Khan's palace where Mohandas K. Gandhi was held in custody in 1942. There are a cotton mill, a paper mill and a few metal and engineering factories. The National Chemical laboratory and the meteorological department observatory are at Poona.

The DISTRICT OF POONA has an area of 6.032 sq.mi.; pop. (1961) 2,465,080. Toward the west the country is undulating and numerous spurs from the Western Ghats enter the district; to the east it opens out into plains. The district is liable to drought. The two most important irrigation works are the Mutha canal and the Nira canal. (D. G. K.)

POOR CLARES, otherwise CLARISSES, Franciscan nuns. so called from their foundress, St. Clare (*q.v.*). She was professed by St. Francis of Assisi (*q.v.*) in the Portiuncula in 1212, and two years later she and her first companions were established in the convent of St. Damian at Assisi. The nuns formed the "Second Order of St. Francis," the friars being the "First Order" and the Tertiaries (*q.v.*) the "Third."

Before Clare's death in 1253, the Second Order had spread all over Italy and into Spain, France and Germany; in England they were introduced about 1293 and established in London, outside Aldgate, where their name of Minoresses survives in the Minories; there were only two other English houses before the dissolution.

St. Francis gave the nuns no rule, but only a "Form of Life" and a "Last Will," each only five lines long and coming to no more than an inculcation of his idea of evangelical poverty. Something more than this became necessary as soon as the institute began to spread; and during Francis's absence in the east, 1219. his supporter Cardinal Hugolino composed a rule which made the Franciscan nuns practically a species of unduly strict Benedictines, St. Francis's special characteristics being eliminated. St. Clare made it her life work to have this rule altered and to get the Franciscan character of the Second Order restored; in 1247 a "Second Rule" was approved which went a long way toward satisfying her desires, and finally in 1253 a "Third," which practically gave what she nanted. This rule has come to be known as the "Rule of the Clares"; it is one of great poverty. seclusion and austerity of life.

Most of the convents adopted it, but several clung to that of 1247. To bring about conformity St. Bonaventura, while general (1264), obtained papal permission to modify the rule of 1253, somewhat mitigating its austerities and allowing the convents to have fixed incomes. This rule was adopted in many convents, but many more adhered to the strict rule of 1253. Indeed a countertendency toward a greater strictness set in, and a number of reforms were initiated, introducing an appalling austerity of life.

POOR LAW. This term denotes a particular system of giving alms to the destitute. To give alms had been recognized as a moral and ecclesiastical duty at least from the establishment of the Christian Church, but a poor law, in the sense of a secular and legal obligation to relieve destitution, was the creation of the 16th century. Though the secondary causes of this development were many, they were all basically connected with the breakdown of the mediaeval economy and social structure of western Europe, which both destroyed the traditional framework of charity and produced new types of poverty.

ENGLAND AND WALES

In mediaeval England poverty had been largely due to an underdeveloped economy in which famine and pestilence were recurring phenomena. By the beginning of the 16th century this kind of destitution was giving place to the "dearth in the midst of plenty" which so perplexed contemporaries. Enclosure for pasture was blamed for causing unemployment, depopulation and vagrancy. The rising price level, resulting from a complex combination of the influx of treasure from the new world and the disastrous monetary debasements of Henry VIII and Edward VI, was popularly attributed to the mania for sheep farming. The breakdown of the mediaeval rural economy. deplorable as it seemed to contemporaries, must not be exaggerated; the areas affected by enclosure for sheep were very limited. It was the expansion of the woollen industry, with its close dependence on foreign markets, which was often responsible for this kind of unemployment. The cycle of boom and slump had come to add a new permanent element of instability to the economic life of England. Of less importance in the creation of Tudor poverty is that cause which has loomed so large in early accounts of the origin of the poor law, the dissolution of the monasteries. By 1536 many of these were too embarrassed financially to do more than relieve the local beggars their presence attracted, while the legend that hordes of monks and nuns were turned adrift to beg their bread has not been substantiated by later research.

This new type of poverty was not confined to England; it was appearing in all the more economically advanced countries of western Europe. It is customary to attribute the pattern of early Tudor legislation to the influence of Juan Luis Vives' De *subventione pauperum* sive de *humanis* necessitatabus, published in 1526, and to the experiment of dealing with poverty by municipal action undertaken at Ypres in 1525, an account of which appeared in an English translation in 1535, but foreign influences may have been overestimated; similar causes were everywhere likely to suggest similar remedies. That the crown evinced any interest in the destitute was attributable to politics not compassion. Vagrants spread disaffection and might provide the raw material for a rebel army. The early efforts of the government, therefore, were directed to stamping out vagrancy. The relief of poverty was left. with some general directives, to local authorities. The first statute dealing specifically aith poor relief was that of 1531, which merely empowered justices to license aged and impotent persons to beg within their own neighbourhood. The interlocked problems of destitution, unemployment and vagrancy seem to have been under discussion in 1535, as in that year draft proposals outlined revolutionary suggestions for dealing with them, including the employment of the able poor on public works and the setting up of both central and local administrative machinery. The statute of 1536, as finally passed, was less drastic and concentrated largely on the organization of voluntary funds for the relief of those unable to work. Despite its lack of administrative machinery, it, like the previous draft, illustrates the new approach to the problem and for this reason is often regarded as the first English poor law. In line with coptinental opinion it prohibited begging and indiscriminate charity, and attempted to classify the poor into the aged and impotent needing relief: and poor children who should be apprenticed. In practice, lacking administrative machinery, it could be put into effect only where the municipal authorities had the organization to finance and implement its provisions. It was towns such as London, Norwich and York that were confronted with turning theory into fact.

In this London took the lead. A serious attempt to deal with the City's poor soon showed that funds provided by voluntary contributions were insufficient and in 1j47 the corporation decided to impose a compulsory poor rate. This was a momentous step forward; it introduced a new administrative device of the greatest importance and broke decisively with the mediaeval conception of charity as a religious duty. Other expedients of an equally modern character followed rapidly. By 1553 a comprehensive scheme for the treatment of the poor was in existence. They were now classified as the poor by impotency, the poor by casualty and the thriftless poor. and appropriate institutional treatment was to be provided, as far as resources would allow, for each group. Similar programs were initiated by other cities, particularly those nhose connection with the fluctuating fortunes of the woollen industry increased the instability of employment. By the end of the 1j70s many of them had evolved workable schemes based on classification, some measure of institutional treatment and compulsory rates.

Before 1572 the state provided little legislation to underpin this system and it looked as if the relief of poverty would become the responsibility of the towns rather than of the nation. Indeed a characteristic feature of the English poor law is the way in which national legislation followed! rather than initiated, local experiment. This, until the adoption of the ecclesiastical parish as the unit of poor law administration, was dictated by the fact that the central authority had no etiective machinery through which to administer statute law locally. It was only in the sphere of providing funds, therefore: that a few fumbling advances were made by the acts of 1551–52 and 1563. Not until 1572 was a straightforward, compulsory rate imposed on a national scale. By then it was clear that the state would have to take a more active part in enforcing on local authorities some responsibility for destitution. The .same act also ordered the compilation of a comprehensive register of persons needing relief and instructed justices in rural areas and mayors in towns to appoint collectors and overseers. It also, like the earlier draft of 1535, recognized the fact that not all the unemployed were work-shy; local authorities were now encouraged to use funds left over from the relief of the aged, sick and infant poor to set the able-bodied pauper "on work" (*i.e.*, provide work for the able-bodied). In 1j76 this permission was transformed into compulsion. All local authorities were to provide funds for the purchase of raw materials for this purpose.

The "Old Poor Law" (1601).—The codification of 1597–98, re-enacted in 1601 with minor changes and finally made permanent in 1623, completed the first stage of the poor law (sometimes known as the "old poor law" in contradistinction to the "new poor law" set up after 1834). The parish was finally and decisively acknowledged as the normal unit of administration. This was entrusted to overseers, 'appointed. annually by the local justices and forced to serve under penalty of a fine, who, together with the churchwardens, were to assess and levy a poor rate on all householders which, when ratified by the justices, was compulsory. With these funds the aged were to be relieved and provided, if necessary, with cottages on the waste, poor children were to be apprenticed and the able poor set "on work." This codification was at once a synopsis of previous urban experience and a break with urban experiments, since the parish, a smaller but ubiquitous unit, was now the basis of the national system. Though later the parish was to prove too small, it is difficult to see what else could have been done. Experience had shown that poor relief confined to the towns put too heavy a burden on them and distributed rather than relieved destitution.

The subsequent period, from 1597 to 1644, is of fundamental importance in the history of the poor laws; in these years the privy council succeeded in building up an administrative hierarchy to make it effective. It is easy for the modern citizen to forget how great was the gap between enactment and enforcement in Tudor England and to assign to early acts a practical importance which they could not possess. After 1597 the exertion of pressure on the justices and the sending of directives became more frequent. Sometimes these took the form of general orders, such as those sent to all high sheriffs and courts of quarter sessions in 1598 to explain the new legislation, sometimes they were concerned with particular problems and were sent to individual authorities. Until 1622 this kind of pressure was irregular, being called into being in response to a sudden crisis, either local or national. The failure of the harvests in 1621 and 1622 and in 1629–31 apparently converted an occasional expedient into a regular routine. In 1631 the privy council applied the experience it had gained since 1597 in dealing with the regulation of supplies of grain in scarcity conditions to the oversight of the local poor law authorities. The system was both practical and detailed. The justices of each county were to divide themselves into groups. so many being responsible for each hundred. They were to hold monthly meetings with the churchwardens and overseers of the parishes within their respective hundreds, to punish neglect by these officers of their statutory duty and to report what had been done every three months to the high sheriff. These reports were sent to the justices of assize and finally submitted to the privy council. In this nay it was possible, at least in theory, for the central government to get a picture of the way in which the local authorities mere carrying out their tasks.

The general impression is one of real but geographically patchy success. Where the pressure of work was not great, or where local charity and endowments were adequate. or the parish remote and difficult to supervise, the poor, if assisted at all. were helped without much reference to the letter of the law. For example, the parish of Sawston in Cambridgeshire levied no regular poor rates until 1658. In contrast. where towns and cities had long been grappling with the problem, or in those rural areas where the justices were accessible to pressure, parishes seem to have been relieving the aged and sick. apprenticing their children and even complying with the obligation to have a "town stock" of raw materials with which to set the poor "on work."

With the outbreak of civil war and the determined attack of the Long Parliament on the coercive power of the privy council. the situation altered. Authorities were once again left to their own devices. The statutory obligations remained but the encouragement and oversight disappeared, not to return until the creation of the poor law commissioners in 1834. Nevertheless. the pressure of the previous 40 years was not without results. The habit of appointing overseers, levying rates, relieving the poor, had become something of a social tradition. It might not be well done, and the difficult task of organizing employment was often dropped, but the laws, far from falling into abeyance. were gradually extended into parishes and areas where earlier they had been little observed.

Parish Organization of Poor Relief, 1662–1795.—The next milestone in the history of the English poor law came a-ith the restoration of the monarchy. There was no attempt to revive the control of any central authority, but in 1662 the responsibility of each parish was defined by an act usually known as the Law of Settlement and Removal. Its preamble contained the statement that "by reason of some defect in the law, poor people are not restrained from going from one parish to another, and do therefore endeavour to settle themselves in those parishes-where there is the best stock, the largest commons or wastes to build cottages and the most woods for them to burn and destroy." To remedy this defect that act provided that any person coming into a parish who neither rented a house of the annual value of £10. which was a rental completely outside the economic resources of the craftsman or labourer, nor was able to give security against becoming a burden on the rates at any future time, could be moved back to his or her place of settlement within 40 days on application made by the overseers to two local justices for a warrant of removal.

There was nothing very new. except in the precise definition of the occasion and method of removal, in this act. The piecemeal legislation of the Tudors, before the final codification of 1601, contained assumptions that the right to relief was a local one, that parishes were entitled to some defense against an influx of strangers and need not relieve, might indeed even remove. "aged, lame or impotent persons" of less than three years' residence. Sixteenth-century municipal authorities had been zealous in removing persons likely to become chargeable. Norwich. which had stringent settlement regulations, for example, ordered one Jane Thornton to leave the city because she "in summer live in the countrie but in wint charge the citie." As E. M. Leonard observes, the act of 1662 merely "stereotyped a custom that had long been in existence in the towns." (See Bibliography.)

The legal basis for the custom however had never been clearly defined,wthough most communities seem to have felt that people had a right to relief only where they lived and were known. Charity both began and ended at home. Even so, why the task of definition should have been undertaken just when it was has been something of a puzzle to historians. The general upheaval and unsettlement of the years after the Civil War and interregnum is usually adduced as the most likely cause. The growth of population may well have been an additional reason. Many of the rural poor lived from hand to mouth, eking out what they could earn by exploiting the resources of the uncultivated, or waste, land which in most parishes was still unenclosed. Such families, clinging to the skirts of economic subsistence, were clearly a potential liability which no parish would want to assume, but with any marked increase in population, unless industry and trade were also booming, which was not the case in 1662, they were just the people who would drift to the more extensive wastes. It is at least arguable therefore that the act of 1662 was passed in response to an overflow of population beyond that which could be absorbed by the immediate economic resources of the country.

Whatever the reasons for its enactment, the act of 1662 with its subsequent amendments was thenceforth the hub around which the administration of the poor law revolved. In 1685 the original act was amended so that the 40 days' residence necessary to gain a settlement only began from "the time of his or her Delivery of a Notice in Writing of the house of his or her Abode, and the Number of his or her Family, if he or she have any, to one of the Church ardens or Overseers of the said Parish." In 1693 the regulations were further tightened by the stipulation that the notice in writing had to be read in the parish church at the time of divine service. After this there was little chance of a stranger's gaining a settlement without the consent of the general body of the ratepayers. In an attempt to make the act work in a reasonable way, the same statute also defined other methods of gaining a settlement. These were by serving an apprenticeship within the parish, by being hired as a servant for a year, by executing some parochial office for the same period or by paying parochial rates. In addition. women gained a settlement on marriage, and legitimate children took that of their father until they reached the age of seven, when they could acquire one of their own. Illegitimate children were settled where they were born.

Betneen 1662 and 1795, after nhich date no person could be removed until he was actually chargeable, the attempts of parish officers to take advantage of the settlement laws distorted almost every aspect of the poor lams except the granting of relief to those aged and sick paupers who were. beyond all doubt, the settled poor of the parish. Despite the condemnation of Adam Smith, the purely economic effect of this legislation appears to have been slighter than might have been expected. Some elasticity was given by an act of 1697. which gave legal sanction to the existing practice, by which parishes gave testimonials to parishioners seeking nork elseuhere, which nere. in effect, promises to take them back should they ever become chargeable. Moreover it was clearly impossible to remove every newcomer, particularly where there was a demand for labour. In practice, able-bodied men, so long as they took no steps to obtain a settlement by presenting a notice in writing rarelv seem to have been removed unless they were actually chargeable. Rural parishes appear to have concentrated on removing married couples, particularly those "overburdened with children." Single women, women with children and orphans were equally unpopular. In industrial areas where young and old could be employed, the family unit was less economically vulnerable. Here women, particularly those with children, were the main victims. In any case the changing distribution of the growing population of the 18th century make it clear that mobility cannot have been unduly restricted.

If the economic consequences of the Law of Settlement were not notably harmful, the social consequences can be more justifiably condemned. Apprenticeship, originally intended to give a child a start in life, was now often used to change its settlement. Children could be compulsorily bound out in their own parishes or, with funds provided from the poor rate, elsewhere. In this case no one questioned the suitability of the master or the trade selected. or the treatment the child reckived. In this matter the urban parishes appear to have been the chief offenders. The result was many runaway apprentices and much misery. Another unfortunate result was the restriction on the building of new cottages, which led to overcrowding and the retarding of marriage. Unmarried mothers were treated with great harshness. An act of 1576 had made it an offense to beget an illegitimate child which was likely to become chargeable, and the father, if known, could be forced to give security "to save the parish harmless." Little proof beyond the woman's oath was required, and many men, guilty or innocent, found refuge in flight. In·such cases the overseers, faced with the responsibility for the child, forced or bribed the woman to take to the roads. Yet whether this widespread distortion of the poor laws really saved parish funds may well be doubted. Removals were expensive and often contested at quarter sessions; sometimes they were taken on appeal to higher courts. Moreover, though each parish struggled to save itself expense, it was in turn the victim of similar practices on the part of other parishes.

The best-administered part of the poor law appears to have been the relief of those aged and sick persons who were unquestionably settled inhabitants. Indeed, care had to be taken to keep this kind of relief within bounds. After 1693 none was to be given, except in case of emergency, without the authority of a justice, the names of such persons to be entered in a book and reviewed annually. Paupers whose claims were allowed received small monthly pensions, though by the act of 1697 they were ordered to wear a large red or blue P on their outer garment. Often their rent was paid and they got occasional gifts of fuel and clothes. Sick paupers were looked after, medical attention that ranged from a bonesetter to the local doctor was provided, and, if death followed, the parish paid funeral expenses.

The obligation to set the poor "on work" was perhaps the most difficult of all the burdens placed on the parish by the act of 1601. To manage a parish stock at a profit was well-nigh impossible. Municipal experiments on the lines of the London Bridewell tended to peter out, while the houses of correction, which an act of 1607 ordered to be set up in every county. were increasingly regarded as penal establishments for the idle rather than as places of employment. Because of the difficulties involved once the oversight of the privy council disappeared the first phase of the attempts to employ the poor came to an end in 1644, though town stocks for this purpose lingered on in some places. After the Restoration the increasing interest taken in political economy refocused attention on this failure to employ the poor. Emphasis was now placed on the loss to the national income sustained through the waste of labour, and many pamphleteers, among whom were John Bellars, Richard Haines and Thomas Firman, outlined schemes for the organization of corporations to employ the poor on a commercial basis. For this purpose stock was to be subscribed and workhouses erected. For the most part they remained on paper, being quite impracticable, but John Cary started a new chapter in poor law history when he persuaded the Bristol parishes to apply for a local act to set up a "Corporation of the Poor" in 1696. This was to be responsible for the poor of the entire city and provide employment for them in a well-run workhouse. At first the experiment appeared successful, and Bristol's example was followed by other towns. These early hopes were not maintained, but. though commercially unprofitable, the workhouse was discovered to have a useful deterrent value. In consequence in 1723 a permissive general act allowed parishes to build and manage workhouses and to refuse relief to those who would not enter them. Though useful in keeping down the poor rate, such workhouses made no effective contribution to setting the poor on profitable work.

Whether the original purpose for which individual workhouses had been promoted had been to punish the idle, deter applicants for relief, house the sick. aged and infant poor or provide work for the able-bodied. they everywhere rapidly degenerated into mixed receptacles of misery where every class of pauper, vicious or unfortunate, young or old. sick, well or lunatic, was dumped. Sometimes they were managed by parochial officials, often they were let out to contractors, either for a lump sum or on a capitation basis. Many parishes fluctuated from one method to the other but neither led to any satisfactory employment of the poor.

Meanwhile the growing humanitarianism of the 18th century was increasingly troubled by the abuses of the general mixed workhouse. At the same time the inadequacy of the parish as a unit for poor law administration was becoming apparent, partly because, particularly in the towns, it was too small for effective action, partly because its unpaid, annually appointed, untrained officers were either lazy or corrupt. Indeed, some parishes, though without legal sanction, were already employing a salaried overseer. In these circumstances Thomas Gilbert promoted the act known by his name in which, in 1782, parishes were permitted to unite for the purpose of building institutions to house all classes of the destitute, except the able-bodied. For these the overseers, in vague terms, were directed to provide relief or work outside the house. This meant a complete reversal of earlier policy in a revulsion from its failure.

Speenhamland System (1795).—Between 1782 and 1793 postwar depression, poor harvests, the frictional unemployment caused by agricultural developments and the early stages of the Industrial Revolution combined to make life difficult for the labouring poor. In many cases wages were traditional and bore little relation to changing conditions. Yet, to men steeped in mercantilist thought, to raise wages to meet what, to contemporaries, must have seemed a temporary crisis appeared plain folly. It had long been the practice to help poor men "overburdened with children" by making them some allowance from the parish. In the same way temporarily soaring prices, caused by a failure of the harvest, were commonly met by ad *hoc* emergency relief measures rather than by raising wages. In line with this tradition the justices of Berkshire. meeting at Speen in 1795, decided that wages below what they considered an absolute minimum should be supplemented by the parish in accordance with the price of bread and the number of dependents a man had. Their example was widely followed and the practice received parliamentary confirmation in 1796. Yet another phase of English poor law history, the so-called Speenhamland system, had begun. (D. Ml.)

The word "system" is misleading, for the Speenhamland decision was a makeshift, grounded in existing social theory and practice, rather than a deliberate proposal for a general poor law policy. Even in Berkshire itself. the decision did not result in any substantial changes in local administration. Parishes continued to maintain their own workhouses, to give or withhold casual relief, to distribute cheap food and to fix bread prices. During the Napoleonic Wars, however, there was a great extension of the allowance system. or various types of allowance systems, in the southern counties of England, and contemporaries found it convenient to describe the extension as part of one general process. Most histcrians have agreed with contemporary critics that the spread of the allowance system was "momentous" and "disastrous."

The "system" had three possible abuses. First. it might lead to the subsidization of wages out of the poor rate. In The State of *the* Poor (1797), Sir F. M. Eden claimed that the larger farmers were able to take advantage of the magistrates' benevolence by forcing the smaller ratepayers, who were not themselves employers of labour, to augment wages. The charge may have been exaggerated, for some tenant farmers were able to pass on the increase in poor rates to their landlords, but such a transfer was not general and did not prevent the poor rate from becoming a redistributive tax. Second, it might entail the general pauperization of large numbers of employed workers on the land. Opponents of the system argued that it made the poor careless and indifferent, checked their incentive to save, encouraged improvident marriages and engendered a large increase in population which. according to Malthusian theory. would inevitably create a new mass of poverty. Some opponents even went so far as to argue that any legal system designed to alleviate poverty was a threat to the well-being of the recipients of relief; as Thomas Chalmers put it. "the system which was working this mischief assumed to be founded on benevolence, but no evil genius could have designed a system of greater malignity for the corruption of the race." Third. it sharpened the contrast between industrial north and agrarian south and perpetuated the division of the labour market into two sectors, the one depending upon a contractual wages system. the other depending upon status and protection. Controversy centred around these points not only during the Napoleonic Wars but also in the period after 1815, when agrarian discontent was accompanied by industrial expansion.

Between 1815 and 1830 contemporaries were mainly concerned, however, with the burden of poor law expenditure, particularly in the area south of the Wash-Severn line. In 1785 the total cost of poor law administration was a little less than £2,000,000; by 1803 it had increased to a little more than £4,000,000; and by 1817 it had reached the total of almost £8,000,000. This final figure represented a cost of about 13*s*. 3*d*. per head of the population or about one-sixth of total public expenditure. Although the total fell a little in the subsequent 15 years, it did not fall as much as the price level, and in 1832 it stood at about £7,000,000, or 10*s*. per head of the population. Some parishes were particularly affected by the burden. One Buckinghamshire village, for instance, reported in 1832 that its expenditure on poor relief was eight times what it had been in 1795 and more than the rental of the whole parish had been in that year. In face of statistics of this kind, the Whig government decided to intervene, and in the year of reform, 1832, a royal commission was appointed to inquire into the whole "system." Its recommendations served as the basis of the reforms which were embodied in the Poor Law Amendment act. 1834.

New Poor Law (1834).—The new act was not merely a return to severity after a period of benevolence; it was inspired by new principles and set up new administrative machinery. Its guiding rule, strongly influenced by the theories of Benthamite political economists, was that poor relief should be granted only to able-bodied poor and their dependents in sell-regulated workhouses under conditions inferior to those of the humblest labourers outside. As the commissioners had argued "every penny bestowed that tends to render the condition of the pauper more eligible than that of the independent labourer is a bounty on indolence and vice." The machinery also was Benthamite. The hitherto independent parishes were grouped into unions, each under an elected board of guardians. with a strong central authority—the Poor Law commission—to enforce a uniform policy.

On paper, the act of 1834 introduced order into the poor law system; in the words of Nassau Senior, one of its chief architects, it was "a measure of social policy." Poverty was considered a crime, which merited a stigma, and the poor were poor not because Providence had ordained them to be so but as a result of their onn failings. Such a harsh philosophy, which was sharply criticized by traditionalists and helped to rouse the Chartist movement, was nonetheless better suited to the mood of an industrial age than Speenhamland. One of the purposes of the act was to stimulate free trade in labour by driving workers onto the labour market The abolition of outdoor relief was intended to provide an incentive to workers to seek regular employment. Unfortunately however, when the poor law commissioners attempted to apply the act in the north of England in 1837, there was much genuine industrial unemployment.

The inadequacies of the act were demonstrated very clearly during the subsequent 30 years. The first and most dramatic crisis in its administration came in 1847 at Andover. The workhouse there was so efficient in applying the principle of less eligibility (*i.e.*, that the condition of the poor should be made "less eligible" than that of the labourer) that labourers were willing to accept as little as js. or 6s. a meek rather than enter the workhouse, but work conditions imposed on inmates were intolerably cruel. A committee set up to investigate conditions at Andover condemned its internal administration and led to the setting up of a new Poor Law board (1847). directly responsible to parliament, in place of the Poor Law commission. The president of the board was now eligible to sit in parliament. Some improvement in workhouse conditions followed the Andover scandal, but in 1852 an experienced lawyer, Robert Pashley, maintained that "a single English workhouse contains more that justly calls for condemnation in the principle on which it is established than is found in the very worst prisons or public lunatic asylums that I have ever seen. The workhouse as now organized is a reproach and disgrace peculiar to England: nothing corresponding to it is to be found throughout the whole Continent of Europe."

There was an inevitable reaction in the middle of the century against the excessive harshness of poor law administration. The attempt to treat as one group all. children, women and men in need of assistance was bound to create social as well as administrative difficulties. To place under the same stringent discipline the young, the sick, the aged and the able-bodied proved as much of a strain to the administrator as it was a grievance to the poor themselves. The new poor law, in consequence, became almost as subject to local variation as the old poor law of the 17th and 18th centuries. In many parts of the country it proved impossible totally to abolish outdoor relief; in other parts, separate poor law institutions were created for the young and the sick; and in some districts, boards of guardians continued to pay small weekly doles to old men and women incapacitated from work. Such signs of "sentimentalism" were bitterly attacked by the faithful supporters of the principles of 1834. The development of democracy. however, associated as it was with the growth of humanitarian feeling. and, after 1880, the discovery of more scientific methods of dealing with destitution, helped to mitigate the harshness of poor law administration.

The extension of the franchise in 1884 was an important turning point in the approach to the poor. From that date onward a move away from the principles of 1834 can clearly be traced. In 1891 supplies of toys and books for workhouses were permitted; in 1892 tobacco and snuff could be provided; in 1893 visiting committees of ladies were allowed to inspect the workhouses; in 1894 guardians were given the right to distribute dry tea. milk and sugar for women to make their own afternoon tea; in 1897 trained nurses could be employed for the care of the sick poor; and in 1900 a government circular. recommended the grant of outdoor relief for the aged of good character.

In addition to these deviations from the principle of less eligibility, changes were made in the fiscal and administrative machinery for supervising the poor laws. In 1871 the Poor Law board was abolished and central authority passed directly to the Local Government board. The new body was as much concerned as the old one had been with fiscal surgery as nell as social policy, and throughout its existence it emphasized the most important social bulwark of 1834, the assertion that poverty deserved a stigma. Men and women in receipt of relief under the poor law were not only subject to a special discipline and compelled to wear pauper uniforms as a symbol of their inferiority; they were robbed of their civil and political rights, including the right to vote. The poor law treated the claims of the poor not as an integral part of the rights of the citizen. but as an alternative to them—as claims which could be met by society only if the claimant ceased to be a full citizen of the community. It was not until 1918 that the pauper disability of disfranchisement was removed, and even after that signs of the stigma still remained.

The changed approach both to poverty and to the poor law began with a new inquiry into the facts of destitution in the last 20 years of the 19th century. Charles Booth's *Life and Labour of the People in London,* the first volume of which was published in 1889, was the first great landmark. It was followed by other important books, such as Seebohm Rowntree's *Poverty: A Study of Town Life* (1901), which gave a new precision to the concept of poverty. Further evidence collected by official committees, particularly the Royal Commission on the Aged Poor, which reported in 189j, helped to direct attention both to existing practices and to basic presuppositions about the poor. The way mas prepared for setting up the Royal Commission on the Poor Laws in 1905.

Reports of the Royal Commission, 1909.—Unlike the commission of 1832. that of 1905 was not the outcome of any sustained agitation or vociferous opposition to the existing structure, nor did its members start with any common theory to apply to the contemporary situation. "There is no one directing purpose shaping the enquiry to a pre-determined end," wrote Beatrice Webb, one of the members, in the middle of the deliberations, "which of the many conflicting or diverging purposes will prevail remains to be seen." But the commission included many experts in dealing with the poor. Some. like Sir Charles Loch, had experience with both poor law and voluntary charity; some, like Charles Booth, Helen Bosanquet and Beatrice Webb herself. had been leaders in social study and research; others, like George Lansbury and Francis Chandler. were representatives of the new labour upsurge as well as experienced guardians; and finally there was Octavia Hill, who had done more than any other woman for the welfare of the London poor. If these distinguished members of the commission had been unanimous, they would, said Canon S. A. Barnett, have been invincible.

In fact no single purpose prevailed and t o reports were produced by the commissioners. The majority (16) recommended that the boards of guardians should be replaced by statutory committees of the county and county borough councils (which had been set up in 1888), and that the neu committees should be called "public assistance authorities" with a number of subordinate public assistance committees working under them in subareas. More important. the general workhouses should be abolished and different classes of the destitute should be relieved in specialized institutions. The able-bodied poor should, as far as possible, be found work, but outdoor relief could be provided after strict inquiry, under supervision and on a uniform basis.

The minority (four) were not content with this retreat from the principles of 1834. They argued that the poor law system was fundamentally bad. It was the business of the community to try to prevent destitution and not merely to palliate it when it occurred. In consequence, the poor law should be broken up, and in its place the state and the local authorities should provide specialized social services to deal with separate categories of poor people. Already administrators had been compelled to note the existence of the sick. the feeble-minded, the aged and pauper children as well as the able-bodied. Now the able-bodied should be placed in charge of a national unemployment authority and the other categories should be transferred to the appropriate local authorities.

Both majority and minority expressed themselves strongly against the views of the surviving supporters of 1834. particularly J. S. Davy, the principal officer of the poor law division of the Local Government board. There mas a remarkable measure of agreement in the condemnation of the past and the assessment of the present. There were two distinct views of the future, however, each of which was to prove influential. The minority report, drafted with skill and driven by passion, advocated optimum social services maintained by specialists, the boundaries of whose activities would be set by the boundaries of perfection in their own expert techniques. In the middle of the picture would be a registrar of public assistance for each local authority, co-ordinating the various schemes. The majority report, building on the social situation as it existed in 1905, was more concerned with minimum social security than with the optimum, and more conscious of the continued role of voluntary action, maintained by an army of trained general or family caseworkers. If the minority report seemed to point more clearly toward the welfare state, it was opposed to the insurance principle on which the welfare state was to be constructed.

Welfare Legislation and the **Poor.**—No action was taken in 1909 to implement the proposals of either the majority or the minority reports, although Beatrice Webb set up the National Committee for the Promotion of the Break-up of the Poor Lam, and Lord George Hamilton created an alternative National Poor Law Reform association. The first was renamed the National Committee for the Prevention of Destitution, and bitterly attacked not only lack of food, clothing and shelter but also the social degradation and "the moral malaria" of an acquisitive society.

The government did not respond to the arguments of this agitation and within the poor law structure itself undertook merely a mild so-called "revolution by administration" under the direction of John Burns, the president of the Local Government board. It did, however, herald a genuine revolution in welfare policy outside the poor law. The Provision of Meals act, 1906, empowered local authorities to supply meals in elementary schools to certain children; the Old Age Pensions act, 1908, provided pensions for the aged without their being punished "by the loss of political rights or the stigma of pauperism"; the Trade Boards act, 1909, regulated squalid conditions in the labour market; the Labour Exchanges act of the same year set up important new institutions designed to reduce local unemployment; and, above all, the National Insurance act, 1911, provided sickness and unemployment benefits on a contributory basis to a selected group of industrial workers. Insurance was extended in 1920 to include large numbers of additional workers. As a result of such piecemeal legislation, the place of the poor law as a relief agency was completely changed. Even during 1909 David Lloyd George, the radical chancellor of the exchequer, exclaimed in introducing his controversial budget, "this is a war budget for raising money to wage implacable warfare against poverty and squalidness. I cannot help believing that before this generation has passed away, we shall have advanced a great step towards that good time when poverty, and the degradation which always follows in its camp, will be as remote to the people of this country as the wolves which once infested its forests." This was a very different 'approach to the poor from that of the 18th and 19th centuries.

Breakup of the Poor Law.—Although new welfare proposals of many kinds were adopted, it was not until 1929 that the Local Government act implemented the main recommendation of both the 1909 reports by replacing the boards of guardians by local authorities. The number of authorities responsible for poor relief was thus reduced from 642 to 145. The Poor Law act, 1930, consolidated previous legislation. The minister of health was charged with the central direction and control of all matters relating to the administration of poor relief; in the localities, to deal with relief problems, most authorities appointed separate public assistance committees, consisting of elected members of the council plus (optionally) a number, not exceeding one-third of the total, of persons co-opted from outside the council. In addition there were subordinate guardians' committees for appropriate workhouse areas in the counties, although they had no power to appoint or dismiss officers without the approval of the public assistance committees. The chief local administrator of the poor law was the public assistance 'officer, who in some cases was also the clerk of the council. He was assisted by the district relieving officer, the direct descendant of the Elizabethan parish officer.

The reforms of 1929 and 1930 were secured only after a period of prolonged inquiry. In 1917 the ministry of reconstruction had set up a committee. under the chairmanship of Sir Donald Maclean, to reconsider the 1909 suggestions. The committee, which included representatives of both the majority and the minority of the 1905 commission, confirmed the earlier sentence of death on the guardians, recommended the transfer of their powers to local authorities and urged the extension of specialized services for special groups, such as the sick and the mentally deficient. Although these proposals were approved by the government and pledges were given that a bill to reform the poor law would be introduced as soon as opportunity offered, nothing was done. Even after the newly founded ministry of health had taken over the functions of the Local Government board in 1919, no reforms were introduced. It was not until 1925 that Neville Chamberlain, the Conservative minister of health, began to implement suggestions generally approved by experts and public alike.

In the 1920s, however, the administration of the poor law had entered on a new and alarming phase. An industrial depression, which had begun in 1920, resulted in a rapid and unprecedented increase of industrial unemployment. Trade-union funds, private savings. insurance benefits and relief works proved inadequate to meet widespread distress. Successive governments failed to meet the challenge of the situation, and. to their sharpest critics, even seemed to be encouraging recourse to the poor law in order to shift as much as possible of the cost of relief from the national taxes to the local rates. Before long the boards of guardians in the worst areas of distress were overwhelmed with applications for assistance, and by June 1922 nearly 2,000,000 persons—or about 1 in 21 of the population—were in receipt of poor law relief. In some unions the proportion was one in five. Despite a short-term recovery, there were pockets of large-scale unemployment in many districts throughout the 1920s, and in 1926, as a result of the coal dispute. there were 8 unions with a third and 14 others with a quarter of their populations in receipt of relief. In two unions, in particular weeks, mare than 50% of the population were paupers. The size of the poor rate reached an alarming figure in many of the crowded industrial districts. On Tyneside, for example, in 1926–27 the Gateshead poor rate was 11*s.* in the pound. Such a heavy burden meant that guardians in badly hit unions with low ratable value were compelled to borrow large sums, thereby further saddling the rates.

In some unions, the rise in poor law expenditure was not the result of fluster, as the parsimonious suggested, nor even of grim necessity, as some of the humanitarians suggested, but of design. Certain boards of guardians deliberately adopted the policy of granting outdoor relief on such a generous scale that there could be no pretense of making the lot of the pauper less eligible than that of the independent labourer. The guardians at Poplar. dominated by a Socialist majority, had long favoured this policy; in the 1920s, however, there was a more general spread of "Poplarism." The Poplar Borough council took the desperate course in 1920 of refusing to collect the rates for the London County council and certain other central bodies. Legal proceedings were taken and the high court ordered the collection of the rates. The borough council ignored the order and 29 of its members were imprisoned for contempt of court. Their imprisonment put the government in an awkward position and forced it to concede the legislation which Poplar had been demanding. The Local Authorities (Financial Provisions) act of 1921 provided for a large measure of equalization of poor rates in London: in particular it laid down that the cost of outdoor relief should be borne by a metropolitan common poor fund within the limits of a scale to be fixed by the minister of health. The fixing of a scale in Jan. 1922 did not satisfy the Poplar guardians. They pressed for a loan, and there was a special inquiry by the government into the circumstances of their case. The report uhich followed was unfavourable to the guardians. and declared that by more economical methods £100.000 a year could be saved. A conflict of principle as well as a financial question was at stake in this dispute. The Poplar guardians insisted that it was not only the right but the duty of the guardians to give adequate relief; the minister retorted that the Poplar conception of adequacy was extravagant and inflated. In 1922 the minister issued a peremptory order applicable to the Poplar union alone, providing that no relief to an able-bodied person or his family in excess of a scale laid down by him should be legal unless he specially sanctioned it. The guardians defied this order and in consequence were heavily surcharged by their auditors, but successive ministers of health were unable to enforce the order, which was finally withdrawn in 1924. Other boards of guardians continued to favour Poplarism and pursued a persistent guerrilla warfare with the ministry of health.

In 1925 the msin scene of the struggle shifted to West Ham, where the guardians, already £2,000,000 in debt, asked for a further loan of £350,000. The treasury and the ministry of health insisted on certain restrictions as a condition. The guardians refused to accept the conditions and, although they eventually yielded to threats, the struggle was not settled and finally they refused to amend their scales. This time the government took decisive action. Under a new act, the Boards of Guardians (Default) act, 1926, the minister superseded the West Ham guardians and handed over their functions to three paid administrators, nominated by himself. Under the new regime the number of outdoor paupers fell sharply, as did average expenditure upon them. The Default act was applied in other areas and succeeded in directing attention to the necessity of a general reform of the system. The basic reforms of 1929 and 1930 were secured only as a result of this bitter controversy.

Great Depression. — The passing of the new legislation coincided with an alarming increase in the number of unemployed and the darkest period of industrial distress in the whole of English history. For the three years 1931–33, the annual average total of unemployed workers was 2,785,000, the equivalent of one worker in every five. In face of this. the insurance scheme broke down, and for six years. from Oct. 1931, less than half the unemployed qualified for insurance benefit.

The financial and political crisis of 1931 was followed by drastic action to cut expenditure on the poor. *Ex gratia* benefits to those whose insurance rights had become exhausted were stopped, and the administration of state-financed relief for the off-insurance unemployed was handed over to the poor law authorities, who proceeded to apply more or less rigid means tests. In consequence the number of able-bodied persons on poor relief increased from 43,000 in the autumn of 1931 to 220,000 (with 440,000 dependents) at the end of 1934. Eventually, after a period of great confusion, a new state agency, the Unemployment Assistance board, was set up in 1934 and began to administer all state relief for the unemployed in Jan. 1935. The new board was an ad *hoc* body consisting of a chairman, a deputy chairman and three salaried part-time members. Its 300 local offices administered relief in accordance with a fixed scale of assistance, based on a household means test, and its area officers were given strict instructions to maintain uniformity. Inevitably this form of administration implied remoteness from an understanding of the real needs of the poor. Nonetheless the setting up of the board was an important step in the breakup of the poor law.

The breakup of social policy could be discerned in many areas. In the 1930s many groups of persons, of whom the unemployed were the most important. were being dealt with not by the poor law but by other welfare agencies. The Blind Persons acts, 1920 and 1938, for example, laid down that the blind were to be treated separately. As groups of this kind were separated from poor law jurisdiction. the public assistance committees of the local authorities became residuary legatees of the expanded but inadequate system of social services rather than agencies dealing with the poor as a whole. Their functions were miscellaneous rather than coordinated. The most important were to provide public assistance pending aid from other sources; to supplement amounts received from other sources) such as widows' pensions, workmen's compensation grants and national health insurance benefits; to grant assistance to those able-bodied persons who were not covered by national insurance legislation; to aid residual classes, such as widows not entitled to pensions, feeble-minded persons not requiring institutional treatment, dependents of imprisoned persons, dependents of persons admitted to hospitals or mental institutions and deserted wives and children; and, above all, to assist the sick poor. The National Health Insurance acts provided inadequate benefits, in respect of both size and duration, even for the insured person; more seriously they made no provision for dependents or for the chronically sick. Public assistance was essential, even though it was still frequently associated in the public mind with the stigma of pauperism.

The constant shrinkage of poor law functions and their replacement by services founded on a more popular basis made it increasingly difficult to justify the more archaic parts of the public assistance system or to resist the political pressure to abolish the poor law altogether.

***Abolition* of the *Poor* Law and Establishment *of the* Welfare State.**—World War II gave a powerful impetus to the demand for comprehensive social security in place of *ad hoc* services, supplemented by public assistance. At the same time the phrase "social welfare" began to be used more generally. The mood was caught in a sentence of the Ttmes in July 1940: "if me speak of democracy. we do not mean a democracy which maintains the right to vote but forgets the right to work and the right to live."

During the war many social services which had previously been tainted with the flavour of the poor law, such as the school meals service, became services for all. The Unemployment Assistance board dropped the word "unemployment" from its title in 1940 and was given the task of administering a new supplementary pensions scheme for old persons and widows over 60. Other relief services were handed over to it between 1940 and 1945, and by the end of the nar it was mainly concerned with widows and old persons rather than with the unemployed, who had in any case fallen to a minute fraction of the working population as a result of wartime full employment. In 1941 its household means test was abolished and was replaced by a more generous personal means test; at the same time various improvements were introduced in its allowance scales. The revelation that large numbers of persons who had been qualified for public assistance had not taken and were not taking advantage of it exposed the unpopularity of the surviving poor law structure. The deterrent element implied in the act of 1834 had left a powerful impression on opinion.

More important than the changed position of the Assistance board was the drafting of a comprehensive scheme of social insurance by Sir William (later Lord) Beveridge in 1942. It was based upon the conception that it was the duty of the state — in collaboration with the individual — to provide income-maintenance for all those families whose normal incomes had been interrupted, or were likely to be interrupted, by social contingencies outside their control. The notion of comprehensiveness or universality marked the greatest single departure from the old conception on which the poor law had been based. The poor as a whole were no longer to be treated as an inferior group within the nation, but rather as individuals and families whose interests were inextricably bound up with the interests of the whole community. The plan marked the end of the concept of divided citizenship.

In 1943 the government accepted the main outline of the Beveridge proposals, and in 1944 it published its own white paper setting out official plans for future social insurance and assistance. It stated clearly that "in a matter so fundamental" as social security "it is right for all citizens to stand in together, without exclusion based upon differences of status, function, or wealth." In 1944 the ministry of national insurance was set up. various legislative measures followed, and in 1948 a new National Assistance act achieved the final break with the old poor law.

The new system mas based upon a blend of insurance and assistance. Insurance. paid for by individuals, employers and the state, was supplemented by direct assistance from the state to persons whose needs were outside the scope of the contributory scheme and to those whose needs could not wholly be met by statutory benefits. Because of the continued rise in prices and the difficulty of adjusting benefits to the cost of living, there was a greater resort to assistance than had been expected. In consequence, the Assistance board, renamed the National Assistance board in 1948, had an important task to perform.

It operated through 11 regional offices and 350 area offices in various parts of the country. In addition, advisory committees were set up to deal with such general questions as rent allowances, although not with individual cases. The variety of cases covered by the board was large, and the general objective was not only to provide financial assistance but to offerhelp "in such a manner as shall best promote the welfare of the persons affected by the exercise thereof." This criterion contrasts plainly with the criterion of 1834. Nonetheless, there was evidence that some persons were still unwilling to apply for assistance because the stigma of the poor law had not finally been removed. During the textile depression of 1952 some Lancashire workers showed reluctance to apply for "charity," as they still tended to regard it. The survival of such attitudes within a welfare state indicated the inadequacy of legislation to remould opinion in such a short period as a generation. *See* also IRELAND; IRELAND, NORTHERN; IRELAND, REPUBLIC OF; SCOTLAND: *Social Services;* SOCIAL SECURITY. (*A.* BRI.)

BIBLIOGRAPHY.—S. and B. Webb, *English Poor Law History,* vol. vii–ix of *English Local Government* (London, 1927–29); Sir G. Nicholls, *A History of the English Poor Law,* 3 vol., new ed., with 3rd vol. by J. Mackay (London, 1898–99); Sir F. M. Eden, *The State of the Poor,* 3 vol. (London, 1797); E. M. Leonard. *The Early History of Poor Relief* (Cambridge, 1900); D. Marshall, *The English Poor in the Eighteenth Century* (London. 1926); F. R. Salter. *Some Early Tracts on Poor Relief* (London, 1926); E. M. Hampson, *The Treatment of Poverty in Cambridgeshire, 1597–1834* (Cambridge, 1934); D. Marshall, "The Old Poor Law," *Economic History Review,* vol. viii, no. 1 (London, 1927); G. R. Elton. "An Early Tudor Poor Law," *Economic History Review,* 2nd series, vol. vi, no. 1 (London, 1948); W. A. Robson (ed.). *Social Security,* 3rd ed. (London, 1948); M. P. Hall. *The Social Services of Modern England* (London, 1952); R. M. Titmuss, *Problems of Social Policy* (London. New York, 1950); T. H. Marshall, *Citizenship and Social Class, and Other Essays* (Cambridge, 1950).

Official Publications: Report of the Commissioners for Inquiring Into the Administration and Practical Operation of the Poor Laws, 1834 (London, 1835); *Report of the Royal Commission on the Poor Laws and the Relief of Distress, Parliamentary Papers,* vol. 37 (London, 1909–13); *Report of the Local Government Committee of the Ministry of Reconstruction* (London. 1918); *Memorandum on the Rescission of the Poplar Order* (London, 1924); *Ministry of Health Provisional Proposals for Poor Laws Reform* (London, 1925); *Report on Social Insurance and Allied Services* (London. 1942); *Annual Reports* of the Poor Law commission, the Poor Law board, the ministry of health, the National Assistance board and the ministry of national insurance.

(D. ML.; A. BRI.)

UNITED STATES

Any discussion of the laws which relate to the relief of the poor in the United States is much complicated by the wide variety of law and practice among the various states, the many laws within states covering the different types of public assistance and the present involvement of the three levels of government—federal, state and local. Prior to 1933 there was no federal agency where comprehensive data could be secured covering state relief laws, their administration or relief expenditures and the number of persons assisted. After 1933 progress was made in the collection of data covering the country generally on various types of outdoor relief. In addition, many important special studies on phases of public welfare were made by various federal agencies.

HISTORY PRIOR TO 1930

State Laws.—Few states had a "poor law" in the sense of a comprehensive statute regulating relief to the poor and its administration before 1930. In many states the subject was dealt with briefly and fragmentarily in sections scattered through the general statutes. In some states, local provisions so modified state law that it was difficult to know what the law really was.

State laws were based largely on the early English poor law. They had been only slightly altered since enactment. with no reflection of changing social conditions and increasing understanding of social prohlems. The most important changes had been effected by taking away certain functions from poor relief officials and not by reorganizing and improving the poor relief system. Under laws largely concerned with the control of vagrancy and able-bodied pauperism. officials attempted to care for the sick, aged and infirm. dependent children. destitute families and in some cases the insane and mental defectives.

Responsibility for Care of the Poor.—The principle of responsibility for the care of the poor by some governmental unit was found in the laws of all states. The legislation tended to be permissive. leaving to the responsible authorities the decision as to whether almshouses should he erected and whether outdoor relief should be granted.

Administrative Systems.—In the New England states the townships cared for the poor. Later, a special poor relief official, the overseer of the poor. was given responsibility. Cities usually had the same responsibilities as the towns. In southern states the county was the governmental unit and poor relief was on a county basis. These two systems. or some combination of them, formed the basis for the administrative systems of all the states. the governmental form adopted in the states depending largely on the system in vogue in the state from which most of the settlers came. In about half the states all poor relief was administered on a county basis. In states having mixed administrative systems the relation of the city and town to the county was complicated and varied greatly from state to state. City charters usually placed the responsibility for the care of the poor on a special official or board, either elected or appointed.

Authorized Relief.—The laws of every state except New Mexico authorized the establishment of almshouses by some governmental unit, either the town, city or county. The law, except in two states, was permissive. Outdoor relief was authorized at the discretion of the poor law authorities. either by specific statement or by implication. As a rule. the laws dealt briefly with outdoor relief! regarding it as a temporary expedient, and tended to place greater emphasis on almshouse care. Medical care was authorized at the discretion of the poor law officials as a form of poor relief.

Eligibility for Relief.—Practically all laws had some definition of what sort of persons were to be cared for by public relief. In about three-quarters of the states, care was to be given to "persons unable to support themselves" or "all poor, indigent, and incapacitated persons." The laws of most of the states established the liability of the community for support of a needy person on the basis of "settlement." a required length of residence in the community. As a rule, legal settlement was acquired by residence for a stated time in the particular governmental unit without receipt of relief. The usual requirement was for residence of one year, though some states required as much as five or seven years. Settlement was generally considered to have been lost in a state by absence for one year from that state.

Liability of Relatives.—The laws of most of the states were based on the principle that relief should be given only when there were no close relatives liable and able to support their dependents. Occasionally grandparents and grandchildren were made liable, but usually only parents and children.

State Supervision.—While 43 states had some central board or department with some degree of administrative or supervisory responsibility relating to some phases of the care of the dependent classes, comparatively few such state bodies had definite responsibilities in regard to the supervision of poor relief. In about one-quarter of the states, state authorities inspected almshouses, received financial reports and made recommendations to local authorities. The recommendations. however, could seldom be enforced. There was even less supervision of outdoor relief. and comparatively few states had accurate figures on expenditures.

Development of Poor Relief.—At first, the poor were cared for by outdoor relief, by indenture of adults or children or by boarding out. As the number of poor increased, the practice grew of auctioning the care of the poor as individuals or as a group. The first almshouse was established in Massachusetts in 1660, but it was not until after 1700 that any great number were established. During the 18th century and the first half of the 19th century the almshouse came to be looked upon as the best method of correcting the abuses inherent in the earlier systems of aiding the poor at home. It soon became a catch-all for all types of persons for whom no other care was available, such as the sick, aged and infirm! children, insane, feeble-minded, vagrants, etc. The period from 1870 was characterized by a growing realization of the failure of the almshouse to care adequately for its varied type of inmates. By steady effort! specialized care was secured for many of these cases. In particular, laws were enacted forbidding the care of children in almshouses and requiring the removal of the insane and feeble-minded.

A report of the United States census on Jan. 1, 1923, showed that there were 78,090 inmates in almshouses, showing a decrease since 1910 when there had been 84.198 inmates. In 1923, 47 states had 2.183 puhlicly owned almshouses. representing an investment of $150,485,230. The annual maintenance cost of the publicly owned institutions was $28,740,523. About 88% of the publicly owned almshouses were directly operated by public officials. The other 12% operated under a contract system whereby the public institution and care of the inmates was given to a private individual on various terms. As to public outdoor relief, very little was known prior to 1930, since no general study had ever been made and few states had even accurate information as to the amount expended by local officials for this purpose. From figures available from a few states. it was evident that many more persons were being aided by outdoor relief than through almshouse care. The administration of outdoor relief was subject to great criticism which certain special studies justified.

Children. — Poor relief officials were originally responsible for all public care given to dependent children, but this function was taken away from them in all but a few states, chiefly during the years following 1900. The inefficiency of almshouse care and the inadequate care given by poor law officials to children resulted in the establishment of new agencies for the care of dependent children. such as county boards of child welfare, boards of children's guardians, county children's courts, county children's homes and state institutions. In all except a few states the poor relief officials came to have practically no responsibility for children cared for away from their families.

Special Types of Assistance. — The inadequacies of the poor relief system also gave rise to statutory provision for special types of assistance, now commonly called categorical assistance, usually administered by other than poor law officials. These types included assistance to veterans, widows' pensions or mother's aid and assistance to the blind and the aged. Relief to war veterans was the earliest type of special assistance. The first state statute providing mother's aid, now known as aid to dependent children, was passed in 1911. Major development in the field of assistance to the blind began in 1910. A law providing for old-age assistance was passed in 1914, but was declared unconstitutional; the next such statute was enacted in 1923. By 1930 there had been substantial growth in all the special types of assistance.

Poor Law Administration. — Faulty administration was undoubtedly the chief weakness of the poor relief system in every state. In only a few states was there any evidence of public interest in poor law reform. Instead, the tendency had been to transfer poor relief functions to agencies caring for special groups of dependents. Some changes made in state laws were in the direction of establishing the county as the unit of administration, as, for example. the poor law passed in Pennsylvania in 1925 and the public welfare law passed in New York state in 1929. The New York public welfare law, replacing a statute which had not been significantly changed for 100 years, embodied the modern philosophy which was to mark later legislation in the relief field.

(H. Fs.)

HISTORY AFTER 1930

When the depression of the 1930s began, the country had a poor relief system based upon programs which were almost entirely locally administered and locally financed. Assistance programs ior special categories of the needy unemployable groups, such as the aged, mothers of young children and the blind, were established in some states, often not on a state-wide basis. Needy persons who were employable had not been numerous, and they mere a responsibility of the local poor law officials. The depression brought about a rapid increase in the number of needy persons willing to but unable to find work. This put an impossible burden on local, especially municipal finances. The first shift to take place as a result of this increase was to state responsibility, because of the financial strain on local government and because the deterrent philosophy underlying local poor law aid was inappropriate ior dealing with mass unemployment.

By 1933 about hali the states had enacted temporary relief lams designed to provide state funds for relief purposes. The state laws generally established separate governmental agencies, even in those states with state public welfare departments. Although local officials retained authority to give assistance, the main burden of providing relief was carried almost entirely by the temporary agency.

Federal Participation. — As the number of unemployed increased to an estimated 15,000,000 in 1933, it became apparent that state resources were insufficient. Already, limited federal aid had been made available to the states in the form of loans (later cancelled) by the Reconstruction Finance corporation, a government corporation established in Jan. 1932 to stimulate economic recovery. In 1933 the Federal Emergency Relief act was passed by the congress and direct grants mere made to the states for unemployment reliei. The iederal government participated in the cost of both direct relief and work relief. The Federal Emergency Relief administration was liquidated in 1935 at the time the Social Security act was adopted, and no more grants mere made to the states for assistance to the unemployed.

Under related legislation, the federal government accepted responsibility for providing work for the able-bodied through the Works Progress administration (later renamed the Work Projects administration). Through the Social Security act, grants-in-aid were made to the states tor public assistance (a term which became more generally used than "reliei") to three groups of needy unemployable persons, the aged, the blind and certain dependent children. Other provisions of the Social Security act were designed to provide income to persons who, except for such income, might need public assistance. These provisions included insurance compensation for the unemployed and old-age insurance (later broadened in 1939 to include benefits to survivors of deceased workers). Thus in 1935 the iederal government adopted a comprehensive plan ior dealing with poverty and with some of its causes.

Effect of Federal Relief. — Federal aid for direct relief had a lasting effect on poor law systems in some states. Not only were assistance standards raised, but a more humane attitude toward the needy was established, medical care was recognized as an essential requirement and efforts mere made to obtain workers qualified by social work training to administer the programs. The Federal Emergency Reliei administration influence did not endure in other states. Direct relief was returned to the localities as soon as iederal funds were withdrawn and standards were left to the decision of the local poor law officials In the poorer states there was an especially severe drop in the standards of care and administration.

World War 11.—The period from 1935 to the beginning of U.S. participation in World War II was marked by the gradual strengthening of state public assistance programs, particularly in the special forms or categories of assistance established bv the Social Security act. During these years there was also a constant, and generally a losing, struggle to maintain the standards for general assistance. Old-age assistance, aid to dependent children and aid to the blind grew in size as more states set up programs, while general assistance rolls declined gradually because oi the transfer of eligible persons to the categories and the increase in work opportunities. The federal government continued to provide work relief for employable persons, although at no time during this period were all of the employable workers eligible for direct relief able to find employment on the WPA. In this period state general assistance (or poor relief) programs varied widely in size and adequacy depending on the traditions and resources of the states.

United States entry into World War II in 1941 brought about a dramatic decline in the number of persons requiring public aid. Federal appropriations for the work reliei program were reduced and then discontinued in 1943. State general assistance loads declined sharply, well below the most optimistic forecast, as a result of the great demand for labour. During the war the number of persons receiving the special categories of assistance under the Social Security act also declined somewhat. Although such persons mere generally unemployable, the high employment level meant that relatives who previously had not been able to assist the needy were now able to do so.

The end of World War II in 1945 mas felt almost immediately by the public assistance agencies administering the special categories ior the needy. The number of persons receiving old-age assistance and aid to dependent children began to increase at once. General relief case loads also increased but less markedly because the high level of employment that had prevailed during the war continued afterward. The increase in the old-age assistance and the aid to dependent children case loads reflected in part the increase in the number of the aged and the very young in the population, the two groups most likely to become dependent.

Public Assistance Under the Social Security Act.—AS stated earlier there were three public assistance programs established under the Social Security act, aid to the needy aged and needy blind and to certain groups of dependent children. A fourth category, aid to the permanently and totally disabled, was added in 1950. Federal funds were made available to the states on the basis of a state plan which must fulfil the requirements stated in the Social Security act. Under the provisions of the Social Security act, the plans must be state-wide in operation, and there must be state financial participation. By the mid-1950s all the states had programs for the aged and for the blind, all states hut one had programs for dependent children and all but eight states had programs for the disabled. These programs were also operating in the District of Columbia and in the territories of Hawaii, Alaska, Puerto Rico and the Virgin Islands.

State definitions of who is needy vary; some states are more exacting than others, for example, in the degree to which relatives are required to support the needy, or in the amount of property a person may hold and be considered needy. Nearly all states require periods of residence in the state, but the poor law concept of settlement is not permitted. Citizenship is required by some states. Assistance is available to persons in their own homes, and usually in private institutions and, with some exceptions, public medical institutions. Aid to dependent children is available only to children in their own home or in the home of close relatives.

In nearly all states one state agency administers or supervises the administration of all four programs. In some of these states that agency either administers or supervises the administration of general assistance also. In all but a very few of the counties in the nation there is a local office serving applicants and recipients.

General Assistance.— In a few states general assistance is administered by the same agency that administers the categories and with the same standards. Frequently, however, different and lower standards apply. In about half the states the general assistance program is locally financed and administered. Eligibility requirements and assistance standards may vary widely within the state. For this reason detailed iniormation about the program may be too scattered to he available. Although some emergency aid is available in nearly all localities, it is often meagre in amount and uncertain in duration. Many states give no assistance to the families of persons who are considered able to work. Residence requirements also are severe in some states, and familiar poor law concepts such as settlement are imposed. General assistance, probably because its importance has not been recognized by the federal government and because the group served has less public appeal than the persons in the federally aided categories, has never achieved status equal to that of the categories.

Relations Between Public Assistance and Social Insurance.— Some economic risks are being insured against under the social insurance system. The effect is to provide income to some persons who otherwise would have to be given public assistance. Even though the old-age and survivors insurance program had not reached maturity in the 1950s, it was significantly reducing the number of persons dependent on the various public assistance programs for support. The major risks against which social insurance protection had been adopted were unemployment, old age and premature death. Formerly these had been major factors contributing to dependency. Prolonged unemployment, disability, family breakup and illness continued to be uninsured risks. Social insurance benefits also were sufficient to meet the needs of only the average person and assumed that he had some other resources. Persons with special needs or with low benefits often needed supplementary help. Social insurance had been accepted as a way to reduce dependency. Much progress had been made, but the goal of a society free from dependency was still far from being attained in the 1950s.

Statistics on Expenditures and Case Loads.— Before 1933 there mere no even approximately complete figures on relief expenditure for recipients. Special studies, however, showed a slight but steady trend upward before 1929 and a sharp upward trend after that year. The predecessor agencies of the Social Security administration of the United States department of health, education and welfare started to collect data on assistance expenditure in 1933, although general assistance data were not entirely complete since they are based upon voluntary reporting by the states. These figures show that expenditures for outdoor relief (public assistance), federal, state and local, increased from $1,223,329,000 in 1933 to a peak of $2,540,009,000 in 1953. Expenditures for the special types of public assistance under the Social Security act reached a peak that same year when $2,337,297,000 was spent from all sources.

As of Aug. 1954 about 700,000 persons were receiving general assistance. 2,578,712 were receiving old-age assistance, 584,720 families totalling 2,093,499 individuals were receiving aid to dependent children, 101,458 received aid to the blind and 217,427 received aid to the permanently and totally disabled. Expenditures for that month totalled $220,879,000 for these groups. It is estimated that in the federally aided programs federal funds comprised about 56% of the total; the remainder mas state and local. In general assistance about 49% was state and the remainder local funds.

Assistance payments in Xug. 1954 averaged 552.43 a case in general assistance (ranging from $13.77 in Mississippi to $77.47 in New Jersey) ; $51.55 in old-age assistance (ranging from $26.41 in Mississippi to $82.76 in Connecticut); $85.07 per family in aid to dependent children (ranging from $26.05 in Mississippi to $135.85 in Wisconsin); $55.94 in aid to the blind (ranging from $25.90 in Alabama to $92.47 in Connecticut); $53.53 in aid to the permanently and totally disabled (ranging from $24.57 in Mississippi to $101.31 in Connecticut). (*See* also SOCIAL WELFARE; SOCIAL SECURITY.)

BIBLIOGRAPHY.—J. L. Gillin, *Poverty and Dependency,* rev. ed. (New York, 1926); *Study of a Group of Almshouses,* report of the Women's Department, National Civic Federation (New York, 1927); A. P. Miles, *Introduction to Public Welfare* (Boston, 1949); "Public Assistance" in *Social Work Year Book, 1954* (New York, 1954); S. P. Breckinridge, *Public Welfare Administration in the United States,* 2nd ed. (Chicago, 1938; Cambridge, 1939); E. M. Burns, *The American Social Security System* (Boston, 1949): F. M. Gentile and D. S. Harvard, *General Assistance . . . Practice in 47 Localities in the United States,* American Association of Social Workers (New York, 1949); American Public Welfare Association, *Public Welfare Directory* (annually); Social Security Administration, U.S Department of Health, Education and Welfare, *Social Security Bulletin* (monthly, March 1938–). (Js. H. B.)

POORWILL, the name (from its cry) of a North American bird (*Phalaenoptilus nuttalli),* allied to the whippoorwill, nightjar and nighthawk (*qq.v.*), which it resembles in habits. It is about eight inches long, the smallest of the family; the primaries are rusty. barred with black. It breeds west of the Mississippi north to British Columbia and south to southern California.

Hibernation of the poorwill in rock crevices was demonstrated by Jaeger (*Condor*, vol. 51, 1949); the bird observed was torpid and aith redyced temperature for about 85 days. (K. P. S.)

POPAYAN, a city of Colombia, capital of the department of Cauca, about 240 mi. S.W. of Bogotá, on the old trade route between that city and Quito, in 2° 26' N., 76° 49' W. Pop. (1961 est.) 61.490.

Popayán is built on a great plain sloping northwest from the foot of the volcano Puracé, near the source of the Cauca and on one of its small tributaries, 5,712 ft. above the sea. Its situation is singularly picturesque, the Puracé rising to an elevation of 15,420 ft. about 20 mi. S.E of the city, the Sotara volcano to approximately the same height about the same distance south by east; behind these at a greater distance is the Pan de Azúcar, 15,978 ft. high. It has rail connection nith Cali.

Earthquakes caused much damage to Popayán, especially those of 1827 and 1834.

Popayán was founded by Sebastián Benalcázar in 1538 on the site of an Indian settlement, whose chief, Payán, had the unusual honour of having his name given to the usurping town. It is noted as the birthplace of Caldas, the Colombian naturalist, and of Mosquera, the geographer

POPE, an ecclesiastical title now used in the West exclusively to designate the head of the Roman Catholic Church. In the 4th and 5th centuries it was frequently used by any bishop (Du Cange, *s.v.*); but it gradually came to be reserved to the bishop of Rome, becoming official. In the East, the title became restricted to the patriarchs of Alexandria. Xntioch, Jerusalem and Constantinople, but is still given by popular usage to priests. Even in the case of the sovereign pontiff the word pope is officially only used as a less solemn style: though the ordinary signature and heading of briefs is, *e.g.,* "Pius P.P.X.," the signature of bulls is *Pius episcopus ecclesiae catholicae,* and the heading, *Pius episcopus, servus servorum Dei,* this latter formula going back to the time of St. Gregory the Great. Other styles met with in official documents are *Pontifex, Summus pontifex, Romanus pontifex, Sanctissimus, Sanctissimus pater, Sanctissimus dominus noster, Sanctitas sua, Beatissirnus pater, Beatitudo sua;* while the pope is addressed in speaking as "*Sanctitas vestra,*" or "*Beatissime pater.*"

Jurisdiction.—The pope is pre-eminently, as successor of St. Peter, bishop of Rome. Writers are fond of viewing him as representing all the degrees of the ecclesiastical hierarchy; they say that he is bishop of Rome, metropolitan of the Roman province, primate of Italy, patriarch of the Western Church and head of the universal Church. This is strictly correct, but, with the exception of the first and last, these titles are seldom to be found in documents. And if these terms were intended to indicate so many degrees in the exercise of jurisdiction they would not be correct. As a matter of fact, from the earliest centuries (*cf.* can. 6 of Nicaea, in 325), we see that the popes exercised a special metropolitan jurisdiction not only over the bishops nearest to Rome, the future cardinal bishops, but also over all those of central and southern Italy, including Sicily (*cf.* Duchesne, *Origines du culte,* ch. 1), all of whom received their ordination at his hands. Northern Italy and the rest of the western Church, still more the eastern Church, did not depend upon him so closely for their administration. His influence was exercised, however, not only in dogmatic questions but in matters of discipline, by means of appeals, petitions and consultations, not forgetting to mention spontaneous intervention.

Primacy.—The primacy of the pope, a primacy of honour and jurisdiction, involving the plenitude of power over the teaching, the worship, the discipline and administration of the Church, is received by the pope as part of the succession of St. Peter, together with the episcopate of Rome. The whole episcopal body, with the pope at its head, should be considered as succeeding to the apostolic college, presided over by St. Peter; and the head of it, now as then, as personally invested with all the powers enjoyed by the whole body, including the head. Hence the pope, as supreme in matters of doctrine, possesses the same authority and the same infallibility as the whole Church; as legislator and judge he possesses the same power as the episcopal body gathered around and with him in oecumenical council. Such are the two essential prerogatives of the papal primacy: infallibility in his supreme pronouncements in matters of doctrine (*see* INFALLIBILITY); and immediate and sovereign jurisdiction, under all its aspects over all the pastors and the faithful. These two privileges. having been claimed and enjoyed by the popes in the course of centuries, were solemnly defined at the Vatican Council by the constitution *Pastor aeternus* of the 18th of July 1870. For the history of the papacy, and associated questions *see* PAPACY. CONCLAVE, CURIA ROMANA, CARDINAL, VESTMENTS. For particulars of the lives of the different popes, *see* the separate articles.

POPE, ALEXANDER (1688–1744), English poet, was born in Lombard street, London, on May 21, 1688. His father, Alexander Pope, a Roman Catholic, was a linen-draper who afterwards retired from business with a small fortune and fixed his residence about 1700 at Binfield in Windsor forest. Pope's education was desultory. Before he was 12 he had obtained a smattering of Latin and Greek from various masters; by his 17th year excessive study had undermined his health and he had developed the personal deformity which later on largely distorted his view of life. Under the treatment, however, of the famous physician John Radcliffe, he recovered his health and continued his studies.

Pope was early an eager aspirant to the highest honours in poetry, and his connections with neighbouring Roman Catholic families of influence in the literary world gave direction to his ambitions. Pope was thus brought under the notice of Sir William Trumbull, a retired diplomatist, living at Easthampstead. Thomas Dancastle, lord of the manor of Binfield, took an active interest in his writings, and at Whiteknights, near Reading, lived another Roman Catholic, Anthony Englefield, "a great lover of poets and poetry." Through him Pope made the acquaintance of Wycherley and of Henry Cromwell, the former introducing him to William Walsh, then of great renown as a critic. Before the poet was 17 he was admitted in this way to the society of London "wits" and men of fashion, and was cordially encouraged as a prodigy.

Pope recognized soon that a long course of preparation was needed for the translation of *Homer* into English verse, on which he had decided. He learnt most, as he acknowledged, from Dryden, but the harmony of his verse also owed something to an earlier writer, George Sandys, the translator of Ovid. At the beginning of the 18th century Dryden's success had given great vogue to translations and modernizations. Dryden had rewritten three of the *Canterbury Tales;* Pope tried his hand at the *Merchant's Tale, Prologue to the Wife of Bath's Tale,* the *House of Fame,* and further experimented with translations from some Latin authors and the *Odyssey.*

Precocious Pope was, but he was also industrious; and he spent nine years in arduous discipline, before anything of his appeared in print. His first publication was his "Pastorals"; they appeared in May 1709 at the end of the sixth volume of Tonson's *Poetical Miscellanies,* containing contributions from Ambrose Philips, Sheffield, Garth and Rowe, with "January and May," Pope's version of Chaucer's "Merchant's Tale."

Pope's next publication was the *Essay on Criticism* (1711), written two years earlier, and printed without the author's name. The sales were slow until Pope caused copies to be sent to Lord Lansdowne and others, but its success was none the less brilliant for the delay. The town was fairly dazzled by the young poet's learning, judgment, and felicity of expressions, and Pope gained credit for much that might have been found where he found it, in the *Institutes* of Quintilian, in the numerous critical writings of René Rapin, and in René le Bossu's treatise on epic poetry. Addison has been made responsible for the exaggerated value once set on the essay, but Addison's paper (*Spectator,* No. 253) was not unmixed praise. He and Pope became acquainted and Pope's sacred eclogue, "Messiah," was printed as No. 378 of the *Spectator.* In the *Essay on Criticism* Pope provoked one bitter personal enemy in John Dennis, the critic, by describing him as Appius, who "stares, tremendous, with a threat'ning eye." Dennis retorted in *Reflections . . . upon a late Rhapsody . . .* (1711), abusing Pope among other things for his personal deformity; and Pope never forgot this brutal attack.

The *Rape of the Lock,* in its first form, appeared in 1712 in *Lintot's Miscellanies;* the "machinery" of sylphs and gnomes was an afterthought, and the poem was republished as we now have it early in 1714. William, 4th Baron Petre, had surreptitiously cut off a lock of Miss Arabella Fermor's hair, and the liberty had been resented; Pope hearing of this, caught at the hint, and treated the subject in mock heroic vein—the result being a poem which is generally admitted to be a masterpiece of airiness, ingenuity, and exquisite finish. It was followed by the publication in March, 1713, of *Windsor Forest,* which was begun, according to Pope, when he was 16 or 17. Hitherto, Pope had avoided politics, but this work appeared with a flattering dedication to the secretary for war, George Granville, Lord Lansdowne, and an opportune allusion to the Treaty of Utrecht. When the poem appeared, it was made the subject of an insidious attack by the Addison coterie, who about this time became estranged from Pope. Addison disavowed connivance of this coarse attack, but a coolness between the two friends ensued.

The attacks upon *Windsor Forest* appeared in a series of papers on "Pastorals" which were published in the *Guardian* (Nos. 22, 23, 28, 30 and 32). No mention was made of the poem, but everyone knew to whom the general principles referred. In the articles the introduction of Greek names, customs and deities was ridiculed and as *Windsor Forest* was fairly open to criticism on this ground, the real subject of the papers was manifest. The real sting of the criticisms, however, lay in their extravagant praise of the second-rate poet Ambrose Philips and the implied comparison with Pope. The latter characteristically succeeded in revenging himself. He secured the publication in the *Guardian* of an anonymous article which ostensibly attacked his own poems, but which actually, by quotation, disposed of the pretensions of Ambrose Philips, and ridiculed the *Guardian's* principles.

The links that attached Pope to the Tory party were strengthened by a new friendship. His first letter to Swift, who became warmly attached to him, is dated Dec. 8, 1713. Swift had been a leading member of the Brothers' Club, from which the famous Scriblerus Club seems to have been an offshoot. The leading members of this informal literary society were Swift, Arbuthnot, Congreve, Bishop Atterbury, Pope, Gay and Thomas Parnell. Their chief object was a general war against the dunces, waged with great spirit by Arbuthnot, Swift and Pope.

The estrangement from Addison was completed in connection with Pope's translation of Homer, which was definitely undertaken in 1713, and was published by subscription. Men of all parties subscribed, their unanimity being a striking proof of the position Pope had attained at the age of 25. But the unanimity was broken by a discordant note. A member of the Addison clique, Tickell, attempted to run a rival version. Pope suspected Addison's instigation; Tickell had at least Addison's encouragement. Pope's famous character of Addison as 'Atticus" in the *Epistle to Dr. Arbuthnot* (ii. 193–215) was, however, inspired by resentment at insults that existed chiefly in his own imagination.

The translation of Homer was Pope's chief employment for 12 years. The new pieces in the miscellanies published in 1717, his "Elegy on an Unfortunate Lady," and his "Eloisa to Abelard," were probably written some years before their publication. The *Iliad* was delivered to the subscribers in instalments in 1715, 1717, 1718 and 1720. Pope's own defective scholarship made help necessary. William Broome and John Jortin supplied the bulk of the notes, and Thomas Parnell the preface. For the translation of the *Odyssey* he took Elijah Fenton and Broome as coadjutors, who between them translated 12 out of the 24 books. (1, 4, 19 and 20 are by Fenton; 2, 6, 8, 11, 12, 16, 18, 23, with notes to all the books, by Broome.) It was completed in 1725. Opinions have varied on the purely literary merits of the poem, but with regard to it as a translation few have differed from Bentley's criticism, "A fine poem, Mr. Pope, but you must not call it Homer." In 1722 he edited the poems of Thomas Parnell, and in 1723–25 made a considerable sum by an unsatisfactory edition of Shakespeare, in which he had the assistance of Fenton and Gay.

Pope, who cleared £8,000 by the two translations. was thus rendered independent and enabled to live near London. The estate at Binfield was sold, and he removed with his parents to Mawson's buildings, Chiswick, in 1716, and in 1719 to Twickenham, to the house with which his name is associated. Here he practised elaborate gardening on a small scale, and built his famous grotto, which was really a tunnel under the road connecting the garden with the lawn on the Thames. He was constantly visited at Twickenham by his intimates, Dr. John Arbuthnot, John Gay, Bolingbroke (after his return in 1723), and Swift (during his brief visits to England in 1726 and 1727), and by many other friends of the Tory party. With Atterbury, bishop of Rochester, he was on terms of affectionate intimacy, but he blundered in his evidence when he was called as a witness on his behalf in 1723.

In 1717 his father died, and he appears to have turned to the Blounts for sympathy in what was to him a very serious bereavement. He had early made the acquaintance of Martha and Teresa Blount, having probably met them first at the house of his neighbour, Englefield of Whiteknights, who was their grandfather. Their home was at Mapledurham, near Reading. He began to correspond with Martha Blount in 1712, and after 1717, the letters are much more serious in tone. He quarrelled with Teresa, who had apparently injured or prevented his suit to her sister, but his friendship with Martha lasted all his life. So long as his mother lived he was unwearying in his attendance on her, but after her death in 1733 his association with Martha Blount mas more constant. His earlier attachment to Lady Mary Wortley Montague was apparently a literary passion, which perished under Lady Xfary's ridicule.

The year 1725 may be taken as the beginning of the third period of Pope's career, when he made his fame as a moralist and a satirist. Edward Young's satire, *The Universal Passion,* had just appeared, and been received with more enthusiasm than any thing published since Pope's own early successes. Swift was finishing Gulliver's *Travels,* and the survivors of the Scriblerus Club resumed their old amusement of parodying and otherwise ridiculing bad writers, especially bad writers in the Whig interest; four volumes of their *Miscellanies in Prose and Verse* were published from 1727 to 1732. According to Pope's own history of the *Dunciad, an Heroic Poem in Three Books,* which first appeared on May 28, 1728, the idea of it grew out of this. Among the Miscellanies was a "Treatise of the Bathos or the Art of Sinking in Poetry," which gave rise to a torrent of abusive falsehoods and scurrilities from those who thought themselves injured by it.

The *Dunciad* was Pope's answer to them, and among the most prominent objects of his satire were Lewis Theobald, Colley Cibber, John Dennis, Richard Bentley, Aaron Hill and Bernard Lintot, who, in spite of his former relations with Pope, was now classed with the piratical Edmund Curll. The book was published anonymously with the greatest precautions. When the success of the poem was assured, it was republished in 1729, and a copy was presented to the king by Sir Robert Walpole. Names took the place of initials, and a defence of the satire, written by Pope himself, but signed by his friend William Cleland, was printed as "A letter to the Publisher." Various indexes, notes and particulars of the attacks on Pope made by the different authors satirized were added. To avoid any danger of prosecution, the copyright was assigned to Lord Oxford, Lord Bathurst and Lord Burlington, whose position made them practically unassailable. The most unprovoked assault was on Richard Bentley, whom he satirized in the reconstruction and enlargement of the *Dunciad* made in the last years of his life at the instigation, it is said. of William Warburton. In the earlier editions the place of hero had been occupied by Lewis Theobald. who had ventured to criticize Pope's *Shakespeare.* In the edition which appeared in Pope's *Works* (1742), he was dethroned in favour of Colley Cibber; Warburton's name is attached to many new notes, and one of the preliminary dissertations by Ricardus Aristarchus on the hero of the poem seems to be by him.

The four epistles of the *Essay on Man* (1733–34) too were intimately connected nith passing controversies. The subject was suggested to him by Henry St. John, Lord Bolingbroke, nho had returned from exile in 1723 and was a fellow-member of the Scriblerus Club. Bolingbroke is said—and the statement is supported by the contents of his posthumous works—to have furnished most of the arguments. In this didactic work, as in his *Essay on Criticism,* Pope put together on a sufficiently simple plan a series of happy sayings, separately elaborated, picking up the thoughts as he found them in miscellaneous reading and conversation and trying only to fit them with perfect expression. His readers were too dazzled by the verse to be severely critical of the sense. Pope himself had not comprehended the drift of the arguments he had adopted from Bolingbroke, and was alarmed when he found that his poem was generally interpreted as an apology for the freethinkers. Warburton is said to have qualified its doctrines as "rank atheism," and asserted that it was put together from the "worst passages from the worst authors" The essay was soon translated into the chief European languages, and in 1737 its orthodoxy was assailed by a Swiss professor, Jean Pierre de Crousaz, in an *Examen de l'essay de M. Pope sur l'homme.* Warburton now saw fit to revise his opinion of Pope's abilities and principles—for what reason does not appear. In any case he now became as enthusiastic in his praise of Pope's orthodoxy and his genius as he had before been scornful, and proceeded to employ his unrivalled powers of sophistry in a defence of the orthodoxy of the conflicting and inconsequent positions adopted in the *Essay on Man.* Pope was wise enough to accept with all gratitude an ally who was so useful a friend and so dangerous an enemy, and from that time onward Warburton was the authorized commentator of his works.

The *Essay on Man* was to have formed part of a series of philosophic poems on a systematic plan. The other pieces were to treat of human reason, of the use of learning, wit, education and riches, of civil and ecclesiastical polity, of the character of women, etc. Of the ten epistles of the *Moral Essays,* the first four, written between 1731 and 1735, are connected with this scheme, which was never completed.

There was much bitter, and sometimes unjust, satire in the *Moral Essays* and the *Imitations of Horace.* In these epistles and satires, which appeared at intervals, Pope was often the mouthpiece of his political friends, who were all of them in opposition to Walpole, then at the height of his power. and Pope chose the objects of his attacks from among the minister's adherents. Epistle III., "Of the Use of Riches," addressed to Allen Bathurst, Lord Bathurst in 1732, is a direct attack on Walpole's methods of corruption and on his financial policy in general; and the two dialogues (1738) known as the "Epilogue to the Satires," professedly a defence of satire, form an eloquent attack on the court. Pope was attached to the prince of Wales's party and he did not forget to insinuate, what was indeed the truth, that the queen had refused the prince her pardon on her death-bed. The "Epistle to Dr. Arbuthnot" contains a description of his personal attitude towards the Scriblerus and is made to serve as a "prologue to the satires." The gross and unpardonable insults bestowed on Lord Hervey and on Lady Mary Wortley Montague in the first satire "to Mr. Fortescue" provnked angry retaliation from both. The descriptions of Timon's ostentatious villa in Epistle IV., addressed to the earl of Burlington, was generally taken as a picture of Canons, the seat of John Brydges. duke of Chandos, one of Pope's patrons. Epistle II , addressed to Martha Blount, contained the picture of Xtossa, which was taken to be a portrait of Sarah Jennings, duchess of Marlborough.

One of the worst imputations on Pope's character was that he left this passage to be published when he had in effect received a bribe of £1,000 from the duchess of Marlborough for its suppression through the agency of Nathanael Hooke (d 1763) As the passage eventually stood. it might be applied to Katherine. duchess of Buckingham, a natural daughter of James II. Pope may have altered it with the intention of diverting the satire from the original object. To appreciate fully the point of his allusions requires an intimate acquaintance with the political and social gossip of the time, but apart from their value as a brilliant strongly-coloured picture of the period, Pope's satires have a permanent value as literature. It is justly remarked by Mark

Pattison (in his edition of the *Satires and Epistles*, 1866), that "these *Imitations* are among the most original of his writings." The vigour and terseness of the diction is still unsurpassed in English verse.

Pope's wit had won for him the friendship of many distinguished men, and his small fortune enabled him to meet them on a footing of independence. He paid long visits at many great houses, especially at Stanton Harcourt, the home of his friend Lord Chancellor Harcourt; at Oakley, the seat of Lord Bathurst; and at Prior Park, Bath, where his host was Ralph Allen. He died on May 30, 1744, and was buried in the parish church of Twickenham. He left the income from his property to Martha Blount till her death, after which it was to go to his half-sister Magdalen Rackett and her children. His unpublished mss. were left at the discretion of Lord Bolingbroke, and his copyrights to Warburton.

If we are to judge Pope fairly there are two features of his times that must be kept steadily in view—the character of political strife in those days and the political relations of men of letters. The age of Queen Anne was pre-eminently an age of intrigue. The Government was almost as unsettled as in the early days of personal monarchy, but it was policy rather than force upon which men depended for keeping their position. Secondly, men of letters were admitted to the inner circles of intrigue as they had never been before and as they have never been since; and Queen Anne's statesmen paid their principal literary champions with social privileges and honourable public appointments. Hence men of letters were directly infected by the low political morality of the unsettled time.

Pope's own ruling passion was the love of fame, and he had no scruples where this was concerned. His vanity and his childish love of intrigue are seen at their worst in his petty manoeuvres to secure the publication of his letters during his lifetime. These intricate proceedings were unravelled with great patience and ingenuity by Charles Wentworth Dilke, when the false picture of his relations with his contemporaries which Pope had imposed on the public had been practically accepted for a century. After manipulating his correspondence so as to place his own character in the best light. Pope deposited a copy in the library of Edward, second earl of Oxford, and then had it printed. The sheets were offered to Curll by a person calling himself P.T., who professed a desire to injure Pope, but was no other than Pope himself. The copy was delivered to Curll in 1735 after long negotiations by an agent who called himself R. Smythe, with a few originals to vouch for their authenticity. P.T. had drawn up an advertisement stating that the book was to contain certain answers from various peers. Curll was summoned before the House of Lords for breach of privilege, but was acquitted, as the letters from peers were not in fact forthcoming. Difficulties then arose between Curll and P.T., and Pope induced a bookseller named Cooper to publish a *Narrative of the Method by which Mr. Pope's Private Letters were procured by Edmund Curll, Bookseller* (1735). These preliminaries cleared the way for a show of indignation against piratical publishers and a "genuine" edition of the *Letters of Mr. Alexander Pope* (1737, fol. and 4to).

Unhappily for Pope's reputation, his friend Caryll, who died before the publication. had taken a copy of Pope's letters before returning them. This letter-book came to light in the middle of the 19th century, and showed the freedom which Pope permitted himself in editing. The correspondence with Lord Oxford, preserved at Longleat, afforded further evidence of his tortuous dealings. But against Pope's petulance and "general love of secrecy and cunning" have to be set, in any fair judgment of his character, his exemplary conduct as a son, the affection with which he was regarded in his own circle of intimates, and many well-authenticated instances of genuine and continued kindliness to persons in distress.

BIBLIOGRAPHY.—Various collected editions of Pope's *Works* appeared during his lifetime, and in 1751 an edition in nine volumes was published by a syndicate of booksellers "with the commentaries of Mr. Warburton." In 1769–1807 an edition was issued which included Owen Ruffhead's *Life of Alexander Pope* (1769), which was largely inspired by Warburton. The notes of many commentators, with some letters and a memoir, were included in the *Works of Alexander Pope*, ed. W. L. Bowles (10 vols., 1806). His *Poetical Works* were edited by Alexander Dyce (1856); by R. Carruthers (1858) for Bohn's Library; by A. W. Ward (*Globe Edition*, 1869), etc. Materials for a definitive edition were collected by John Wilson Croker, and formed the basis of what has become the standard version, *The Works of Alexander Pope* (10 vols., 1871–98), including unpublished letters and other new material, with introduction and notes by W. Elwin and W. J. Courthope. The life of Pope in vol. v. was contributed by Prof. Courthope. The chief original authority besides Pope's correspondence and Ruffhead's *Life* is Joseph Spence's *Anecdotes*, published by S. W. Singer in 1820. Samuel Johnson gives a good estimate of Pope in his *Lives of the Poets*. The best modem lives are that by Prof. Courthope already mentioned; and *Alexander Pope*, by Sir L. Stephen, in the *English Men of Letters* series (1880). *See* also George Paston, *Mr. Pope: his Life and Times* (1909). The first check to the admiration that prevailed during Pope's lifetime was given by the publication of Joseph Warton's *Essay on the Genius and Writings of Pope* (vol. i., 1757; vol. ii., 1782). Thomas Campbell's criticism in his *Specimens of the British Poets* provoked a controversy to which William Hazlitt, Byron and W. L. Bowles contributed. For a discussion of Pope's position as one of the great men of letters in the 18th century who emancipated themselves from patronage, *see* A. Beljame, *Le Public et les hommes de lettres en Angleterre au dix-huitième siècle* (1881); a section of Isaac D'Israeli's *Quarrels of Authors* is devoted to Pope's literary animosities; and most important contributions to many vexed questions in the biography of Pope, especially the publication of his letters, were made by C. W. Dilke in *Notes and Queries* and the *Athenaeum*. These articles were reprinted by his grandson, Sir Charles Dilke, in 1875, as *The Papers of a Critic.*

POPE, JOHN (1822–1892), American soldier, was born at Louisville, Ky., on March 16, 1822. He graduated at the United States military academy in 1842 and was assigned to the engineers. He served in the Mexican War, subsequently engaged in engineering and exploring work, and was commissioned captain in 1856. Early in the Civil War he was placed, as a brigadier general U.S.V., in charge of the district of Missouri, which by vigorous campaigning against guerrilla bands he quickly reduced to order. In 1862, along with the gunboat flotilla (commanded by Commodore A. H. Foote) on the Mississippi, Pope obtained a great success by the capture of the defences of New Madrid and Island No. 10, with nearly 7,000 prisoners. Pope subsequently joined Halleck, and in command of the Army of the Mississippi took part in the siege of Corinth. He was now a major general (U.S.V.). The reputation he had thus gained as an energetic leader quickly placed him in a high command, to which he proved to be quite unequal. The "Army of Virginia," as his new forces were styled, had but a brief career. At the very outset of his Virginian campaign Pope, by a most ill-advised order, in which he contrasted the performances of the western troops with the failures of the troops in Virginia, forfeited the confidence of his officers and men The feeling of the Army of the Potomac (which was ordered to his support) was equally hostile, and the short operations culminated in the disastrous defeat of the second battle of Bull Run. Pope was soon compelled to realize the impossibility of retrieving his position, and resigned the command. Later, in command of the department of the North-West, he showed his former skill and vigour in dealing with Indian risings. In 1882 he was promoted to the full rank of major general, U.S. army. He died at Sandusky, O., on Sept. 23, 1892.

He was the author of various works and papers, including railway reports (*Pacific Railroad Reports* vol. iii.) and *The Campaign of Virginia* (Washington, 1865).

POPE, JOHN RUSSELL (1874–1937), U.S. architect, was born in New York city on April 24, 1874. In 1895 he was fellow of the American Academy at Rome and in 1896–97 held the Schermerhorn traveling fellowship in architecture. In 1900, after attending the École des Beaux-Arts in Paris, he began practice in New York city. In addition to many private residences he designed the Scottish Rite temple, Washington, D.C.; Plattsburg (N.Y.) city hall; the Terminal station, Richmond. Va.; the McDonough memorial at Plattsburg; and the Lincoln memorial at Hodgenville, Ky. He was chosen architect for the Roosevelt memorial and the Mellon art gallery in Washington and the Roosevelt memorial in New York city.

POPE, SIR THOMAS (*c.* 1507–1559). founder of Trinity college. Oxford. was born at Deddington, Oxfordshire. probably in 1507, and educated at Eton college. By 1532 he was holding a minor post in the court of chancery and in October he became clerk of briefs in the Star Chamber. Later he was warden of the mint (1534–36), clerk of the crown in chancery (1537), and in 1536 he was appointed treasurer and second officer of the new court of augmentations. set up to deal with the financial business arising from the dissolution of the monasteries. In this last office he mas superseded in 1541, but from 1547 to 1553 he was again employed as fourth officer.

He was enriched by grants of monastic lands, was knighted in 153j and made a privy councillor in March 1544. The changes made by Edward VI were repugnant to him, but at the beginning of Mary's reign he again became a member of the privy council, and he retained the royal favour under Elizabeth.

As early a s 1555 Pope had begun to arrange for the endowment of a college at Oxford. for which he bought the site and buildings of Durham college, the Oxford house of the abbey of Durham. He received a royal charter for the establishment and endowment of a college of the "Holy and Undivided Trinity" on March 8. 1555. The foundation provided for a president. 12 fellows and 8 scholars. The number of scholars was subsequently increased to 12. On March 28 the members of the college were put in possession of the site. and they were formally admitted on May 30, 1556. Pope died at Clerkenwell on Jan. 29, 1559.

POPISH PLOT: *see* OATES. TITUS.

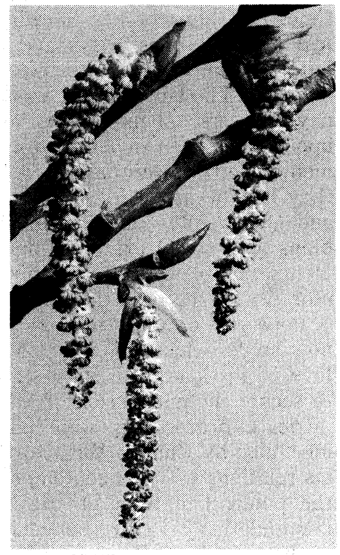
POPLAR, a metropolitan and parliamentary borough of London. Eng.. in the extreme east of the county of London, bounded north by Hackney. east by the Lea river (and the county borough of West Ham). south bv the Thames (and Greenwich). west by Stepney and Bethnal Green. The Blackn-all tunnel goes from between the East and West India docks to Greenwich. Pop. (1951) 73.579. Area 3.6 sq.mi. including 180 ac. water area in its docks. The Lea is believed to have been crossed toward the north by a Roman road. now recalled by the district of Old Ford; Bow acquired its name from the original arched bridge built over the Lea in the early 12th century at the direction of Queen Matilda. South of Bow lies Bromley; in the southeast. Blackwall; and a deep southward bend of the Thames encompasses the Isle of Dogs. In Blackwall and the Isle of Dogs, streets give place to the extensive India and Millwall docks system with shipbuilding. engineering. chemical and other works along the waterfront. Blackwall has been a shipping centre from early times.

The West India (opened in 1802). East India (1806) and Millwall docks have a total area of 515 ac.. of which 1jj ac. is nater: there are 8 mi. of quays. The capacity of the warehouses is about 93.000 tons; goods stored are principally hardwoods. sugar and grain. The central granary at the Millwall dock can accommodate 24.000 tons. Large quantities of green fruit are discharged at two new berths at the West India import dock. The West India docks include export and import docks covering a water area of 24.1 ac. and 27.j ac. respectively: a quayage length of 2.017 yd. and 2.289 yd.; and a maximum depth of 29 ft. In addition, these docks include Blackwall basin with an area of 7.2 ac. and a depth of 26 ft.; Junction dock. area 1.3 ac. and depth 25 ft.; South dock, area 36.3 ac.. maximum depth 30.j ft. and quayage 2,627 yd. Millwall docks are connected with the West India docks. The outer Millwall dock has a water area of nearly 25 ac. and quayage of 2,037 yd., while the inner dock area is 10.5 ac. with 1,638 yd. of quayage. Their maximum depth is 29.8 ft. The new entrance lock to these docks is jd4 ft. long and 80 ft. wide, with a depth of 3j ft. on the sill. The East India docks, to the east. consist of the import dock and a basin with total water area of 23.4 ac. and 2.047 yd. of quay: the depth in the dock being 28 ft. and in the basin 32 ft. Impounding stations raise water in these docks from 19 in. to 2 ft. above Trinity high water.

In the 19th century the district of Cubitt Town in the Isle of Dogs was laid out by Sir William Cubitt. for shipbuilding was then on a large scale (the "Great Eastern" of I. K. Brunel was built there) but by the end of the century the industry began to decline. The population of Poplar reached its height in 1901 (169,000) but by 1931 it had fallen to 155.000 and by 1951 to about half this figure. Northwest of the East India dock road lies the community unit of Lansbury, named in honour of Poplar's former mayor. labour leader George Lansbury (1859–1940), and constructed as part of the comprehensive Stepney-Poplar redevelopment scheme of the London county council after extensive devastation by bombs during World War II. Industries include the manufacture of matches, chemicals, clothing, steel and iron products, and general engineering.

For "Poplarism" *see* POOR LAW.

POPLAR, the name commonly applied to several species of trees comprising a subgeneric group of the genus *Populus,* belonging to the willow family, the Salicaceae (*q.v.*). Aspens (*q.v.*), also members of the genus *Populus,* comprise a second subgeneric group. Several of the poplars are better known in some areas as cottonwoods. This name alludes to their minute. air-borne, hairy-tufted seeds which are released in profusion, and which in accumulations suggest cotton. Others, with fragrant. balsamic-resinous winter buds are commonly called balsam poplars. (Buds of aspens are essentially nonresinous.)



JOHN MARKHAM

MALE CATKINS OF BLACK POPLAR (POPULUS NIGRA)

Populus comprises a group of about 35 species of trees. and a number of natural hybrids. These are widely distributed through the northern hemisphere and range from northern Africa through Eurasia and North America; a few species extend even beyond the Arctic circle.

The leaves of poplars are alternate, deciduous, and are mostly triangular to oval in outline. with finely to coarsely toothed margins and long, cylindrical and tapering, or laterally compressed petioles. The poplars are a dioecious (unisexual) group. with the flowers of both sexes borne in long drooping catkins (aments) in advance of leaf emergence. Flowers on staminate (male) trees consist of 12 to 60 stamens inserted in a cuplike disk subtended by a many-fingered bract (those of the aspens with but 6 to 12 stamens). Flowers from pistillate (female) trees are composed of a single two to four-cell ovoid to globular ovary surmounted by a large spreading stigma, and are similarly inserted on a disk with bract attached. The fruit, a thick-walled (thin-walled in aspens) two to four-valved capsule, contains many minute seeds clothed in cottony pubescence.

There are about a dozen poplars and cottonwoods; including stable varieties and natural hybrids, indigenous to and widely distributed through North America, exclusive of central and southern Mexico.

The eastern cottonwood (*P. deltoides),* a large tree with coarse! deeply furrowed bark and triangular-shaped leaves which are about as broad as long, often attains a height of 150 or more feet and a diameter of 48 to 96 in. Ranging from Quebec westward to Montana and south to Florida and Texas. it is not only a pulpwood and timber tree of major importance, but it is also planted in many localities as a street and shade tree. Numerous forms of this poplar are prized ornamentals in both Europe and America, several of which are hybrids with the European black poplar *(P. nigra)* or one of its varieties. Among these are the Carolina poplar (P. × *canadensis* [hybrid between *P. deltoides* × *P. nigra]),* a vigorous tree with strongly ascending limbs. widely used in parks and streets; and the Eugene poplar *(P. canadensis eugenei* [hybrid between *P. deltoides* × *P. nigra italica*]), a tree of narrow-pyramidal habit that originated in France in 1832. Pistillate trees of the two forms have never been found.

The black cottonwood (*P. trichocarpa*) is the largest of the American poplars. and not infrequently attains a height of more than 200 ft. and a diameter of more than 80 in. It is found along the Pacific slope from southern coastal Alaska to Lower California, and eastward in Canada to Alberta and in the United States to western Montana and Nevada, but is most abundant at low elevations. Reaching its maximum development on deep, moist alluvial or sandy soils, it is often the first tree species to become established on newly formed sand bars and food plains. While very abundant in some areas, its exploitation was retarded for many years, due in large measure to a preponderance of readily accessible softwood timber of quality throughout its range. Since the turn of the 20th century. however, it has been harvested in ever increasing quantities for use in the production of lumber. slack cooperage, excelsior, veneer and paper pulp.

The balsam poplar or the tacamahac (*P. balsamifera* [*tacamahaca*]), the "liard" of the early Canadian *voyageurs*, is a large tree of transcontinental distribution with a pyramidal crown and shallow root system. Essentially a Canadian tree, it occurs along the northern border of the United States from New England westward through the lake states and northern Rocky mountains to Oregon and Washington. Northward it ranges from Labrador westward across nearly all of Canada to beyond the Arctic circle in Alaska. The balm of Gilead poplar, once known botanically as *P. candicans* and widely used ornamentally throughout much of the northeastern United States and southern Canada. is now generally regarded to be either a clone from a pistillate tree of the heartleaf balsam poplar (P. *balsamifera* var. *subcordata*) or a hybrid between the balsam poplar and the eastern cottonwood.

The principal poplar of the swamps and river bottoms of the coastal plains and the blississippi river drainage basin is the swamp cottonwood (*P. heterophylla*). In the Mississippi valley where it reaches its maximum development, trees are often 80 to 90 ft. tall and 36 to 42 in. in diameter.

The plains cottonwood (P. *sargenti),* is one of the most frequently encountered trees in the essentially treeless areas of the central United States. Narrowleaf cottonwood (*P. angustifolia*) is a tree of the Rocky mountains and adjacent plains to the east. The ranges of these two species overlap, and at least one natural hybrid between them has become well established. This is known as the lanceleaf cottonwood (P. × *acuminata* [hybrid between *P. angustifolia* × *P. sargenti*]).

Fremont cottonwood (P. *fremonti)* and its variety, Rio Grande cottonwood (*P. fremonti* var. *wislizenii*), are two tree forms not infrequently found along the margins of streams and water holes in the semiarid areas of the southwestern United States. Palmer cottonwood (P. *palmeri*) is a little-known tree of central and the trans-Pecos regions of Texas and northern Mexico.

Of the European forms, the white poplar or abele (P. *alba*) is probably the most important. This is a large tree with rounded and spreading crown composed of several massive. curved branches which. like the trunk. are clothed with grayish-white bark. Its leaves are oval ovate to nearly circular. with deeply wavy or more or less lobed margins and heart-shaped bases. The foliage. although dark green above, is clothed below in dense. white pubescence. as are also the young shoots which. with the bark, give a rather hoary aspect to the tree. Of its several varieties. P. *alba* var. *pyramidalis* (Bolleana poplar). a tree of narrow columnar habit. probably enjoys the greatest ornamental use. 4 closely related species, the gray poplar (*P. canescens*). with grayish deltoid leaves, is equally well known. Some taxonomists. however, regard this form as a hybrid between the white poplar and the European aspen (P. *tremula*). Both trees have extended ranges through Europe and Asia. and often attain a height of 90 or more feet. Their white. soft. even-grained timber is employed by turners and toymakers, and is used in quantity in the construction of boxes and crates. Both also enjoy extended ornamental use, although the tendency of white poplar to produce root suckers some distance from the tree restricts its ornamental value in some areas.

The black poplar (*P nigra*) a tree of 100 or more feet in height. nith smooth, dark green. deltoid leaves and dark, deeply furroned bark, is a Eurasian species of wide distribution. Its almost universally known variety. the Lombardy poplar (*P. nigra* var. *italica*), is easily identified by its narrow-pyramidal crown composed of many closely appressed and vertically ascending branches. Its origin appears to have been in Iran or some adjacent country. for it was unknown in Italy in the days of Pliny. From remote times it has been an inhabitant of Kashmir. Punjab and Iran. where it is still commonly to be observed along road sites and in formal gardens. It was probably brought to southern Europe from one of these countries, and derives its common name from its abundant use along the rivers of Lombardy. It was introduced into Great Britain in the early 18th century. and somewhat later into the United States. Lombardy poplar's value lies chiefly in its ornamental use. since its rapidly tapering bole. densely clothed in branches for the greater part of its length, is incapable of producing any appreciable volume of utilizable lumber. This tree makes very rapid growth on a variety of sites. and often attains a height of 100 or more feet. The white, black and Lombardy poplars are widely planted in eastern United States and Canada; the first two of these have become naturalized in many areas.

P. euphratica, believed to be the weeping willow of the Scriptures. is a large tree remarkable for its variability in the shape of its leaves. It is a native of northern Africa and western and central Asia.

Yellow poplar (*Liriodendron tulipifera*), an unrelated species of the magnolia family, is one of the most important hardwoods of eastern United States. *See* TULIP TREE. (E. S. HR.)

POPLAR BLUFF, a city of southeastern Missouri, U.S., 156 mi. S. of St. Louis at the head of navigation on the Black river; the seat of Butler county. Situated in the Ozark perimeter above a broad alluvial plain that forms the rich delta land of one of Llissouri's most prosperous farming areas. Poplar Bluff is essentially a farm marketing centre with diversified light industries. It is located at the intersection of two main transcontinental highways and is served by two major railroads.

Founded in 1849 and named for a forest of yellow poplars on the bluffs of the Black river, the city nas almost destroyed by guerrilla and troop foragers during the American Civil War. Its subsequent development gained impetus with the construction of the St Louis, Iron Mountain and Southern railway (Missouri Pacific) in 1872. Agricultural growth followed a lumbering boom and reclamation of vast swamp lands betneen the St. Francis and Black rivers The county produces cotton. rice, grain. livestock and lumber. For comparative population figures *see* table in MISSOURI *Population.* (W. E. Ro.)

POPLIN, a fine and plain ribbed fabric produced from any class of textile material, comprising a variety of different textures and qualities, and containing fine ribs or cords of uniform size extending across the width of the fabric, from selvage to selvage; *i e*, in the direction of the weft. The ribbed effect in a poplin fabric is obtained by employing a relatively high number of warp threads of fine counts of yarn and interweaving these on the principle of the plain calico (q *v*) weave, with picks of weft of coarse counts Hence, during weaving, the finer and weaker narp threads bend or interlace quite freely under and over the coarser and stronger picks of weft which therefore, lie in a perfectly straight line across the entire nidth of the fabric and thus develop the fine ribs or cords that characterize all poplin fabrics. Cotton poplin fabrics are used for making blouses, dresses, shirts, jackets and other garments. Irish poplin, composed of silk warp and worsted weft, is used for ties. dresses, coats and other clothing.

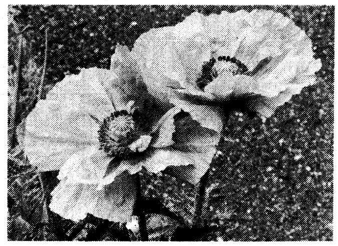
POPOCATÉPETL (Aztec *popoca* "smoke," *tepetl* "mountain'), a volcano nith a large bell-shaped crater approximately 2.008 by 1,312 ft., and a snow-covered cone rising to a height of 17.887 ft. in México state. central Mexico. Popocatépetl and its twin Ixtacihuatl (Ixtaccihuatl; *q.v*) dominate Mexico city, 45 mi. N.W. It is believed that Diego de Ordaz. one of Cortès lieutenants, was the first European to make the ascent. The last major eruption was in 1802 but there have since been minor ones. There is a road from the town of Amecameca to the foot of the volcano. *See* also MEXICO: *Physical Geography: Mountains.*

POPOV, ALEKSANDR STEPANOVICH (1859–1906), Russian physicist and electrical engineer, among the earliest scientific investigators of electromagnetic waves (as later used in wireless communication), was born on March 16, 1859, in a mining village in the Ural mountains where his father mas a priest. He graduated from St. Petersburg university in 1883 and became an assistant in the physics laboratory, later joining the staff of the torpedo school at Kronstadt. where he subsequently became head of the physics department. Popov became interested in the work of H. R. Hertz (*q.v.*), and began to develop a device for receiving electromagnetic waves (*q.v.*). To detect the oscillations resulting from these waves he made various modifications to the coherer, containing metallic filings, used by Edouard Branly and Sir Oliver Lodge. In particular, he added to his coherer an arrangement for automatically tapping back the filings to a sensitive condition after they had cohered on the reception of oscillations. By this means each received impulse of oscillations caused a bell to ring or a mark to be made on a simple recorder which could operate for 12 hours at a time. This apparatus was used for detecting lightning discharges at a distance and was demonstrated at a meeting of the St. Petersburg Physical society in May 1893. Later, it was set up at the meteorological observatory, the coherer being connected to a lightning conductor and used for the study of atmospheric electrical discharges received at distances up to almost 20 mi. In a second lecture before the society in March 1896. Popov showed the transmission of Hertzian waves between different parts of the university buildings. In June 1896. Guglielmo Marconi took out the first patent granted for wireless telegraphy based on the use of electric waves. The news of this aroused Popov to fresh activity, and working in conjunction with the Russian navy he effected ship-to-shore communication over distances of about 6 mi. by 1898. This was increased to about 30 mi. by the end of the following year. Unfortunately Popov's work was not sufficiently appreciated and supported by the Russian government. and in 1901 he returned to St. Petersburg as professor at the electrotechnical institute. of which, a few years later, he was elected director. Popov died on Jan. 13, 1906 (Dec. 31. 1905. by the old Julian calendar). (R. L. S.-R.; X.)

POPPY, common name for plants of several genera of the poppy family (Papaveraceae), especially the type genus *Papaver*. This genus comprises annual and perennial erect herbs containing a milky juice, with lobed or cut leaves and generally long-stalked regular showy flowers, which are nodding in the bud stage. The sepals, usually two in number, fall off as the flower opens; the four (very rarely five or six) petals. which are crumpled in the bud stage. also fall readily. Numerous stamens surround the ovary. which is surmounted by a flat or convex rayed disk bearing the stigmas. The ovary develops into a short many-seeded capsule, opening by small valves below the upper edge. The valves are hygroscopic, responding to an increase in the amount of moisture in the atmosphere by closing the apertures. In dry weather the valves open, and the small seeds escape through the pores when the capsule is shaken by the wind. The genus contains perhaps 90 species! mostly natives of central and southern Europe and temperate Asia. Five species occur in Great Britain; *Papaver* rhoeas, the corn poppy, found in fields and waste places also in the U.S. Cultivated forms of this, with exquisite shades of colour and without any blotch at the base of the petals, are known as Shirley poppies. P. *somniferum,* the opium (*q.v.*) poppy, with large white or blue-purple flowers, is native to Greece and the orient and widely cultivated for medical uses, although it is often grown illicitly.

The oriental poppy (P. orientale) and its many varieties are fine garden plants, having huge bright crimson flowers with black blotches at the base. Many hybrid forms of varying shades of colour have been raised, especially in the U.S. The Iceland poppy (P. nudicaulej is one of the showiest species, with gray-green pinnate leaves and flowers varying in colour from pure white to deep orange-yellow and orange-scarlet shades.

The Welsh poppy (*Meconopsis cambrica*) is a perennial herb with a yellow juice and pale-yellow poppylike flowers. It is found in the southwest and north of England, Wales, Ireland and western Europe. The prickly poppy belongs to the related tropical American genus Argemone. *A.* grandiflora is a popular Central American annual with large white flowers. The horned poppy *Glaucium flavum,* found on sandy seashores along the Mediterranean and characterized by the waxy bloom of its leaves and large golden-yellow short-stalked flowers is naturalized in the U.S. The plume poppies (*Macleaya*) are ornamental foliage plants of great beauty. The snow poppy (*Eomecon chionantha*) is a pretty Chinese perennial, having roundish slightly lobed leaves and pure-white flowers about 2 in. across. The Mexican tulip poppy or golden cup (*Hunnemannia fumariaefolia*), a perennial usually grown as an annual, has very showy yellow flowers. The celandine poppy is *Stylophorum diphyllum; Hydro*cleis *nymphoides* is the water poppy of ponds and aquaria.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ORIENTAL POPPY (PAPAVER ORIENTALE)

The poppy group is well represented in western North America, especially in California, where about 20 native species, together with numerous varieties, are found. The best known is the California poppy (*Eschscholtzia californica*) an annual with brilliant, orange-coloured flowers, widely grown in gardens and extensively naturalized in Australia and India. Other notenorthy Californian species. more or less cultivated, are the tree poppy (Dendronzecon rigida), a rigid, leafy shrub, 2 to 10 ft. high, with golden-yellow flowers, about 2 in. across; the Matilija poppy (Romneya coulteri), a widely branched subshrub, 3 to 8 ft. high, with large white fragrant flowers, 6 in. across; the cream-cups (*Platystemon* californzcus), a low, delicate annual, with light-yellow flowers, 1 in. across; and the flaming poppy or wind poppy (*Meconopsis heterophylla*), bearing brick-red flowers 2 in. across.

The cultivation of common garden poppies (*Papaver* species) is simple if the plants are provided with rich well-drained soil in an open sunny location and are watered during dry spells. Some varieties of P. *orientalis* have enormous flowers in nearly all colour shades, but are ephemeral and useless as cut flowers. Seed should be sown where plants are to grow, for poppies, especially the annuals, do not transplant well. (N. TR.; X.)

POPPY OIL (*Oleum* papaveris), a vegetable oil obtained by pressure from the minute seeds of the garden or opium poppy, *Papaver somniferum.* The white-seeded and black-seeded varieties are both used for oil pressing; but, when the production of oil is the principal object of the culture, the black seed is usually preferred. The qualities of the oil yielded by both varieties and the proportion they contain (from 50% to 60%) are the same. By cold pressing, seeds of fine quality yield from 30% to 40% of virgin or white oil (huile blanche), a transparent limpid fluid with a slight yellowish tinge, bland and pleasant to taste, and with almost no perceptible odour. On second pressure with the aid of heat an additional 20% to 25% of inferior oil (huile de fabrique or huile russe) is obtained, reddish in colour, possessed of a biting taste, and a linseedlike smell. The oil belongs to the linoleic or drying series, having as its principal constituent linolein; and it possesses greater drying power than raw linseed oil. Its specific gravity at 15° C. is 0.925.

Poppy oil is a valuable and much used medium for artistic oil painting. The fine qualities are largely used in the north of France (*huile* d'oeillette) and in Germany as a salad oil, and are less liable than olive oil to rancidity. The inferior qualities are principally consumed in soapmaking and varnishmaking, and for burning in lamps. The oil is used in the valley of the Ganges and other opium regions for food and domestic purposes. Ordinary poppy-oil cake is valuable feeding material. rich in nitrogenous constituents. with an ash showing an unusually large proportion of phosphoric acid.

See also OILS. FATS AND WAXES.

POPULATION. The number of people in the world reached 3,000.000.000 during the year 1960, according to the estimates by the Cnited Nations secretariat. The world's population was then increasing at about 1.8% per year. This rate, which if continued would double the number in 40 years, or by 2001, was well above that prevailing in any previous epoch. According to widely accepted estimates, the average rate of increase rose from less than 0.1% per year in ancient and medieval times to about 0.3% at the beginning of the 18th century and about 0.6% during the

TABLE I.—*Estimated Population, 1900–50, and Population Projections, 1950–2000*

A. Numbers in 000,000							
Year	World	Africa	North America	Latin America	Asia*	Europe†	Oceania
1900	1,550	120	81	63	857	423	6
1925	1,907	147	126	99	1,020	505	10
1950	2,497	199	168	163	1,380	574	13
1975	3,828	303	240	303	2,210	751	21
2000	6,267	517	312	592	3,870	947	29
B. Percentage Increase per Quarter-Century							
Period	World	Africa	North America	Latin America	Asia*	Europe†	Oceania
1900–25	23	22	56	57	19	19	57
1925–50	31	35	33	65	35	14	36
1950–75	53	52	43	86	60	31	59
1975–2000	64	71	30	95	75	26	40

*Excluding the U.S.S.R. †Including the U.S.S.R.
Source: United Nations, The *Future Growth of World* Population, Population Studies, no. 28, p. 23 (1958).

middle decades of the 19th century. The acceleration of population increase in the 20th century was the result of progressive and world-wide lowering of mortality.

Differences in population trends among the various regions of the world are strongly affected by differences in fertility. Estimates of population increases and projected trends, by continents, prepared by the Cnited Nations secretariat, are shown in Table I.

No population projections are prophetic. Projected trends for the continents having less-developed countries may be modified by social changes affecting births and deaths, the discovery of new techniques for the control of fertility or in other ways. Trends in the more-developed countries, where mortality at early ages is very low and fertility is already subject in large measure to voluntary control, are peculiarly sensitive to changes in economic conditions and cultural values. The projections merely show the expected effects of processes already in force if these continue without drastic modification. Projections were made on several sets of hypotheses; those shown in Table I follow from a central assumption of medium, or average, fertility and mortality.

Some idea about variations in population trends among particular countries is given by the information on countries with more than 30,000,000 inhabitants presented in Table II.

KNOWLEDGE ABOUT POPULATION

The scientific study of population, known as demography, began with investigations by John Graunt in the 17th century. Graunt was one of a group of associates in London who were fired with enthusiasm for observations and experiments and received a charter as the Royal Philosophical society, the first scientific academy in the modern world. Graunt, who was a haberdasher by trade. discovered many significant regularities in a series of periodic records of christenings and burials, with reports on the apparent causes of deaths. issued by parish clerks. He published his findings in a pamphlet, *Natural and Political Observations . . . Made upon the Bills of Mortality* of London (1662). This pamphlet. in which Graunt had sketched a hypothetical life table to show the proportions of persons born alive who live to successive ages and the expected years of future life at each age, attracted the attention of scientists in England and on the continent and stimulated other inquiries.

TABLE II.—*Population of Countries with 30,000,000 or More Inhabitants, 1960*

Country	Population (in 000,000)	Average per cent annual increase	Persons per square mile
China (mainland)	660	2.5	178
India	432	2.0	343
U.S.S.R.	214	1.8	25
U.S. (50 states)	180	1.6	50
Japan	93	1.0	653
Indonesia	93	1.4	161
Pakistan	93	2.1	254
Brazil	66	2.4	20
United Kingdom	53	0.5	558
Germany, Fed. Rep.	53	1.3	558
Italy	49	0.5	424
France	46	1.0	214
Nigeria	34	2.0	101
Mexico	34	2.9	45
Poland	30	1.7	247
Spain	30	1.2	155

Source: *Population Index*, vol. 28, no. 1, Jan. 1962. The rates of increase refer to varying recent periods prior to 1960. The figures for China and Nigeria are subject to large errors.

In 1693 Edmund Halley, the astronomer, constructed the first empirical life table on the basis of information about deaths by age in Breslau, Ger.. which had been forwarded to the London Philosophical society by Leibnitz. The measurement and analysis of mortality, which involved study of the frequency of births and the distribution of persons by ages, engaged the attention of scientists in many countries through successive decades. Eventually their investigations led to the systematic exposition of possible interrelations among births, deaths and the age structure of populations. Alfred J. Lotka developed the classic formulation of these relations. Though most of his work was carried out in the United States. his definitive exposition was presented in French: *Théorie analytique des associations biologiques. II. Analyse démographique avec application particulière à l'espèce humaine* (1939).

Censuses.—The major source of basic information on population during the 18th century was the civil register of vital events, established in most European nations to supersede reliance in legal affairs on church records of christenings, marriages and burials. There had already been occasional countings of people in some nations, but these early censuses were sporadic. Usually there was neither a complete tabulation of the returns nor any publication of the results. Quite different opinions were often entertained about the population of a country, even as to whether its population was increasing or decreasing. Scientists investigating these questions experimented with new methods of observation and analysis.

The constitution of the United States prescribed representation in congress on the basis of a periodic census of the population beginning in 1790. Periodic censuses were initiated both in England and in France in 1801. Since that time censuses have gradually spread through the world and supply basic information on most of the world's inhabitants. The greatest gap was apparently closed by the census of China. 1953–54, though its results must be accepted with some reservation. Three-fourths of the population of Africa has been described by complete enumerations or national inquiries on the basis of scientific sampling. However, the scope and reliability of censuses differ greatly among nations. (*See* also CENSUS; *VITAL* STATISTICS.)

Information on births, deaths and migration is less satisfactory. In the United States, the registration of births and deaths was still very defective in most states at the beginning of the 20th century. Federal birth and death registration areas, initiated at that time, were first extended to include all states in 1933. Reliable vital statistics are still lacking for countries containing more than half the world's population; *i.e.*, Asia (except Japan. Taiwan, Ceylon and Israel). most of Africa and much of Latin America.

Estimates of fertility and mortality can sometimes be obtained by the systematic exploitation of indirect and fragmentary information. but even the critical and skilful use of incomplete information is not a satisfactory substitute for adequate basic data. The measurement of migration, especially within nations, is inherently difficult Census inquiries are used in many countries to obtain some Information on this subject.

MORTALITY

The risk of death varies with age and sex. In general the risk at any given age is less for females than for males, though under some conditions the death rates of women in the childbearing ages may be above those of men at the same ages. The risk of death is high immediately after birth and, with diminishing force, through early childhood; it decreases to a minimum at 10 to 12 years of age. The risk then rises again until at late ages it surpasses that in the first year of life. So the crude death rate of a population (usually expressed as deaths per year per 1,000 persons) is powerfully influenced by its age composition. For comparative purposes. the effect of age composition must always be taken into account in the measurement of mortality. Various standardized death rates have been devised for this purpose, but each is subject to certain technical objections. The expectation of life at birth, as given by a life table. is the most efficient index of the general level of mortality of a population. This is a hypothetical figure. It shows the average years of life to be expected at birth if the risks of death at particular ages in a specified year continue in effect. In Table III the calculated expectations of life at birth are shown for certain countries at particular times.

Mortality Levels.—The range in levels of mortality, shown in Table III, mainly reflects degrees of progress in technology. especially in sanitation and medicine. Prior to the 18th century, the range in levels of mortality was much narrower, except at times of famine, plague or war. In normal times the mean expectations of life at birth were then in the vicinity of 25 to 30 years.

The figures for Ceylon in 1954 are surprisingly high; a decade earlier, in 1945–47, the figures had been 46.8 for males and 44.7 for females. The change was due mainly to a campaign in that country, with the assistance of the World Health organization, for the control of malaria by DDT spraying and related advances in sanitation. Mortality can be substantially reduced in underdeveloped countries by mass programs without great changes in levels of living or education—and at a more rapid pace than the earlier gradual lowering of death rates in Europe. A great advance along this line has been in progress throughout the world

TABLE III.—*Life Expectancy at Birth in Selected Populations*
(in years)

Country	Date	Males	Females
Norway	1951–55	71.1	74.7
Netherlands	1953–55	71.0	73.9
England and Wales	1959	68.1	73.8
United States			
Whites	1958	67.2	73.7
Nonwhites	1958	60.6	65.5
Canada	1955–57	67.6	72.9
France	1952–56	65.0	71.2
U.S.S.R.	1957–58	64.0	71.0
Italy	1954–57	65.8	70.0
Japan	1959	65.2	69.9
Ceylon	1954	60.3	59.4
Costa Rica	1949–51	54.7	57.1
Chile	1952	49.8	53.9
Guatemala	1949–51	43.8	43.5
India	1941–50	32.5	31.7

Source: United Nations Demographic Yearbook 1960, table 23.

Class Differences.—There are still important differences among social classes within technically advanced nations in levels of mortality, especially in infancy and early childhood. This is indicated by the differences between the figures for whites and nonwhites in the United States (*see* Table III) and by other information concerning families at different economic levels. However, such differences have generally been narrowed in North America and in Europe. especially since World War II. On the other hand. differentials in mortality between males and females have generally widened—notably in the United States. Various reasons for this phenomenon have been advanced, but none has as yet won a clear consensus among scientists.

Life Expectation.—The lengthening of the span of life is due chiefly to the control of infectious diseases which are especially dangerous in infancy and early childhood Where the expectation of life at birth is only 30 years, about half of the newborn infants die before age 25 years; but where the expectation is 70 years, over 95% of those born alive pass the 25-year point. Past progress in lowering mortality and that now going on in underdeveloped countries, therefore, exerts a powerful influence on rates of population increase. Future progress in the extension of life in technically advanced countries, being largely dependent on the reduction of deaths at late ages, may be relatively slow. See also DEATH RATE.

FERTILITY AND REPRODUCTION

The word fertility is used to denote the actual production of offspring, whereas fecundity refers to biological capacity. The average capacity of a population for reproduction cannot be precisely measured; it varies to an unknown degree under different conditions and perhaps among different stocks. The average capacity of couples under widely prevalent conditions has been estimated at 8 5 to 10 or more births; some couples can have more than 20 births, but others in every society are sterile or become so after the birth of one or several children. In any case. reproduction in human societies is always influenced by customs affecting the frequency of and ages at marriage, divorce and separation, the remarriage of widowed and divorced persons, prohibitions against sexual intercourse under particular conditions. and in many other ways. Various practices. largely magical, both to promote fertility and under certain conditions to prevent conception or induce abortion, are found in most preliterate societies. but they usually have little effect on actual performance. Among technically advanced societies. variations in levels of fertility are determined mainly by attitudes and practices; they have little relation to possible variations in fecundity—though post-World War II increases of birth rates in Europe and North America may have been due in small part to a reduction in the frequency of complete or partial sterility.

Reproduction Ratios.—In most of Asia (except Japan), in Africa and in America from Brazil north through Mexico, each woman who lives through the childbearing years has on the average about six children—though there is. of course, some variation among regions. Between 48% and 49% of all babies are girls. So the average number of daughters born alive per surviving woman (gross reproduction ratio) under these conditions is about three. If the number of children which newborn female infants might eventually bear if all lived through the childbearing period is cut in half by deaths between birth and successive adult ages, there will still be about 150 daughters in each generation per 100 daughters in the previous generation (net reproduction ratio). The population will then tend to increase by 50% during an intergeneration interval. usually somewhere between 25 and 30 years. In past times, this tendency was checked by recurrent disasters. With the same gross reproduction ratio (three) but improvement in sanitation so that only one-third of the potential reproduction is lost by mortality, the net reproduction ratio becomes two. In other words, the population then doubles in each generation. Due to reductions in mortality and the persistence of high fertility, the population of the less-developed countries is generally moving toward. or has already exceeded, this reproductive level. This statement. in the absence of reliable vital statistics, is necessarily based on inferences from census data. investigations in various localities and other indirect evidence; but it is supported by cumulative evidence from many sources.

The general level of fertility in Europe prior to the Industrial Revolution. and perhaps throughout medieval times, was significantly below that now generally prevalent in Asia, Africa and Middle America. The moderation of fertility in preindustrial Europe was not due to the control of fertility within marriage but to social restraints on marriage or procreation at early ages—associated with an emphasis on the nuclear family (husband, wife and children) as contrasted with the larger kinship groups in many societies. These restraints on early marriage were eased among settlers in the open spaces of the new world, so that fertility in colonial America was much higher than in Europe. Different social conditions, also, led to some reduction of fertility in premodern Japan, but in this case by resort to abortion and infanticide.

Control of Fertility.—The growth of commerce, new opportunities for individuals to achieve higher levels of living, the withdrawal of children from economic production and provisions for their education stimulated a new interest in the control of fertility within marriage. At the same time. the lowering of mortality increased the probability that most infants would survive to maturity. Then, too. the progress of science and education fostered rationalistic behaviour in the pursuit of personal goals. Incidentally. it seems that men were at least equally and probably more insistent than women on the control of births. So a trend toward the regulation of births within marriage began in France and in the United States near the beginning of the 19th century. Later, but with long lags. it spread through all western and central Europe and then eastward and southward and from cities into rural areas. The control of fertility was at first achieved through an intensification of ancient folk practices, but it was later facilitated by mechanical and chemical means of contraception. It first gained momentum in professional and commercial classes and then spread more slowly through the families of skilled and unskilled workers. This pattern brought wide differences in fertility among the social classes.

As the regulation of fertility has become more nearly universal in Europe, North America. Australia and New Zealand, 'social class differentials in fertility have been narrowed. though they have not entirely disappeared. The trend toward the regulation of fertility in these regions was apparently approaching completion. in the sense of bringing fertility more or less into conformity with the personal interests of couples, when the world-wide economic depression generated a wave of anxiety to avoid. or at least to postpone. the enlargement of families. Wartime opportunities for employment and postwar prosperity brought a shift toward earlier marriages, a reduction in the frequency of childless or one-child families and some increase in the number of subsequent births to couples who already had t o children—notably in North America, Australia and New Zealand and, to a lesser extent, in Europe. Assuming 1.057 male births per female birth. with 95% of the female infants living to the centre of the childbearing period, of whom 90% marry, an average of 2.16 births per woman living through the childbearing years, or 2 4 births per ever-married woman. will maintain a constant population. Around 1960 fertility was well above this level in North America and Oceania

TABLE IV.—*Estimated Birth Rates by World Regions, 1954–58*

Region	Per 1,000 population per year	Region	Per 1,000 population per year
World	35	U.S.S.R.	26
Africa	45	Northern America.	25
Southwest Asia	42	Oceania	24
South central Asia	41	Southern Europe	21
Southeast Asia	46	Central Europe	19
Middle America	42	North and western Europe.	18
South America	40	Japan	18

Note: The general birth rate in Africa may be higher than in Southwest, Central, and Southeast Asia, but this is speculative. The estimate for "East Asia," which includes mainland China, is omitted.
Source: United Nations *Demographic Yearbook 1959*, Tables 2 and 3.

and in some European countries; in some other European countries it was fluctuating in this vicinity. Fertility in the Soviet Union was then similar to, but slightly above, that in the United States. The rapid decline of fertility in Japan brought it into line with the low-fertility countries in Europe. In both instances, sharp declines mere initially effected by widespread resort to abortion. with a gradual shift toward increased reliance on contraception.

Meanwhile fertility remained at a fairly constant level in most of the underdeveloped countries. Except in periods of rapid change, crude birth rates usually give a fair indication of levels of fertility (in contrast to crude death rates, which are strongly influenced by differences in age composition). Estimated birth rates by world regions are shown in Table IV.

See also BIRTH CONTROL; BIRTH RATE.

AGE AND SEX STRUCTURE

The age and sex composition of a population is determined. apart from the effects of migration. by the frequencies of births in previous years. the sex ratio at birth and the proportions of male and female infants living to successive ages. The age and sex composition of a closed population (not affected by migration) in which the relative frequencies of vital events (births, deaths by age and by sex, and the sex ratio at birth) have been constant for a long time can be calculated mathematically from information on these vital rates. The effects of particular changes in vital rates can also be calculated, but such calculations are more complex.

A population with persistently high fertility has a large proportion of children and a small proportion of aged persons. A population. such as that of France, in which fertility has been low for a long time, has a smaller proportion of children and a larger proportion of aged persons. Changes in fertility have an immediate effect on numbers of children, but 15 years must pass before

TABLE V.—*Age Distribution of Enumerated Populations in Selected Countries*

Country and date of census	Per cent in specified classes: Under 15 years	15–59 years	60 years and over
Philippines, 1948	44.2	51.0	4.9
Nicaragua, 1950	43.3	51.9	4.8
Costa Rica, 1950	42.9	52.4	4.8
Thailand, 1947	42.3	53.5	4.2
Brazil, 1950	41.9	53.9	4.3
South Korea, 1949	41.7	53.0	5.3
Egypt, 1917	38.1	55.9	6.0
India, 1951	37.4	56.9	5.7
Japan, 1950	35.4	56.9	7.7
Argentina, 1947	30.9	62.6	6.6
Canada, 1950	30.3	61.9	7.8
Netherlands, 1947	29.3	60.0	10.7
United States, 1950	26.9	61.0	12.2
Australia, 1954	28.5	59.8	11.7
West Germany, 1950	23.6	62.7	13.8
Sweden, 1950	23.4	61.6	14.9
France, 1954	23.3	59.7	17.0
England and Wales,'1951	22.1	61.9	15.9
Belgium, 1917	20.6	63.8	15.6

Source: United Nation3 *Demograpkic Yearbook 1956*, p. 9.

the change affects the numbers above this age, and 60 years before it affects the numbers of older persons. Therefore, a population that has experienced a recent decline in fertility tends to have relatively small numbers both of children and of aged persons and a large proportion of adults in the middle ages. An upswing in births will again bring an increase in the proportion of children. Thus the rise of fertility in France during the post-World War II period increased the proportion of children in its population while the proportion of aged persons remained relatively high In technically advanced countries reductions in mortality at late ages may be expected to increase the proportions of aged persons. (A systematic exposition of these principles is given by Ansley J. Coale, "The Effect of Changes in Fertility and Mortality on Age Composition." *The Milbank Memorial Fund Quarterly, 34*:79–114 [Jan. 1956].)

The age distributions of population in different countries *(see* Table 5') are mainly due to differences in the levels and trends of fertility. They have also been influenced in varying ways by migrations, war losses and differences in mortality—though these effects are generally less important than the influence of variations in fertility. The migration of young adults. who bring children with them or soon have children in the area to which they move, is likely to swell the numbers both of adults in the middle ages and of children in the receiving country while the proportion of aged persons remain low—with reverse effects on the population of an area from which there is a large net out-movement.

The division by sex of a population. or of its component age classes. at any moment is determined quite simply. apart from the influence of migration, by the ratio of males to females at birth and the relative proportions of males and of females who have survived from birth to successive ages. See SEX; SEX RATIO.

MIGRATION

It is possible to distinguish three major kinds of spatial population movements: tribal wanderings and expansion by conquest into new lands—a process continued in the form of military occupation and colonization; forced transfers of people, including the acquisition of captives, the movement of slaves and the expulsion of minorities for political reasons; and the free movement of individuals. (The movement of indentured or contract labourers, which in some situations includes an element of force or fraud. is somewhat intermediate between the last two types.) Migration usually refers to the free movement of individuals; but other types of movement have been important forces in determining the present distribution of the world's population, and the 20th century has been plagued by forced movements on a large scale *(see* MINORITIES; REFUGEES).

The free movement of individuals is directed mainly toward the adjustment of people to economic opportunities—though it is influenced by diverse motives and has complex social and cultural aspects. Migration as a process of economic adjustment is often impeded by ignorance. attachment to habitual sites, the costs and risks of migration, and political barriers. Moreover, the sheer magnitude of population and the force of natural increase in the major regions of limited opportunity exclude the possibility that international migration can be a major factor in raising the levels of living of these regions. Migration seems to have been economically most effective when great resources held by small populations have been open to migrants, or there has been a great expansion of economic activities in which prospective migrants could be absorbed, and when migration has been associated with other transitional economic and demographic processes in the countries of origin.

The second of these relations is illustrated by the progressive shift southward and eastward of the areas of overseas emigration from Europe, with a spontaneous diminution of outflows from western and northern Europe as their industries expanded and their birth rates declined. It is also illustrated by the post-World War II movement of Puerto Ricans to the mainland of the United States, associated with the formation of new economic enterprises, progress in education and an initial trend toward modification of fertility.

Although migration varies greatly in magnitude and significance under different conditions. some approaches have been made to the formal analysis of internal migration (within nations) and the magnitudes of various streams of international migration at different times have been estimated. There is also much information about the characteristics of migrants and their adjustments. but this is not easily summarized. The total number of overseas migrants passing from Europe to the Americas. Oceania and Africa from 1800 to 1940 is estimated as being in the vicinity of 60.000,000 persons. of whom about two-thirds to three-fourths remained abroad. These immigrants and their descendants have increased more rapidly than the people in the countries of origin so that their number now approaches that of the population of Europe outside the Soviet Union. There were also smaller but important movements from China, Japan and India to other continents, as well as within Asia.

The partition of India in 1947 involved the forced movement of some 17,000,000 persons. World War II uprooted 25.000 000 to 30,000.000 people in Europe. There were 600.000 displaced persons on the rolls of the International Relief organization in 1946. These were absorbed in new situations; but, because of unresolved political conflicts, the Arabs displaced by the formation of Israel remained in refugee camps into the 1960s.

There was a net overseas migration of more than 4,000,000 persons from Europe during the first postwar decade. 1946–1955. The principal areas of origin and destination are shown in Table VI. Emigrants from Italy, Spain and Portugal went mainly to Latin America. Most of those from northern and western Europe, including Germany, went to the United States or to Commonwealth countries. Migrants from eastern Europe, mostly displaced persons, were widely dispersed; but they contributed a large contingent to the formation of the population of Israel.

TABLE VI.—*Net Oversees Emigration From Europe and the Soviet Union, 1946–55*
(in 000)

Country	Number	Country	Number
Areas of origin		Principal destinations	
Italy	939	United States	1,239
Great Britain and Ireland	860	Canada	954
Poland	488	Latin America:	
Germany	487	Argentina	586
Spain	301	Brazil	329
Portugal	278	Venezuela	206
U.S.S.R.	243	Other	70
Rumania	165	Australia	754
Netherlands	117	New Zealand	116
Yugoslavia	114	South Africa	127
Other	371	Israel	378
Total	4,363		

Source: Dudley Kirk, "Major Migrations Since World War II," in Milbank Memorial Fund, *Selected Studies of Migration Since World War II* (1958).

See also MIGRATION.

THEORIES AND POLICIES

The movement and structure of a population involves the formation of new lives and their persistence through spans varying from a moment to a century. These demographic processes can be measured, and possible interrelations among them can be analyzed in abstraction; but they are essentially biological processes and in human societies they are largely controlled by economic, social and psychological conditions. Moreover, population movements in turn influence all other human affairs. They have social determinants and consequences. The objective study of population in its biological and social context, therefore, can aid in the formation of realistic public policies.

Turning to aspects of population theory that are related to social issues. mention still must be made of the century-old debate between the exponents of two conflicting dogmas, expounded by Thomas Malthus and by Karl Marx, about relations between population and economic conditions. Each of these dogmas contains sufficient truth to inspire enthusiasm in its disciples, but each is a gross oversimplification and distortion of actual situations.

Malthus, who in 1798 published the first edition of *An Essay on the Principle of Population as It Affects the Future Improvement of Society, wzth Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers,* held that the increase of population enforced by "the attraction between the sexes" constantly tends to exceed the resources for its sustenance and is always subject to the "positive checks" of famine, war and disease. Each advance in the arts is absorbed by a consequent increase of population, thus preventing any rise in the general level of living. This is, indeed, a fair statement of the situation in much of the world prior to the time of his essay and in some areas at later times. But he proceeded on the fallacious assumption that increases in production could never exceed, or even equal. increases in population. He later modified this position by suggesting that under some conditions population might be brought into a more favourable balance with production through the "preventive check," by which he meant the postponement or avoidance of marriage and procreative activity. He repudiated M. Condorcet's suggestion that fertility might be controlled within marriage not only on moral grounds but also for economic reasons because he viewed poverty as a necessary stimulus to economic activity. Some later proponents of birth control who drew support from his economic doctrine called themselves Neo-Malthusians. Malthus applied his exposition of "the population principle" in opposing certain welfare measures which he viewed as futile and dangerous and, in general, repudiated the idea of improving the condition of mankind through changes in economic and social institutions. Marx viewed revolutionary changes in economic and social institutions as inevitable and as leading toward an ideal society. He violently attacked Malthusian theory, just as Malthus had attacked the utopian socialism of Condorcet and Godwin. He equated overpopulation with actual, or latent, unemployment; he described relative overpopulation in this sense as essentially and purely a phenomenon of the capitalist system. Exponents of Marxist doctrine view the control of population and changes in economic institutions as alternative and incompatible approaches to the advancement of levels of production and income.

Most contemporary demographers and economists view constructive changes in economic institutions. the advancement of education and the control of fertility as essentially complementary processes—none of which can be effective in the long run unless reinforced by the others. They point to specific ways in which rapid increase of population in low-income countries hampers economic and social development. This type of analysis was well summarized in the following quotation from a statement prepared by the United Nations secretariat.

To sum up, population enters into the problem of achieving satisfactory standards of living in the under-developed countries in three principal ways. First, their high birth rates create a heavy load of dependent children per adult. This makes it difficult to save enough, over and above what is required for the support of the workers and their dependents, for needed investments in equipment for economic development. It also seriously complicates the problem of providing the children with the education that is essential for social and economic progress in the long run. This aspect of the population problem is common to all the under-developed countries. Second, falling death rates with high birth rates bring about a rapid increase of population. Large investments must be made to keep the growing numbers of workers equipped even with the same inadequate amounts of working equipment per man as they have had in the past. So the possibilities for investments which would improve the equipment and raise productivity per worker are diminished. This speeding up of population growth, aggravating the shortage of capital, is now taking place in very many under-developed countries, wherever successful public health campaigns have greatly reduced death rates. Third, many of the under-developed countries have an excessive density of agricultural population in relation to the area of cultivated land. The average iarmer has too little land to make a satisfactory living for himself and his family. Not all under-developed countries face this difficulty, but it exists in some which have large amounts of unused land, as well as in those where nearly all the cultivable land is fully occupied. At least some of the countries now suffering from acute agricultural over-population might be able to employ all their numbers to good advantage, and benefit in the long run from a substantially larger population, if they were better equipped to utilize the land resources which they possess, or if they could industrialize. But neither the necessary improvements of agriculture nor the development of industry can easily be accomplished, and the difficulties are increased by high birth rates and rapid population growth. It appears that even in a country where population growth would be economically advantageous in the long run, economic progress will be hindered if the birth rate is so high and if the population grows so rapidly as to put an excessive strain on the economy. (From *Population Growth and the Standard of Living in Under-Deneloped Countries,* a summary of relevant chapters of UN Dept. of Social Affairs. *Tha Determinants and Consequences of Population Trends, UN* Population Studies no. 20 [1954].)

The social aspects of population have generally received much less attention than the economic aspects. though in some situations they may be even more important. For example, there are important relations between population trends and education. A high ratio of children to adults. characteristic of many poor areas with high fertility. requires a larger expenditure per adult to maintain a given standard of schooling than where the proportion of adults is higher and may hamper the recruitment of qualified teachers. Again, the-character of the adult population in areas of heavy inmigration, e g., most cities. is strongly affected by levels of education in other regions. This reinforces the thesis that education is not purely a matter of local concern. Moreover. if the less-educated elements in a population are more reproductive than those with higher education, the cultural force of education in successive decades is weakened. This trend may be largely a transitional phenomenon; but the extent to which it may reflect persistent conditions requires greater attention. On the other hand, the advancement of education may be a potent force in promoting the regulation of births. These brief comments suggest larger and more complex problems on which as yet there is little knowledge. The distribution of genetic factors is inevitably affected by differences in reproduction rates. But, again. this is a momentous issue on which present knowledge is sadly deficient. Some governments, including among others those of Sweden the Soviet Union. Japan and many of the state governments of the United States, have taken special measures (sterilization) to control fertility by persons handicapped by defects or diseases that frequently involve genetic factors.

During the late 1920s and the 1930s, when birth rates were falling rapidly in Europe, North America and Oceania, there was much alarm about "the retreat from parenthood"—reinforced in some countries by considerations of national security. Demographers were to some extent responsible for exaggerating the dangers in this situation through misplaced confidence at that time in the net reproduction ratio as an index of intrinsic population trends. Moreover, some economists viewed the slackening of population growth as tending to cause economic stagnation and chronic unemployment. It was. in any case, apparent that demographic changes were increasing the proportion of aged persons in the population.

These considerations led to the advocacy of measures for promoting the maintenance and growth of population as a matter of public policy. Quite different measures to this end were advanced in different countries and by different groups within the same country. In France concern about population trends. in conjunction with other interests, led eventually to a comprehensive system of family allowances and related measures, in which the government still makes a large investment each year, which actually offset at least in large part the costs of additional children in many French families Some programs of financial aid to families with children have been adopted in most European and many non-European countries, including Canada. These programs are usually designed to serve various ends, and it is often difficult to say to what extent they express population policies. Moreover, most governments have been reluctant to authorize expenditures on a scale comparable to that accepted in France. More blatant but less expensive pronatalist measures were inaugurated by the Italian Fascist and the German National Socialist regimes.

Laws against the promotion or sale of contraceptives, as such, as well as stringent legislation against abortion are supported in some countries by demographic as well as religious considerations. The qualitative aspects of population trends were taken explicitly and seriously into account in general population policies only in Sweden. And even there the early program. which included this emphasis along with other welfare features, has been revised in favour of direct subsidies to families with children. Many governmental programs designed to promote fertility without much expenditure of public funds had practically no effect. In some other countries, notably in France. it is impossible to say to what extent pronatalist programs may have influenced actual population trends.

Policies designed to promote the limitation of births have been officially adopted by the governments of Japan. India. Pakistan and Puerto Rico and have been proposed with various reservations in China, Ceylon and Egypt. The inauguration of the Japanese program was followed by a rapid decrease in births, but the method most widely accepted to achieve this end (abortion) is not acceptable in most countries. Governmental action in this field in Puerto Rico has been restrained by strong opposition, but there has been some lowering of fertility in the island. The government of India has intensified its efforts in this direction. with increased appropriations. Governmental action on this question in Pakistan dates from 1960. These programs may eventually influence actual population trends, but they encounter inherent difficulties under the conditions of rural life in the Indian subcontinent.

The importance of population questions is officially recognized in the councils of the United Nations. The 15-member Pooulation commission, a permanent expert body of the United Nations Economic and Social council, keeps population problems under continuous review. Areas of concern include population problems of underdeveloped countries, mortality, fertility and migration studies. age structure, labour supply and aging, and population estimates and forecasts.

See also references under "Population" in the Index volume.

BIBLIOGRAPHY.—International journals of demography: *Population Index* (Princeton), an annotated bibliography of current books and articles on population; *Population Studies* (London); *Popirlntion* (Paris). United Nations: *Demographic Yearbook;* also "Population Studies" (a series of monographs). Philip M. Hauser and Otis Dudley Duncan (eds.), The *Study of Population, An Inventory and Appraisal* (1959). (F. Lo)

POPULATION ECOLOGY. A relatively recent research interest among biologists is the study of groups of organisms as contrasted with the study of individuals. As is meli appreciated, much of biological knowledge rests upon the morphology, physiology and biochemistry of those units that comprise the organism (*e.g.,* cells, tissues, systems) and upon knowledge of the entire organism considered as a whole. However, it is becoming increasingly evident that significant problems and principles emerge when the reactions of animals considered as populations are investigated. This has many parallels in scientific inquiry including many areas of biology. Thus, in the study of tissues (histology). a cell as a single unit, groups of cells and the particular tissue itself all must be subject to analysis. This is equally true of population research. Not only is it essential to understand the interactions between an individual and its surroundings but, also, it is equally necessary to understand those new interactions that emerge when the group operates as a unit within its particular physical environment. This, once accomplished, is logically followed by consideration of different kinds of populations so that a body of general information about the subject is built. It is in this may that population biology grows as a unified science in its own right.

Population biology falls into two broad categories: population genetics and population ecology. The first, concerned with the processes of organic evolution, lies outside the scope of this article but is treated elsewhere (see EVOLUTION, ORGANIC; GENETICS OF POPULATIONS). The second forms the subject matter here to be discussed. A general distinction between the two subdivisions can be drawn as follows: The student of population genetics is concerned primarily with events within the population leading to qualitative hereditary differences—with the transmission in time of genes through the group and with those agents that affect this transmission such as mutation, selection (*q.v.*), isolation, breeding structure and so on. The student of population ecology on the other hand is concerned primarily with quantitative events within the population—with those environmental factors, regardless of type, which affect the group's size, its composition and its growth and life history. This distinction between these two major fields becomes somewhat arbitrary if carried too far. because actually both depend to a considerable extent upon each other.

The subject matter of ecology (see ECOLOGY, ANIMAL) can be considered under four categories, each of which represents a grade of biological organization of increasing functional and structural complexity. The four are: the individual organism, the single species population, the mixed or several species population and the community. Knowledge of the ecology of single organisms—that is, of the interactions between one animal and its immediate environment—is designated autecology and is fundamental for an understanding of populations. Similarly, information about populations is fundamental for an understanding of the ecology of communities (synecology), those complex plant and animal assemblages existing in nature as essentially self-sustaining units. Although, when investigating a population, the ecologist must be informed about the autecological relations of its members, he must also study the groups as such. It follows, too, when communities are studied, that, in addition to research on the component populations, a suitable synthesis cannot be formulated without analysis of the communities as wholes.

The primary focus of population research is on numbers. A population may be defined appropriately in several ways: "The organisms, collectively, inhabiting an area or region"; or, in another version, "A group of living individuals set in a frame that is limited and defined in respect of both time and space." These definitions have at least four implications: number of individuals, likeness of kind enumerated, aliveness and limitation of universe in space and time. In other words, the definition of a biological population deals with these questions: (1) How many organisms are there? (2) Are the forms counted biologically alike? (3) Are members of the group living? (4) Where do the forms live and in what places?

Census Methods.—Since the study of populations involves a count of those organisms present in a circumscribed area or volume, it follows that the single most significant technical procedure in population research is the taking of an adequate census. This assumes several forms, depending upon the particular situation. Population size is usually determined, or at least approximated, by one of the following methods:

Total Count of All Individuals of *All* Stages *or Classes.*—This is the only single census method that is completely accurate. It counts in a delimited environment every individual regardless of age, sex, stage of development or location. It is only occasionally that the method can be used because: (1) the number of animals usually is too great; (2) it is technically impossible or at best not feasible; and (3) the precision it affords is not worth the effort. Modern censuses of human populations for civilized countries approach the perfection the total census method demands.

Total *Count* of All Individuals of a Certain Stage or *Class.*—This method is used either because it is sufficient to know only how many members of a specified category are present within a population or else it represents the best that can be done under the circumstances. For example, in censusing an insect population the student may be concerned only with the number of adults and ignore, say, the number of eggs, larvae and pupae.

Method of Sampling.—This is the usual method employed in estimating population size. It assumes that the investigator can form a judgment about the entire group, however delineated, by withdrawing replicated aliquots. This method can be highly accurate when the pattern of distribution of the forms is understood and the samples are taken with this in mind. On the other hand, it is replete with pitfalls at the hands of the unskilled and can lead to gross errors of interpretation.

The successful application of sampling methods depends on firsthand information about the ecology of the group under study; on a knowledge of what constitutes an adequate sample, followed by appropriate statistical treatment of the data once collected; and, above all, on wisdom and judgment in 'evaluation of the findings.

Method of Biomass.—This method utilizes weights of population samples (biomass) instead of counts of individuals. The weights are always reported relative to some defined spatial unit and may be treated directly as such in analysis of the data or else converted into number of individuals.

Registration *Method.*—This method requires that, after an initial census has been taken, each birth, death, immigration and emigration within the population shall be recorded at stated time intervals. Population size is then enumerated as follows:

$$\text{population size} = \text{initial size} \pm ([\text{births} + \text{immigrations}] - [\text{deaths} + \text{emigrations}]).$$

This method is of minor practical importance because it frequently is difficult to obtain the requisite facts about births, deaths and dispersion, and because it is usually simpler to count the members directly.

Method of &farking.—This useful technique is gaining rapid adoption among students of insect and mammal populations. In one of its variants the procedure is as follows: a known number of marked animals is turned loose within the habitat. It is assumed that, since these presumably redistribute themselves as they were before being caught, then in a sample taken later the proportion of marked to unmarked forms can be determined with total population size estimated by solving this equation:

$$\frac{\text{total number of marked animals released}}{\text{total number of unmarked animals}} = \frac{\text{marked animals caught in census period}}{\text{unmarked animals caught in census period}}.$$

The unknown to be solved for is the denominator of the first fraction—a solution readily obtainable by simple algebra.

Indirect Methods.—Sometimes it is impossible to count numbers of animals at all but it is possible to approximate their abundance only by some product of their activity—the greater the product, the larger the size of the group. This is the poorest of all census methods and is, or should be, used only as an extension of other techniques or as a last resort. These are certain manifestations that have been utilized in estimating population numbers: the number of fecal pellets (rabbits, foxes); of shed antlers (deer); of tracks (rabbits, birds); pelt records (fur-bearing mammals of commercial significance); the frequency of vocalization (bird calls, howls, etc.), and so on.

In certain instances, as has been recommended, various methods can be combined to advantage.

Scope of Population Ecology.—Modern population research falls into the following practical categories:

1. Studies of natural (field) populations. These are both intraspecies (single species) and interspecies (several species) in character.
2. Studies of experimental laboratory populations (both intraspecies and interspecies).
3. Studies of human populations (intraspecies).

4. Epidemiological studies (interspecies, as interpreted in this article).
5. Theoretical population ecology (both intraspecies and interspecies).

Natural population studies usually deal with the distribution, total size, territorial relations, predation and other interspecies competitions and the relation of the population to its immediate physical environment. Insects, fishes and their planktonic foods, birds and mammals have been most studied as natural populations.

Laboratory population studies make their prime contribution through control of the physical and biotic environment. They attempt to analyze a specific group relationship that would be either extremely difficult or impossible to study in many natural populations. The objective of such research is to illuminate population operations by means of relatively simple, yet not artificial, models, and then to apply the results to groups in nature. In the laboratory these are the general problems most studied: at the intraspecies level, population growth form, analysis of population density and the effects of density on reproduction and death; at the interspecies level, competition for a shared food supply or niche in which to live, and the interactions between predators, parasites and prey. Microorganisms (protozoa, bacteria, yeasts), insects and certain rodents have been employed most extensively in such investigations.

Human population studies are treated elsewhere from other points of view (*see* SEX RATIO: *Human, at Birth and Death;* LONGEVITY).

Epidemiological studies as viewed here are limited to population aspects of host-parasite interactions, although some students refer to epidemics of single species. Many of these are statistical, deal with pathogenic organisms and hence are of clinical significance. Such diseases in epidemic form as tuberculosis, diphtheria, the common cold, influenza, acute anterior poliomyelitis, septic sore throat, typhoid fever, typhus, sleeping sickness and malaria have been investigated from this point of view. In these instances man is the host organism, but the findings are of distinct importance for population ecology. In a book by F. M. Burnet, himself a medical scientist, entitled *Biological Aspects of Infectious Disease,* the following pertinent statement appears:

> Other workers with an appreciation of modern developments in biology are finding that infectious disease can be thought of with profit along ecological lines as a struggle for existence between man and micro-organisms of the same general quality as many other types of competition between species in nature (by permission of the Cambridge University Press).

In addition to the studies with a clinical motivation there exist important laboratory studies of host-parasite interactions using insect materials.

Theoretical population ecology is still in an early stage of development. Workers have concentrated on three aspects: mathematical rationalizations, the problem of the origin and integration of social groups and synthesis of knowledge to build a conception of population integration, that is, how a group as such is controlled through its own functional organization.

Natality, Mortality and Dispersion.—In all scientific inquiry there are particular focal points of study. The physicist stresses the behaviour of atoms and molecules; the geneticist, the transmission and physiology of genes; the cytologist, the structure of the cytoplasm and the nucleus, and so on. The student of population ecology is always concerned in final analysis with three composite statistical factors—natality, mortality and dispersion—and those forces that affect them. These factors shape the course of population growth form, its composition and survival as to age, sex and stage of development, and its distribution in space and time. Natality has the effect of increasing the size of the group. Mortality, the total deaths exhibited by the population, has the effect of decreasing the size of the group. Dispersion can operate, at least temporarily, in either direction depending upon the form it assumes, numbers being increased by immigrations and decreased by emigrations.

Natality can be viened as either potential or realized. Potential natality is that maximum number of eggs that the species can produce; realized natality is the birth rate. Were potential natality realized, each individual member of the population would need to exist under ideally optimal conditions. Obviously, this situation is rarely if ever attained in nature, which suggests that populations characteristically produce many fewer offspring than their physiological capacities allow. A valid ecological generalization is that species with high natality potentials are subject to excessive mortality of their eggs. while the converse is typically true for species with lower natality potentials. For example, P. S. Galtsoff (1930) estimated that a single oyster has the capacity of producing 55,000.000–114,000,000 eggs during a lifetime, when it is clear that only a relatively few of these mature. Similarly, J. L. Hart and A. L. Tester (1934) reported that a population of 1,000,000–9,000,000 herring in certain areas of the Strait of Georgia produce annually 8,000,000,000–75,000,000,000 eggs, of which perhaps 95% hatch and less than 0 1% reach maturity. On the other hand, the potential natality of the human female is comparatively low but the realization of this potential in terms of reproductive effort is high.

It is meaningful also to view mortality as potential or realized. F. S. Bodenheimer (1938) defined the former, which he called physiological longevity, as ". . . the average longevity of individuals of a population living under optimal conditions and of genetically homogeneous stock," and the latter, which he called ecological longevity, as ". . . the empirical average longevity of the individuals of a population under given conditions" (*Problems of Animal Ecology,* Oxford University Press). If a population is studied under situations approaching potential mortality, and if these data, expressed as survival against time, are then compared with a similar population under known conditions of realized mortality, the difference between the two curves indicates that approximate part of the total mortality caused by a suboptimal environment and that part which would occur even under the most favourable conditions. In a sense, potential mortality connotes the best that a group can do in terms of its life duration. while realized mortality connotes how much a group actually is decimated when confronted with hazards of various sorts. Among these hazards may be mentioned such items as unfavourable climate, excessive cronding, adverse biotic pressures engendered by predatory and parasitic organisms and accidents.

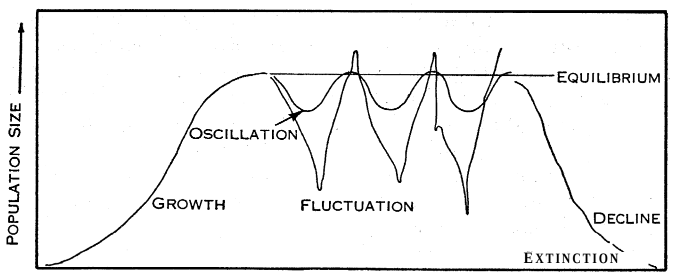
Obviously, great differences exist betneen species in the extent of ecological mortality to which they are subjected, some regularly having many deaths because of many causes and others having few deaths because of few causes. with numerous gradations between. Populations of grasshoppers living under exposed conditions in plain and prairie habitats exemplify a group with a high realized mortality; honeybees living protected in hives with a highly perfected social organization exemplify a group with relatively low realized mortality.

Cases of potential mortality that approach the theoretical conditions were reported by R. Pearl and S. L. Parker (1924) on *Drosophila melanogaster*, by B. Noyes (1922) and Pearl and C. R. Doering (1923) on the rotifer *Proales decipiens*, and by B. P. Wiesner and N. M. Sheard (1935) on laboratory populations of albino rats. Ecological mortality was assessed by Bodenheimer for natural populations of the locust *Schistocerca.* He reported these specific mortalities for the various stages of the life cycle: eggs 13%. nymphal period 67.5% and adult period 19.5%. Not all causes of death were accounted for, but it does seem clear that the eggs are particularly subject to insect parasitization and fungus disease, while the nymphs and adults are eaten by lizards, birds, small mammals and, sometimes, by man.

Although it is necessary to discuss natality and mortality as if they are single factors, it becomes immediately apparent, however, that it is their interaction that is significant in terms of the behaviour of the total population. Thus, a high birth rate taken by itself is of minor value without knowledge of the corresponding death rate reported for the same group over the same time interval. Such a birth rate might suggest that the population is vigorously expanding, while actually, as is so frequently true, the death rate could be so severe that members added by reproduction are canceled by deaths, uith the result that the population remains stationary. Similarly. a low birth rate does not necessarily indicate a declining population, because it may be associated with a correspondingly lower death rate. A single empirical statistic has been proposed, known as the birth-death ratio or vital index, which shows at a glance this relationship between natality and mortality. This is defined as 100 births ÷ deaths, and yields upon solution the number of births for each 100 deaths. In the absence of sustained immigration or emigration a vital index greater than 100 shows that the group is growing; less than 100, that the group is contracting; and equal to 100, that the group is stationary.

The interactions of natality and mortality are decisive in controlling the growth form of populations only when the group is not dispersing over its territory to any extent or when it is not adding to or subtracting from its membership as a result of migratory phenomena. Thus, as mentioned above, the pattern of movement of animals must be considered in all population studies, in addition to reproduction and death, whenever it effectively alters size or composition. Dispersion may take the form either of slight movements or rearrangements within the population, mass movements of the group itself or income from immigrations and outgo from emigrations. In nearly all natural populations such movements are occurring either sporadically or with considerable regularity. When these are of a magnitude to alter markedly the size of the population, internal adjustments must occur. Characteristically, but with exceptions, if a group loses constituents, the spaces thus made available are filled through more effective reproduction. If it gains members through the influx of new organisms, the pressure of competition for food, shelter, mates, etc., increases, and a higher death rate is brought about.

Population Growth Form.—As populations pass through their life history they assume certain patterns that are called, collectively, growth form. Knowledge of growth form is basic for the development of population ecology in that it provides a single numerical statement about how groups have behaved in time. It is obvious that a particular growth form is the product of the interactions between natality, mortality and dispersion. The following somewhat arbitrary phases constituting the growth form can be recognized and are stylized in fig. 1.



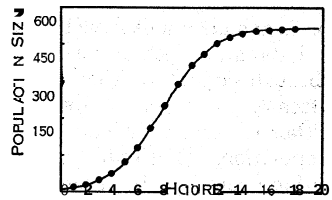
POPULATION LIFE HISTORY

FIG. I.—STYLIZED REPRESENTATION OF POPULATION GROWTH FORM

1. The period of positive growth (the population increasing).
2. The period of equilibrium (equilibrium is defined as mean numerical stability).
3. Oscillations and fluctuations (departures from equilibrium).
   A Oscillations (relatively symmetrical departures).
   B. Fluctuations (relatively asymmetrical departures).
4. The period of negative growth (consistent and progressive decline of the population below equilibrium or below the lower range of usual fluctuations and/or oscillations that jeopardize the population's survival).
5. Extinction (the disappearance of the population).

The growth (*q.v.*) of populations usually follows a sigmoid (S-shaped) curve when represented by number of organisms on the ordinate axis (vertical) against time on the abscissal axis (horizontal). This holds for many species of animals, including man, and abundant data have been accumulated for both laboratory and natural groups. In fact, a considerable segment of population biology has been concerned with fitting such data with a particular equation known as the logistic curve that, upon solution, yields a growth curve which is characteristically sigmoid. Fig. 2, from Pearl, The Biology of Population Growth (1930), illustrates this curve when applied to the multiplication of yeast cells within a spatially limited environment. The smoothed line is the calculated function, the dots are the actual census counts. The curve demonstrates that rate of growth is at first slow, then rapid, then slow again as the maximal number possible (asymptote) under the existing ecological conditions is approached.

After this asymptote is attained, assuming there are no marked changes in the exploitable potentialities of the environment, several courses are open to the population. It can maintain itself with slight variability at the mean maximal size (equilibrium); it can oscillate in even and regular dips and peaks about that maximum (oscillation); it can vary above and below the average equilibrium value in a more-or-less irregular fashion (fluctuation) or it can steadily contract (decline). If the contraction continues, the entire population dies (extinction).



ADAPTED FROM PEARL, THE BIOLOGY OF POPULATION GROWTH" (KNOPF)

FIG. 2.— THE LOGISTIC GROWTH OF A LABORATORY POPULATION OF YEAST

Initial sigmoid population growth is rarely demonstrable with any precision in nature, primarily because most groups have long since passed that original phase of their life history when censused. It can be demonstrated readily in the laboratory, however. Nor is equilibrium, oscillation. protracted decline or extinction often seen under field conditions. Most groups react so sensitively within themselves and with their surroundings that an even, sustained equilibrium is unusual. Oscillations demand such a regularity and repeatability of causal mechanisms that they too are rare events. A population decline that jeopardizes the future survival of the group is seen somewhat more often in nature, especially following an unfavourable climatic disturbance leading to increased mortality or decreased food supply or after exposure to a particularly virulent epidemic, but it too is exceptional. The extinction of definitive populations is likewise infrequent. Cases of species extinction are known, and occasionally the underlying reasons are understood; but as a rule populations are adaptable enough so that they compensate in one way or another for environmental vicissitudes before their contraction goes irreparably far.

Thus, by elimination, fluctuation remains the usual event so far as population growth form is concerned. Populations characteristically vary above and below an average equilibrium value. This variation may be caused by chance alone, but it is more likely to result from fundamental, yet temporary, adjustments between the group and its effective environment. The magnitude of the variation can be great or small in terms of total population size (ordinate axis). in terms of the time intervals between the fluctuations (abscissal axis) and in terms of the species involved.

Density-Independent and **Density-Dependent** Factors.—It is necessary to develop population ecology beyond a consideration of natality, mortality and growth form. While these aspects constitute the background for such studies in the sense that interactions of the first two induce a pattern of growth, it is clear that they in turn are influenced by factors of ecological origin. These, falling into two broad categories known as density-independent and density-dependent factors, merit brief definition and illustration (see bibliography, H. S. Smith).

It will be apparent from the discussion above that, as a population passes through the phases of growth form, the degree of crowding, or density, of its members characteristically varies to a considerable extent. Certain factors of the environment have virtually the same effect on the group's members regardless of this density relation. and these are called density-independent. Another set of factors, known as density-dependent, achieve notably different results when crowding is slight, as compared with the results obtaining when crowding is extreme. Thus, a particular unfavourable temperature might eliminate through mortality 60%, say, of a population, whether that population had a census of 100 or 1,000 members per unit area. On the other hand, this same population might not be vulnerable to predatory attack, or to disease in epidemic form, when composed of only 100 individuals but, alternatively, highly vulnerable when 10 times larger. These important distinctions can be clarified by actual cases.

Density-independent factors are largely products of the physical-chemical environment. Density-dependent factors stem primarily from biotic interactions between organisms. For terrestrial populations the more usual density-independent factors are the following: temperature (high, low and alternating), precipitation (both excess and deficient), wind and storms, atmospheric pressure. humidity, light and certain aspects of food supply. For aquatic populations, the' physical and chemical qualities of the water, water movements, light penetration, substratum effects and. again, selected aspects of food supply constitute the more characteristic density-independent agents.

A satisfactory illustration of a density-independent interaction between a particular environmental factor and a particular population is afforded by the report of Gordon Gunter (1941) on the relation of unusually low temperatures to mortality of fishes inhabiting the gulf waters of the Texas coast. The winter of 1939–40 was severe in that area, and on Jan. 18, 1940, an extremely cold wave brought about a drop in temperature within a few hours from 65° to 25° F., and then reached 16° that night. Many fish died from the cold, as was ascertained by experimental seining and the presence of corpses along the beaches. These deaths were also reflected in the fishery statistics reported annually for this region. For example, while the months of February–March–April for 1938 yielded 1,331,302 lb. of fish, and the same months for 1939 yielded 911,133 lb., the catch for 1940, subsequent to the cold spell mentioned above, was only 335,431 lb. Unquestionably. this decline reflected direct mortality caused by cold. When these statistics are broken down in various ways, as for example by localities and species, the same point holds. Of all the forms. the flounders were the most susceptible. The catch of these was 94.8% less after the cold days than it was for the winter months immediately preceding the unusual temperatures. This clearly illustrates a density-independent phenomenon in that the mortality is directly caused by temperature and appears to be unrelated to the density of the various fish populations.

Studies of the pollution of waters by industrial wastes, when coupled with the consequent effects of this chemical poisoning upon a particular population, offer further instructive examples of density-independent operations. This phenomenon is well kno n for a number of species, and frequently it can be shown that mortality stands in direct proportion to the kind and quantity of the pollutant but is primarily independent of the crowding of the group members. In general, the pollutants affect organisms in several ways. Acting directly, they can predispose to infection, increase egg and juvenile mortality. drive motile forms from their habitats and actually kill the adult members of the population subjected to them. Acting indirectly, they can reduce oxygen supply, harm or at least change the flora and further limit the habitats and food supply.

Although many examples could be selected to illustrate the density-independent action of pollution, a cogent one is that reported by P. S. Galtsoff, W. A. Chipman, A. D. Hasler and J. B. Engle (1938) concerned with oyster populations of the Tork river in Virginia. The years from the 1920s have seen a progressive decline of this population and the industry depending upon it. This started with the liberation of trade wastes into the river by a pulp mill. Apart from pollution, the York river is favourable for oyster culture. Careful comparative studies with ecologically similar neighbouring streams well populated with oysters show this to be true. This fact, along with the observed reduction of oysters follouing pollution, incriminates the latter as the causal agent. Experimental studies in the laboratory demonstrated that the wastes had a decided effect upon the mollusk's physiology. The pollutant induced a prolonged contraction of the adductor muscles with the consequence that the shells remained closed for undue periods of time, thus interfering with respiration and feeding. Also, the pollutant inhibits the ciliary activity of the gills, thereby preventing water from circulating with its customary efficiency. Such impairments of the oysters' physiology causes the individuals to be dwarfed, and they fail to store normal levels of glycogen. The entire case is proved, for when the oysters mere returned to clean water, and provided they had not been exposed to the poison for too long, their normal rate of growth was restored and glycogen was again deposited in adequate amounts.

Thus, a single density-independent factor, pollution, is identified, its effect on population decline is appraised and the physiological channels through which it acts are experimentally detected. It is interesting to note in passing that the authors found some oysters which resisted the pollution enough to continue to survive and reproduce and so maintain a relatively small population in the York river.

Although the above examples of density-independent operations deal with aquatic populations, it should be pointed out that terrestrial forms have also been actively studied from this point of view. In fact, much of the research along this line actually was developed by ecologically minded entomologists (see bibliography, B. P. Uvarov; A. J. Nicholson: H. S. Smith; W. R. Thompson).

Analysis of population density has been an active research interest of the population ecologist and leads, of course. into a consideration of density-dependent factors—those agents nhose effect upon the population varies with the crowding of its members. A systematic treatment of population density falls under three categories: the sorts of processes and events that are known to be influenced by density; the type of end result brought about by density regardless of the mechanisms involved (density as related to growth form) and the constitution of density per se.

A wide variety of processes are known to be affected by changes in density. Among these the following should be mentioned: the three primary variables governing population growth form—natality, mortality and dispersion—and such responses as the postembryonic development of insects; the individual growth of organisms; the rate of oxygen consumption; protection from noxious agents in the surrounding environment; resistance of marine forms to sea water diluted as to salt content; aggregating activity of bacteria and protozoa; sex determination and, occasionally, even the modification of anatomical characters.

Operating through reproduction and mortality, density affects the growth form of populations either by inducing decline or stimulating growth. The former aspect has been extensively studied and much is known of it. The latter aspect received the active attention of W. C. Allee (1931) and his associates, who marshaled many data showing that, under a wide variety of conditions, organisms crowded to some degree respond more effectively than others of their own kind that are either isolated, or nearly so, or else exist under extremely dense conditions. This optimal population effect has been advanced as evidence for an unconscious co-operation—an expression of the fact that, through its own integrative mechanisms. a group of certain size and composition is better adjusted within its environment, usually with reference to its survival, than is one either larger or smaller.

Analytical studies have shown that population density usually brings about an effect through one of two mechanisms. In some cases it is the actual behaviour relations between organisms that are responsible for the observed result, such interactions varying in their intensity with the degree of crowding. In other cases, density may operate through some secondary effect upon the environment as, for example, reduction of the available food supply or addition of waste products to the habitat, both of which obviously change with the size of the population. Two examples, the relation of crowding to production of eggs by cultures of the fruit fly (Drosophiln *melanogaster*) and the conditioning of flour by beetles (*Tribolium confusum*), illustrate these points.

The Drosophiln case was originally investigated by Pearl (1932) and was extended by F. IV. Robertson and J. H. Sang (1944). Pearl demonstrated that as the population density of adult flies increases, the number of eggs produced per individual female decreases. In other words, fecundity is inversely proportional to crowding. In an analysis of the causal factors underlying this effect, experiments were set up that varied the air volume in the culture bottles in the presence of initial fly densities ranging from 1 to 128 paired Drosophila, with the area of agar surface to which the flies were exposed the same in all cases. It was reported that, while this volume of air above the surface had no significant effect on oviposition, the degree of crowding of the flies on the agar was highly significant. That is to say, the real density effect is essentially limited to one niche within the system. Through a careful series of observations on the behaviour of crowded and uncrowded flies, Pearl concluded that Drosophila will not oviposit if they are in contact with, or disturbed by, other flies, and that individual flies do not obtain as much food under such conditions even though there is an ample supply available. This was called interference or collision, and it was suggested that the probability of collisions between flies on the surface of the agar plate increased with the density. This investigation thus links the population effect through egg production to two behaviour mechanisms — the inability of the flies to lay eggs and to feed adequately when disturbed by their fellows. The later experiments of Robertson and Sang showed that the reduced fecundity associated with crowding reported by Pearl could occur only when the flies were competing for food and therefore inadequately nourished because of this competition.

As suggested above, density can also affect a population by altering the habitat as well as by influencing the interactions between the component organisms. It was shown for the flour beetle (Thomas Park and Nancy Woollcott, 1937, and Park, 1941) that, as these beetles occupy their flour, which they never leave, they modify it through reduction of its nutritive value and the liberation of harmful waste products. This modification, designated environmental conditioning, is density-dependent because the degree of such conditioning is related in time to the number of beetles that have inhabited the flour. Conditioning thus emerges as a population product owing its existence entirely to the alteration of the habitat by the group activity. Studies have shown that flour beetle populations always decline when the medium (flour) is not renewed. that it thus becomes progressively more conditioned and that this is a cause of decline as well as an effect. It has been demonstrated that the conditioning operates primarily by reducing the beetles' fecundity and, secondarily, by extending the duration of their metamorphosis and increasing the mortality during this period.

Although density-independent and density-dependent factors have been treated as though they fall into discrete categories, the impression should not be left that this is always true. One environmental factor, or several in conjunction, frequently can operate in both ways at the same time. In fact, for natural populations this may be the rule rather than the exception.

Summary. — Even in so brief a treatment as that developed in this article, the following points should be apparent and are offered as a general summary:

1. Populations as such may be effectively studied in the field or laboratory either as intraspecies or interspecies units, using many sorts of species from widely divergent habitats.
2. Such study forms an integral part of ecology and is closely related to population genetics, evolution and biometry (*q.v.*).
3. The population constitutes a distinct level of biological organization and is to be thought of as a fundamental, responsive unit within its particular environment.
4. Since population size furnishes a convenient end index of many population phenomena and since size is usually determined by counting, census methods become the single most significant technique for population ecology.
5. The change in size of populations with time is divisible into certain continuous phases spoken of collectively as growth form.
6. Growth form is under the control of prior interactions between natality, mortality and dispersion. Natality as a single factor is related to population increase; mortality, to population decrease; and dispersion may induce either result depending upon the pattern it assumes.
7. Natality, mortality and dispersion are in turn influenced by ecological factors falling into two broad categories, density-independent and density-dependent.
8. Population density affects many responses in addition to natality, mortality and dispersion; it can favour both population growth and decline, depending upon local conditions, and it can operate either through actual behaviour interactions between constituent organisms or through modifications imposed upon the habitat.

Research Areas of Population Ecology. — In concluding this article it is meaningful to list those actual problems which characterize the significant research areas under study by population ecologists. These are as follows:

1. Numerical studies describing population growth form.
2. The effect of weather and other factors of the physical environment on growth form.
3. Analysis of population equilibria.
4. The problems of underpopulation, optimal population and overpopulation. This involves analyses of population density from various points of view.
5. The productivity of populations, and factors that influence it.
6. The problem of the optimum yield. Simply stated, this means to what extent can a group be exploited and still maintain itself?
7. Description and analysis of population cycles.
8. Analysis of dispersion within and between groups.
9. Analysis of ranges and territories established and inhabited by natural populations.
10. Epidemiological aspects of the interactions between host and parasite populations.
11. Intraspecies and interspecies competitions.
12. The organization of social populations; as, for example, the social insects, infra-human primate hordes and man.
13. Improvements and extensions of population census techniques.
14. Study of population integration; that is, those interactions between the factors that control population activities.

Several brief comments are appropriate about these problems. It is clear that some of them are primarily intraspecies, some primarily interspecies and some can be either, depending upon how the problem is specifically formulated. It can be stated didactically that all 14 problems have significant theoretical content for ecology generally and, also, that many of them have decided economic applications. Population studies assume a pragmatic value for man: (1) when a desirable species is not perpetuating itself to a great enough extent and something needs to be done about it; (2) when a species is so heavily exploited by man that he must intervene in an effort to counteract the exploitation by artificially stimulating the species to increase (this is a special case of [1] above and is illustrated by the fishing industry or by problems centring on the conservation of game and fur-bearing animals); (3) when a noxious form, for example an insect pest, endangers a particular crop or product and either must be exterminated or controlled; and (4) when a pathogenic population endangers the public health and, again, must be controlled or eradicated.

These situations as stated in the above four cases cannot be solved with any lasting validity, and without unforeseen complications, unless the entire population is viewed as an integral, functional part of its complete environment, the analysis then proceeding accordingly. Specifically, it could prove unwise to stimulate or decimate populations beyond their normal growth form solely on the grounds that the species were valuable or deleterious to man's interests. Such procedures may do more harm than good. For example, the indiscriminate use of such a potent insecticide as DDT in eliminating admittedly injurious organisms from an area might, by also eliminating locally necessary species, bring about irreparable damage even if measured only in terms of economic loss. It seems inescapable that real understanding of these applied problems of ecological character must rest upon extensive knowledge of the fundamental biology involved, and it is here that population ecology can contribute in a practical way to human well-being in addition to its more intangible, but equally exciting, contribution of a strictly intellectual nature.

BIBLIOGRAPHY.—H. G. Andrewartha and L. C. Birch, *Distribution and Abundance of Animals (1954)*; F. M. Burnet, *Biological Aspects of Infectious Disease (1940)*; P. S. Galtsoff, "The Fecundity of the Oyster," *Science, 72 (1930)*; J. L. Hart and A. L. Tester, "Quantitative Studies on Herring Spawning," *Trans. Amer. Fish. Soc., 64 (1934)*; F. S. Bodenheimer, *Problems of Animal Ecology (1939)*; R. Pearl and S. L. Parker, "Experimental Studies on the Duration of Life. X. The Duration of Life of *Drosophila melanogaster* in the Complete Absence of Food," *Amer. Nat., 58 (1924)*; B. Noyes, "Experimental Studies on the Life-History of a Rotifer 'Reproducing Parthenogenetically (*Proales decipiens*)," *J. Exp. Zool., 35 (1922)*; R. Pearl and C. R. Doering, "A Comparison of the Mortality of Certain Lower Organisms with That of Man," *Science, 57 (1923)*; B. P. Wiesner and N. M. Sheard, "The Duration of Life in an Albino Rat Population," *Proc. Roy. Soc. Edinb., 55 (1934)*; R. Pearl, *The Biology of Population Growth (1930)*; H. S. Smith, "The Role of Biotic Factors in the Determination of Population Densities." *J. Econ. Ent.. 28 (1935)*; Gordon Gunter, "Death of Fishes due to Cold on the Texas Coast January, 1940," *Ecology*, 22 (1941); P. S. Galtsoff, W. A. Chipman, A. D. Hasler and J. B. Engle, "Preliminary Report on the Cause of the Decline of the Oyster Industry of the York River, Va., and the Effects of Pulp-Mill Pollution on Oysters," U.S. Department oi Commerce, *Investigational Report*, 37 (1938); B. P. Uvarov, "Insects and Climate," *Trans. Roy. Entomol. Soc. London*, 79 (1931); A. J. Nicholson, "The Balance of Animal Populations," *J. Anim. Ecol.*, 2 (1933); W. R. Thompson, "Biological Control and the Theories oi the Interactions of Populations," *Parasitology*, 31 (1939); W. G. Allee, *Animal Aggregations* (1931); R. Pearl, "The Influence of Density of Population Upon Egg Production in *Drosophila melanogaster*," *J. Exp. Zool.*, 63 (1932); F. W. Robertson and J. H. Sang, "The Ecological Determinants of Population Growth in a *Drosophila* Culture. I. Fecundity of Adult Flies," *Proc. Roy. Soc., B*, 132 (1944); Thomas Park and Nancy Woollcott, "Studies in Population Physiology. VII. The Relation of Environmental Conditioning to the Decline of *Tribolium confusum* Populations," *Physiol. Zool.*, 10 (1937); Thomas Park, "The Laboratory Population as a Test of a Comprehensive Ecological System," *Quart. Rev. Biol.*, 16 (1941); W. C. Allee, A. E. Emerson, Orlando Park, Thomas Park and K. P. Schmidt, *Principles of Animal Ecology* (1919); *M*. E. Solomon, "The Natural Control of Animal Populations," *J. Anim. Ecol.*, 18:1, 1–35 (1949). (T. Pk.)

POPULIST PARTY, a short-lived minor political party that flourished in the United States in the 1890s. Officially named the People's Party of the United States of America, it was founded at Cincinnati, O., May 21, 1891, by a mass convention of delegates representing the discontented farmers of the northwest and the south. Following another preliminary convention held at St. Louis. Mo., in Feb. 1892, the Populists met in national convention at Omaha, Neb., on July 4, 1892, and nominated James B. Weaver of Iowa for president and James G. Field of Virginia for vice-president. The platform of the new party demanded principally the free and unlimited coinage of silver at the ratio of 16 to 1; the repossession by the. government of unused lands it had given to the railroads; government ownership and operation of all railroad, telegraph and telephone facilities; and a graduated income tax. In the presidential election of 1892 the Populist ticket polled 22 electoral votes and more than 1,000,000 popular votes. By fusing with the Democrats in certain states the Populists mere able also to elect several members of congress, three governors and hundreds of minor officials and legislators. nearly all in the northwest. In the south most of the farmers refused to endanger white supremacy by voting against the Democratic party.

Populist gains in the midterm elections of 1894 were considerable, but when the Democrats nominated William Jennings Bryan in 1896 on a free silver platform, the Populists endorsed him, although nominating their own vice-presidential candidate, Thomas E. Watson of Georgia. After Bryan's defeat, most Populists became Democrats. A small residue known as "fusionists" endorsed Bryan, the Democratic candidate, again in 1900, while another element of the party nominated Wharton Barker of Philadelphia. A splinter group supported "middle-of-the-road" tickets, both state and national, as late as 1912.

See J. D. Hicks, *The Populist Revolt* (1931); Richard Hofstadter, *The Age of Rejorm* (1955). (J. D. H.)

POPULONIA, an ancient seaport town of Etruria, Italy (Etruscan Pupluna), at the north end of the peninsula of Monte hfassoncello, at the south end of which is situated the town of Piombino (*q.v.*). The place, almost the only Etruscan town built directly on the sea, was situated on a lofty hill now crowned by a conspicuous medieval castle and a poor modern village (Populonia). It commands a fine view, and Corsica is sometimes visible, though not Sardinia, as Strabo and, following him, Lord Macaulay erroneously state. Considerable remains of its town walls, of large irregular, roughly rectangular blocks (the form is that of the natural splitting of the schistose sandstone), still exist, enclosing a circuit of about $1\frac{1}{2}$ mi. The remains existing within them are entirely Roman—a row of vaulted substructions, a water reservoir and a mosaic with representations of fishes. Strabo mentions the existence there of a lookout tower for the shoals of tunny fish. There are numerous tombs outside the town, from the Villanova period (9th century B.C.) to the middle of the 3rd century B.C. Under heaps of ancient slag removed for resmelting in modern times, a considerable number of chambered inhumation tombs of the 8th–7th century B.C. were discovered; all were originally covered by circular mounds of earth; the roof was a false dome formed by the projection of each course of stones beyond the one below it. The remains of a temple, devastated in ancient times, were also found. The iron mines of Elba and the tin and copper of the mainland were owned and smelted by the people of Populonia; hot springs lay about six miles to the East (Aquae Populaniae) on the highroad—Via Aurelia—along the coast. At this point a road branched off to Saena (Siena). According to Virgil the town sent a contingent to the help of Aeneas, and it iurnished Scipio with iron in 205 B.C. It offered considerable resistance to Sulla, who took it by siege; and from this dates its decline which Straho, who describes it well, already notes as beginning. Four centuries later Rutilius describes it as in ruins The harbour continued to be of some importance and the place was still an episcopal see under Gregory the Great.

See A. Minto, *Populonia* (Elorence, 1922) for a full description.

PORBANDAR (properly PORBUNDER), a port on the south-western coast of Bombay state, India; pop. (1951) 58.824. The seaboard terminal of the railway line from central Saurashtra, Porbandar is also a centre for cement, silk and cotton manufactures and cotton ginning and pressing. It was the birthplace of Mahatma Gandhi.

The former princely state of PORBANDAR (area 642 sq.mi.; pop., 1941, 146,648) extended along the coast northwest and southeast of the port, its capital. It was within the Western Kathiawar States agency before its merger with Saurashtra on Feb. 15, 1948. Saurashtra merged with Bombay state in the reorganization of Nov. 1. 1956.

PORBEAGLE (Lamna *cornubica*), a species of shark, belonging to the Selachians (*q.v.*). The body is short and stout and contrasts strikingly with its much-attenuated tail, which is strengthened by a keel on each side and terminates in a powerful caudal fin. The porbeagle has formidable pointed teeth, but is a fish eater, not considered dangerous to man. It attains a length of 10 to 12 ft. and is a pelagic fish chiefly of warm seas but not rare in the North Atlantic and Mediterranean and frequently wandering to British and more rarely to North American shores as far as Nova Scotia. See SHARK.

PORCELAIN: see POTTERY AND PORCELAIN.

PORCELAIN ENAMELING. A porcelain enamel is a thin layer of glass fused to a metal to enhance its beauty, to prevent corrosion, or both. Porcelain-enameled iron is used extensively for both domestic and industrial articles. In addition to its use for kitchenware (see Enamel-wave, below), bathtubs and sinks, it is used extensively for table tops, refrigerators, washing machine tubs and stoves. Industrially, it is used for advertising signs, chemical and food tanks of large sizes, hospital furniture, grocery, meat market, supermarket and restaurant equipment, and has found application in architecture for the facing of the outsides of buildings. A porcelain enamel, being a glass, has the properties of glass; namely, its hard. glossy surface and resistance to solution, corrosion and scratching. The metal backing and design greatly influence its strength and resistance to damage. The quality of porcelain enamels varies greatly, depending upon the glass used, the design and the manufacturing technique.

History.—Although the term porcelain enameling (also called vitreous enameling or enameling) did not come into common use until about 1929, enamels were used far back in the early history of man, first as glass beads fused onto metal, later as medallions and finally, in the first half of the 18th century, as a protective surface". Although jewelry enamels, art pieces and photographs in enamels are still made and highly prized (for cloisonné, champlevé, etc., see ENAMEL; JEWELLERY). enamels on sheet steel and cast iron constitute the principal part of the modern industry.

Manufacture.—Although the early developments took many years, the transition of enameling from an art to an industry in the early part of the 19th century proceeded very rapidly. Cast-iron dry-process enamels were the first to be used on a large scale. In this process, the castings, such as bathtubs. mere first sand-blasted to give them a clean surface. The grip or ground coat was then applied. This ground coat consisted of a powdered glass, clay and water suspension uith a consistency about like that of cream. This was dipped, slushed or sprayed on the cool casting and allowed to dry. The ware was then introduced into a furnace at about 900° C. and allowed to come to the temperature of the furnace. The hot ware was withdrawn from the furnace and powdered glass dusted through a screen over it. This powdered glass melted as it fell on the hot ware and formed a continuous layer of enamel. Several applications were generally made, the ware being returned to the furnace for reheating before each application. This process is particularly applicable to the manufacture of heavy castings.

Another process which has come into common use is that of wet-process cast-iron enameling. This is used on lightweight or thin castings and has been adopted extensively in the stove industry. In this process, the ground coat is generally applied as a suspension of the glass with clay in water, dried and then fired in a furnace at about 750° C. The ware is removed from the furnace, cooled: the second coat applied and then refired. This process is sometimes known as the U.S. process for enameling cast iron.

Sheet-steel enameling has become the process most widely used for porcelain enamels. In this process, the sheet steel is fabricated and put through a cleaning and pickling process which prepares the surface for enameling. Sheet-steel enameling requires a ground coat containing a small percentage of cobalt to give it adherence. This ground coat is applied by the wet process, dried and then fired in a furnace at about 830° C. After the ware has been removed from the furnace and cooled, a second coat of cover enamel is applied by the wet process. This cover coat may be of any desired colour and may have special properties depending upon the use to which the ware is to be put. It is commonly sprayed or dipped onto the ware, allowed to dry and then fired at about 830° C. Additional coats of enamel are sometimes applied. and finally the decoration is applied and fired into the last coat.

Although enameling is an important industry in most countries, the use of automatic equipment. technical control and mass production is outstanding in the United States.

Enamelware. — Metal kitchenware, such as pots and pans, the surface of which is protected and decorated by a thin layer of porcelain enamel is known as enamelware. Prior to the advent of enamelware such utensils were made of pottery, copper, cast iron and to some extent tinned sheet iron. Aluminum and stainless steel, introduced in the 19th century, have come into common use.

In the kitchenware industry, enamelware is produced chiefly in large modern plants, with machine operations and a great deal of automation and control. Ware made in the second half of the 20th century is far superior to any of that made prior to World War II. In the manufacture of enamelware a good grade of low-carbon sheet iron is formed in the shape of the utensil by pressing or drawing, by spinning and by trimming; the handles, spouts and ears are welded in place by spot or resistance welding. The ware is then cleaned in a chemical detergent bath, rinsed in water, pickled in acid (usually 5% sulfuric acid), rinsed and neutralized in a bath of sodium hydroxide. borax or sodium cyanide. In some cases the ware is treated in a nickel sulfate bath prior to neutralizing to improve enamel adherence. The shapes are finally dried, sorted and inspected.

Enamel glasses are prepared by melting the raw materials together and quenching in a water spray and bath. These operations are called smelting and fritting, and the product, which is broken glass, is called frit. The frit is dried and weighed with mill additions such as water, clay and special suspending agents. This mill batch is charged into ball mills of about 1,000- to 3,000-lb. capacity and ground to a fineness of about 2% on a 200-mesh sieve. The product is a thick slurry called slip, the properties of which must be accurately controlled.

Enamel usually is applied in two coats each being fired separately. The first coat, called a ground coat, is an enamel containing cobalt. A typical composition is shown in the accompanying table. It usually is applied to the shapes by dipping, the properties of the slip being such that the excess drains off or is thrown off in the special handling of the ware just after it is removed from the slip bath. After drying it is fired, usually in a continuous conveyor furnace, at about 1,500" F., with four minutes in the hot zone of the furnace.

The ground-coated ware is next coated with the slip of the cover enamel (see table) in a similar manner, dried and fired. Where white is desired, the cover enamel is usually an acid-resistant titanium opacified enamel. Special compositions are needed for the colours, for the bead on the rim or for handles. In very special

Typical Enamel Compositions

Component	Ground coats (%)		White cover enamel (%)
	A	B	C
Borax	35.0	35.0	—
Feldspar	21.0	21.0	—
Quartz	28.0	21.0	41.5
Soda ash	4.5	6.0	—
Soda nitre	4.0	4.5	5.7
Fluorspar	5.0	10.0	—
Cobalt oxide	0.5	0.5	—
Nickel oxide	0.5	0.5	—
Manganese dioxide	1.5	1.5	—
Dehydrated borax			22.6
Titanium dioxide			17.6
Potassium silicofluoride			8.0
Sodium silicofluoride			1.3
Monosodium phosphate (dehydrated)			3.3
Totals	100.0	100.0	100.0

Mill additions	Ground coat (parts)	Cover coat (parts)
Frit A	40% }100	
Frit B	60% }100	
Enamel clay	7	5
Water	40	40
Frit C	—	100
Electrolytes	Various	Various
Totals	147	145

cases a third firing is used for special decorations.

Enamelware is usually acid-resistant, withstanding fruit and vegetable acids to a high degree. When made under modern conditions, it is very resistant to impact. The enamel fails only when the piece is subjected to a deformation of the iron, which results in a cracking of the glass coating. Enamelware is very resistant to thermal shock, but cold water should not be put in a hot dry pan. Enamelware will withstand all temperatures used in cooking. It has a hard, scratch-resistant surface and can be cleaned with all common cleaning materials, but harsh abrasives such as sand should not be used as they scratch any glass surface.

BIBLIOGRAPHY.—A. I. Andrews, *Enamels* (1935) ; A. I. Andrews and R. L Cook, *Enamel Laboratory Manual* (1941) ; American Society for Testing Materials, *Symposium* on *Porcelain Enamels and Ceramic Coatings as Engineering Materials* (1954). (A. I. A.)

PORCH, originally a roofed structure, usually open at the sides, to protect the entrance of a building; loosely used of any projecting portico, or even of any colonnade and, in the United States. of any roofed structure open at the sides and front, attached to a house or other building; synonymous with veranda or piazza. A sleeping porch is such a structure usually opening from an upper story.

ALINARI

PORCH OF SAN ZENO MAGGIORE. VERONA. 12TH-CENTURY ITALIAN ROMANESQUE

Of the porch proper there are few extant remains prior to the classic period. although Egyptian wall paintings seem to indicate their occasional use with houses. The most important Greek porches are those of the Tower of the Winds at Athens (1st century B.C.), in which two columns of a simple Corinthian order carried a pediment. A similar porch exists in the so-called villa of Diomed at Pompeii. Houses in Rome sometimes had long colonnades facing the street which served as porches. During the Romanesque period simple projecting porches covering the western doors of churches are found instead of the earlier basilican colonnaded narthices. Especially interesting are the projecting porches of the Italian Romanesque. such as that of S. Zeno Maggiore at Verona (12th century), in which the columns are carried on marble lions (as frequently in Lombard work) and at

Modena (12th century) and Parma (13th century). In Apulia there are many similar porches of distinct Lombard character

In France, especially in Burgundy, an even greater development of the porch occurred, in which it became a vaulted structure of great height and importance, two or more bays long and sometimes as wide as the entire church. The great porch of the abbey church at Vézelay (1132–40), sometimes termed an antechurch, is the largest and richest. In Norman work in England church porches are more frequently at the sides of the nave than at the west end. An interesting example is that at Southwell minster (early 12th century).

The English love of picturesqueness sometimes developed the porch to such an extent that it became almost a separate building which was called a "galilee," like that at Durham (1175). Galilees in medieval churches are supposed to have been used sometimes as a court of law, or a place where corpses were placed before interment, but the galilee probably served chiefly as a chapel for penitents before their admission to the body of the church. Many fantastically rich projecting porches occur in French Flamboyant churches. such as that of the church of Notre Dame at Alençon (c. 1500), the pentagonal porch of St. Maclou at Rouen (c. 1520) and the side entrance of the cathedral at Albi (early 16th century).

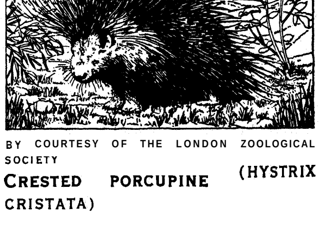
The same richness of porch design is not found in English Gothic churches. where western doors are often small and unimportant; an exception. all the more remarkable for its unique character, is the west front of Peterborough cathedral (c. 1220), in which the doors are deeply recessed within great arches, 81 ft. high, forming a most impressive porch. The other type of porch, the small projecting gabled feature projecting from the north or south walls of the nave, was, however, highly developed throughout the course of English Gothic. In small examples, in parish churches, the porches are usually of wood. with a richly decorated bargeboard running up the gable and often panels of intricate tracery at the sides.

In the larger city churches there was frequently a room over the porch, sometimes known as a porch chamber and sometimes incorrectly termed a parvis. These seem to have been used sometimes as vestries, sometimes as treasuries and sometimes as chantry chapels. Similar porches, with chambers above, occur occasionally in Tudor mansions, as in the house of Compton Winyates (c. 1520).

In Germany churches of the Flamboyant Gothic period are frequently decorated with western porches of the most fantastic richness, with a great use of cusping, pierced tracery and canopy work. Such are the double-arched entrance of the cathedral at Ulm (c. 1390) by Ulrich von Ensingen and the triangular porch of the cathedral at Regensburg by M. Roritzer (1482–86).

During the Renaissance the porch was usually treated as a portico (*q.v.*), but simple porches of two or four columns were exceedingly common features of the late 18th-century houses of England and the United States. (T. F. H.)

PORCUPINE, the name of the largest European terrestrial rodent, distinguished by the spiny covering from which it takes its name. The European porcupine (Hystrix cristata) is the typical representative of a family of old world rodents, the Hystricidae, all the members of which have the same protective covering. They range over the south of Europe, the whole of Africa, India and the Malay archipelago as far east as Borneo. They are all stout, heavily built animals, with blunt rounded heads, fleshy mobile snouts and coats of thick cylindrical or flattened spines, which form the whole covering of their body and are not intermingled with ordinary hairs. Their habits are strictly terrestrial. The common porcupine, which occurs throughout the south of Europe and north and west Africa, is replaced in south Africa by H. africaeaustralis and in India by the hairy nosed porcupine (H. *leucura*).


BY COURTESY OF THE LONDON ZOOLOGICAL SOCIETY
CRESTED PORCUPINE (HYSTRIX CRISTATA)

There are several smaller species with long tails in northeast India, the Malay region and Africa. In the new world the porcupines are represented by the family Erethizontidae. The spines are mixed with long soft hairs. They are less nocturnal in their habits, and with one exception live entirely in trees; certain of the species accordingly have long prehensile tails. They include three genera, of which the first is represented by the Canadian porcupine (Erethizon dorsatum), a stout, heavily built animal, with long hairs almost or quite hiding its spines, four front and five hind toes and a short, stumpy tail. It is a native of the greater part of Canada and the United States, wherever there is any remnant of the original forest left.

Coendou contains some eight or ten species, known as tree porcupines, found throughout tropical South America, with one extending into Mexico. They are of a lighter build than the ground porcupines, with short, close spines, often mixed with hairs, and prehensile tails The hind feet have only four toes as a result of the suppression of the first.

PORDENONE (GIOVANNI ANTONIO DE' SACHIS) (c. 1483–1539), a north Italian painter who, although basically influenced by Venetian painting, shows an element of violence which probably derives from Germany. He was born at Pordenone, in Friuli, in about 1483; however, the date of his birth rests only on the statement by G. Vasari that he died in 1540 (instead of 1539) at the age of 56. Pordenone was a pupil of Pellegrino da S. Daniele and other Friulian masters, but his style is founded on Venetian models and in particular on Titian; later he was influenced by Correggio and also by the Roman works of Michelangelo and Raphael and it is assumed, therefore, that he went to Rome, probably about 1515/16.

He worked in Treviso, Mantua, Genoa and Cremona as well as in Friuli and all over northern Italy. Even in Venice his work was so popular that for a short time he was a serious rival to Titian himself, and on one occasion the senate of Venice gave him the preference for a commission. Unfortunately, his frescoes in Venice have perished, but he painted a dome in Piacenza in the illusionistic manner of Correggio (1529–31). He was invited to Ferrara by Ercole II but died there soon after his arrival and was buried on Jan. 14. 1539. There are many documented and dated works by Pordenone, the earliest being a fresco at Valeriano, signed and dated 1506.

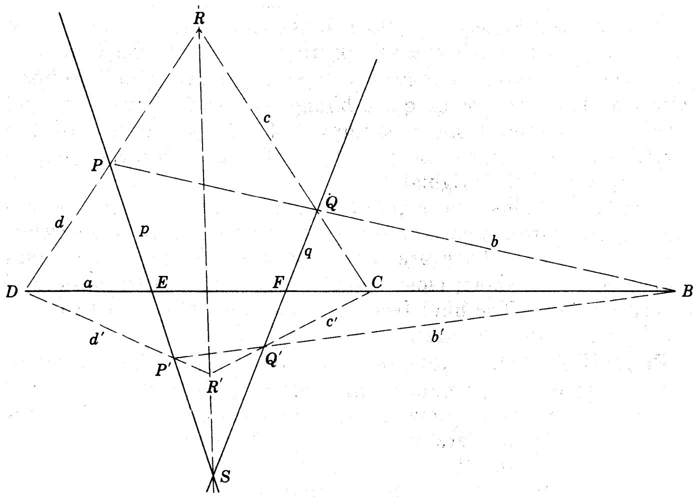
See C. Ridolfi, Le Maraviglie dell' Arte, etc. (1648; ed. by Hadeln, 1914–24); G. Fiocco, Giovanni Antonio Pordenone, 2nd ed. (1943). (P. J. MY.)

PORDENONE, a town of the province of Udine, Friuli-Venezia Giulia. Italy. 30 mi. W. by S. of Udine on the railway to Treviso. Pop. (1951) 21,895. It was the birthplace of the painter generally known as Pordenone (*q.v.*). Paintings from his brush adorn the cathedral (nhich has a fine brick campanile), and others are preserved in the Gothic town hall. Cotton industries are active. also silk and pottery.

PORI, formerly Bjorneborg, a seaport of Finland in 61° 29' N., 21° 43' E., on the Kumo river, 18 mi. from its harbours, Reposaari and Mantyluoto. Pop. (1950) 43,213. It imports coal, coke and flour. and exports timber and timber products. The river is 9 ft. deep. The town has ship-repairing yards. but vessels larger than 300 or 400 tons have to be careened. Reposaari, the "town harbour," used only for local traffic. is usually icebound from December to March. Mantyluoto is the new harbour, equipped with cranes, railroad tracks and quays for five large steamers, being ice-free until January.

PORIFERA, a phylum of the animal kingdom comprising the sponges. See SPONGES.

PORISMS, the title of a treatise written by Euclid (c. 300 B.C.), the author of the Elements. This book, no longer extant, is known only through the account given by Pappus (*q.v.*) of Alexandria (c. A.D. 320) in the seventh of the eight books of his Collection. The calibre of this material is such that Sir Thomas Heath characterized the Porisms as "a distinctly advanced work, perhaps the most important that Euclid ever wrote" (*The* History *of Greek Mathematics,* London. Oxford University Press, 1921). Translated from the Greek into Latin toward the close of the 16th century, this work of Pappus was the subject of study by scholars who endeavoured to reconstruct the original, an effort not unconnected with the development of projective geometry.



FROM B L VAN DER WAERDEN SCIENCE AWAKENING (P NOORDHOFF LTD)

ILLUSTRATION OF THE FIRST OF EUCLID S PORISMS SOLID LINES INDICATE THOSE THAT ARE FIXED IN POSITION. BROKEN LINES SHOW TWO POSITIONS OF THE VARIABLE LINES

The word porism (from *porizein,* "to carry" or "to produce") has several shades of meaning. In Euclid's *Elements* there are instances when a theorem (*q.v.*) is followed by the words "*Porism.* From this it is manifest that . . ." and a statement that is a corollary to the theorem. For example:

Euclid III, 1. *To find the centre of a circle. Porism* . . . if in a circle a straight line cuts a straight line into two equal parts and at right angles, the centre of the circle is on the cutting line.

Euclid IV, 15. *In a given circle to inscribe an equiangular and equilateral hexagon. Porism* . . . the side of the hexagon is equal to the radius

Euclid VII, 2. *Given two numbers not prime to one another, to find their greatest contmon measure. Porism* . . . ii a number measure two numbers, it will also measure their greatest common measure.

Pappus, quoting "older writers,' gave three classes of propositions:

A theorem is directed to *proving* what is proposed.
A *problem* is directed to *constructing* what is proposed.
A *porisnz* is directed to *producing* or *finding* what is proposed.

Heath suggests that the usual form of a porism was "to prove that it is possible to find a point with such and such a property or a straight line on which lie all the points that satisfy given conditions." Tobias Dantzig summarizes the matter in these terms: "The only thing certain about the *Book of Porisms* is the title, and even here there is no general agreement as to the sense in which Euclid used the term'! *(Bequest of the Greeks,* p. 36, Charles Scribner's Sons, New York. 1955).

As noted above, knowledge of Euclid's *Porisms* comes from the statements of Pappus of Alexandria, who has been characterized as a "belated geometer" because his work came at a time when higher geometry had been neglected for more than five centuries. He assembled materials dealing with many topics — higher plane curves, the trisection of an angle. the squaring of the circle, the duplication of the cube and others. From these he compiled a handbook and wrote a commentary to be read together with the classic that was being treated. In many cases, he described improvements on or extensions of the proofs in the original documents, and inserted additional theorems or lemmas. Since this is true of those works that are still extant, it may be assumed that it was true in the case of those which subsequently were lost.

Pappus states that the *Porisms* contained 171 propositions and 38 lemmas. He gives examples of a few of the propositions and adds 38 lemmas of his own. He begins by stating a proposition that he says epitomizes the first ten of Euclid's porisms. It reads:

If in a system of four straight lines which cut one another two and two, three points on one straight line be given, while the rest except one lie on different straight lines given in position, the remaining point also will lie on a straight line given in position.

Thus in the accompanying diagram, three points of intersection of the lines b, *c,* d lie on *a,* namely D, *C, B.* Two other points *P* and Q are on the fixed lines *p* and *q,* with *p* and *q* intersecting *a* at E and F, respectively. In a second position the variable lines *b', c', d'* intersect the lines *p* and *q* at *P'* and *Q',* respectively. It follows that the remaining point of intersection R' lies on the line that passes through the join of *p* and *q* and the point R. Pappus stated that this theorem is true of any number of straight lines intersecting two by 'two.

B. L. van der Waerden discusses the 13 lemmas that Pappus added to this porism, noting first that when two different positions of the variable lines are drawn, as is the case in the accompanying diagram, it is the theorem of Desargues (1636):

If two triangles are so situated that the lines joining pairs of corresponding vertices are concurrent, then the points of intersection of pairs of corresponding lines are collinear, or, as it appears in projective geometry, if two triangles are perspective from a point, they are perspective from a line, and conversely.

The lemmas that follow include the seeds of the ideas of the theorem of the complete quadrangle, of six points in involution, of four harmonic points and a special case of Pascal's hexagon.

Pappus' *Collection* was translated from the Greek into Latin by Federico Commandino (1509–75). Several editions of this work appeared, and in 1660 there mas a revision of it by Carlo Manolesse. The Latin and Greek text with notes was published by F. Hultsch in 1876–78.

The problem of reconstructing the *Porisms* from the evidence offered by Pappus is a challenging one. H. W. Turnbull describes it as being like trying to follow a chess game by listening to the comments of an intelligent onlooker. Pierre de Fermat (1601?–65) was one of the first to attempt the reconstruction, Michel Chasles (1860) was one of the latest. In the course of this work Chasles was led to the important idea of anharmonic ratios. In his opinion, the *Porisms* belong to the modern theory of transversals and to projective geometry. H. G. Zeuthen (1886) suggested that the *Porisms* may have been corollaries to a fully developed projective geometry of conics.

BIBLIOGRAPHY.—T. L. Heath, *The History of Greek Mathematics,* 2 vol. (1921), and *Manual of Greek Mathematics* (1931); B. L. van der Waerden, *Science Awakening,* Eng. trans. by A. Dresden (1954).

(V. SD.)

PORK. Pork is the flesh of the domestic pig used for food. It is the most popular meat in the American dietary, probably because its cost is usually lower than that of other meats and because of the variety of ways in which it can be used. Pork is used both fresh and cured. Because of its high fat content, pork is an energy food. The lean of pork is a good source of high-quality protein. phosphorus and iron. Pork is rich in vitamin B_1 or thiamin. Pork liver is one of the best sources of food iron.

Pigs are among the most efficient converters of grain and by-product feeds to fat. The majority of pigs are marketed during the winter and spring months. Since the major portion of the pork carcass is processed by curing. the marketing of pork products may be spread out over the entire year. Most pigs are marketed at 6 to 12 months of age and at weights ranging from 185 to 250 Ib. Pigs are usually dressed packer style; *i.e.,* head off, leaf lard and ham facings off and centre split. The average dressing yield is 69%.

Soft Pork. — The flesh of immature pigs and also that from pigs which have been fed feeds high in soft fats, is likely to be soft. Such pork does not firm up on chilling, is unattractive and, therefore, is discriminated against by consumers. Soybeans, peanuts, rice polish and mast! when used extensively, produce soft pork. The nutritive value of soft pork is as high as firm pork.

Pork carcasses are classified as butcher, packing and bacon hogs. Butcher carcasses are smooth, high-quality, well-finished carcasses suitable for choice, fresh and cured cuts. Packer hogs are usually coarse, low-grade, under- or over-finished carcasses which must be used for lower-priced products. A considerable number of sows which have been discarded from the breeding herds gravitate into this class. Bacon carcasses are light in weight, moderately finished and suitable for making Wiltshire sides (*see* BACON) or choice breakfast bellies.

Grades of pork carcasses and cuts are fewer in number than of beef and lamb. This is due to the fact that most pigs are slaughtered when they are relatively young and nearly all pigs are well-fattened at slaughter time. Consequently, there is less difference between grades. Grades are frequently designated numerically, No. 1, No. 2, No. 3 and cull; or choice, good, medium and cull.

The ideal pork carcass should be compact, straight-sided and thick-fleshed. The shanks should be short and the ham plump and the loin thickly-fleshed. The belly or bacon should be deep, long and smooth. The shoulder should be compact and should blend into the body smoothly.

A choice carcass should be well but not excessively fattened. The fat down the back should be about 1½ in. thick, although there will be some variation with different classes and weights of carcasses. Both excessive or deficient fat will cause a lowering of grade. The fat down the back should be uniform in thickness, firm, white and flaky, not rubbery.

Quality in a pork carcass is indicated by a thin, white skin free from wrinkles; fine joints and shanks. The lean should be a bright pink and fine-textured.

The most sought-after cuts of pork are ham, loin and belly or bacon. Hams are usually cured and may be sold regular (skin on), skinned, or boned. The loin is usually sold fresh, being used for roasts and chops. Heavy loins are sometimes boned out after the tenderloins are removed. The boneless loin strips are cured and smoked as Canadian style bacon.

The entire shoulder is called a long-cut or New York style shoulder which is used as a fresh cut. Many shoulders are cut in two, the lower half usually being cured as a picnic shoulder. The upper half has the layer of fat (clear plate) removed after which it is designated a Boston style of butt which is used for roasts and steaks. Sometimes the blade bone also is removed from the butt in which case the butt is known as a boneless butt. Boneless butts are usually cured and smoked.

The fat back, the covering over the loin, if more than 1¼ in. thick, may be cured in dry salt. If less than 1¼ in. thick, it is skinned and rendered for lard. The fatty covering over the shoulder is cured if sufficiently thick. The jowl or cheek also may be cured and smoked.

The belly or bacon if of choice quality, may be cured and smoked. Low-grade bellies are used for dry salt meats.

To a large degree, weight determines dollar-and-cents values of pork cuts. Within certain limits, the lighter-weight cuts are preferred because of their leanness.

The major portion of the pork carcass may be cured or processed. The proportion actually cured will depend upon price differentials between cured and fresh cuts. Pork trimmings are used for a wide variety of sausages and lunch meats. The fat of the pig is rendered into lard which is one of the most popular culinary fats. It is almost completely digestible, has a wide plastic range and produces very tender, flaky pastry. Lard is manufactured by three methods; kettle rendered, steam rendered and dry rendered. The best lard is made by the kettle-rendered process in which the hashed lard is cooked in an open kettle with constant stirring. Most of the commercial lard is made by the prime steam method whereby the stock is cooked in a tank by steam under pressure and in direct contact with the lard. Refined lard is prime steam lard which has beep bleached either with Fuller's earth or activated charcoal. Sometimes lard stock is hashed and rendered in a steam-jacketed cooker. This is known as dry rendering. About 13% of the live weight of a pig is lard.

Pork **By-products.**—The by-products of hog slaughter are less valuable proportionately than those of cattle or sheep. Aside from sausage and lard, there are edible offal such as livers, hearts, tongues, brains, pork feet, ears, lips, snouts, tails and chitterlings (made from the large intestine). Pigskin is a light but durable leather suitable for gloves, insoles and novelties. Some pigskin is used for gelatin manufacture. Hog casings are used for sausage. Pig stomachs are used for sausage containers and are a source of pepsin. Some of the glands are used in making pharmaceutical preparations. Pork fat not suitable for edible use is designated as grease. It is used for soapmaking and other industrial uses. Animal feeds are made from residues not suitable for human food. Hog hair is used for upholstery and insulation. (For diagram of cuts of pork see FOOD PREPARATION.)

BIBLIOGRAPHY.—Henry W. Vaughan, *Types and Market Classes of Livestock* (1941); Rudolf A. Clemen, *The American Livestock and Meat Industry* (1923); Rudolf A. Clemen, *By-products in the Packing Industry* (1927); *Readings in Packing House Practice, Part 1, Pwk operating* (1924). (W. J. L.)

POROS or PORO ("the Ford"), Greece, an island off the east coast of the Peloponnesus, separated at its western end by a narrow channel from the mainland at Troezen, and consisting of masses of limestone and trachyte connected by a sandy isthmus. Area 7 sq.mi. Pop. (1951) 4.141. The harbour town faces S. toward the mainland The English, French, and Russian plenipotentiaries met at Poros in 1828 to discuss the basis of the Greek government.

The ancient Calauria, with which Poros is idehtified, was traditionally given by Apollo to Poseidon in exchange for Delos; and in historic times was famous for a temple of the latter, the centre of an amphictyony of maritime states—Hermione, Epidaurus, Aegina. Athens, Prasiae, Nauplia, and Orchomenus, the distribution and legends of which suggest that their association goes back to Minoan times. Here Demosthenes took sanctuary with "gracious Poseidon," and, when this threatened to fail him, sought death. The temple of Doric architecture, excavated in 1894, lay on a ridge commanding a view of Athens and the Saronic gulf. Traces also of porticoes and other buildings remain.

See Chandler, *Travels;* Leake, *Morea;* Le Bas, *Voyage archéologique;* Curtius, *Peloponnesos;* Pouillon-Boblaye, *Recherches;* Bursian, *Geographie von Griechenland;* Rangabé, "Ein Ausflug nach Poros," in *Deutsche Revue* (1883); and S. Wide, in *Mitteilungen d. deutsch. Inst. Athen.* (1895), vol xx.

PORPHYRIA includes a group of genetic abnormalities with excessive formation and excretion of porphyrins or their precursors. Porphyrins are red pigments, of which protoporphyrin is most widely represented in nature, imparting the red colour to the circulating hemoglobin. Two main forms of porphyria are recognized, porphyria erythropoietica (bone marrow) and porphyria hepatica (liver). The former is characterized by greatly excessive porphyrin formation in certain of the developing red blood cells. The urine is dark red, bones and teeth reddish brown, due to uroporphyrin, normally present only in traces in the body and excreta. This is also responsible for light sensitivity appearing in early infancy, with blisters and eventual scarring and deformity of face and hands. Enlargement of the spleen and anemia are common. Removal of the spleen has benefited some cases. Protection from sunlight is essential.

The hepatic group comprises (1) an intermittent acute form represented by formation of colourless precursors in the liver, attacks of abdominal pain, nervousness, weakness or paralyses. at times fatal; (2) a late cutaneous form (commonly fourth to eighth decades of life, at times earlier) with marked porphyrin formation in the liver, photosensitivity and scarring; and (3) cases combining features of (1) and (2). (C. J. WA.)

PORPHYRY (Πορφύριος) (A.D. 233–*c.* 304), Greek scholar, historian, and Neoplatonist, was born at Tyre, or Batanaea in Syria. He studied grammar and rhetoric under Cassius Longinus (*q.v.*). His original name was Malchus (king), which was changed by his tutor into Porphyrius (clad in purple), a jesting allusion to the colour of the imperial robes. In 262 he went to Rome, attracted by the reputation of Plotinus, and for six years devoted himself to the study of Neoplatonism. Having injured his health by overwork, he went to live in Sicily for five years. On his return to Rome, he lectured on philosophy and endeavoured to render the doctrines of Plotinus intelligible to the ordinary understanding. His most distinguished pupil was Iamblichus. When advanced in years he mamed Marcella, a widow with seven children and an enthusiastic student of philosophy. Nothing more is known of his life, and the date of his death is uncertain.

Of his numerous works on a great variety of subjects the following are extant: *Life* of *Plotinus* and an exposition of his teaching in the Ἀφορμαὶ πρὸς τὰ νοητά (Sententiae ad *intelligibilia* ducentes, Aids to the study of the Intelligibles). The *Life* of *Pythagoras,* which is incomplete, probably formed part of a larger history of philosophy down to Plato. His work on Aristotle is represented by the Introduction (εἰσαγωγή) to and Commentary (ἐξήγησις, in the form of questions and answers) on the Categories. The first, translated into Latin by Boetius, was extensively used in the middle ages as a compendium of Aristotelian logic; of the second only fragments have been preserved. His Χρονικά, a chronological work, extended from the taking of Troy down to A.D. 270.

Other grammatical and literary works are Ὁμηρικὰ ζητήματα (*Quaestiones homericae*); and *De* antro *nympharum,* in which the description in the Odyssey (xiii, 102–112) is explained as an allegory of the universe. The Περὶ ἀποχῆς ἐμψύχων (De abstinentia), on abstinence from animal food, is especially valuable as having preserved numerous original statements of the old philosophers and the essence of Theophrastus' Περὶ εὐσεβείας (*On* Piety): It also contains a long fragment from the Cretans of Euripides. The Πρὸς Μαρκέλλαν is an exhortation to his wife Marcella to practise virtue and self-restraint and to study philosophy. The letter to the Egyptian priest Anebo, dealing with religious questions, was answered by a member of the school of Iamblichus, who called himself Abammon, in the *De mysteriis.* It is frequently referred to by Eusebius, Cyril and Augustine. Eusebius preserved fragments of the Περὶ τῆς ἐκ λογίων φιλοσοφίας (De *philosophia* ex *oraculis haurienda*), in which he expressed his belief in the responses of the oracles of various gods as confirming his theosophical views.

Porphyry is well known as a violent opponent of Christianity and defender of Paganism; of his Κατὰ Χριστιανῶν (*Adversus Christianos*) in 15 books, perhaps the most important of all his works, only fragments remain. Porphyry's view of the book of Daniel, that it was the work of a writer in the time of Antiochus Epiphanes, is given by Jerome. There is no proof of the assertion of Socrates, the ecclesiastical historian, and Augustine, that Porphyry was once a Christian.

BIBLIOGRAPHY.—There is no complete edition of the works of Porphyry. Separate editions: *Vita Plotini* in the *Enneades* of Plotinus (edit. R. Volkmann, 1883); *Sententiae* (edit. B. Mommert, Leipzig, 1907); *Vita Pythagorae, De antro nympharum, De abstinentza, Ad. Marcellam* (edit. A. Nauck, Leipzig. 1885); *Isagoge et in Arzstotelis categorias commentarium* in *Commentaria in Aristotelem graeca* (edit. A. Busse, 1887); *Boethii in Isagogen Commenta* (edit. S. Brandt, Vienna, 1906); fragments of the *Chronica* in *Fragmenta historicorum graecorum* (edit. C. W. Müller, 1849); *Quaestiones homericae* (edit. H. Schrader, 1880, 1890); *Letter to Anebo* in Iamblichus, *De mysteriis* (edit. W. Pharthey, 1857); *De philosophia ex oraculis Haurienda* (edit. E. Wolff, 1856); fragments of the *Adversus Christianos* (edit. G. Georgiades, Leipzig, 1891); English trans., Thomas Taylor, *De abstinentia, De antro nympharum* and *Sententiae* (1823), *De antro nympharum* (new ed. 1917); T. Davidson, *Sententiae,* in *Journal of Speculative Philosophy* (vol. iii, 1869); S. Hibberd, *De abstinentia* (1857), and A. Zimmern, *Ad. Marcellam* (1896).

On Porphyry and his works generally, *see* J. A. Fabricius, *Bibliotheca Graeca* (edit. Hailes, 1790–1809): article in *Suiidas* (edit. G. Bernhardy, 1853); Eurapius, *Lives of the Philosophers* (with Eng. trans. by W. C. Wright, 1922); Lucas Holstenius. *De vita et Scriptis Porphyrii* (Cambridge, 1655); M. N. Bouillet, *Porphyre, son rôle dans l'école neoplatonicienne* (1864); A. I. Kleffner, *Porphyrius der Neuplatoniker* (Paderborn, 1896); W. Christ. *Geschichte der griechischen Litteratur* (1898); J. E. Sandys, *History of Classical Scholarship* (1906): J. Bidey, *Vie de Porphyre* (Ghent, 1913). *See* also C. P. Mason in W. Smith. *Dict. of Greek and Roman Biography* (1849), and for philosophy, T. Whittaker, *The Neo-Platonists* (2nd ed., 1918) and NEOPLATONISM.

PORPHYRY, a beautiful red or purplish rock used by the ancients for ornamental purposes when cut and polished. The name porphyry (Greek *porphyreds,* "purple") was derived from the older name porphyrites, which in the time of Pliny was applied to purplish and reddish rocks mottled with light spots. Although most of this material was of igneous (volcanic or shallow intrusive) origin, the early Italian sculptors erroneously considered it a variety of marble, of metamorphosed sedimentary origin. The famous red porphyry (*porfido* rosso antico) came from Egypt where it was used in sculpture. Its beauty and decorative value were recognized by the Romans in the time of the emperor Claudius. It was obtained on the west coast of the Red sea, where it forms a dike 80 or 90 ft. thick. For a long time the knowledge of its source was lost, but the original locality of the ancient quarries was rediscovered at Jebel Dhokan.

In a dark red groundmass porphyry contains many small white or rose-red plagioclase feldspars, black shining prisms of hornblende and small plates of iron oxide. The red of the feldspars and of the groundmass arises from the partial conversion of the plagioclase feldspar into thulite (see ZOISITE) and manganese epidote (*q.v.*). These minerals also occur in thin veins crossing the rock. Many specimens show effects of crushing, which in extreme cases has produced brecciation.

Applications of Term.—In petrography the term porphyry is used to designate an igneous rock characterized by abundant relatively large crystals (phenocrysts) set in a matrix or groundmass of fine-grained to amorphous (apparently without crystal structure) material. The porphyries belong to a larger group of rocks, all of which possess a porphyritic texture (phenocrysts and groundmass). Thus, all porphyries have a porphyritic texture, but by no means are all porphyritic rocks true porphyries. Most generally perhaps, the term porphyry is restricted to those porphyritic rocks in which the phenocrysts abound or predominate and which consolidated at shallow depths beneath the earth's surface (hypabyssal rocks). Hence, the true porphyries are most commonly found in sills, dikes and other minor intrusive bodies. Not uncommonly, however, the term is also applied to certain highly porphyritic volcanic rocks, which may resemble the intrusive porphyries.

In the United States the term porphyry is used chiefly in a textural sense. A simple and rather precise scheme is to modify the term by prefixing the common rock name which the porphyry most closely resembles chemically or mineralogically. Thus, granite porphyry, diorite porphyry, etc., are porphyries, compositionally equivalent to the plutonic (coarse-grained) rocks, granite, diorite, etc., respectively. Rhyolite porphyry and andesite porphyry, for example, correspond in composition respectively to the volcanic rocks rhyolite and andesite.

A distinction is to be made, however, between such terms as porphyritic granite and granite porphyry. The former is a true granite; that is, its texture is phaneritic (constituent grains visible without magnification). The latter is not a granite, because its groundmass is aphanitic (constituent grains indiscernible without magnification). A similar distinction is to be made between such terms as porphyritic rhyolite and rhyolite porphyry. Generally the porphyritic rhyolite has a higher proportion of groundmass, which is in itself finer grained or richer in glassy constituents, than the rhyolite porphyry.

The early petrographers (particularly in Europe), in their studies of porphyries and related hypabyssal rocks, placed great emphasis upon the mineral composition of the large crystals, the geologic age of the rocks and the degree to which the rock had been altered. As a result a very complex and confusing nomenclature evolved. Some petrographers prefer to restrict the term porphyry to those types in which the large crystals are principally feldspar (with or without quartz) and to place those types with abundant, large crystals of olivine, pyroxene, amphibole and mica under the lamprophyres.

It is the general practice outside the United States to subdivide the highly porphyritic rocks with an aphanitic groundmass into two classes. Those in which potash feldspar is dominant are called the true porphyries, whereas the plagioclase feldspar types are called porphyrites. The porphyries, under this scheme, are essentially equivalent compositionally to the granites, syenites and nepheline syenites, whereas the porphyrites are compositional equivalents of the diorites and gabbros. In the United States the term porphyrite is nearly obsolete.

Origin.—Theories of origin of porphyries are manifold, and it is highly probable that different porphyries have formed in equally different ways. Many porphyries may have had an interruption in their course of crystallization. The phenocrysts may have formed largely at depth (intratelluric crystals), where cooling of the magma (molten rock material) proceeded slowly, permitting the growth of large scattered crystals. Before complete congelation, however, the magma, with its suspended crystals, was erupted to higher levels and injected as dikes and sills into colder rocks. The cooling effect upon these thin injected sheets was so marked that the liquid phase was rapidly transformed to a fine-grained or aphanitic groundmass.

In other porphyries the large crystals may have developed mainly subsequent to injection. Certain minerals may have developed well-formed crystals before the viscosity of the melt increased sufficiently to retard and restrict diffusion. Changes in pressure on the magma and the loss of dissolved volatiles may have contributed to the formation of porphyritic textures. The role of certain trace elements in controlling crystal growth rates is of possible importance and needs further investigation. Inoculation and incorporation of foreign crystals may explain the porphyritic character of some rocks. (For processes of crystallization see GEOCHEMISTRY: Geochemistry of the Lithosphere.)

Occurrences. — Porphyries occur abundantly as dikes and sills, satellitic to larger masses of compositionally equivalent plutonic rock. Thus, granite porphyry and quartz porphyry are exceedingly common in regions where granitic intrusive rocks occur, Nepheline and leucite rich porphyries, though rare, are associated with larger intrusions of nepheline syenite and leucite syenite. Diorite porphyries (porphyrites) accompany plutonic masses of diorite. Coextensive masses of porphyry may extend as veinlike projections and offshoots from larger parent masses of plutonic rock. Some porphyries, furthermore, appear as marginal phases of the larger intrusions. In such cases the plutonic masses and associated porphyries were probably derived from a common magma.

See A. Johannsen, *A Descriptive Petrography of the Igneous Rocks*, vol. iii (1937). (C. A. CN)

PORPOISE, the common name often applied to any of the smaller, round muzzled toothed whales, but properly restricted to the genus Phocaena. Porpoises, along with dolphins and whales, are included in the mammalian order Cetacea. There is no sharp scientific distinction between porpoises and dolphins, but, generally speaking, the porpoise is smaller and does not have the characteristic beak nose of the dolphin. In North America "porpoise" is generally used to indicate the bottle-nosed dolphin (see DOLPHIN).

Like most other mammals, these superficially fishlike forms breathe air directly and bear live young nhich they suckle. The adult porpoises mate in late summer, and the female bears a single calf, almost a yard long. in about a year. Their life expectancy has been estimated at 30 years. Porpoises feed on schoolin fish, such as herring and mackerel, as well as on squid and other marine animals.

The wide mouth is bounded by stiff, immobile lips, and the underjaw projects slightly. The teeth number betneen 80 and 100. In colour, the porpoise is black or dark gray above and white below, with black flippers. A single dorsal fin is triangular in shape and low.

The common, or harbour porpoise (Phocaena phocaena) attains a length of 4–6 ft. It prefers coastal waters to the open sea and inhabits the North Atlantic area, entering the Baltic in summer; it is rare in the Mediterranean. A distinct form of the common porpoise appears in the Black sea; one or two other species are found in the South Atlantic. The Pacific porpoise is a distinct species. The black finless porpoise (*Neophocaena pho*caenoides) inhabits the warm coastal waters of the Indian ocean.

Porpoise has been used for food — the flesh resembles pork but has a somewhat disagreeable odour to most persons. The oil obtained from the soft fat of the head and jaw of the common porpoise has been used as a lubricant in the manufacture of watches, clocks and other delicate mechanisms made of hard steel. The value of the oil lies chiefly in the fact that it is free from a tendency either to gum or thicken by oxidation, or to corrode metal, and in its ability to withstand exposure to very low temperatures without freezing or thickening to any great extent. The oil was also formerly used in lamps. (K P S.; X.)

PORPORA, NICCOLA [or NICCOLO] **ANTONIO** (1686–1766), Italian operatic composer and teacher of singing, was born in Naples on Aug. 19, 1686. His first opera, Basilio, was produced at Naples; his second, Berenice, at Rome. Both were successful. and he followed them up by innumerable compositions of like character; but his fame rests chiefly upon his unequaled power of teaching singing. At the Conservatorio di Sant' Onofrio and the Poveri di Gesu Cristo he trained Farinelli, Caffarelli, Mingotti, Salimbeni. and other celebrated vocalists. Unfortunately no written account of his method exists; all that remains is the tradition as handed down by his pupils In 1725 Porpora visited Vienna, but the emperor Charles VI disliked his florid style, especially his constant use of the trillo. He then settled in Venice, teaching regularly in the schools of La Pietà and the Incurabili. In 1729 he was invited to London as a rival to Handel; but his visit was unfortunate. Little less disastrous was his second visit to England in 1734, when even the presence of his pupil, the great Farinelli, failed to save from ruin the dramatic company of Lincoln's Inn Fields theatre, set up in opposition to that directed by Handel. The sequence of dates and visits in Porpora's life are variously stated by different biographers. The electoral prince of Saxony and king of Poland had invited him to Dresden to become the singing master of the electoral princess, Maria Antonia, and in 1748 he is supposed to have been made *Kapellmeister* to the prince. Difficult relations, however, with Hasse and his wife resulted in his departure, of which the date is not known. From Dresden he is said to have gone to Vienna, where he gave lessons to Joseph Haydn (*q.v.*), and then to have returned some time betaeen 1755 and 1760 to Naples. From this time Porpora's career was a series of misfortunes. His last opera, Camilla, failed; and he became so poor that the expenses of his funeral were paid by subscription.

PORRENTRUY (1,400 ft.), a town in the northern or French-speaking part of the canton of Bern, Switzerland, a station on the railways Basle-Delémont Delle and Altkirch-Mulhouse. It has famous schools and is an industrial centre; the great majority of the inhabitants are Roman Catholics. The castle overlooking the town was once the residence of the bishop of Basle.

Population of commune (1960) 7,095.

PORRES, SAINT MARTÍN DE (1579–1639), Peruvian Dominican lay brother, was born in Lima, the illegitimate son of a noble Spaniard, Don Juan de Porres. and a Negro woman, Ana Velázquez. As a youth. he was taken by his father to Ecuador and placed in school there. When official duties transferred the father to Panami, the boy returned to the care of his mother in Lima, and the remainder of his life was spent in that city.

When he was about 15 years old, Martin was apprenticed to a barber surgeon In 1601 he became a Dominican oblate, his first duties being to care for the sick friars in the monastery of Santo Domingo. It was not customary at that time to permit a mulatto to enter a religious order in Peru, but because of the exceptional qualities and virtue exhibited by Martin. he was ordered to become a lay brother in the Dominican order in 1610. As a friar. Martin was noted for his kindness to all persons but especially to the poor and the unfortunate; animals also found in him a friend of rare understanding. His greatest sympathy was won by the youth of Lima, for whom he established an asylum and a school, considered by some to be his monument. He died on Nov. 3. 1639. was beatified in 1837 and canonized in 1962; his feast is celebrated on Nov. 5. In 1939 the Peruvian government declared him the national patron of social justice.

See Cyril Martindale, ***Blessed Martin de Porres*** (1920). (A. S. TR.)

PORRIDGE (an altered form of "pottage," Fr. potage, soup, that nhich is cooked in a pot), a food made by stirring meal, especially oatmeal, in boiling water and cooking it slowly until the whole becomes soft. The dish and its name are particularly identified with Scotland; in Ireland it is commonly known as "stirabout." The former application to a broth made of vegetables or of meat and vegetables thickened with barley or other meal is obsolete, and the earlier "pottage" is the usual word employed. The form "porridge" apparently dates from the 16th century. In "porringer," a porridge bowl, the n is inserted as in "passenger" and "messenger."

PORSENA (or PORSENNA), **LARS,** king of Clusium in Etruria. He is said to have undertaken an expedition against Rome in order to restore the banished Tarquinius Superbus to the throne. He gained possession of the Janiculum, and was prevented from entering Rome only by the bravery of Horatius Cocles (*q.v.*). Porsena then laid siege to the city, but was so struck by the courage of Mucius Scaevola that he made peace on condition that the Romans restored the land they had taken from Veii and gave him 20 hostages. He subsequently returned both the land and the hostages (Livy, ii, 9–15; Dion. Halic., v, 21–34; Plutarch, *Poplicola,* p. 16–19). This story is probably an attempt to conceal a great disaster. According to other authorities, the Romans were obliged to surrender the city, to acknowledge Porsena's supremacy, to abandon their territory north of the Tiber, to give up their arms, and in future to use iron for agricultural purposes only. It is curious that, in spite of his military success, Porsena made no attempt to restore the Tarquinian dynasty. Hence it is suggested that the attack on Rome was merely an incident of the march of the Etruscans, driven southward by the invasion of upper Italy by the Celts, through Latium on their way to Campania. This would account for its transitory effects, and the speedy recovery of the Romans from the blow. With the departure of Porsena all traces of Etruscan sovereignty disappear *(see* Tacitus, *Hist.* iii, 72; Pliny, *Nat. Hist.* xxxiv, 39 [14]; Dion. Halic. v, 35, 36, vii, 5). The tomb at Chiusi described by Pliny (*Nat. Hist.* xxxvi, 19) as that of Porsena cannot have been his burial place *(see* CLUSIUM).

For a critical examination of the story, *see* Schwegler, *Romische Geschichte,* bk. xxi, 18; Sir G. Cornewall Lewis, *Credibility of Early Roman History,* ch. xii, 5; W. Ihne, *Hist. of Rome,* vol. i; E. Pais, *Storza di Roma,* i, ch. iv (1898); Macaulay's *Lays of Ancient Rome* gives a dramatic version of the story.

PORSON, RICHARD (1759–1808), English classical scholar, was born on Dec. 25, 1759, at East Ruston, in Norfolk, of humble parents. After attending the village school, he was entered on the foundation of Eton in 1774, and in 1778, through the generosity of Sir George Baker, the physician, entered Trinity college, Cambridge, of which he became a fellow four years later. The publication of his *Notae breves ad Toupii emendationes in Suidam* in 1790 established his fame as a scholar. During the same year, in the *Gentleman's Magazine,* he wrote the three letters on Hawkins's *Life of Johnson,* which have been reprinted in Kidd's *Tracts and Criticisms of Porson,* and in a volume of Porson's *Correspondence.* They are admirable specimens of his dry humour, and prove his intimate acquaintance with Shakespeare and the other English dramatists and poets. In the same periodical, in the course of 1788 and 1789, the *Letters to Archdeacon Travis, on the spurious verse i. John v. 7* (collected in 1790 into a volume), written in defense of Gibbon, had appeared. In 1792, his fellowship being no longer tenable by a layman, Porson moved to London, but in November of the same year was elected to the Greek professorship at Cambridge. Apart from his duties, the tragedians, Aristophanes, Athenaeus, and the lexicons of Suidas, Hesychius and Photius occupied most of his time.

In 1795 there appeared from Foulis' press at Glasgow an edition of *Aeschylus* in folio, printed with the same types as the Glasgow *Homer,* without a word of preface or anything to give a clue to the editor. Many new readings were inserted in the text with an asterisk affixed, while an obelus was used to mark many others as corrupt. It was at once recognized as Porson's work; he had superintended the printing of a small edition in two volumes 8vo, but this was kept back by the printer and not issued till 1806, still without the editor's name. There are corrections of many more passages in this edition than in the folio; and, though the text cannot be considered as what would have gone forth if with his name and sanction, yet more is done for the text of Aeschylus than had been accomplished by any preceding editor. It formed the substratum for all subsequent editions. It was printed from a copy of Pauw's edition corrected, which is preserved in the library of Trinity college.

Soon after this, in 1797, appeared the first instalment of what was intended to be a complete edition of Euripides—an edition of the *Hecuba.*

In the preface he pointed out the correct method of writing several words previously incorrectly written, and gave some specimens of his powers on the subject of Greek metres. The notes are very short, almost entirely critical; but so great a range of learning, combined with such felicity of emendation whenever a corrupt passage was encountered, is displayed that there was never any doubt as to the quarter whence the new edition had proceeded. He avoided the office of interpreter in his notes, which may well be wondered at on recollecting how admirably he did translate when he condescended to that branch of an editor's duties.

His work, however, did not escape attack; Gilbert Wakefield had already published a *Tragoediarum delectus;* and, conceiving himself to be slighted, as there was no mention of his labours in the new *Hecuba,* he wrote a "diatribe extemporalis" against it, a tract which for bad taste, bad Latin and bad criticism it would not be easy to match. Gottfried Hermann of Leipzig, then a very young man, who had also written a work on Greek metres, which Dr. Peter Elmsley styled "a book of which too much ill cannot easily be said," issued an edition of the *Hecuba,* in which Porson's theories were openly attacked. Porson at first took no notice of either, but went on quietly with his Euripides, publishing the *Orestes* in 1798, the *Phoenissae* in 1799 and the *Medea* in 1801, the last printed at the Cambridge press, and with the editor's name on the title page. But there are many allusions to his antagonists in the notes on such points as the final *v*, the use of accents, etc.; and on v. 675 of the *Medea* he holds up Hermann by name to scorn in caustic and taunting language. And it is more than probable that to Hermann's attack we owe the most perfect of his works, the supplement to the preface to the *Hecuba,* prefixed to the second edition published at Cambridge in 1802.

The metrical laws promulgated are laid down clearly, illustrated with an ample number of examples, and those that militate against them brought together and corrected, so that what had been beyond the reach of the ablest scholars of preceding times is made clear to the tyro. The laws of the iambic metre are fully explained, and the theory of the pause stated and proved, which had been only alluded to in the first edition. A third edition of the *Hecuba* appeared in 1808, and he left corrected copies of the other plays, of which new editions appeared soon after his death; but these four plays were all that was accomplished of the projected edition of the poet. Porson lived six years after the second edition of the *Hecuba* was published, but his natural indolence and procrastination led him to put off the work. He found time, however, to execute his collation of the Harleian ms. of the *Odyssey,* published in the Grenville *Homer* in 1801, and to present to the Society of Antiquaries his wonderful conjectural restoration of the Rosetta stone.

In 1806, when the London institution was founded (then in the Old Jewry, since removed to Finsbury Circus), he was appointed principal librarian with a salary of £200 a year and a suite of rooms; and thus his latter years were made easy as far as money was concerned.

Among his most intimate friends was James Perry, the editor of the *Morning Chronicle;* and this friendship was cemented by his marriage with Perry's sister, Mrs. Lunan, in Nov. 1796. The marriage was a happy one for the short time it lasted, as Porson became more attentive to times and seasons, and would have been weaned from his habits of drinking; but she sank in a decline a few months after her marriage (April 12, 1797), and he returned to his chambers in the Temple and his old habits. Perry's friendship was of great value to him in many ways; but it induced him to spend too much of his time in writing for the *Morning Chronicle;* indeed he was even accused of "giving up to Perry what was meant for mankind," and the existence of some of the papers he wrote there can be only deplored.

For some months before his death he had appeared to be failing: his memory was not what it had been, and he had some symptoms of intermittent fever; but on Sept. 19, 1808, he was seized in the street with a fit of apoplexy, and after partially recovering died on Sept. 25 at the age of 49. He was buried in Trinity college, close to the statue of Newton, at the opposite end of the chapel to where rest the remains of Richard Bentley.

In learning, Porson was superior to Valckenaer; in accuracy, to Bentley. It must be remembered that in his day the science of comparative philology had scarcely any existence; even the comparative value of mss. was scarcely considered in editing an ancient author. With many editors, mss. were treated as of much the same value, nhether they were really from the hand of a trustworthy scribe, or what Bentley calls "scrub manuscripts," or "scoundrel copies."

Thus, if we are to find fault with Porson's way of editing, it is that he does not make sufficient difference between the mss. he uses, or point out the relative value of early copies whether in ms. or print. Thus he collates minutely Lascaris' edition of the *Medea,* mentioning even misprints in the text, rather from its rarity and costliness than from its intrinsic value. And his wonderful quickness at emendation has sometimes led him into error, which greater investigation into mss. would have avoided; thus, in his note on Eur., *Phoem.* 1373 an error, perhaps a misprint (κε for με), in the first edition of the scholiast on Sophocles has led him into an emendation of v. 339 of the *Trachiniae* which clearly will not stand. But his most brilliant emendations, such as some of those on Athenaeus, or on the *Supplices* of Aeschylus are such as to convince the reader of their absolute certainty; and this pouer was possessed by Porson to a degree no one else had ever attained. No doubt his mathematical training had something to do with this; frequently the process may be seen by which the truth has been reached.

A few words are called for on his general character. No one ever more loved truth for its own sake; few have sacrificed more rather than violate their consciences, and this at a time nhen a high standard in this respect was not common. In spite of his failings few have had warmer friends: no one more willingly communicated his knowledge and gave help to others; scarcely a book appeared in his time or for some years after his death on the subjects to nhich he devoted his life without acknonledging assistance from him. And if it be remembered that his life nas a continued struggle against poverty and slight and ill-health, rather than complain that he did little. we should wonder hon he accomplished so much.

His library was divided into two parts, one of which was sold by auction; the other. containing the transcript of the Gale Photius, his books with ms. notes, and some letters from foreign scholars. was bought by Trinity college for 1.000 guineas His notebooks were found to contain, in the nords of Bishop Charles James Blomfield. "a rich treasure of criticism in every branch of classical literature — everything carefully and correctly nritten and sometimes renritten — quite fit to meet the public eye. without any diminution or addition" They have been carefully rearranged and illustrate among other things his extraordinary penmanship and poner of minute and accurate writing. Much remained unpublished. James Henry Monk. his successor as Greek professor. and Charles James Blomfield (both afterwards bishops) edited the *Adversaria,* consisting of the notes on Athenaeus and the Greek poets. and his prelection on Euripides: Peter Paul Dobree. afterwards Greek professor, the notes on Aristophanes and the lexicon of Photius.

Besides these. from other sources. Professor Thomas Gaisford edited his notes on Pausanias and Suidas and Thomas Kidd collected his scattered reviens. And. when Bishop Burgess attacked his literary character on the score of his *Letters to Travis,* Professor Thomas Turton (afterwards Bishop of Ely) came forward with a vindication (1827).

See Barker, *Porsoniana* (London, 1852); Kidd, "Imperfect Outline of the Life of R.P.," prefixed to his collection of the *Tracts and Criticisms;* the *Life by* J. S. Watson (1861): *Dict. Nat. Biog.;* and J. E. Sandys, *History of Classical Scholarship,* ii (1908). Porson's publications include: *Notae in Xenophontis anabasin* (1786); *Appendix to Toup* (1790); *Letters to Travis* (1790); *Aeschylus* (1795. 1806); *Euripides* (1797–1802); *Adversaria* (Monk and Blomfield, 1812); *Tracts and Criticism* (Kidd, 1815); *Aristophanica* (Dobree. 1820); *Notae in Pausaniam* (Gaisiord, 1820); *Photii lexicon* (Dobree. 1822); *Notae in Suidam* (Gaisford, 1834); *Correspondence* (Luard, edited for the Cambridge Antiquarian Society, 1867).

PORT: *see* PORT WINE; *see* also RULE OF THE ROAD AT SEA.

PORTA, GIACOMO DELLA (*c.* 1537–1602), Italian architect whose work represents the development in style from late mannerism to early baroque. was born and died at Rome. He was the chief Roman architect during the latter third of the 16th century. Della Porta continued two of Michelangelo's greatest architectural projects. the Piazza del Campidoglio and St. Peter's in the Vatican at Rome. whose dome, mith a more pointed profile than Michelangelo intended, became the prototype of the baroque dome.

In a similar manner the façade he added to Giacomo da Vignola's church of Il Gesu at Rome was the model for the typical baroque church façade. (D. R. CN.)

PORT ADELAIDE: *see* ADELAIDE.

PORTADOWN, a municipal borough (charter granted, 1947) in County Armagh, N.Ire., lies on the river Bann 26 mi. S.W. of Belfast by road. Pop. (1951) 17,202; (1961) 18,605. Area 2.9 sq.mi. An important road and railway junction, Portadown owed its origin to a ford on the river. Its wide Market and High streets are overlooked by the parish church of St. Mark (1824) with its war memorial tower. Fine business thoroughfares stretch from the town centre and there is a spacious covered market. The town hall (1890) and Carnegie library and museum (1903) are on Edward street.

Portadown has a college, two secondary intermediate schools and a maternity hospital. There is an annual music and drama festival. Two parks cater to most sports. The main industries are linen weaving, pottery, iron founding, bacon curing, flour milling, fruit canning and the manufacture of lace, furniture, clothing, carpets and metal cans. The renowned McGredy rose nurseries are located there. (WI. H. W.)

PORTAELS, JEAN FRANÇOIS (1818–1895), Belgian painter and teacher of art. was born at Vilvorde. Belgium. on April 30, 1818, and studied at the Brussels academy. In 1874 Portaels was appointed director of the academy of Brussels. His works include decorative paintings in the church of St. Jacques-sur-Caudenberg; biblical scenes and genre pictures, portraits, oriental scenes and pictures of fancy female figures, many of which are in the Brussels gallery. But it is as a teacher of art that Portaels is famous. He died at Brussels on Feb. 8, 1895.

PORTAGE LA PRAIRIE, a port of entry and the chief city of Portage la Prairie county, Manitoba, Can., 56 mi. W. of Winnipeg, on the Canadian Pacific and the Canadian National railways at an altitude of 856 ft. above the sea. Pop. (1961) 12,388.

The name had its origin in the fact that its situation on the Assiniboine is at the south end of a portage from Lake Manitoba used by the French fur traders. Industries include foundry and machine works and major brickyards.

PORTAEEGRE, a Portuguese district and a city on the Lisbon Madrid railway. City pop. (1960) 29,530 (mun.). Dist. pop. (1960) 192,706.

Portalegre is the Roman *Amaea* or *Ammaia,* and Roman and prehistoric remains have been discovered there.

PORTALES, DIEGO JOSÉ VICTOR (1793–1837), Chilean politician and *caudillo,* was born at Santiago on June 26, 1793. By 1824 he had built a profitable commercial firm that held a monopoly on tobacco in return for servicing a public loan contracted in England. When the Chilean government abrogated his contract he thren himself into politics as an ultraconservative. In 1830 the conservative Joaquin Prieto became president but Portales as chief minister ruled from behind the scenes and identified the objectives and defined the methods of the new power elite. He speedily silenced his liberal opponents. forced the military to submit to civilian dominance, and re-established Chile's credit standing abroad. The constitution of 1833. nhich reflected his political doctrines created a highly centralized state controlled by and for the landed oligarchy and the Roman Catholic church and provided 60 years of social stability and political order unequaled in Latin America. In 1836 he forced war on the Peru-

Bolivian confederation in order to distract attention from his repressive domestic measures. He was assassinated at Valparaiso on June 6, 1837, while reviewing troops preparing to embark for Peru. Hated and feared alive, in death he became a hero around whom the Chilean people rallied to win the war in 1839 and then to enter a period of aggressive nationalism and cultural flowering in the 1840s under Manuel Bulnes.

See also CHILE: *History.* (J. J. J.)

PORTALIS, JEAN ETIENNE MARIE (1746–1807). French lawyer and statesman, one of the chief architects of the *Code Civil,* was born at Bausset in Provence on April 1, 1746. He practised at the bar of Aix and in 1778–81 was one of the assessors or administrators of Provence. In Nov. 1793, after the republic had been proclaimed, he came to Paris and mas promptly imprisoned as the brother-in-law of Joseph Jérôme Simeon, the leader of the Federalists in Provence. Upon his release he resumed practice in the capital, but in 1795 was elected deputy to the *Conseil des Anciens,* later becoming its president. As a leader of the moderate party opposed to the Directory he was proscribed at the *coup d'état* of Fructidor and escaped to Switzerland. In 1800, when Napoleon became first consul, he returned to Paris and was appointed by Napoleon a *conseiller d'état* and a member of the commission charged with the drawing up of the *Code Civil.* As this body's most industrious member, he sought to permeate the code with the ideas of Roman law; many of the most important titles, notably those on marriage and succession, are his work.

In 1801 he was placed in charge of *cultes,* or public worship. and was chiefly responsible for drawing up the provisions of the concordat between Napoleon and Pius VII. He entered the French Academy in 1806 and died in Paris on Aug. 25, 1807. (L. N. B.)

PORTAL OF HUNGERFORD, CHARLES FREDERICK ALGERNON PORTAL, 1ST VISCOUNT (1893–), British air marshal and chief of air staff during World War II, was born at Hungerford in 1893 and educated at Winchester and Christ Church, Oxford. At the beginning of World War I he joined the royal engineers as a dispatch rider, and in 1915 he was commissioned in the royal flying corps. He distinguished himself as a fighter pilot by shooting down several enemy aircraft; for this he was awarded the Distinguished Service order and bar and the military cross. Between the wars his posts in the Royal Air Force included those of commander of the British forces, Aden; instructor at the Imperial Defence college; and director of organization and air member for personnel at the air ministry.

In 1940 for a short time he held the appointment of air officer commander in chief, bomber command. Soon after he became chief of the air staff, the highest post in the R.A.F., which he held with great distinction until 1945. In addition to his duties at the air ministry, directing the policy and operations of the R.A.F., he took a prominent part in all the important Allied conferences as a member of the chiefs of staffs committee. From 1946 to 1948 Lord Portal was responsible for work connected with atomic energy. He was appointed knight grand cross of the Order of the Bath in 1942, knight of the Garter and to the Order of Merit in 1946. He was created a baron in 1945 and a viscount in 1946. (E. B BN.)

PORT ARTHUR, a city and seat of Thunder Bay district in southwestern Ontario, Can., is on Thunder bay. a northwestern arm of Lake Superior. With its twin city Fort William (*q.v*). it is known as the lakehead. Port Arthur is a major transportation centre on the Canadian Kational and Canadian Pacific railways and the Trans-Canada highway. The passenger and freight ships of the Great Lakes transportation systems meet the rail lines of western Canada there.

There are important gold mines in the tributary area to the northeast. Extensive and rich hematite iron ore deposits at Steep Rock are tributary to the west, but most of the Steep Rock ore is shipped via special ore docks at Port Arthur. The city is noted for its large grain storage and shipment capacity.

There are extensive pulp and paper mills, shipbuilding and repair are important industries. and lumbering is a major activity. Pop. (1961) 45,276.

The Canadian lakehead is the gateway to a vast hunting and fishing area. (F. A. CK)

PORT ARTHUR (LÜ-SHUN), city and naval base in Liaoning province. China, at the southern extremity of the Kuantung peninsula of Manchuria. On the only part of the Manchurian coast line that is ice-free throughout the year. it occupies a strong strategic position, commanding the entrance to Po-hai wan a gulf of the Yellow sea Until the Chinese-Japanese war of 1894–95 Port Arthur was the chief Chinese naval base It fell in 1894 to Japan. which was. however. forced to return it to China under European pressure. Russia was anxious to obtain an ice-free port for its Pacific fleet. and the capture of Chiao-chou (Kiaochow) by the Germans in 1897 provided the occasion for Russian ships to occupy Port Arthur and the near-by commercial port of Dairen (q *v.*). In 1898. by agreement. Russia acquired from China the entire Kwantung peninsula for 25 years and the right to build a railroad to connect nith the Trans-Siberian railway. Port Arthur was made an apparently impregnable stronghold.

During the Russo-Japanese War (*q.v.*), Port Arthur was the scene of a victorious Japanese siege from the landward that undoubtedly had considerable influence on the outcome of the war. In May 1904 the Japanese 2nd army landed at P'i-tzu-wo and gained control of the isthmus that connects the Kwantung peninsula with the mainland. Dairen was seized without fighting and its port was used to debark the Japanese 3rd army in June The folloning month the Japanese broke through the outer defenses of Port Arthur and forced the Russians, under Gen. Anatoli M Stossel, to withdraw to the main defense norks of the base. Costly Japanese assaults were repeatedly frustrated during the next four months, until the key Russian position on 203-Metre hill nas finally overcome in late November. The Russian garrison capitulated Dec. 20, 1904. Even before the start of the siege. the Russian far eastern squadron, consisting of 7 battleships, 7 cruisers and 25 destroyers, had been bottled up in Port Arthur by a blockading Japanese naval force and fell to the Japanese at the time of the capitulation.

By the Treaty of Portsmouth (1905) Port Arthur mas transferred to the Japanese, who called it Ryojun. Japan retained control over the base and the entire Kwantung lease until the end of World War 1 Soviet forces seized Port Arthur in Aug. 1945. By treaty arrangements with the Chinese Nationalists and, later, with the Communists, the Soviet Union secured joint Soviet-Chinese control over Port Arthur until 1955. when the naval base passed to exclusive Chinese Communist use.

Port Arthur became part of the joint municipality of Port Arthur-Dairen, known in Chinese as Lüshun-Talien. or simply Lu-ta. with its seat at Dairen The population of Port Arthur in the 1953 census was 126,000; that of Lu-ta 1,200,000. (T. SD.)

SIEGE OF PORT ARTHUR, 1904

While the fortunes of the siege of Port Arthur had undoubtedly a considerable influence on the outcome of the Russo-Japanese war (*q.v.*), its execution was separated both in space and design from the main operations of the field armies. The first clash of the armies took place on the Yalu on May 1. 1904, and five days later. Gen. Oku's 2nd Army. which had been waiting at Chinampo for the ice to melt, landed near Pitszewo. By storming Nanshan Hill, he gained command of the isthmus which connected the Port Arthur peninsula with the mainland. This mission was a prelude to the siege, and to the 2nd Army's advance northward, its place being taken by the 3rd Army under Gen. Kogi.

Nogi landed on June 1. and his army (1st and 11th Divisions) gradually separated itself from Oku's and got into position for the advance on Port Arthur. Dalny, the commercial harbour. mas seized without fighting, and a month was spent in preparing a base there. But so far from retiring within his fort-line, the Russian commander. Gen. Stossel took up a strong position outside. Dislodged from this on June 26, the Russians checked Nogi's further advance on July 3–4. by a fierce, though unsuccessful. counter-stroke Having been reinforced by the 9th Division and two extra brigades of infantry, Nogi advanced again on the 26th The Russians, having had a month wherein to intrench themselves, held out all along the line; but after two days and one night of fighting amongst rocks and on precipitous hill-sides, the Japanese broke through on the night of July 27–28. Stossel then withdrew in good order into Port Arthur, which, in the two months he had gained by his fighting manoeuvre, had been considerably strengthened. Nogi had already lost 8,000 men.

The defences of Port Arthur, as designed by the Russians in 1900, and owing to the meagre allotment of funds only partially carried out before the war, had some tincture, but no more, of modern continental ideas. The main line of defence followed the outer edge of the amphitheatre of hills surrounding the harbour. These hills had their greatest development on the north-east side, their outer crests being some 4,000yd. from the Old Town. Running south-west and south back to the coast, the line gradually drew in quite close to the south-west end of the harbour. The total length from sea to sea was some 12 miles. Its most obvious weakness was that 5,000yd. N.W. of the harbour and New Town, the now famous "203-Metre Hill" overlooked both. Here it had been intended to construct permanent works, but consideration of expenditure had caused this to be deferred.

The permanent works along the main line were supplemented before the siege began by a prodigious development of semi-permanent works and trenches. Every knoll had its redoubt or battery, and the trenches were arranged line behind line, to give supporting, cross and enfilade fire in every direction. On the north-west front, 203-Metre Hill, in advance of the main line, was occupied by strong, semi-permanent works, with trenches and redoubts on either flank. Wire entanglements were disposed in repeated lines in front of the defences, but they were not of a strong type. The Russians, with the resources of the fleet at their disposal (just as at Sevastopol, in the Crimean War), used great numbers of machine guns and electric lights, and the available garrison at first was probably, including sailors, 47,000 men.

Such were the defences that the Japanese attacked, with a force at the outset (July 30) barely superior in numbers to the defenders, and an entirely inadequate siege train (18 6-in. howitzers, 60 4.7-in guns and howitzers, and about 200 field and mountain guns). They were imperfectly informed of the strength of the garrison and the nature of the defences. Recollections of their easy triumph in 1894 and perhaps thoughts of Sevastopol, German theories of the "brusque attack." the fiery ardour of the army, and above all the need of rapidly crushing or expelling the squadron in harbour, combined to suggest a bombardment and general assault. The bombardment began on Aug. 19 and continued for three days, while the infantry was spreading along the front and gaining ground where it could. The real assault was made on the night of the 21st on the two Pan-Lung forts (semi-permanent) on the centre of the north-eastern front. Although the stormers captured the two forts they were unable to make any further progress under the fire of the permanent forts Erh-Lung and Chi-Kuan on either side of, and the Wan-tai fort behind, Pan-Lung. Every attempt to bring up support to the captured positions failed. On the night of the 23rd–24th, just as the assault was being renewed, Stossel delivered a fierce counter-attack against the lost positions, and the result of an all-night battle was that though the forts were not recaptured, the assault was repulsed with over 5,000 casualties, and the Japanese in Pan-Lung were isolated. This sortie raised the spirits of the Russians to the highest pitch They seemed, indeed, to have broken the spell of defeat. On the Japanese side 15,000 men had been killed and wounded in three weeks, and their army had now to resign itself to a methodical siege. Small sorties, partial attacks[1] and duels between the Japanese guns and the generally more powerful ordnance of the fortress continued. The siege approaches were first directed against the Temple-Waterworks group, which was stormed on Sept. 19 and 20. Pan-Lung was connected with the Japanese lines by covered ways, approaches were begun towards several of the eastern forts, and on Sept. 20, 180-Metre Hill was stormed, though the crest was untenable under the fire from 203-Metre Hill. Further progress on the western side of the fortress was foiled after hard fighting, and the eastern forts remained the principal objective. Heavier howitzers had been sent for from Japan and on Oct. 1 the first batteries of 28-centimetre (11in.) howitzers came into action. They fired a shell weighing 485 lb. On the 12th, the Japanese took the trenches between the Waterworks Redoubt and the Erh-Lung, and from this time forward there was a desperate struggle at the sap-heads on the north front.[2] A lodgement on the counterscarp of Sung-Shu prepared the way for mining. On Nov. 17, seven mines were exploded.

On Nov. 26, another assault was made on the same lines as the earlier ones. By this time the besiegers were sapping under the escarps of the northern forts, and it would have been better to delay. But the situation was serious in the extreme. In Manchuria Kuropatkin's army had reasserted itself. From Europe Rozhestvenski's squadron was just setting sail for the Far East. Marshal Oyama sent his principal staff officers to stimulate Nogi to fresh efforts, and some exhausted units of the besieging army were replaced by fresh troops from Japan. With 100,000 men and this urgent need of immediate victory, Nogi and the marshal's staff officers felt bound to make a third general assault. The siege works had, indeed, made considerable progress. The ditches of Sung-Shu and Erh-Lung were partially filled. They held most of the ditch of Chi-Kuan Fort and were cutting down the escarp, and two parallels had been made only 30 yd. from the Chinese Wall at Pan-Lung.

The general attack was made at one o'clock in the afternoon. At Sung-Shu the stormers got into the fort, but suffered much from the artillery on the western side of the Lun-ho valley, and were beaten out of it again in 20 min.; 2,000 men tried in vain to get up the Lun-ho valley to take Sung-Shu in rear. At Erh-Lung they could not get over the outer parapet. At "G" they took a portion of the Chinese Wall and lost it again, other trenches with a cross fire being behind. At Pan-Lung the machine guns on the wall prevented them from leaving the parallel. At Chi-Kuan Fort the *terreplein* of the fort had been covered with entanglements defended by machine guns on the gorge parapets, and the Japanese could make no way. Briefly, there was a furious fight all along the line, and nothing gained. On Nov. 27, after losing 12,000 men, the assault was abandoned. On the north front the Japanese returned to mining.

But so urgent was the necessity of speedy victory that the fighting had to continue elsewhere. And at last, after every other point had been attempted, the weight of the attack was directed on 203-Metre Hill. A battery of 11-in. howitzers was established only one mile away. On Nov. 28 and 30, assaults were made and failed. On Dec. 1, there was a fresh bombardment by the big howitzers, which obliged the Russians to take shelter in the rear of the ruined works. On Dec. 2, the Russians tried a counterattack. During the next two days the artillery was busy. The engineers sapped up to the ruins of the western work, saw the shelters on the reverse slope and directed artillery fire by telephone. Thirty-six guns swept the ground with shrapnel. Finally, on Dec. 5, the Japanese attacked successfully. Their losses in the last 10 days at 203-Metre Hill had been probably over 10,000. Those of the Russians were about 5,000, chiefly from artillery fire.

This was the turning point of the siege. At once the 11-in. howitzers, assisted by telephone from 203-Metre Hill, opened upon the Russian ships; a few days later these were wholly hors *de* combat, and at the capitulation only a few destroyers were in a condition to escape. The siege was now pressed with vigour by the construction of batteries at and around 203-Metre Hill, by an infantry advance against the main western defenses, and by renewed operations against the eastern forts. The escarp of Chi-Kuan was blown up, and at the cost of 800 men, General Sameyeda (11th division), personally leading his stormers, captured the great fort on Dec. 19. The escarp of Ehr-Lung was also blown

[1] A feature of these constant night-fights was the effective use of the defenders' searchlight, both to show up the enemy and to blind him.

[2] Hand grenades and extemporized trench mortars were used on both sides with very great effect. The Japanese hand grenades consisted of about 1-lb. of high esplosive in a tin case; the Russian cases were all sorts, including old Chinese shell. The Japanese employed wire-netting screens to stop the Russian grenades. Various means were tried for the destruction of entanglements. Eventually it was found that the best plan was to sap through them.

up, and the ruins of the fort were stormed by the 9th division on Dec. 28, though a mere handful of the defenders prolonged the fighting for eight hours and the assailants lost 1,000 men. Sung-Shu suffered a worse fate on Dec. 31, the greater part of the fort and its defenders being blown up, and on this day the whole defense of the eastern front collapsed. The Japanese 7th and 1st divisions were now advancing on the western main line; the soul of the defense, the brave and capable General Kondratenko, had been killed on Dec. 15, and though food and ammunition were by no means exhausted, Anatoli M. Stossel surrendered on Jan. 2, 1905, with 24,000 effective and slightly wounded and 15,000 wounded and sick men, the remnant of his original 47,000. The total losses of the 3rd Japanese army during the siege were about 92,000 men (58,000 casualties and 34,000 sick).

PORT ARTHUR, a major deepwater port of east Texas, U.S., is on the northwest shore of Sabine lake, 9 mi. from the Gulf of Mexico. The city is 16 mi. S.E. of Beaumont (q v.) and 17 mi. S.W. of Orange (*q.v.*), the three points of the Golden Triangle, site of an important petrochemical industry. Port Arthur's population in 1960 was 66,676; for comparative population figures see table in TEXAS: Population.

The area, known in 1840 as Aurora, was an important base for a considerable illegal African slave trade into Texas during the mid-19th century. In the 1890s Arthur E. Stilwell, for whom the city was named, decided to use the port as the southern terminus for the Kansas City Southern railroad which he was promoting. Stilwell bought 53,000 ac. of land in the area in 1895, organized a town and arranged in 1899 for the dredging of a deep-sea canal to bring vessels directly to the city's docks.

In 1901 oil prospectors discovered the remarkable oil well known as Spindletop a few miles from Port Arthur. This event marked the birth of the Texas oil industry. James Stephens Hogg, a former governor of Texas, and the promoter and financier John W. ("Bet-a-Million") Gates stepped in to exploit the area and the port became a major sea outlet for a fabulous oil industry. Gates, in gratitude for a fortune made in the area, left the city funds for a library, art gallery, hospital and an industrial college.

Port Arthur has a council-manager form of government, in effect since 1932. (E. W. F.)

PORTATIVE ORGAN, a small mediaeval organ, not to be confounded with the positive (or portable) organ (*q.v.*). These miniature organs, used during the 14th and 15th centuries, were revivals of those used by the Romans, of which a specimen excavated at Pompeii in 1876 is preserved in the museum at Naples. The case measures $14\frac{1}{2}$ in. by $9\frac{1}{3}$ in. and contains nine pipes, of which the longest measures but $9\frac{3}{4}$ in.

PORT AUGUSTA, at the head of Spencer gulf, an arm of the sea which penetrates far toward the interior of South Australia. This position lends Port Augusta a potential importance which, however, is somewhat impaired by a shallow approach and a channel which requires dredging. It is the natural port for the wheat-growing areas to the east, and for the pastoral areas to the north and northwest. After the construction of the east to west transcontinental line (Perth-Brisbane), Port Augusta became a break-of-gauge station. Pop. (1954) 6,704. The rainfall (93") is too low for crops in the immediate vicinity.

PORT-AU-PRINCE, capital, chief port and commercial centre of the republic of Haiti, situated on a magnificent bay at the apex of the Gulf of La Gonbve which strikes inland for about 100 mi. between the two great peninsulas of the west coast, with its upper recesses protected by the island of Gonbve (30 mi. long and 2 mi. broad). Pop. (1950) 134,117. The National palace, rebuilt in 1918, the army barracks and an itnposing statue of Jean Jacques Dessalines dominate the Champs-de-Mars in the centre of the city. The most picturesque site is the Iron market where the merchants are almost exclusively women. Other notable buildings include the National archives, the National library and the National museum. It is the centre of the political and intellectual life of the nation and is the seat of the University of Haiti (established 1944), but Haiti's poverty makes the city one of the most unsanitary and backward capitals in the western hemisphere. During the U.S. occupation. 1915–34, sanitary conditions were

PUBLIX PICTORIAL SERVICE, INC.

GATE OF THE IRON MARKET (MARCHÉ FER), BUILT IN LATE 19TH CENTURY, PORT-AU-PRINCE

improved. The climate is warm and humid, average 81° F. with little seasonal change.

Port-au-Prince is linked by railroad to Saint-Marc, about 45 mi. N.W., and by paved road to Cap-Haïtien; buses run on irregular schedules to all parts of the country. There are air services to most of the Caribbean islands and to New York. During the 1950s several luxury hotels were built to accommodate tourists. Textiles, cottonseed oil, flour and sugar mills are located in or near the capital.

The city was first laid out in 1749 by the French and its bicentenary was commemorated in 1949 by an international exposition, the site of which is now a pleasant palm-fronted promenade. In 1751, and again in 1770, it was destroyed by earthquakes; in subsequent years the city was ravaged frequently by fire. (R. W. LN.)

PORT AUTHORITY. For Great Britain the discussion of the constitution and powers of the different port authorities will be found in the articles on the various ports, *e.g.,* London, Liverpool, etc. The U.S. port authority, in many respects peculiar, calls for special discussion. The American Association of Port Authorities issued a port authorities directory for North America which indicated the adoption by an increasing number of American ports of some modification of the form of government established at European ports, notably at London and Liverpool.

Ownership of all facilities on the San Francisco, Calif., waterfront was acquired by the state of California and operated by the board of state harbour commissioners, the state guaranteeing the bonds issued, the principal and interest of which are payable from harbour revenue. No funds were to be raised by taxation and the harbour was self-supporting from its inception.

Under the 1925 charter for the city of Los Angeles, Calif., the board of harbour commissioners obtained possession and control of the entire waterfront. It might collect rates or charges for the use of facilities in connection with Commerce and navigation, might acquire and operate such facilities and secured power to regulate and control the construction, maintenance, operation or use of any such facility.

An act approved on March 14, 1911, authorized the establishment of port districts in the various counties of the state of Washington, and the port of Seattle came into existence under this act a municipal corporation with power to levy taxes and to issue bonds. It might acquire lands, etc., and exercise the right of eminent domain. Commissioners are elected.

The port of Portland, Ore., was established and incorporated by the laws of 1891. It acquired broad powers, among them full control of the Willamette and Columbia rivers between Portland and the sea to the extent of the state's control, the right of eminent domain, the power to levy regular and special taxes on the property within the district and to bond the district to provide funds for carrying on its operations.

Operation of the port of Houston, Tex., was entrusted to the navigation and canal commission controlling the commercial activities of the port and the maintenance and construction of the terminal facilities. The board of commissioners of the port of New Orleans was created by a Louisiana statute enacted in 1896 to administer the public wharf system, construct and operate a public cotton warehouse, public grain elevator, public coal and bulk commodity handling plant and the great inner harbour navigation canal. The Virginia assembly in 1926 created the state port authority of Virginia, superseding the Hampton Roads port commission.

The board of harbour commissioners for the city of Wilmington, Del., an agency of the mayor and council of Wilmington, was created in 1917 by an act of the general assembly, which act was amended in 1921 and 1925. The board was given authority to fix rates and charges for wharfage and other services rendered in the loading and unloading of vessels, as well as warehouse and storage charges.

The Albany, N.Y., port district commission was created by the legislature of New York in 1925, with broad powers to lease or construct and maintain and operate port facilities, to acquire real property, to contract with municipalities for the construction of port facilities, issue bonds, fix rates, charges and wharfage for the use of all port facilities and collect charges for facilities owned by the district. Provision for tax in the several municipalities in the port district was made.

(J. H. Co.; X.)

The Port of New York is unusual in that it lies within the boundaries of two states, New York and New Jersey, each an independent sovereignty. As early as 1834 the two states found it necessary to enter into a treaty settling the jurisdiction of each over the harbour's waters.

In 1917, in its decision in the New York harbour case involving freight rates and other points of conflict between the harbour's New York and New Jersey sides, the Interstate Commerce commission held that "historically, geographically and commercially New York and the industrial district in the northern part of the State of New Jersey constitute a single community" and recommended that immediate steps be taken to reorganize and coordinate the terminal facilities at the port. In 1920 the New York-New Jersey Port and Harbor Development commission, organized to study the problem, recommended creation of a port authority and a port district. This was accomplished when, on April 30, 1921, the two states entered into a compact or treaty. The consent of congress was given by joint resolution approved Aug. 23, 1921.

By the compact, which supplemented the treaty of 1834, the two states pledged, "each to the other, faithful cooperation in the future planning and development of the Port of New York." The port authority operates under the direction of 12 unsalaried commissioners, 6 from each state, appointed by the governors for overlapping terms of 6 years. It has full authority to purchase, construct, lease and operate any terminal or transportation facility within the port district; to own, hold, lease and operate real or personal property; to borrow money and secure it by bonds or by mortgage on any property held or to be held by it. It has no powers of taxation and must be entirely self-supporting. No property held by any municipality within the port district, or by either state, may be taken by the port authority without the owner's consent. In 1922 the legislatures of both states adopted a plan for the comprehensive development of the port, as provided for in the compact, and this was approved by congress. Under these and subsequent statutes, the two states authorized the construction or operation of additional transportation and terminal facilities, beginning with the Goethals bridge and Outerbridge crossing across the Arthur Kill between Staten Island and New Jersey, opened to traffic in 1928. Within the next 25 years there were added to port authority operations four more interstate crossings: the Bayonne, N.J., bridge across the Kill van Kull between Staten Island and New Jersey, and the George Washington bridge and Holland and Lincoln tunnels across the Hudson river between Manhattan and New Jersey; two air terminals, La Guardia airport and New York International airport in New York city and two in New Jersey, Newark airport and Teterboro airport; two union motor truck terminals, one in New York city and one in Newark, N.J.; a less-than-carload railroad freight terminal and a union bus terminal in Manhattan; the city of Newark's seaport; and a grain terminal in Brooklyn.

To finance its extensive operations the port authority had issued $711,701.258 in revenue bonds by 1952, including numerous refunding issues. The debt outstanding on March 31, 1952, was $228,172,000. The port authority's credit had improved so that the interest costs on long-term bonds had dropped from $5\frac{1}{4}\%$ to 2%.

The port authority's actual investment and commitments in facilities as of March 31, 1952, totaled $395,395,396. Retirement of bonds was provided for out of revenues from the vehicular crossings and terminals.

The building and operation of transportation and terminal facilities represents only part of the port authority's work. It is charged by statute with the protection of port commerce and appears before such regulatory bodies as the Interstate Commerce commission, the Civil Aeronautics board and the Federal Maritime board in the interest of the welfare of the unified port area. It established branch offices in Washington, D.C., Chicago, Ill., Cleveland, O., and Rio de Janeiro, Braz., to promote commerce through the Port of New York.

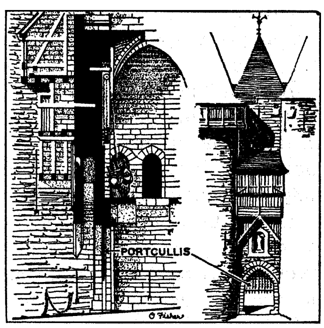
(L. K. J.)

PORT BLAIR, capital of the Andaman and Nicobar islands (*q.v.*), India, in the Indian ocean, lies on the southeast shore of the South Andaman Island, in 11° 42′ N., 93° E. Pop. (1951) 8,014. Occupied in 1789 by Capt. Archibald Blair, R.N., it was named Port Cornwallis. The site was abandoned after two years, but was resettled in 1857 and named Port Blair.

It possesses one of the finest harbours in Asia. From 1858 to 1945 there was a penal settlement on the islands and Port Blair was the headquarters. In World War II it was in Japanese occupation from 1942–45.

PORT CHESTER, a village in Westchester county, N.Y., U.S., on Long Island sound at the mouth of the Byram river, which separates it from Connecticut. Port Chester's earliest history began with Peter Disbrow's purchase of the southern part of its present site on Jan. 3, 1660, from the Siwanoy Indians, a Mohegan tribe. In 1661 he and his associates proclaimed Charles II their lawful monarch in defiance of the claims of the Dutch West India company (*see* LONG ISLAND: *History*). As early as 1732 the settlement was known as Saw Pit because of the important shipbuilding trade that had developed there. On March 11, 1837, the name was changed to Port Chester, and the village was incorporated under that name on May 14, 1868. Although Port Chester is a residential suburb, there were in the 1960s more than 600 business firms and manufacturing establishments making or selling such products as candy, cough drops, bread products, plastics, porcelainized products, nuts and bolts, women's hats and men's shirts. For comparative population figures see table in NEW YORK: *Population.*

(M. D. HH.)



A PORTCULLIS: LEFT, A SECTIONAL VIEW SHOWING OPERATION; RIGHT, FRONT VIEW

PORTCULLIS, a strong-framed grating of wood, the lower points shod with iron, and sometimes entirely made of metal, counterbalanced, and hung so as to slide up and down in grooves, and intended to protect the gateways of castles, city gates, etc. The defenders, having opened the gates and lowered the portcullis, could send arrows and darts through the gratings. The Romans used the portcullis in the defense of gateways. It was called *cataracta* (from the Gr. *katarraktes,* "a waterfall"). Vegetius speaks of it as an old means of defense. Remains of a *cataracta* are clearly seen in the gateway of Pompeii.

PORTE, THE SUBLIME, the name once given to the Turkish government. derived from the high gate giving access to the building in Constantinople where the offices of the principal state departments were situated.

PORT ELIZABETH, a seaport situated 436 mi. E. of Cape Town by sea, in the Cape of Good Hope, South Africa, in latitude 33" 58' S. and longitude 25° 37' E. The population in 1960 was 245,985, of whom 84,505 were Europeans, 51,453 coloured (mixed), 3,865 Asians and 106,162 natives.

Port Elizabeth is the third port of South Africa. midway between Cape Town and Durban. The area south of the harbour has developed into a seaside resort with one of the finest beaches in South Africa and extensive residential development has also taken place there.

The main business centre of Port Elizabeth is situated immediately inland from the harbour with further residential areas stretching about 7 mi. inland. To the north of the town more than 1,500 ac. of land have been developed with industries, the largest establishments being those of the automotive industry. Projects for further industrial expansion over an area of more than 600 ac. have also been planned.

The harbour, with a water area of 314 ac., is enclosed and has two main quays, one 3,540 ft. long and the other 1,700 ft. long. The depth of the water in the harbour is 36 ft. above low water ordinary spring tides and is capable of taking any ocean-going liner. In 1951 it handled more than half the imports for the Rhodesias by virtue of its excellent rail communication system with the hinterland. Ample cold storage facilities have been installed in the harbour to handle products of the increasing citrus industry. After World War II Port Elizabeth developed more rapidly industrially than any other town or city in South Africa and by the mid-1950s there were more than 400 factories engaged in about 80 different types of industrial activity.

History. — Algoa bay was discovered by the Portuguese explorer Bartolomeu Dias in 1488. In 1754 the Dutch settlement at the Cape was extended eastward to this point. With the arrival of 3.000 British settlers in 1820 — known as the 1820 settlers — Port Elizabeth was established under the supervision of Sir Rufane Donkin. At first Port Elizabeth was merely a commercial and shipping centre, but after 1925 its industrial development leaped forward and by 1953 it had become the largest municipality in South Africa, with an area of 106 sq.mi.

PORTEOUS, JOHN (d. 1736), captain of the city guard of Edinburgh, whose name is associated with the riots of 1736, was the son of an Edinburgh tailor. Having served in the army, he was employed in 1715 to drill the city guard for the defense of Edinburgh in anticipation of a Jacobite rising, and was promoted later to the command of the force. In 1736 a smuggler named Wilson, who had won popularity by helping a companion to escape from the Tolbooth prison, was hanged; and, a disturbance occurring at the execution. the city guard fired on the mob. Porteous, who was said to have fired at the people with his own hand, was brought to trial and sentenced to death. The granting of a reprieve was hotly resented by the people of Edinburgh, and on the night of Sept. 7, 1736, an armed body of men in disguise broke into the prison, seized Porteous and hanged him on a signpost in the street. It was said that persons of high position were concerned in the crime; but although every effort was made for the apprehension of the perpetrators, no one was ever convicted of participation in the murder.

BIBLIOGRAPHY.—Sir Daniel Wilson, *Memorials of Edinburgh in the Olden Time,* 2 vol (1846–48); *State Trials,* vol. xvii; William Coxe, *Memoirs of the Life of Sir R. Walpole,* 4 vol. (1816); Alexander Carlyle, *Autobiography* (1860), which gives the account of an eyewitness of the execution of Wilson; pamphlets (2 vol., in British Museum) containing *The Life and Death of Captain John Porteous* and other papers relating to the subject; W. E. H Lecky, *History of England in the Eighteenth Century,* vol. ii, p. 324, note, 7 vol (1892). *See* also Sir Walter Scott's notes to *The Heart of Midlothian.*

PORTER, DAVID (1780–1843), U.S. naval officer who commanded the frigate "Essex" on her famous expeditions during the War of 1812, was born in Boston, Mass., on Feb. 1, 1780. His father. David, commanded U.S. ships in the American Revolutionary War. In 1796 he accompanied his father to the West Indies; on a second and on a third voyage he was impressed on British vessels, but he escaped. He became a midshipman in the U.S. navy in April 1798; served on the "Constellation" and was midshipman of the foretop when the "Constellation" defeated the "Insurgente"; was promoted lieutenant in Oct. 1799 and was in four successful actions with French ships in that year.

In 1803, during the war with Tripoli, he was first lieutenant of the "Philadelphia" when that vessel grounded, he was taken prisoner and was not released until June 1805. He was commissioned master commandant in April 1806; from 1807 to 1810 he served about New Orleans, where he captured several French privateers, and in 1812 was promoted captain. He commanded the "Essex" in her famous voyage (1812–14). In the Atlantic he captured seven brigs, one ship, on Aug. 13, 1812, the sloop "Alert," the first British war vessel taken in the War of 1812. Without orders from his superiors he then (Feb. 1813) rounded Cape Horn, and in the South Pacific captured many British whalers and took formal possession (Nov. 1813) of Nukuhiva, the largest of the Marquesas Islands. The United States, however, never asserted any claim to the island, and in 1842. with the other Marquesas, it was annexed by France. During most of February and March 1814 he was blockaded by British frigates in the harbour of Valparaiso. and on March 28 was defeated. Released on parole, he sailed for New York.

He was a member of the new board of naval commissioners from 1815 until 1823, when he commanded a squadron sent to the West Indies to suppress piracy. One of his officers, who landed at Fajardo (or Foxardo), Puerto Rico, in pursuit of a pirate, was imprisoned by the Spanish authorities on the charge of piracy. Porter, without reporting the incident or awaiting instructions, forced the authorities to apologize. He was recalled (Dec. 1824), court-martialed and suspended for six months. In Aug. 1826 he resigned his commission, and until 1829 was commander in chief of the Mexican navy, then fighting Spain. Pres. Andrew Jackson appointed him consul general to Algiers in 1830, and in 1831 created for him the post of chargé d'affaires at Constantinople, where in 1841 he became minister. He died in Pera on March 3, 1843.

He wrote a *Journal* of a *Cruise Made to the Pacific Ocean in the U.S. Frigate "Essex" in 1812–13–14* (1815; 2nd ed., 1822), and *Constantinople* and *Its Environs* (1835), which is a valuable guidebook.

See the *Memoir of Commodore David Porter* (1875), *by* his son, Adm. David D. Porter.

PORTER, DAVID DIXON (1813–1891), U.S. naval officer, who held important commands during the American Civil War, was born in Chester, Pa., on June 8, 1813. His first voyage, with his father, Capt. David Porter, in West Indian waters (1823–24), was terminated by the Fajardo affair *(see* PORTER, DAVID). In April 1826 he entered the Mexican navy, of which his father was commander in chief, and which he left in 1828 after the capture by the Spanish of the "Guerrero," on which he was serving under his cousin, David H. Porter (1804–28), who was killed before the ship's surrender. He became a midshipman in the U.S. navy in 1829 and was in the coast survey (1836–42). Porter became a lieutenant in Feb. 1841 and served at the naval observatory from 1845 to 1846, when he was sent to the Dominican Republic to report on conditions there. During the Mexican War he served as lieutenant and then as commanding officer of the "Spitfire." a paddle vessel built for river use, and took part in the bombardment of Veracruz. In 1855 and in 1856 he made trips to the Mediterranean to bring to the U.S. camels for army use in the southwest. In April 1861 he was assigned to the "Powhatan," and was sent under secret orders from the president for the relief of Ft. Pickens, Pensacola. Porter was promoted commander on April 22, and on May 30 was sent to blockade the Southwest pass of the Mississippi. Upon his return to New York in November he urged an expedition against New Orleans (*q.v.*), and recommended the appointment of Comdr. D. G. Farragut (*q.v.*), his foster brother, to the chief command.

In the expedition Porter himself commanded the mortar flotilla, which, when Farragut's fleet passed the forts on the early morning of April 24, 1862, covered the passage by a terrific bombardment that neutralized the fire of Ft. Jackson. At Vicksburg Porter's bombardment assisted Farragut to run past the forts (June 28). On July 9 Porter was ordered, with ten mortar boats, to the James river, where McClellan's army was concentrated. On Oct. 15 he took command of the gun vessels and had a share in the capture of Arkansas Post (Jan. 11, 1863). In the operations for the capture of Vicksburg in 1863 unsuccessful attempts were made by Porter's vessels to penetrate through connecting streams and bayous to the Yazoo and reach the right rear of the Confederate defenses on the bluffs, but the fleet ran past the Vicksburg batteries, mastered the Confederate forts at Grand Gulf and made it possible for Grant's army to undertake the brilliant campaign which led to the fall of the place (*see* AMERICAN CIVIL WAR and VICKSBURG). Porter received the thanks of congress for "opening the Mississippi river" and was promoted rear admiral. He co-operated with Maj. Gen. N. P. Banks in the Red river expeditions in March–May 1864, in which his gunboats, held above Alexandria by shallow water and rapids, narrowly escaped isolation. On Oct. 12, 1864, he assumed command of the North Atlantic blockading squadron, then about to engage in a combined military and naval expedition against Ft. Fisher, N.C. Porter claimed that his guns silenced Ft. Fisher, but Maj. Gen. B. F. Butler, in command of the land forces, refused to assault, asserting that the fort was practically intact.

After Butler's removal, Porter, co-operating with Maj. Gen. Alfred H. Terry and commanding the largest fleet assembled at any one point during the war, took the fort on Jan. 15, 1865; for this he again received the thanks of congress. From 1865 to 1869 he was superintendent of the U.S. Naval academy, Annapolis, which he greatly improved, his most notable change being the introduction of athletics. On July 25 he became vice-admiral. From March 9 to June 25, 1869, while Adolph E. Borie (1809–80) of Pennsylvania was secretary of the navy in President Grant's cabinet, Porter was virtually in charge of the navy department. In 1870 he succeeded Farragut in the grade of admiral. He died in Washington, D.C., Feb. 13, 1891.

Porter wrote a *Life of Commodore David Porter* (1875), gossipy *Incidents and Anecdotes of the Civil War* (1885), a none too accurate *History of the Navy During the War of the Rebellion* (1887), two novels, *Allan Dare* and *Robert le Diable* (1885; dramatized, 1887) and *Harry Marline* (1886), and a short "Romance of Gettysburg," published in *The Criterion* in 1903.

See J. R. Soley, *Admiral Porter* (1903).

Admiral Porter's three brothers were in the service of the United States: WILLIAM DAVID PORTER (1809–64) commanded the "Essex" on the Tennessee and the Mississippi in the Civil War and became commodore in July, 1862; THEODORIC HENRY PORTER (1817–46) was the first officer of the U.S. army killed in the Mexican War; and HENRY OGDEN PORTER (1823–72) resigned from the U.S. navy in 1847, after seven years' service, fought under William Walker in Central America, returned to the U.S. navy, was executive officer of the "Hatteras" when she was sunk by the "Alabama" and received wounds in the action from the effects of which he died several years later.

PORTER, ENDYMION (1587–1649), English royalist, born at Aston-sub-Edge in Gloucestershire, was brought up in Spain—where he had relatives—as page in the household of Olivares. He afterward entered successively the service of Edward Villiers and of the marquis (later duke) of Buckingham, and through the latter's recommendation became groom of the bedchamber to Prince Charles, who then and after his accession employed him on diplomatic business, including negotiations connected with the Spanish marriage. About 1620 Porter married Buckingham's niece, Olivia Boteler. During the Civil War he remained a faithful servant of the king.

At the end of 1645, when the cause of the king was finally lost, Porter abandoned England, and resided successively in France, Brussels and the Netherlands. He returned to England in 1649, after the king's death, and was allowed to compound for what remained of his property. He died shortly afterward, and was buried on Aug. 20, 1649, at St. Martin's-in-the-Fields. Porter had a great reputation in the world of art and letters. He wrote verses, was a generous patron of Sir William Davenant, of Dekker, Gervase Warmstrey, Thomas May, Herrick and Robert Dover, and was included among the 84 "essentials" in Edmund Bolton's "Academy Royal." He was a judicious collector of pictures, and as the friend of Rubens, Van Dyck, Daniel Mytens and other painters and as agent for Charles in his purchases abroad he had a considerable share in forming the king's magnificent collection. He was also instrumental in procuring the Arundel pictures from Spain. The authorship of Εἰκὼν πιστή (1649), a vindication of the Εἰκὼν Βασιλική, has been attributed with some reason to Porter.

See D. Townshend, *Life and Letters of Mr. Endymion Porter* (London, 1897); *Dictionary of National Biography,* vol. xlvi (London, 1896) and authorities there cited.

PORTER, FITZ-JOHN (1822–1901), American soldier, was born at Portsmouth (N.H.) on Aug. 31, 1822. He was the son of a naval officer, and nephew of David Porter of the frigate "Essex." He graduated at the U.S. Military academy in 1845; in the Mexican War he won two brevets for gallantry. He served at West Point as instructor and adjutant (1849–55), and at the outbreak of the Civil War in 1861 he was employed on staff duties in the eastern States. He became colonel of a new regiment of regulars on May 14, and soon afterwards brig.-general of volunteers. Under McClellan he commanded a division of infantry in the Peninsular campaign, directed the Union siege operations against Yorktown, and was soon afterwards placed in command of the V. Army Corps. When the Seven Days' battle (*q.v.*) began Porter's corps had to sustain alone the full weight of the Confederate attack, and though defeated in the desperately fought battle of Gaines's Mill (June 27, 1862) the steadiness of his defense was so conspicuous that he was immediately promoted maj.-general of volunteers and brevet brig.-general. His corps, moreover, had the greatest share in the successful battles of Glendale and Malvern Hill. Soon afterwards, the V. Corps was sent to reinforce Pope in central Virginia. Its inaction on the first day of the disastrous second battle of Bull Run (*q.v.*) led to the general's subsequent disgrace; but it made a splendid fight on the second day to save the army from complete rout, and shared in the Antietam campaign.

On the same day on which McClellan was relieved from his command, Porter, his friend and supporter, was suspended and tried by court-martial on charges brought against him by Pope. On Jan. 21, 1863, he was sentenced to be cashiered "and for ever disqualified from holding any office of trust under the Government of the United States." In 1878 Porter's friends succeeded in procuring a revision of the case by a board of distinguished general officers. General Grant had now taken Porter's part, and wrote an article in vol. 135 of the *North American Review* entitled "An Undeserved Stigma." Against much opposition, a relief bill finally passed Congress, and Porter was on Aug. 5, 1886, restored to the United States army as colonel and placed on the retired list, without compensation. After the Civil War he was engaged in business in New York, and held successively many important municipal offices. In 1869 he declined the offer made by the khedive of the chief command of the Egyptian Army. He died on May 21, 1901, at Morristown (N.J.).

See, besides General Grant's art., Cox, *The Second Battle of Bull Run as connected with the Porter Case* (Cincinnati, 1882); Lord, *A Summary of the Case of F. J. Porter* (1883), and papers in vol. ii. of the pub. of the Military Hist. Soc. of Mass.

PORTER, HENRY (*fl.* 1596–1599), English dramatist, author of *The Two Angry Women of Abingdon,* may probably be identified with the Henry Porter who matriculated at Brasenose

College, Oxford, on June 19, 1589. From 1596 to 1599 he was writing plays for Henslowe for the Admiral's Men, and his closest associate seems to have been Henry Chettle. None of the plays mentioned by Henslowe as being written by him are extant, unless, as has been suggested, *Love Prevented* is another name for *The Pleasant History of the Two Angry Women of Abingdon* of which Gayley says: "No play preceding or contemporary yields an easier conversational prose, not even the *Merry Wives.*"

Alexander Dyce edited the *Angry Women* for the Percy Society in 1841; and it is included in W. C. Hazlitt's edition of Dodsley's *Old Plays* (1874). It was edited by Havelock Ellis in *Nero and other plays* (1888, "Mermaid Series,") and in *Representative English Comedies* (1903), with an introduction by the general editor, Professor C. M. Gayley.

PORTER, HORACE (1837–1921), American diplomatist and soldier, was born in Huntingdon, Pa., on April 15, 1837; son of David Rittenhouse Porter (1788–1867), governor of Pennsylvania in 1839–45. During the Civil War he served in the Army of the Potomac until after Antietam; took part in the battles of Chickamauga and Chattanooga; and in April, 1864, became aide-de-camp to Gen. Grant, in which position he served until March 1869. From Aug. 1867 to Jan. 1868, while Gen. Grant was secretary of war *ad interim,* Porter was an assistant secretary, and from March 1869 to Jan. 1873, when Grant was president, Porter was his executive secretary. He resigned from the army in Dec. 1873, when he became vice president of the Pullman Palace Car Company and held other business positions. From March 1897 to May 1905 he was United States ambassador to France. At his personal expense he conducted (1899–1905) a successful search for the body of John Paul Jones, who had died in Paris in 1792. For this he received (May g, 1906) a unanimous vote of thanks of both Houses of Congress. In 1907 he was a member of the American delegation to the Hague Peace conference. He died in New York city on May 29, 1921. His publications include *West Point Life* (1866) and *Campaigning with Grant* (1897).

PORTER, JANE (1776–1850), British novelist, daughter of an army surgeon, was born at Durham in 1776. Her life and reputation are closely linked with those of her sister, ANNA MARIA PORTER (1780–1832), novelist, and her brother, SIR ROBERT KER PORTER (1775–1842), painter and traveller. After their father's death, in 1779, the mother removed from Durham, their birthplace, to Edinburgh, where the children's love of romance was stimulated by their association with Flora Macdonald and the young Walter Scott. Mrs. Porter moved to London, so that her son might study art, and the sisters subsequently resided at Thames Ditton and at Esher with their mother until her death in 1831. Anna Maria Porter published *Artless Tales* in 1793–95, the first of a long series of works of which the more noteworthy are *The Lake of Killarney* (1804), *The Hungarian Brothers* (1807), *Don Sebastian* (1809) and *Barony* (1830).

Jane Porter—whose intellectual power, though slower in development and in expression, was greater than her sister's—had in the meantime gained immediate popularity by her first work, *Thaddeus of Warsaw* (1803), which was translated into several languages and procured her election as canoness of the Teutonic order of St. Joachim. In 1810, four years before the appearance of *Waverley,* she attempted national romance in her *Scottish Chiefs.* The picturesque power of narration displayed by Miss Porter has saved the story from the oblivion which has overtaken the works of most of Scott's predecessors in historical fiction. Her later works included *The Pastor's Fireside* (1815), *Duke Christian of Lüneburg* (1824), *Coming Out* (1828) and *The Field of. Forty Footsteps* (1828). In conjunction with her sister she published in 1826 the *Tales round a Winter Hearth.* She also wrote some plays, and frequent contributions to current periodical literature. On Sept. 21, 1832, Anna Maria died, and for the next ten years Jane became "a wanderer" amongst her relations and friends. She died at Bristol on May 24, 1850.

Robert Ker Porter painted altar-pieces and battle-scenes of imposing magnitude. He went to Russia as historical painter to the emperor in 1804, travelled in Finland and Sweden, where he received knighthood from Gustaws IV. in 1806, and accompanied Sir John Moore to Spain in 1808. In 1811 he returned to Russia and married a Russian princess. He was knighted by the Prince Regent in 1813. In 1817 he travelled to Persia by way of St. Petersburg (Leningrad) and the Caucasus, returning through Bag. dad and western Asia Minor. He examined the ruins of Persepolis, making many valuable drawings and copying cuneiform inscriptions. In 1826 he became British consul in Venezuela. He died at St. Petersburg on May 4, 1842.

His works include: *Travelling Sketches in Russia and Sweden* (1808), *Letters from Portugal and Spain* (1809), *Narrative of the late Campaign in Russia* (1813), and *Travels in Georgia, Persia, Armenia, Ancient Babylonia, etc., during the years 1817–1820* (1821–22). After leaving Venezuela (1841) he again visited St. Petersburg, and died there on May 4, 1842. Jane Porter, who had joined him in Russia, then returned to England and took up her residence with her eldest brother at Bristol, where she died on May 24, 1850.

PORTER, KATHERINE ANNE (1894–), U.S. writer of fiction, was born May 15, 1894, at Indian Creek, Tex., and educated at southern convent schools. For many years she lived abroad—in Mexico, where she did much to stimulate interest in Mexican art and culture, and in Paris and Berlin. These experiences as well as those of her girlhood in the south are reflected in her stories. Though she wrote early and voluminously, she made no attempt to publish until about 1925. The appearance in 1930 of her first collection of stories, *Flowering Judas,* won her immediate critical acclaim. *Hacienda* followed in 1934 and in 1939 *Pale Horse, Pale Rider: Three Short Novels.* This volume established her as one of the foremost short-story writers of the period. Critics praised her for the extraordinary purity and concentration of her style, but her style never becomes a mere preciosity: it is made to serve her vision of life whether her theme is the individual's fight to maintain spiritual integrity or the vicissitudes of growing up or the attempt to discover the meaning of one's past. Other works by Miss Porter include *The Leaning Tower, and Other Stories* (1944) and *The Days Before* (essays and reviews) (1952).

See Edward Schwartz, *Katherine Anne Porter: a Critical Bibliography* (1953). (C. Bs.)

PORTER, NOAH (1811–1892), U.S. educationalist and philosophical writer, of Puritan ancestry, was born in Farmington, Conn., on Dec. 14, 1811. He graduated at Yale college in 1831, for two years taught in the New Haven grammar school, was for two years a tutor at Yale, then becoming a Congregational minister. He was elected professor of moral philosophy and metaphysics at Yale in 1846, and from 1871 to 1886 he was president of the college. His best-known work is *The Human Intellect, With an Introduction Upon Psychology and the Human Soul* (1868), abridged as *The Elements of Intellectual Science* (1871). He died in New Haven, March 4, 1892.

See *Noah Porter, a Memorial,* ed. by G. S. Merriam (1893).

PORTER, WILLIAM SYDNEY: *see* HENRY, O.

PORTES GIL, EMILIO (1891–), Mexican statesman and provisional president (Dec. 1, 1928, to Feb. 5, 1930), was born at Ciudad Victoria, Tamaulipas, on Oct. 30, 1891. He studied in the law school of the National university and was graduated in 1915 at the peak of revolutionary disorders. He took a prominent part in the revolutionary movement, serving in a judicial capacity in Sonora during P. E. Calles' administration as governor and in the legal section of the war department while Gen. Alvaro Obregon was secretary of war. In 1919 he worked in favour of the candidacy of Obregon and was imprisoned for a time for his activities. Following the overthrow of V. Carranza in 1920, Portes Gil acted as provisional governor of Tamaulipas and subsequently was elected a deputy from that state for four terms. He took office as elected governor of Tamaulipas in Feb. 1925 and held this post until appointed secretary of the interior and head of the cabinet by President Calles in Aug. 1928. While governor, he worked on behalf of labour legislation. The number of schools in the state was increased from 280 to more than 600, and special attention was given to agricultural and industrial instruction. He also abolished gambling and established partial prohibition.

Portes Gil was elected provisional president of Mexico by a unanimous vote of the Mexican congress (Sept. 25, 1928) to fill a temporary gap caused by the assassination of President-elect Obregon. His selection was supported by President Calles as well as the powerful Agrarian party. His brief administration was marked by a revolt in Veracruz and northern Mexico, and he retired in 1930 after the election of Pascual Ortiz Rubio. In 1931 and 1932 he was minister to France and from 1932 to 1934 attorney-general of Mexico. He was secretary of foreign affairs, 1934–36, and president of the National Athenaeum of Science and Art in 1949.

PORT GLASGOW, a large burgh of Renfrewshire, Scot., on the south bank of the Firth of Clyde, 19 mi. W.N.W. of Glasgow by road. Pop. (1961) 22,551. Area 1.8 sq.mi. It is continuous with Greenock. The industries include large shipbuilding and engineering works and sawmills. The area of the docks. both wet and graving, is $16\frac{1}{2}$ ac. The graving dock (1762) was the first dock of the kind in Scotland. The first Clyde steamship, the "Comet," was built at Port Glasgow in 1812. In 1775 it was made a burgh of barony. Nearby are the ruins of 16th-century Newark castle.

PORT HARCOURT, the second port of Nigeria. Africa, lies about 41 mi. from the sea on the Bonny river. an eastern distributary of the Niger, in an area of mangrove swamps and rain forest. The climate is hot and humid with an annual rainfall of 94 in.. largely between April and November. The most congenial months are January and December. Pop. (1960 est.) 42,553. It covers about 12 sq.mi. between the Bonny river (W.), the Amadi (E.) and Nwatugbo (S) creeks. First marked out in 1912 on a derelict site known as Obomotu, and linked by rail in 1916 with the Enugu coal fields, the port has continually expanded. The main streets are wide, with modern-style buildings and the principal commercial and residential houses are grouped around a central area known as The Circle. though there are new residential quarters to the northwest and southeast. The many open spaces include Jubilee Memorial park and a sports stadium.

Port Harcourt is in the Eastern Region and is the terminus of the eastern branch of Nigerian railways; it is linked by road and internal air services with the rest of the federation. The airport is 7 mi. N.E. on the Aba road. Local industries include cement, cigarette and metal window frame and door manufacture. The port has deepwater berths and bulk palm oil storage plants, and its increasing traffic necessitated a further large expansion of the facilities in the late 1950s. Its exports, mainly palm oil and kernels, cocoa. coal. tin and peanuts, were extended in 1958 by mineral oil from the newly developed oil fields of the Niger delta.

(W. H. I.)

PORT HUDSON, a village in East Baton Rouge parish, La., U.S., on the left bank of the Mississippi, about 135 mi. above New Orleans. At the sharp turn of the Mississippi there the Confederates in 1862 built on the commanding bluffs powerful batteries covering a stretch of about 3 mi., their strongest fortifications along the Mississippi between New Orleans and Vicksburg. On the night of March 14, 1863, Adm. David Farragut, with seven vessels, attempted to run past the batteries, commanded by Brig. Gen. William M. Gardner, but four of his vessels were disabled and forced to turn back, one, the "Mississippi" was destroyed, and only two, the "Hartford" and the "Albatross" got past. Gen. N. P. Banks's land attack on May 27 was unsuccessful. the Union loss, nearly 2,000. being six times that of the Confederates. A second attack on June 14 entailed a further Union loss of about 1,800 men. But on July 9, two days after the news of the surrender of Vicksburg, after a siege of 45 days, General Gardner surrendered the position to General Banks with about 6.400 men, 50 guns. 5,000 small arms and ammunition, and two river steamers. The Union losses during the siege were probably more than 4.000; the Confederate losses about 800. The capture of Vicksburg and Port Hudson secured to the Union the control of the Mississippi.

PORT HURON, a city of southeastern Michigan, U.S., 57 mi. N.E. of Detroit at the lower end of Lake Huron on the St. Clair river. opposite Sarnia, Ont.. with which it is connected by a railway tunnel and the Blue Water International bridge. It is a port on the St. Lawrence seaway. Port Huron, the seat of St. Clair county, the centre of a thriving agricultural community, has many industries and is a popular summer resort. It has a commission-manager form of government and a public junior college, established in 1923. (For comparative population figures see table in MICHIGAN: Population.)

In 1686 Ft. St. Joseph was built within the present city limits by Daniel Greysolon, Sieur du Lhut (Dulhut), a French trader and explorer; the British took possession in 1761 and the Americans built a fort on the site in 1814, naming it Ft. Gratiot for Capt. Charles Gratiot, who supervised its construction. The settlement which had grown up around the fort was incorporated as the village of Fort Gratiot in 1840; in 1893 it joined the other communities along the St. Clair river which had formed the city of Port Huron in 1857. Thomas A. Edison (*q.v.*) lived there as a boy; a boulder in Pine Grove Park stands near the site of his home.

(V. A.)

PORTICI, a town of Campania, Italy, in the province of Napoli, 5 mi. S E. of Naples by rail, on the shores of the bay. and at the foot of Vesuvius. Pop. (1957 est.) 42,285 (commune). The palace, erected in 1738, once contained the antiquities from Herculaneum, later removed to Naples (with the exception of some mosaic pavements), and in 1873 it became a government institute of agriculture.

Just beyond Portici. on the southeast, is Resina (commune pop. [1957 est.] 44,571). on the site of the ancient Herculaneum. with several fine modern villas.

The inhabitants are engaged in fishing, silk growing and silk weaving. The town was completely destroyed by the eruption of Vesuvius in 1631.

PORTICO, in architecture, a term loosely applied to many types of structure in which columns or colonnades are the most important part. Thus an entrance porch with columns is called a portico, and the colonnade at the end of a classic temple is also so named.

In Rome an arcaded and colonnaded building surrounding an open space or temple. and built for a public covered promenade mas termed a *porticus,* like the portico of Octavia (built by Augustus and restored by Septimius Severus and Caracalla, 203), of which there are extensive remains.

PORT JACKSON: see SYDNEY.

PORT KEMBLA, a town and port of New South Wales, Austr., lies 55 mi. S. of Sydney and forms part of Greater Wollongong (see WOLLONGONG). Pop. (1954) 6,570. Since the establishment of iron and steel works in 1926, Port Kembla has developed into an important industrial centre, producing about 2,600,000 tons of steel ingots annually.

Other industries include the smelting and refining of copper and other metals, and the manufacture of tin plate, wires and cables, sulphuric acid, fertilizers and metal products. There is also a large power station.

The artificial harbour has grown from a jetty built in 1883 to ship coal mined at Mount Kembla in the Illawarra range to the west; after 1960 a new harbour was built to provide many more berths, with a depth of 32 ft. at low water. The chief imports are ironstone, limestone and liquid fuels; iron and steel products and coal are the chief exports.

PORTLAND, EARLS OF. The English title of earl of Portland was held by the family of Weston from 1633 to 1688, and by the family of Bentinck from 1689 to 1716, when it was merged in that of duke of Portland.

Sir Richard Weston (1577–1635), according to Clarendon "a gentleman of very good and ancient extraction by father and mother," was the son and heir of Sir Jerome Weston (c. 1550–1603) of Skreens in Roxwell. Essex. his grandfather being Richard Weston (d. 1572), justice of the common pleas. He was lord high treasurer from 1628 until his death on March 13, 1635. He received the earldom in 1633.

The title became extinct in 1688. In 1689 it was revived by William III, who bestowed it upon William Bentinck (*q.v.*).

Sir Richard Weston must be distinguished from two contemporaries and namesakes: Sir Richard Weston (c. 1579–1652), baron of the exchequer; and Sir Richard Weston (1591–1652), who introduced notable improvements in English agriculture and was mainly responsible for introducing locks on the Wey which made this river navigable. Another family of Weston produced Robert Weston (c. 1515–73), lord chancellor of Ireland from 1566 until his death on May 20, 1573.

PORTLAND, WILLIAM BENTINCK, EARL OF (1649–1709), English statesman, was born on July 20, 1649. The son of Bernhard Bentinck of Diepenheim, he was descended from an ancient and noble family of Gelderland. As page of honour and gentleman of the bedchamber to William, prince of Orange, he secured the friendship of William, which he justified by his prudence and ability.

In 1677 he was sent to England to solicit for the prince of Orange the hand of Mary, daughter of James, duke of York, afterward James II, and he was again in England in 1683 and in 1685. When, in 1688, William was preparing for his invasion, Bentinck went to some of the German princes to secure their support, or at least their neutrality, and he was also a medium of communication between his master and his English friends. He superintended the arrangements for the expedition and sailed to England with the prince.

The revolution accomplished. Bentinck was made groom of the stole, first gentleman of the bedchamber and a privy councilor; and in April 1689 he was created Baron Cirencester, Viscount Woodstock and earl of Portland. He fought at the battle of the Boyne (1690), the battle of Landen and at the siege of Namur, but his main work was of a diplomatic nature. He helped to arrange the peace of Ryswick (1697); he negotiated with Louis XIV for a partition of the Spanish monarchy and, as William's representative, signed the two partition treaties. Jealous of the rising influence of Arnold van Keppel, earl of Albemarle, Portland resigned all his offices in the royal household in 1700, but he did not forfeit the esteem of the king, who continued to trust and employ him.

He received 135,000 ac. of land in Ireland, and only the strong opposition of a united house of commons prevented him from obtaining a large gift of crown lands in north Wales. For his share in drawing up the partition treaties he was impeached in 1701, but the case against him did not proceed.

He was occasionally employed on public business under Anne until his death at his residence, Bulstrode in Buckinghamshire, on Nov. 23, 1709.

Portland's eldest surviving son Henry (1682–1726) succeeded as 2nd earl. He was created marquess of Titchfield and duke of Portland in 1716.

BIBLIOGRAPHY.—M. E. Grew, *William Bentinck and William III* (1924); N. Japikse (ed.), *Correspondentie van Willem III en van Hans Willem Bentinck,* 6 vol. (1927–37); A. Turberville, *History of Welbeck Abbey,* vol. ii (1939).

PORTLAND, WILLIAM HENRY CAVENDISH BENTINCK, 3RD DUKE OF (1738–1809), prime minister of England, son of William, 2nd duke (1709–62), and grandson of the 1st duke. He was born on April 14, 1738, and was educated at Oxford. Under the marquess of Rockingham he was, from July 1765 to Dec. 1766, lord chamberlain, and on the return of Rockingham to power in April 1782 he was made lord lieutenant of Ireland. After the short ministry of the earl of Shelburne, succeeding the death of Rockingham, the duke of Portland was selected by Charles Fox and Lord North as a "convenient cipher" to become the head of the coalition ministry, to the formation of which the king was with great reluctance compelled to give his assent. The duke held the premiership from April 5, 1783, until the defeat of the bill for "the just and efficient government of British India" caused his dismissal from office on Dec. 17 following. Under William Pitt he was, from 1794 to 1801, secretary of state for the home department, after which he was, from 1801 to 1805, president of the council. In 1807 he was appointed a second time prime minister and first lord of the treasury. Ill-health caused him to resign in Oct. 1809, and he died on Oct. 30. He owed his political influence chiefly to his rank, his mild disposition and his personal integrity.

He married in 1766 Lady Dorothy Cavendish (1750–94), daughter of the 4th duke of Devonshire, and was succeeded by his son William Henry (1768–1854). The 4th duke married a daughter of the famous gambler, Gen. John Scott. His son, the 5th duke, William John Cavendish Bentinck-Scott (1800–79), died unmarried.

PORTLAND, the largest city in Maine, the seat of Cumberland county and a port of entry, is located on Casco bay 110 mi. N.E. of Boston. The city is built largely on two hilly peninsulas which command arresting views of Casco bay and its many islands. Pop. (1960) city 72,566; standard metropolitan statistical area (the cities of Portland, South Portland and Westbrook and the towns of Falmouth and Cape Elizabeth) 120,655. (For comparative population figures see table in MAINE: Population.)

Portland was first settled in 1632 by the Englishmen Richard Tucker and George Cleeve. During its early years it was known by several names and suffered various disasters. It was destroyed in 1676 by Indians and in 1690 by French and Indians. In 1775 a British fleet bombarded the settlement as punishment for patriotic activities. It was rebuilt and then mas incorporated as a town in 1786, when it took the name of Portland. When Maine became a state in 1820 Portland served as the capital until 1832. It also was incorporated as a city in 1832. A fire which resulted from an Independence day celebration destroyed much of the centre of the city on July 4 and 5, 1866. Reconstruction soon took place, however, and the city continued to grow. Portland's traditional fishing, shipping and commercial activities were increasingly supplemented by the development of manufacturing industries. The city was important in the building and operation of naval ships in both World Wars I and II. It has a council-manager form of government which it adopted in 1923.

Portland is the transportation and commercial centre of southwestern Maine. It has an excellent harbour, which is served by several steamship lines. It is a major petroleum port and is the eastern terminus of the Portland-Montreal oil pipeline. The metropolitan area has a diversified manufacturing base. Among the chief products are pulp and paper, a variety of canned and processed foods, textiles, lumber and wood products, furniture, footnear, chemicals, metal goods and various types of machinery. There is also considerable shipbuilding, printing and publishing in the area. Fishing is an important source of employment.

Educational facilities include a branch of the University of Maine and Westbrook, a private junior college for women. Two museums, an art gallery and music and drama groups contribute to the area's cultural activities. (H. A. PE.)

PORTLAND, the largest city of Oregon, U.S., and the seat of Multnomah county. is in the northwestern part of the state. Its original site was a shallow bench of land between low but steep wooded hills and the west bank of the Willamette river, 10 mi. from its entrance into the Columbia river. This remains the financial and commercial centre of the city. Zoned residential, commercial and industrial developments have spread out to occupy the plain on the east side of the Willamette, extending to the Columbia. From the city's heights, to the east, can be seen an encirclement of low foothills climaxed in the snow-capped summit of Mt. Hood, 75 mi. away, and in the farther distance, the peaks of Mt. St. Helens and Mt. Adams in Washington. To the west lie the Tualatin valley, the Coast Range mountains and beyond, less than 100 mi. away, the Pacific ocean. Pop. (1960) city 372,676; standard metropolitan statistical area (Multnomah, Washington and Clackamas counties in Oregon, and Clark county, Washington) 821,897.

History. — Portland was founded in 1845 and was named for the city in Maine. Deep water for ocean-going vessels and the opening of a road to the wheat producing farms of the Tualatin valley in the early 1850s gave it commercial advantages over rival town sites. By 1860, when its population was less than 3,000, it was the largest town in the Pacific northwest and remained so until outstripped by Seattle at the turn of the century. Between 1850 and 1870 Portland was the outfitting point and supply centre for northwest gold rushes and interior settlement. Thrifty and conservative businessmen, many originally from New England, invested capital earned during these prosperous times in real estate and transportation facilities. Locally owned stern-wheelers navigated the rivers and carried agricultural traffic to Portland; after 1880 it became one of the nation's chief grain exporting ports In the 1860s and 1870s Portland's residents invested heavily in railroad lines to California and in the Northern Pacific Railway company which gave them their first transcontinental connection in 1883. By 1910 all major western steam railroad lines entered Portland.

In 1889 a local company brought electric power to Portland from Oregon City, 14 mi. up the Willamette. over the world's first long-distance transmission line. With the completion of Bonneville dam on the Columbia in 1940 the availability of hydroelectric power began to attract metallurgical and chemical industries to the metropolitan area.

Local residents early advertised Portland as the city of homes as well as "the city of roses," celebrated in an annual rose festival Multiple-unit dwellings mere slow to develop until the mid-20th century. when long-range urban renewal projects, a new airport and the building of an express highway also began to change the appearance of the city.

Government. — Portland is governed by an elected. nonpartisan board of five commissioners and a mayor. It operates only minimum public utilities A port commission with taxing powers and a public dock commission supervise harbour facilities.

Education and Cultural Activities. — Institutions of higher education in the city include Cascadia, a private interdenominational college chartered in 1918 as the North Pacific Evangelistic institute; Lewis and Clark, a Presbyterian college founded in 1867; Reed, a private nonsectarian college founded in 1904; the University of Portland, a Roman Catholic coeducational institution established in 1901; Multnomah opened in 1897 and organized as a junior college in 1931; Portland State college (which grew out of Vanport Extension centre, established in 1946) became a degree-granting college in the Oregon state system of higher education in 1955, and the medical and dental schools of the University of Oregon. Wealthy and influential patronage supported such cultural institutions as a library, art museum and school, historical society and symphony by the turn of the 20th century In 1925 one of the first junior symphonies in the nation nas founded in Portland. The Multnomah county library, with headquarters in Portland, operates a number of branches and several bookmobiles.

The city school district, a separate taxing agency, operates elementary and high schools and a radio station and provides special programs for exceptional children.

Parks and Recreation. — Portland has over 100 park and recreational areas, including rose and zoological gardens, totaling over 6,000 ac. Forest park. 3,500 ac., is a primitive area within the city limits. (D. O J.)

PORTLAND, ISLE OF, a peninsula on the coast of Dorset, Eng., connected to the mainland by the Chesil bank, or beach, an unbroken ridge of shingle that stretches as far as Bridport. Pop of urban district (1951) 11,377. Four miles long and nearly $1\frac{3}{4}$ mi. in extreme breadth, it has an area of 4.5 sq.mi. Its precipitous shores are inaccessible from the sea except toward the south, and its highest point is the Verne hill in the north. A raised beach is seen at Portland Bill. The substratum of the island is Kimmeridge clay, overlain by beds of sand and strata of oolitic limestone — the famous Portland stone. In the dirt bed on the oölitic strata are numerous specimens of petrified wood, some of great size. A freight railway runs south from Weymouth to Portland and Easton; passengers travel by omnibuses. The island is a royal manor whose court leet still functions.

On the isle are the famous prison buildings, now a Borstal, and the Verne prison, formerly a barracks. Portland castle, built by Henry VIII in 1520, is open to the public. The remains of a Norman fortress. Bow and Arrow or Rufus castle, are on a rock on the eastern side, in the grounds of Pennsylvania castle, built by John Penn, governor of the isle and grandson of William. founder of the state of Pennsylvania.

Portland harbour was built by the admiralty in 1847–62. A breakwater stretching northward from the northeastern corner of the island partially enclosed a large area of water naturally sheltered on the south and west. An inner arm ran nearly east from the island to a masonry head and fort, and an outer detached arm bent north to a circular fort, a narrow entrance for shipping being left between the two. Two new breakwaters, built after 1895, closed the gap between the end of the outer breakwater and the Bincleaves rocks near Weymouth. The completely enclosed harbour covers 2.200 ac. to the one-fathom line. of which 1,500 ac. have a depth of not less than 30 ft at low water. After World War II there was further naval building toward Portland Bill.

PORTLAND CEMENT: *see* CEMENT.

PORTLAOIGHISE (MARYBOROUGH), the county town of Laoighis. Republic of Ireland. lies on the Triogue river 52 mi S.W. of Dublin Pop (1956) 3.196. Area 8 sq mi. One of the sand and gravel ridges called eskars runs northward from the town to Mountmellick and thence to Tullamore Portlaoighise, established as Fort Protector during the reign of Mary I (hence its common English name), was granted its charter in 1570. and a bastion of the castle still remains. The main industries are flour milling and the manufacture of worsted goods. On the Rock of Dunamase (the fort of Masg), 3 mi. E.. are the ruins of an old castle. the former seat of the kings of Leinster (*q v.*). It was destroyed in 1650 by Oliver Cromwell's army.

PORT LOUIS, the capital and port of Mauritius, is built round a small, well-sheltered harbour on the northwestern coast, and backed by an almost semicircular ridge of mountains which form part of an extensive range stretching toward the centre of the island. Because of these protective mountains. the town and harbour are almost entirely cut off from the normal east and southeast trade winds, and this makes Port Louis one of the hottest places in Mauritius in summer. The town covers an area of 2.1 sq.mi. Pop. (1952) 69,693.

Port Louis was founded in about 1736 by the French governor, Mahé de La Bourdonnais, and considerably improved in 1770. In appearance it seems a curious and fascinating assemblage of ancient and modern, oriental and European, shabby and luxurious. Its streets are laid out in a rectangular netnork and it is dominated by an old fortress, the Citadel (1838), built on a hill almost in its centre. Port Louis also possesses two cathedrals and two fine Roman Catholic churches, a stately town hall, a natural history museum and art gallery, two public libraries, a theatre, a large public hospital and several colleges. A little race course lies on the southeastern extremity and a public park on the northeastern seaboard. The Grand River North West, which runs on the outskirts, furnishes part of the fresh water supply.

The port, mhich is the main harbour on the island, has one deep-sea quay. From the Central railway station and clearing yard lines branch off to all parts of the island. Port Louis contains no large industrial establishment. Its industrial activity, besides that connected with docks and warehousing, is restricted to minor mechanical workshops, small food and wine manufactures, oil extraction and refining, sawmilling, printing, etc. On the outskirts of the town proper, however, there are a big tobacco warehouse, a modern cigarette factory, a thermal power station and a railway workshop. As the central collecting and clearing ground for all merchandise imported or exported from the island, the commercial activity of Port Louis is extensive in wholesale and retail sales. The main export is sugar (98% of domestic exports in value). (M. V. M. H.)

PORT MAHON (MAHÓN), capital and principal seaport of Minorca (*q.v.*) in the Spanish province of the Balearic Islands. Pop. (1950) 15,732 (mun.). Mahón is on the east coast, at the head of a deep inlet which extends inland for $3\frac{1}{2}$ mi. It is an important harbour. Mahon is the ancient Portus Magonis, which under the Romans was a *municipium* (Mun. *flavium magon*tanum) and probably included the whole island under its authority. As the name suggests, it had previously been a Carthaginian settlement. The Moors, who occupied Minorca in the 8th century, were expelled by James I of Aragon in 1232. Khair ed-Din Barbarossa besieged and captured the city in 1535; and in 1558 it was sacked by a corsair called Piali. The British seized the island in 1708 and in 1718 declared Mahon (which they called Port Mahon) a free port. In 1756 it fell into the hands of the French. Restored to the British in 1762, it was recovered by the Spanish in 1782. In 1802 it was finally ceded to Spain by the treaty of Amiens.

Many of the houses date from the British occupation. The King's Island is so called as the landing place of Xlphonso III of Aragon in 1287; farther southeast on the shore is the village of Villa Carlos or George Town; and at the mouth of the port, on the same side, are the remains of Fort San Felipe, originally erected by Charles V and twice the scene of the capitulation of British troops. Opposite San Felipe is the easily defended Peninsula of La Mola (256 ft. high) where extensive Spanish fortifications were established.

PÔRTO ALEGRE, a city and port in southern Brazil, the capital of the state of Rio Grande do Sul. Pop. (1960) 617.629. It is located 670 mi. S.W. of Rio de Janeiro and 150 mi. N.N.E. of the seaport, of Rio Grande at the entrance to the lake. Pôrto Alegre is at the northern end of the Lagôa dos Patos on an arm of the lake known as the Rio Guaiba. Into this end of the lake five short but deep rivers empty their waters: the Gravataí, Sinos, Cai, Jacui and its tributary the Taquari. Since the lower courses of these rivers are all navigable, Pôrto Alegre has become the most important centre of inland navigation in all of Brazil. The outlet of the Lagôa dos Patos, near Rio Grande, is too shallow to accommodate ships of more than 16½-ft. draft. The lake and rivers, however, provide a fine system of inland waterways to serve the chief area of concentrated settlement in the state. The city is built on a ridge of high ground on the edge of the lake. It is located about 30° south of the equator and its climate is one of mild winters and hot summers, with abundant rainfall (average of 50 in.). In winter cold waves from the south bring occasional frosts.

In addition to its function as administrative centre of the state PBrto Alegre is also the chief commercial centre serving the whole of this southernmost part of Brazil. From the rural hinterland come a variety of agricultural and pastoral products: meat and hides, wool, rice, tobacco, grapes, cereals, manioc meal and maize. From the forests lumber is produced. In the city are many business and financial establishments serving this economically active region. Educational institutions include two universities, a medical school, a normal school and a school of agronomy and veterinary medicine. The city also ranks high among the industrial centres of Brazil. Manufacturing industries are chiefly those engaged in processing the products of the farms, forests and ranches; they include meat packing, lard refining, leather tanning, the weaving of woolen yarn and cloth and the manufacture of clothing, the brewing of beer and the manufacture of cigarettes, furniture. soap, candles, macaroni, farinha (manioc flour) and a variety of preserves and wines. There are also metal factories producing stoves, furnaces and iron safes and a shipbuilding and ship repair works. The city is provided with electric power by a large steam-electric plant making use of coal from the nearby mines at São Jerônimo, brought to PBrto Alegre by river barge. Although this coal has a high ash content and requires the use of especially designed grates, it is cheaper than imported coal.

The city is connected by rail with the Uruguayan railroads at Sant'Anna do Livramento and with the Argentine railroads at Uruguaiana. From the junction of Santa Maria, a rail connection exists all the way to São Paulo and Rio de Janeiro. Modern all-weather highways also connect PBrto Alegre with the rest of Brazil and with neighbouring countries. Regular air connections tie the city to these same countries and regions.

PBrto Alegre was founded in 1742–43 by immigrants from the Azores and was first known as PBrto dos Cazaes. In 1825 the first German immigrants were settled in the country north and northwest of the city; later Italian settlers also came into this region. The administrative centre of Rio Grande do Sul was moved from Rio Grande to PBrto Alegre in 1773; it was officially named capital of Rio Grande do Sul in 1807. (P. E. J.)

PORTO BELLO (PUERTO BELLO), a village on the Caribbean, 18 mi. N.E. of Colón, Panamá. Columbus named its site "beautiful harbour" in 1502; the city was founded March 20, 13'97, by Francisco de Valverde y Mercado. As a point of transshipment and exchange for the colonial merchandise of Spain and South America it was famous for its annual fairs and notorious for its high prices, congested quarters and tropical fevers. Once the busiest city in the new world and target of concentrated wealth, it was attacked by the English buccaneers Sir Francis Drake (who mas buried in Porto Bello bay), William Parker. Sir Henry Morgan and Edward Vernon. In 1713 Spain opened it to the trade of one British ship annually. The abandonment by Spain in the 18th century of the fleet system and fairs, the building of the Panama railroad in the 1850s and the opening of the Panama canal brought about its eclipse. It has ruins of great historic interest. Pop. (1960) 591. (A. R. W.)

PORT OF SPAIN, the capital city and chief port of Trinidad, the West Indies, lies on the west coast of the island, below the northern peninsula, on the Gulf of Paria which separates Trinidad from the northeastern coast of Venezuela. Pop. (1946) 92,793; (1960) 91,596.

On the hills behind Port of Spain there are residential suburbs, such as Goodwood Park, and the city itself is beautifully laid out with parks and squares. U'00dford square is the principal one, in the business section, near Holy Trinity cathedral. Queen's Park Savannah is at the centre of the city and from it radiate many of the most important streets, such as Frederick street, the main shopping thoroughfare. Charlotte street, with its markets and small shops. Cipriani boulevard, Marli street and St. Clair avenue, which are' residential.

Around Queen's Park savannah there are several buildings of historical and architectural interest: Government house, standing in the grounds (63 ac.) of the Royal Botanical gardens; the palace of the Roman Catholic archbishop of Port of Spain; Knowsley house, which accommodates certain government ministries; All Saints church; and the Princes' building. The Royal Victoria institute nearby houses a museum, concert hall and the federal supreme court.

The principal administrative building is the Red house near Woodford square. It was decided in 1957 that the legislative body of the federation should meet there until the federal capital of the West Indies was built in Trinidad. Among educational institutions in Port of Spain are Queen's Royal college, Fatima college, St. Mary's college and an extramural department of the University College of the West Indies.

Industries. — Port oi Spain is the market town and the centre of the commerce and industry of the island. The main industries of Trinidad, apart from those concerned with oil and cement, are the production of sugar, cocoa, citrus fruits, coconuts and bananas, and are all situated deep in the country. There are secondary industries within a 16-mi. radius to the east of the city; these include the production of rum, bitters, beer, margarine and oils, cigarettes, plastics, building blocks, prefabricated culverts and tiles. There are sawmills, textile mills and citrus-fruit canning works.

Communications. — Although situated in the extreme north, Port of Spain is linked by good roads with other parts of the island. From Queen's Park Savannah, St. Clair avenue joins the Western Main road leading out to the northern peninsula; Maraval road passes through various suburbs and valleys to the north and reaches Maracas bay, a very beautiful bathing beach. A highway has been cut through the southern hills of the St. George range giving access to Piarco airport and to the remainder of the country. Transport within the city is by diesel buses and numerous privately owned taxis which ply as public service vehicles at regular charges.

Port of Spain is a key port on the world's shipping routes and a centre of trade within the West Indies. The sheltered harbour accommodates medium-sized ships anchoring alongside the eight berths; there are several smaller wharves and jetties and two slipways. The harbour basin is 32 ft. deep and has a mean width of 900 ft. and a length of 5,500 ft. It is approached by a dredged channel 350 ft. wide marked by automatically lighted beacons.

The airport at Piarco, 16 mi. east of the city, is used by the principal airlines operating in the western hemisphere. (H. E. CN.)

PORTOLÁ, GASPAR DE (c. 1723–c. 1784), commander of the expedition sent from New Spain to colonize Upper California, was born about 1723 in Balaguer, Catalonia. At the age of 11, according to his military record, he became an ensign in the dragoon regiment of Villaricosa. He was promoted to lieutenant of dragoons and grenadiers in the Numancia regiment, where he served 21 years, and later was made captain of the España regiment and took part in the campaign against Portugal.

After José de Galvez was sent to New Spain in 1765 as *visitador,* he became aware of British and Russian interest in the Pacific coast of North America, an area which Juan Rodriguez Cabrillo' in 1542 and Sebastián Vizcaino and Bruno Heçeta later had visited and partially charted in behalf of Spain. He secured the appointment of Portolá, then of noble rank and unmarried, as governor of the Californias. Portolá took office in Oct. 1767 and after organizing an expedition, sailed from San Blas and landed at La Paz, Lower California, on July 6, 1768.

For the colonization of Upper California he prepared both a land and a sea expedition with the intention that both were to rendezvous at San Diego and later advance to Monterey, a harbour which had been reported in 1603 by Vizcaino. Portolá led the land force, taking with him Fathers Junipero Serra, Juan Crespi and several other priests to establish missions. He arrived at San Diego on July 1. 1769, after an arduous journey of four months from Loreto. On July 14 Portolá began the trip to Monterey but. failing to recognize the bay. he passed on to San Francisco bay. There, realizing that the party had gone too far, he turned back on Nov. 11 and arrived in San Diego on Jan. 24, 1770. Within a few months he tried again and was successful in reaching and identifying Monterey. He returned by sea to Mexico. surrendering his governorship in Sept. 1770.

He became governor of the city of Puebla on Feb. 23, 1777. In 1784 the viceroy of New Spain reported that he had advanced Portolá 12 salary payments in order to permit him to return to Spain, but whether or not the trip was attempted remains unknown.

BIBLIOGRAPHY.—"Diary of Gaspar de Portolá during the California Expedition of 1769–70," *Academy of Pacific Coast History*, i, 33–89 (1909); "Narrative of the Expedition by Miguel Costansó," ibid., i, 93–159; Francisco Palóu, *Historia de la Vida del Fray Junipero Serra* (Mexico, 1787); F. Palóu, *Historical Memoirs of New California*, ed. by H. E Bolton, 4 vol. (Berkeley, Calif., 1926). (R. G. RR.)

PORTO MAURPZIQ: *see* IMPERIA.

PORTO NOVO, a town on the Coromandel coast in South Arcot district, Madras state, India, 30 mi. S. of Pondicherry. Pop. (1951) 15.084. It is famous for the battle of July 1781, in which Sir Eyre Coote with 8,000 men defeated Hyder Ali with 60,000 and thus saved the Madras presidency.

PORT OPERATION. The term "port operation" includes the receiving of ships in harbour, putting them in position to discharge or load their cargoes, the handling of the cargo and its dispatch to or reception from inland destinations. The primary aim of all modern dock operation is to give ships quick dispatch; *i.e.*, to keep down the time in port.

Before the cargo can be distributed it has to be landed, sorted to the various bills of lading, passed by the customs officers, customs and port charges paid and the goods released by the shipowner to the merchant.

The shipper when dispatching goods receives from the master of the ship a bill of lading. which is a negotiable document of title and which he sends to his consignee. While the goods are in the ship they are by law the property of the shipowner, and he has a prior lien on the goods for his freight. This lien is removed by the consignee's taking the bill of lading to the shipowner and paying the freight, receiving in exchange a release, which is the authority to the port authority or wharfinger to deliver the goods. But in order that the discharge of the ship shall not be delayed while the consignees are obtaining releases. the discharge of the goods is commenced at once into the transit sheds alongside. These transit sheds are, in the eye of the law. part of the ship. So long as the goods are in the transit shed the shipowner retains his lien for freight, and the port authority cannot allow the goods to leave the transit sheds until a release has been produced.

In the case of goods liable to customs duty for which it is not desired to pay the duty at once, they are after being released passed under customs guard into bonded warehouses. In the case of goods of high customs value, such as wines and tobacco, the goods usually remain in bond until passed into consumption, the owner thus being relieved from the premature payment of heavy duty. Both transit sheds and bonded warehouses have, therefore, to be under double locks of the customs and wharfinger respectively, so that goods can be handled only in the presence of both parties.

To protect the customs, goods can by British law be landed only at duly authorized landing places called legal quays and sufferance wharves, the only difference between these terms being that the first receives a permanent licence issued by the treasury and the second a restricted licence issued by the commissioners of customs. The services of the officers of the customs for watching goods in course of discharge in ordinary hours are paid for by the state, but all overtime is at the cost of the ship, and as customs hours do not coincide with port hours, a ship working the ordinary hours has to pay at least one hour of customs overtime, and more if she is herself working overtime.

Rough cargoes such as ores, timber, etc.. which do not require shelter, are landed at open quays, and the limitation of the shipowner's lien sometimes gives rise to difficult questions.

In the days before free trade, when nearly all goods were dutiable, it was the British custom to constitute a customs area of the whole dock estate and to secure it within high walls and massive gates. These will still be found in the older ports, but in modern times it has become the practice to localize the control at sheds and wharves, and transit beyond these limits is free.

Custom of the Port.—A shipowner by his contract of carriage undertakes to deliver to the consignee the goods according to the bill of lading, which implies that he has to separate each man's goods from other people's goods and deliver them in one parcel. But this general rule of law is materially affected by the local custom of the port which varies everywhere and is a cause of much dispute and litigation. In some ports the custom ordains that the ship shall put the goods on the quay indiscriminately, and the work of sorting and removal is at the charge of the merchant; in some cases, goods are removed from the crane sling by one party, sometimes by the other, or sometimes shared by both parties. In some exceptional cases the cost of craning the goods from the hold is held to be on account of the merchant. For these reasons comparison of the working charges of different ports is alwavs difficult.

Large cargoes carried and the very mixed nature of the commodities necessitate in most cases landing on the quay for sorting before delivery. This requires much floor area, and led to the introduction of two or more floor transit sheds to avoid excessive congestion of the cargo when landed. And for the subsequent delivery of these goods by rail or road, special facilities are needed. A single cargo of 8,000 tons of general cargo, if all had to be dispatched by rail, would require 1,000 freight cars to take it away. These freight cars would occupy 3.000 yd. of railway, which is some measure of the amount of siding accommodation which has to be provided for the efficient working of a discharging berth and also the great relief obtainable when a large part of the work is done by barge. The movement of these freight cars has to be performed without interference with the work at adjacent wharves; hence the proportions which the three methods, barging, railway and road transport, bear to each other must largely affect the design of the shore equipment of a port.

The quick and economical movement of cargo is now largely obtained by the provision of mechanical appliances in substitution for manual labour, and the main staples when arriving or being dispatched in whole cargoes, or in large quantities in mixed cargoes, are usually dealt with by special machinery. For example, specially designed conveying machinery is installed at every port where the tonnage is sufficient to justify the expenditure to deal with the export of coal and the import of grain, timber, meat and provisions. Mixed cargoes are discharged either by cranes on the shore or by the ship's gear. Such equipment is usually provided by the port authority.

The Provision of Port Machinery.—As ships are often required to receive and deliver cargo in the open roadstead or at ports abroad not equipped with shore appliances, they must necessarily be fitted with booms and winches, and it is, therefore, often economical to make use of these appliances even when shore plant is available. In practice, however, competitive reasons compel port authorities to provide cranes and in many cases more specialized working plant. Coal is shipped by means of: (1) tips or hoists in which the freight car is lifted to a height above the ship's deck, the contents tipped into a chute to fall into the hold; (2) staithes, when the configuration of the ground permits, where the freight car is pushed to above deck level and the contents tipped into the hold; and (3) conveyors, in which case the freight car at quay level is discharged onto a conveying band to the hatch. Grain is mostly imported in bulk and is discharged by means of elevators which lift it in a continuous stream from the hold, convey it to the quay and there deposit it onto conveying bands which carry it to silos where it is either stored or delivered by gravity into sacks for inland transport. Pneumatic elevators have largely replaced the older bucket-type elevators in quayside granaries. When grain is imported in sacks the modern practice is to cut the bags in the ship and "start" the contents into bulk for discharge by this more economical method.

Grain elevators may be either movable shore appliances or mounted on floating pontoons. The latter, though more costly, have the advantage of greater mobility. The development of transport of grain in bulk, by rail or road, has led to the provision of vehicles with bottom doors, end doors or tippler devices. Among apparatus developed to facilitate the unloading of cargoes, mention may be made of fork-lift trucks, which, operated by gasoline, diesel or electricity, can pick up, raise, transport and pile suitable packages or palletized loads, and can also unpile loads and transport them to outgoing vehicles. They may be fitted with platforms to deal with goods in cases or with forks for lifting cargo in bags.

Ores are generally discharged by grab cranes which are self-filling and save the labour of loading into tubs. Iron is largely discharged by means of an electrified block on a crane which attracts the iron and when over the selected site releases by cutting off the current.. Petroleum is usually discharged through pipelines from the shore storage to the quays. The pipe is connected by means of a flexible hose to the ship's tank and pumped to the storage tanks. The same method is employed for vegetable oils where the volume of trade is sufficient to justify the cost of the installation.

There is an increasing modem tendency for the importing merchant to sell his goods "ex ship," and for goods to pass at once on discharge into consumption, but raw materials are still largely stored in dock warehouses or in adjacent warehouses of private owners for later consumption. Such deliveries are largely of a retail nature, and many of the chief ports have provided elaborate facilities for the storage, sampling, handling and accounting of warehoused goods. This branch of activity prevails in British and in some U.S. ports more than on the continent of Europe.

Rail Terminals and **Docks.**—At ports where barging is not the predominant method of handling cargo and at all modern ports to a greater or lesser degree the railway facilities are an important feature as affecting the cost of distribution. There is great variety of method. At some railway-owned ports the docks are treated as a terminal goods station under main line control. At others, the railway working is self-contained under the docks superintendent. This affects the design of the railway system and the methods of working. In nonrailway docks in some cases the railway company is given running powers to the quays; in others the port authority conducts its own railway operation. As in every properly conducted dock the first and principal aim is to give the ship dispatch and with that object to avoid, by its rapid removal, the congestion of cargo at the ship's side, modern practice is to confide the control to the auth'ority responsible for the dispatch of the ship, providing an area away from the ship where the traffic is interchanged with the main line railway. In the United Kingdom this area is called the exchange sidings; in the United States the belt line. One or more such points of interchange may be provided in accordance with the physical conditions of the main railways serving the port.

The development of road transport introduced a new problem into the question of dock layout, and the need for providing facilities for economical loading to road vehicles in docks equipped only for loading to barge and rail called for many modifications of design.

Port Ownership.—The several types of port ownership and operation may be classified under the following heads: (1) national ownership; (2) trust ownership; (3) municipal ownership; (4) railway ownership; (5) private ownership.

1. Examples of national ownership are Rotterdam and all the larger French ports. None are to be found in the United Kingdom and the United States except naval dockyards which do not come within the scope of this article.

2. Examples of *trust* ownership, are in England, London and Liverpool; in Canada. Montreal and Vancouver; in the United States. New York and New Orleans; in Australia, Sydney and Melbourne.

3. Examples of municipal ownership are, in England, Bristol and Preston; on the continent, Hamburg, uhich is the property of the Free City of Hamburg and might perhaps be classed under national ownership; and Antwerp, the financing of which is divided between the state and the city.

4. Railway *Ownership.*—Before the amalgamation of the railways of Great Britain in 1921 a number of docks were railway owned, some having been acquired by railways when they had difficulty in maintaining themselves as independent authorities. Examples are Southampton and Hull. Others were constructed by companies which, though nominally railway companies, were mainly ports (examples, Cardiff and Newport) to serve the surrounding coal fields. By provision of the Transport act, 1947, the former railway-owned docks in Great Britain passed into the ownership of the British Transport commission, together with the country's railways, inland waterways and some road haulage concerns.

An outstanding example of railway ownership is South Africa where all the ports are worked as part of the state-owned railways. A few examples may be found in the United States, but the tendency in that country is to separate the port and railway ownership.

5. Private Ownership.—In the United Kingdom few ports are to be found in this class, but the Manchester ship canal and the Gloucester Docks and Canal company may be instanced.

The acceptance as a national liability of a larger or smaller proportion of the cost of construction, maintenance and working of a port prevails on the continent much more widely than in the United Kingdom. For example, at Rotterdam and Antwerp the construction, dredging and maintenance of the harbour up to quay level are carried out by the state as a national charge against the general revenues of the country, only the superstructure above water level being provided by the municipality and being the only portion of the charges to be recovered from the trade passing through the port. This is a potent cause of the lower charges prevailing on the continent as compared with the United Kingdom. Under the policy which has generally prevailed in the United Kingdom of nonintervention by the state, economic forces have been allowed free play.

Public Ownership.—In the British dominions the policy of state or national ownership is almost universal, but the methods differ widely. In Australia the ports are financed by state loans and administered by nominated commissioners under the control of the minister for public works. In South Africa they are combined with the state-owned railways under the general manager of the latter. In New Zealand and in India the ports finance themselves, but with the government guarantee behind them, and are administered by a state-appointed chief commissioner assisted by commissioners elected by the users of the port with. in some cases, representatives of the local inhabitants. In Canada ownership and administration are with the several states through the agency of nominated commissioners.

Port trusts are statutory bodies not working for a profit but they are obliged, in order to keep themselves solvent, to levy charges high enough to cover all their outgoings. The capital account has to bear all the cost of construction and of equipping the port, and the revenue account has to bear the interest and sinking fund on such capital expenditure. Charges, therefore, have to be fixed so as to bring in sufficient revenue to pay this interest and sinking fund in addition to current working expenses. Surplus revenue is applied either to improving the facilities or reducing the charges of the port.

Municipal ports can, if the owners so desire as a matter of policy, be subsidized out of the general rates of the city, and in England these are the nearest analogy to the national ports of the continent. As port works from their nature take a long time to construct, and as new trade offering naturally cannot wait while facilities are being provided, it is necessary if a port is to maintain its position to provide facilities in advance of the current demand. It is, therefore, in the power of a municipality. if it is prepared to accept a present burden upon its rates in the hope of being eventually recouped, to provide for the future to an extent which private enterprise cannot afford. In some cities of the United States the practice prevails of levying a specific rate on houses and property in aid of port improvements, and an early example in England is the case of Bristol, the largest municipally owned port, which from 1849 to 1897 levied a rate of £4,000 a year on houses for port purposes. Since the last date this levy has been merged in the general rate-in-aid to balance the revenue account which, however, for many years has been less than the annual contribution toward the sinking fund for the extinction of the capital.

Before the nationalization of the railways, railway-owned docks were enabled, subject to certain provisions of the 1921 Railways act, to meet any shortage of earnings out of their general revenues. The 1947 Transport act sought to integrate all the activities of the British Transport commission and to make them pay as a whole, and the nation at large rather than a group of shareholders became responsible for the financial position of all undertakings managed by the commission. The Transport act, 1953, although modifying the commission's activities, did not affect this arrangement.

Private Ownership. — In the case of the fifth class of ports, the property of private companies, the same end can only be obtained by the shareholders' foregoing their dividends during a long fructifying period, which has actually been the experience of both the ports named above. In fact, in the case of the Manchester Ship Canal company, the outstanding example of a successful company port, the period of fruition was so long delayed that its capital and credit were exhausted and the Corporation of Manchester had to come to its aid by the provision of additional capital on which it had for a period to forgo interest, and in consideration of which it was entitled to representation on the board of directors. But as the management is still with the company's directors, the classification of the undertaking here adopted remains correct.

The decadence of so many English ports under private ownership may be traced to this natural law. Ports constantly tend to become out of date as a result of the increasing size of ships, and are faced with the alternative of seeing their trade depart or of undertaking expenditure on which the return must be far distant and which often proves to be beyond their unaided resources. London and Bristol. Southampton and Hull are examples of company-owned undertakings which were becoming derelict when they obtained outside aid. The first was absorbed by a powerful trust under the direct aegis of the government, the second by the local authority, and both became self-supporting. The last two, though returning large profits to the railway companies which owned them, never directly gave a commensurate return on their cost. Immingham and Fishguard, both railway owned from the beginning, were never remunerative undertakings to their owners or any great advantage to the trade of the country. The relation between the several classes of ports in the United Kingdom was largely affected by the Railways act of 1921 under which the great railway systems became great port proprietors in competition with others dependent on their own resources. This implied a combination of the two systems of extraneous subsidy and self-containment, each of which had been applied successfully in some countries but never before both in the same country.

Functions of Port Authority. — The functions of a port authority may be classified as conservancy and dock ownership. The first head comprises all operations connected with making the port available for shipping, maintenance of navigation channels, surveying the same. buoying and lighting, removal of wrecks, signal service, pilotage service, supervision of foreshore to prevent interference with navigation channels.

The conservancy boundaries of a port are laid down in its acts of parliament, or in the case of ancient ports may be derived from royal charters, and if any portion of those waters forms a highway to other ports, the lighting and charting of that portion is usually undertaken by the state. *e.g.*, Trinity House for English waters and the commissioners of northern lighthouses for Scottish waters.

As dock owner the authority provides the equipment necessary for the accommodation of ships, their loading and discharging and the movement of their cargoes, including the provision of transit sheds, cranes and other cargo working machinery, power plants, railway lines and roads, etc.; facilities. as working of lock gates (if any), lighting, berthing masters and everything necessary to enable a ship to get with safety to a position to discharge and load its cargo; and services, which include everything connected with the handling of cargo, discharging or loading, receiving, sorting, dispatching and storing. Facilities are necessarily provided by the dock owner. In regard to the rendering of services, the practice varies within wide limits. In some ports these are rendered by the dock owners in whole or in part. In others the policy is to leave the services to private enterprise. The port of Manchester is the only example in the United Kingdom of a statutory monopoly of all the services within the dock area, but all ports have power under their acts to provide services and to make "reasonable" charges therefor. The policy, however, differs materially in the various ports, some encouraging departmental working and others favouring separate private enterprise. The principle of a complete monopoly of all the services within the port limits is more prevalent in foreign ports.

The growing tendency to provide large-scale equipment for handling staple commodities makes it seem possible that in the future, despite the objection that it would deprive the shipowners of the advantage of competition, economic reasons will force the more general undertaking of services by dock owners and the acceptance of the position by shipowners. In the case of Manchester the powers giving the authority the exclusive right are coupled with the proviso that their charges to their customers must not provide more than a 10% profit, and it is a generally accepted principle of port finance that the several departments, viz., conservancy, facilities and services, should each be separately self-supporting, though many exceptions to this rule may be found.

In some cases the two functions of conservancy and dock ownership are combined in one authority; in others they are under separate ownership and administration. There is considerable difference of opinion as to which is the better system, but it is perhaps more generally held that more satisfactory co-ordination can be secured and therefore better efficiency and economy obtained when both functions are combined in the same authority. This is the case in most of the larger authorities of the United Kingdom. Examples of ports where the conservancy authority is separate from the dock-owning authority are Southampton, Glasgow and Newport.

Port Revenues. — The revenues of port authorities are principally obtained under the following heads: as conservancy authority, light dues, pilotage dues and sometimes tonnage dues levied entirely on the shipping; as dock authority, dues on shipping calculated on the net register ton, import and export dues on the cargoes. Subsidiary but sometimes very important items of revenue are: profits on the handling of cargo, warehousing, railway working round the docks and rents of lands.

Most ports endeavour to obtain sufficient land to establish industries in the immediate neighbourhood of the docks and, because of the high cost of inland transport and the fact that with most commodities the finished article weighs less than the raw material required to produce it, the tendency is to move industries more and more from inland centres to the coast in the immediate neighbourhood of the great ports, and when possible to obtain the economic advantage of establishment within the dock area to avoid the cost of haulage either by railway or road between such an inland centre and the port.

A problem in port economics which has always been the subject of much difference of opinion is the proper distribution of the burden as between the ships and the goods they carry. The principle generally accepted is that the burden should be divided as equally as can be between the two, but this has many exceptions. Some ports adopt the policy of making the charges on shipping very light with a view that thereby freights will be kept low, greater cargoes obtained and the revenue recouped from the tonnage of those cargoes. Other ports hold the view that the incidence of the port charges on the total expenses of a voyage is so small that it cannot affect the freight, and low charges on goods encourage manufacturers and merchants to use the port This is the policy of all the railway-o ned ports where dues on goods are not only fixed on a low basis but which frequently render services for less than cost, recouping the amount of the cost from the profits on railway haulage.

Important factors affecting the quantum of port and harbour dues are the nature and the cost of the works necessary under the particular physical conditions of each harbour. In the United Kingdom, because of the great variation of tides. it is in most cases necessary for the efficient working of ships to maintain a constant level in the docks by impounding the water within lock gates (a notable exception is Southampton, uhich has been favoured by nature with four tides in the 24 hours, reducing the difference between high and low water to a few feet). The Pacific and Indian oceans and the Mediterranean sea, on the other hand, with their low rise and fall of tide, enable their ports to dispense with such expensive equipment, and at the great ports of these oceans. Sydney, San Francisco, Singapore, Marseilles, etc.. the features of the port as left by nature have been almost entirely retained. For this reason the capital cost, as measured by the accommodation afforded, is much lower and is reflected in the lower scale of dues which can be imposed.

The working expenses of a port are for the greater part in the nature of fixed charges, e g., interest and depreciation on the capital cost of the accommodation and working of the entrances nhich are the same whether they lead to few or to many berths and whether the berths are occupied or not. Those expenses have to be distributed, as a rate per ton, over the shipping using the port. Hence economy of port charges can be obtained by concentrating the trdde of a country into a few ports. But this may involve a longer and more expensive carriage to point of origin or destination, and there is constant play of these contending forces. England is a small island with a comparatively large number of ports. On the continent of Europe, on the other hand, the area of distribution or collection runs into many thousands of square miles served in almost all cases by water ays concentrating in the mouths of a few great rivers. The number of ports is, therefore, fewer and the tonnage concentrated in each to a much greater extent than in Great Britain, thus allowing of lower dues per ton to obtain the necessary revenue.

In England, again, transport inland has mainly to be made by road or rail. On the continent of Europe the goods are carried for the most part on waterways of a width and depth to take barges sometimes nearly as large as ocean-going ships.

Comparison is frequently made of the charges in English and continental ports to the disadvantage of the former. The explanation can be found in the foregoing paragraphs, and may be summarized as: (1) substantial national expenditure not brought onto the port's accounts; (2) concentration of a greater tonnage over which to spread the fixed charges; and (3) the larger units and therefore the lower cost of transfer from ocean to land transport. (D. R.-J ; X.)

See 4. H. J. Bown and C. A. Dove, *Port Operation and Administration* (London, 1950) ; E H. Lederer, *Port Terminal Operation* (Cambridge, Md , 1945).

UNITED STATES

United States ports are on three coasts: the Atlantic. Pacific and Gulf of Mexico; they are also on the inland waterways. principally the Great Lakes and the Mississippi river system. Because of the size of the Great Lakes and the vessels employed on them, lake ports have many of the characteristics of ocean ports. Ports of the Mississippi and its tributaries are accessible by barges of up to nine feet of draught. Most United States ports have a much higher proportion of domestic—coastwise, intercoastal and internal—traffic in proportion to foreign traffic than is characteristic of ports throughout the world.

Harbours.—United States harbours are diversified in physical type. Few have tidal ranges comparable with those of major harbours of northwestern Europe: fluctuations in water level are generally not sufficiently great to impede cargo operations, making locked wet docks unnecessary. Low water depths at major ocean ports vary irom about 27 to 40 ft., at Great Lakes ports irom 18 to 25 ft. (except for ports handling traffic through the proposed St. Lawrence seaway) and 6 or 9 ft. at Mississippi river system ports accessible by barges.

With few exceptions, channels are improved and maintained by the U.S. army corps of engineers under specific project authorization and appropriation by congress.

Port Administration. — Although channels are generally maintained by the federal government, planning, financing, constructing and operating of port terminal and auxiliary facilities is for the most part by private interests or by local. state or interstate ad *hoc* agencies. Unified development and operation of all iacilities of a port is relatively uncommon.

Some ports, such as Gary, Ind., are private facilities of a single industrial establishment. Many port facilities are operated by railroads, nhich offer free berthage to vessels with full or partial cargoes moving over the lines of the respective companies, in competition with other privately and publicly operated facilities at the same and other ports.

In the first half of the 20th century, public development and ownership of port terminal facilities, in order to make them available to all carriers on equal terms. became increasingly common. Public port authorities which operate facilities are municipal departments as in New York city. Philadelphia and Milwaukee, state agencies as in North Carolina, Georgia, Alabama and in Boston and San Francisco, and interstate authorities, the oldest and largest of uhich is the Port of New York authority. In some instances, as in New York. two or more public authorities may own different port terminal iacilities, often with competition from privately owned facilities including those of the railroads.

Port Finance. — Use of harbours and channels maintained by the federal government is free. Terminal facilities operated by industries and carriers for their own traffic are maintained as part of their capital plants. Other private terminals and public terminals charge a berthage fee against vessels, as well as demurrage and special service charges as for heavy lifts. Berthage and other charges are customarily absorbed by the carriers.

Although some public port agencies receive tax revenues, most are supported entirely by receipts from operation of their facilities either directly or through leases to private operators. The specialized-function port authority is a popular device for relieving municipalities, counties and states of financial obligations with respect to their port terminal developments by having specific responsibility for amortizing its bonds from revenues derived from operation of the port facilities. Many port terminals have been financed by revenue bonds. In some instances the bonds are amortized by rentals paid for operation of the facilities by private companies which, in turn, assess berthage and other charges against the carriers. Commonly, the port authorities are authorized to issue bonds independently of the legal debt limit imposed upon municipalities and other public jurisdictions, the geographic boundaries of nhich may coincide with those of the port authority.

Many port terminals, although meeting out-of-pocket costs by user charges, cannot cover their full costs, including depreciation and amortization, aithout direct or indirect subsidy. In some instances the port authority is also a general transportation authority, operating river crossings, inland terminals and airports, some of which produce revenues in excess of amortization and operating costs the excess being used in part to finance port terminals.

Port Competition. — The success of a port in capturing the trade beyond its immediate metropolitan area is the result of the efficiency of its facilities in fast turn around of vessels, thereby attracting liner and tramp services; the strength of its own metropolitan and regional economic base in providing minimal traffic to justify regular shipping services; freedom from work stoppages by strikes and other disturbances; promotional activities by local port agencies; easy access to and from the hinterland by land and inland waterway carriers; and the structure of inland freight rates.

Beyond the local area there is a noncompetitive hinterland in which the port has rate advantages. Beyond is a competitive hinterland, in which rates to and from groups of ports are equal or nearly so, in which the frequency and dependability of services will determine routings. Ocean rates are generally equalized for all ports of a "range," as, for example, the transatlantic rates via the North Atlantic range which includes all ports from Portland, Me., to Norfolk, Va. Ports within that range have differential land rates. For example, to and from the midwest, transatlantic rates are equalized. but land rates via Philadelphia are lower than via New York and Boston, and via Baltimore are lower than via Philadelphia. Rates via Gulf of Mexico ports are also competitive with North Atlantic ports. Port equalization has been an issue before regulative bodies for many years.

The foreign trade zone or free port has, from 1937, been used to stimulate traffic, without outstanding success. In a foreign trade zone goods may be received, sorted, traded, processed and transshipped without payment of import duties unless and until passing the barrier which surrounds the zone. Such zones in New York, New Orleans, Los Angeles harbour, San Francisco and Seattle include small areas of terminal facilities together with adjacent land, under lease to private operators.

Terminal Design.--Older portions of United States coastal ports are characterized by piers at right angles to the shore line with inadequate landward access. congestion on the piers and marginal streets. wharf aprons too narrow for easy movement of modern mechanical handling equipment such as fork-lift trucks, slips of inadequate width for easy berthing of ships without tugs and for handling of barges and lighters alongside and unavailability because of high land costs and congestion of nearby sites for industrial plants requiring direct access to deep-draught shipping. Most modern port developments are of the marginal quay type, in which the vessels tie up parallel to the shore line, usually without aid of tugs. Such quays typically have paved aprons of 40 to 50 ft. width with access by rail and truck, transit sheds parallel to the wharf and at least 120 ft. wide. adequate marginal streets and a marginal belt railroad with adequate capacity in nearby holding yards, and nearby warehouses and open storage areas. Such developments meet the need for more shoreward area for cargo handling and less lineal footage of berths for vessels, resulting from larger but fewer vessels and faster turn arounds than were heretofore common. Such modern port developments are best accommodated at some distance from the older sections of cities, and there has been a tendency for newer port terminals to be located downstream and upstream from the older ones as a result of the necessity to provide larger space for sorting and classifying inbound and outbound shipments, as well as the warehousing and open storage. These tracts are generally in proximity to extensive. areas available for industrial sites.

United States port terminals are generally not provided with large cranes. as are European terminals! relying rather upon ships' tackle for transfer of cargoes between vessel and wharf and upon tractors and fork-lift trucks for movement between wharf and transit shed or storage areas. Pallets are extensively used for transfer of general cargo. Many ports are provided with floating cranes for heavy lifts. Except for lighterage in New York harbour, direct transfer of cargoes between ocean and inland vessels is not common. (H. M. M.)

PORTO-RICHE, GEORGES DE (1849–1930), French dramatist, born on May 20. 1849, at Bordcaux. In 1873 his pieces in verse began to be produced at the Parisian theatres; he also wrote some books of verse which met with a favourable reception. hut these early works were not reprinted. In 1898 he published *Théâtre d'amour,* which contained four of his best pieces, *La Chance de Françoise* (1888). *L'Infidèle* (1890), *Amoureuse* (1891) and *Le Passé* (1897). The title given to this collection indicates the difference between the plays of Porto-Riche and the political or sociological pieces being written by many of his contemporaries.

In Germaine, the passionate and exacting heroine of *Amoureuse,* Mme. Réjane found one of her best parts. In *Les Malefilâtre* (Odéon, 1904), also a drama of passion, the characters are drawn from the working classes. Later plays are *Le vieil homme* (1911) and *Le Marchand d'Estampes* (1917). He published in 1920, under the title *Anatomie sentimentale,* extracts from his works, which well illustrate his sense of the inevitableness of the continual duel between men and women.

Porto-Riche was a member of the French Academy, and a director of the Bibliothèque Marazine. He died in Paris on Sept. 5, 1930.

BIBLIOGRAPHY.—Etienne Rep, *G.* de *Porto-Riche* (1924); Henry Marx, *G* de *Porto-Riche* (1924); *E* Sée, *Porto-Riche* (1932); *W.* Muller, *Georges de Porto-Riche* (1934).

PORTO RICO: *see* PUERTO RICO.

PORT PHILLIP: *see* MELBOURNE.

PORT PIRIE, a seaport of South Australia situated on the eastern shore of the northern portion of Spencer gulf. Pop. (1954) 14,223. The harbour is poor, and Pirie won its place as the second port of the state because it is the nearest convenient maritime outlet for all the exports and imports for Broken Hill (*q.v.*) in New South Wales. 205 mi. inland to the northeast. The Broken Hill ores have been smelted at Port Pirie since 1897 to produce lead bullion which is later refined. Coal from Newcastle, New South Wales. is used for the smelters which are on a large scale. The main exports are lead. ores and wheat and in 1952–53 they totalled 586.859 tons. The imports for the same period were 239,905 tons.

PORTRAIT PAINTING. A portrait is a record of certain aspects of a particular human being as seen by another. The sitter may be deified or merely flattered by the painter, satirized or even maligned but. as long as some sense of his individuality remains, a painting of him will be a portrait. The artist may be interested only in the sitter's physical appearance, his social position, his soul or his unconscious problems, but again. as long as the sitter's identity remains, the artist will have painted his portrait. Finally the painter may paint him with a concern for precision of detail or with apparent abandon, with an interest in photographic realism or with a composition of cubes; but still, whatever the style is, as long as the artist can suggest some aspect of a particular person. the work will be a portrait. (It may not be a very good portrait but that is another problem.)

The Portrait **and** History. — By its very nature the portrait grows out of a respect for the differences between human beings; therefore it is only in periods primarily interested in individual differences that portrait painting thrives. In classical Greece, where the ideal mattered more than human particularities, portraiture had no place. In the middle ages, when man should ideally have lost his identity in the contemplation of God. again portraiture had an insignificant role. In the 20th century, portrait painting, with certain exceptions, has not been an important art form, perhaps because photography has provided an inexpensive substitute or perhaps because the norm is worshipped more than specific human characteristics.

The reasons for a concern with the individual and a subsequent desire for portraits vary according to the period. The wish to have a portrait may be for religious reasons; *e.g.*, the ancient Egyptians needed a durable portrait in stone enough like the body of the dead person with which it was buried to suggest his authority and thus deceive his ka (or double) so it would not haunt the survivors. At other times the moving force may have been a conviction of the importance of the individual to the family's prestige, as it was for the noble Romans or for the great of Georgian England. The cult of the hero, whether knight or courtier, grew up in the late middle ages and was developed in the Renaissance; his individual virtues had to be recorded. In contrast to this, the 19th and 20th centuries have observed the human being realistically, almost critically; portrait painters (as well as novelists) have emphasized his physical peculiarities and his psychological problems. Circumstances such as these have helped determine the character of the portrait historically.

The Painter and the Sitter.—In a portrait the personality of the sitter is obviously of primary importance. It may not be equally apparent that the personality of the painter is just as significant. and that the character of the relationship between them is perhaps most relevant of all. When a fashionable patron commissions a portrait from a fashionable painter the relationship between painter and sitter may be a formal one, and the work will reflect that formality. When an artist instead chooses to paint a portrait from his own affection or interest the relationship between the painter and the sitter becomes intimate and revealing. A portrait may reveal the shyness, the apprehension, the arrogance, the amusement or the casualness with which the sitter regarded the artist.

The great moments in the history of portraiture are probably those when the personality of the artist can most completely comprehend his sitter's—when a Hans Holbein is capable of identifying himself with the Merchant Gisze or a Diégo Velázquez can meet the challenge of the realism of an Innocent X or a Jean Ingres can love the vulgarity of a Mme. Moitessier. Out of such a rapport the greatest portraits are painted.

HISTORY

The beginning of the Renaissance, about 1400, introduced the first consistent tradition of portrait painting in the west. The Egyptians and the Romans who, unlike the Greeks, were portraitists, preferred sculpture. During the middle ages interest in the individual's mortal life had a lesser place; it was only toward the end of this period that a donor felt a need to have his individual piety recorded—not just by a symbol, his coat of arms perhaps, used to decorate some object he had given—but by having his own features reproduced as he knelt in devotion before the Virgin Mary.

The Sitter's Piety.—In the late middle ages Richard II (1367–1400) of England was painted kneeling, under the protection of his three patron saints, before a Madonna and Child surrounded by a circle of angels who look and point to ard the suppliant king (Pl. II, fig. 1). There is some question whether this work, the "Wilton Diptych," was painted during Richard's lifetime or was commissioned by some admirer after his death. Whatever the circumstances were, the artist was not interested in visual probability; rather he imposed upon the scene the traditional conception of religious decorum by making the Virgin Mary appropriately larger than the three patron saints, who are bigger than the king, and by isolating Richard and the three saints in the left of the two panels which form the diptych.

The artist imposed the same medieval conventions in the portrait of Richard that he did in the arrangement of the whole. Richard's kneeling body has no apparent existence under the heavy robes which enclose it. All that is exposed are the head and the hands. The hands are held apart in a rather uncertain suppliant gesture before the Madonna to emphasize the humility of the king. That he is king is indicated by his crown and his gold brocaded robes, that he is Richard by the white hart with which his robe is decorated and which also hangs as an emblem around his neck. Finally, instead of using the three-quarter view of the face as he did for most of the other figures, the artist chose the position in which a person's features are most easily remembered—the profile. Richard's face is smooth, bland and young, its features delicate and somewhat pointed, his expression content. As long as he was identifiable, perhaps as much by the heraldic symbols as by his features, the purpose of the painting was served. The artist had clearly achieved the suggestion of the piety of this particular king.

RENAISSANCE

The Sitter Seen.—The convention of including the portrait of a donor in a religious work continued into the 17th century. but early in the 15th century during the Renaissance in both Italy and northern Europe independent portraits became common as an expression of the renewed interest of the Renaissance in the individual human being. One of the greatest portrait painters of the time was the Flemish artist Jan van Eyck (1385?–1441), and his most remarkable portrait was of an Italian merchant, "Jan Arnolfini and His Wife" (see EYCK, VAN). It has been shown that, more than a double portrait, this is a witness to the marriage of the Arnolfinis which Van Eyck shows taking place. The painting is full of late medieval symbolism referring to the event. The single candle in the candelabra burning in daylight represents the unity of marriage. The fruit, so casually placed on the chest by the window sill, suggests the state of man before the fall. Even the dog represents domestic bliss.

However, as a portrait "The Marriage of Giovanni (?) Arnolfini and Giovanna Cenami (?)" is more important because it is a rare attempt in the 15th century to paint a full standing figure and because both these figures are placed in their own familiar setting, no matter how fraught with symbolism it may be.

Although the garments the Arnolfinis wear are full they do not conceal their figures entirely; so Jan van Eyck, more than the artist of the "Wilton Diptych," makes use of their bodies to enrich his interpretation. The Italian merchant has narrow, sloping shoulders, he stands with his legs apart and his feet outspread; there is no suggestion of classical beauty or power. His body is, still in medieval terms, unimportant. He holds himself erect like an ascetic. somewhat aloof from his wife at whom he does not look, his head and his lifted right hand concentrating upon the troth he is pledging. Jeanne, his wife, is a gentler figure; her shoulders are bent, her head is modestly lowered in her husband's direction. Although Jan van Eyck proved here that full figures could be used meaningfully in a portrait it was another hundred years before the practice became common.

The Arnolfini portrait is also remarkable in its effort to make the figures seem very natural in their environment. Their slippers, the wooden planks of the floor. the bed, the opened window with the warm sunshine streaming through it, the obvious details of a prosperous 15th-century home can be seen. Although the Arnolfinis are quite large for the scale of the room, the slippers and the dog in front of them seem to place them convincingly back into it. This position, combined with the visual interest demonstrated in the textures, in the quality of light and shadow and even in the reflection of the mirror (all of which the new technique of oil painting made more possible), makes this work a step toward a greater naturalism, a desire to give the illusion of the Arnolfinis as they might actually be seen in their own drawing room. This interest in the thing seen is apparent in Van Eyck's choice of the three-quarter view of the heads, which also brings the two sitters, particularly Jan, into a closer relationship with the spectators.

This portrait is in some respects essentially a tour de force which had no imitators; however, it displays a visual realism, characteristic of all Jan van Eyck's work (*e.g.*, Pl. II, fig. z), which became an integral part of northern Renaissance painting, particularly in the work of such gifted followers of Van Eyck as Rogier van der Weyden (c. 1400–64), Petrus Christus (1420?–73) and Hans Memling (c. 1430–94).

The Sitter of Authority.—In Italy in the 15th century portraiture took a somewhat different form. Federigo da Montefeltro, duke of Urbino (1444–92), might have the Umbrian painter, Piero della Francesca (c. 1418–92), paint him kneeling piously before the Madonna and Child but he also felt quite free to have himself painted as the symbol of authority over the world he ruled, without any of the implicit humility which Van Eyck's work still possessed (Pl. II, fig. 3). Like the painter of the "Wilton Diptych," Piero imposed relationships upon the work which are rational rather than visual. However, the basis for his reasoning was quite unlike the medieval painter's. The duke of Urbino is exaggeratedly and imposingly large in relation to the countryside, his own territory, behind him; Piero has made it quite clear that his sitter was master over nature rather than, like Richard, small and humble before God. In describing the silhouette of the

"Portrait of a Lady," 1937, by Pablo Picasso (1881-). Spanish

PORTRAIT PAINTING

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PORTRAITS OF THE 14TH–17TH CENTURIES

1. Left panel of the Wiiton diptych, international style, 1380–1425. National gallery, London. 2. "Portrait of a Man" by Jan van Eyck (1385?–1441), Flemish. National gallery, London. 3. "Duke of Urbino" by Piero della Francesca (de' Franceschi) (1418?–1492), Italian. Uffizi gallery, Florence. 4. "Portrait of the Artist" by Albrecht Dürer (1471–1528), German. The Prado, Madrid. 5. "Merchant Gisze" by Hans Holbein the Younger (1497–1543), German. Staatliche Museen, Berlin. 6. "Man With a Glove" by Titian (Tiziano Vecellio; 1477?–1576), Venetian. The Louvre, Paris. 7. "Julius II" by Raphael (Raffello Sanzio; 1483–1520), Italian. Pitti gallery, Florence. 8. "Innocent X" by Diego de Silva y Velazquez (1599–1660), Spanish. Doria palace, Rome. 9. "Cardinal Guevara" by El Greco (Domenico Theotocopuli; 1542?–1614), Cretan by birth but identified with the Spanish school. Metropolitan Museum of Art, New York city

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17TH–20TH CENTURY PORTRAITS

1. "Lady With a Pink" by Rembrandt van Rijn (1606–69), Dutch. Metropolitan Museum of Art, New York city
2. "Charles I" by Anthony Van Dyck (1599–1641), Flemish. The Louvre, Paris
3. "Mrs. Graham" by Thomas Gainsborough (1727–88), English. The National Gallery of Scotland, Edinburgh
4. "Baron Schwiter" by F. V. Eugkne Delacroix (1798–1863), French. The National gallery, London
5. "Mrs. Seymour Fort" by John S. Copley (1737–1815), U.S.-English. Wadsworth Atheneum, Hartford, Conn.
6. "Mme. Moitessier (Seated)" by Jean A. D. Ingres (1780–1867), French. The National gallery, London
7. "Victorine Meurend" by Édouard Manet (1832–83), French. Museum of Fine Arts, Boston
8. "Duke and Duchess of Morbilli" by Hilaire G. Edgar Degas (1834–1917), French. Museum of Fine Arts, Boston
9. "Jacques Lipchitz and His Wife" by Amedeo Modigliani (1884–1920), Italian. Art Institute of Chicago

"THE WYNDHAM SISTERS" by John Singer Sargent (1856–1925). U.S.

duke's head and shoulders Piero used firm, clear contours which grow even more abrupt in the face — quite unlike the delicate, continuous lines which describe the figure of Richard. Their very severity suggests the harshness of the duke whose portrait is being painted to record his power rather than his piety. At the back of this small panel painting there is another study of the duke as part of a classically inspired triumphal procession; this makes the motivation for the portrait quite clear since, crowning the duke of Urbino, is the allegorical figure of Fame.

This portrait is a profile portrait. Since the duke had lost his right eye in the same tournament which had given his nose its distinctive shape, a profile portrait was probably mandatory. However, it was the position most characteristically chosen for Italian 15th-century portraits. One reason it was so popular may have been the authority of classical medals and gems. It is also possible that these artists may have felt, like the painter of the "Wilton Diptych." that the profile could most clearly characterize the distinctive features of a sitter's face. The profile places the emphasis upon the head as we know it or remember it to be rather than upon the visual impression which interested Jan van Eyck. Consistently the head is built up of separate facts, like the features revealed in the profile or in each curling strand of hair, rather than upon the visual unity of the whole; the imperfections of the moles and wrinkles, for example, do not destroy the alabaster smoothness of the skin.

Although the duke possessed the supreme kind of self-confidence which did not demand that a painter flatter him, indeed permitted Piero to enumerate any facts with brutal honesty, the ultimate purpose was not a record of his appearance — but rather of his authority. And it is generally true of 15th-century Italian portraiture that. although the painter recorded the anatomical features of his sitters as he knew them to be, he was primarily concerned with the ideal to which these sitters aspired. Therefore as Piero in painting the duke suggested his worldly power, Domenico Ghirlandajo (1449–94) in painting Giovanna Tornabuoni degli Albizzi would emphasize her female dignity or Gentile Bellini (c. 1429–1507) in painting a doge would show his keen intelligence—always qualities represented in their most perfect form.

The Sitter Idealized. — In Florence. at the turn from the 15th to the 16th century, painters and sculptors were not so interested in Piero's unequivocal realism of detail. An artist as renowned as Leonardo da Vinci (1452–1519) was seldom willing to paint a portrait and, when he did, it seems to have been because his sitter could be made to represent an ideal rather than a particular human being. The most famous portrait painting by his hand is of the wife of Francesco del Giocondo. the "Mona Lisa." This work, from 1504, not only makes it clear that Leonardo was interested in idealization but also that he was perhaps sufficiently tempted by the technique of oil painting to want to achieve the illusionary effects for which Jan van Eyck had also strived.

More even than Van Eyck, Leonardo, in his portrait. makes the transitions so subtle that the illusion of a body of flesh and blood occupying space is almost complete; however, in spite of the fact that she seems so physically convincing, the "Mona Lisa" remains aloof. Her dress is simple but the bearing of her head, the position of her hands and the triangular form she occupies make her seem imposing and regal. The face which, more than mere flesh and blood, seems to radiate with an inner warmth is so provocative. so eternally enigmatic in its expression that it has tantalized the millions who have seen it in the Louvre or in reproduction. The landscape behind her increases the mystery; it is so much sheer fantasy that it seems related to the world of imagination rather than fact. The "Mona Lisa" is so generalized that it is perhaps not even a portrait; rather she is characteristic of the short-lived High Renaissance desire to concentrate upon the ideal rather than the particular.

The ideal which the "Mona Lisa" represents, no matter how illusive it is, is certainly a matter of inner life rather than physical externals; it radiates through her flesh and skin. The best portraits by Raphael (1483–1520) have somewhat the same quality. However, the inner spirit within a Raphael is neither so enigmatic nor so timeless; *e.g.*, in the portrait of "Julius II" (1443–1513) in the Uffizi the inner spirit can show the effects of age and care (Pl. II, fig. 7). Raphael's ideal, at least in this portrait. was of a dignified and noble maturity. The weary shoulders, the head weighed forward, the white beard, the shadows under the eyes, the wrinkles enhance that effect. And the simple pyramidal composition, of the kind Raphael had studied in Leonardo's work, contributes to the sense of the pope's dignity.

In Venice about 1520 Titian (*c.* 1477–1576) painted a portrait of an unknown young man which shows another aspect of the search for the ideal in the portraiture of the Renaissance (Pl. II, fig. 6). This young man, whose elegance Titian proclaimed in the relaxed pose, the long fingers, the gloves and particularly by the extended "V" of his white shirt. has at the same time a youthful vulnerability. Instead of idealizing the dignity of old age. as Raphael did in his "Julius II," Titian is reminding us of the potentialities of youth; this is a man who may yet form himself into a maturer ideal. Although it is this suggestion of anticipation that makes this work most characteristic of the High Renaissance, it is the elegance of the man and the visual beauty of the arrangement within the painting that had most influence. Artists later in the 16th century, in the style called Mannerist rather than Renaissance, developed this self-conscious grace in paintings of polished and affected beauty. The type spread throughout Europe so that such Italians as Jacopo da Pontormo (1494–1556), Parmigianino (1504–40) and Bronzino (1503–72), such Frenchmen as François Clouet (d. 1572), such Flemings as Anthony More (c. 1512–75) and such Englishmen as Nicholas Hilliard (c. 1537–1619) painted Mannerist portraits.

During the Renaissance artists like Leonardo, Raphael and Titian had positions as courtiers rather than as artisans. This increase in social prestige helped to make the artist more conscious of his own personality. This consciousness accomplished two things: it encouraged the artist to paint portraits of himself and it made him impose himself in some fashion upon portraits he painted of others. Leonardo, Raphael and Titian did not efface themselves before their sitters as did Piero or Van Eyck; instead they revealed their own preoccupations by making these men conform to their particular ideals.

The Self-Conscious Sitter. — The same change in the social position of the artist took place in the north, with the same effects. The German Albrecht Durer (1471–1528), at 13, was sufficiently aware of himself to make an exquisite silverpoint self-portrait. He later revealed his personal ambitions in paintings of himself. The self-portrait in Madrid (1498) shows Diirer in the costume of an elegant young man (Pl. II, fig. 4). Proudly displayed in the background are the Alps the painter had crossed on his way to Italy. In 1505, conscious of the religious troubles of his time, Dürer painted a self-portrait which showed another ideal — the desire to lead a ljfe in imitation of Christ.

Durer's compatriot, Hans Holbein the Younger (1497–1543), excelled in superb and rather detached portrait drawings and paintings. His paintings show a desire for elegance, an enjoyment of the description of textures and a delight in the surface of the panel. 4 portrait such as that of the "Merchant Gisze" may at first seem cold and objective (Pl. II. fig. 5). Like Van Eyck in the portrait of the Arnolfinis, Holbein indicates the man's environment, his occupation (he is a Hanseatic merchant in the Steelyard in London) and even his habits by the details of the setting, and suggests his dignity and his position by the merchant's bearing and costume. However it soon becomes evident that Holbein is as much concerned with the nature of this man as with such externals. Here there is none of the easy grace of Titian's "Man With a Glove." Indeed Gisze holds himself rather tensely; he looks far to his right, well beyond us, not casually but with an expression which shows apprehension. Holbein uses the ingredients of the setting masterfully, building them around the Merchant Gisze in space so that he is hemmed in one corner. This position, combined with the dark shadow he casts, makes even the gesture of his opening the envelope a furtive one. On the wall is inscribed his appropriate motto: "No Joy Without Sorrow." Holbein tries to remain objective but within the formal restraint he gives his portraits strong emotional overtones which ask the spectator to respond as he once presumably responded before his sitter.

El Greco (c. 1542–1614) did not feel as much need to discipline his responses to his sitters some 66 years later. A comparison of his "Cardinal Guevara" (Pl. II, fig. 9) with Raphael's "Julius II" shows how differently from a Renaissance artist this painter approached an important ecclesiastic. El Greco does everything to destroy the pyramidal order and calm of Raphael's work by choosing an elongated canvas, emphasizing its verticality, showing the figure full length and by giving the red silk of the robe an independent life by the angular and dynamic play of the folds. The cardinal does not sit with the heavy gravity of the pope; instead he perches on the edge of his chair, his feet nervously protruding from beneath his robes, his right hand conspicuously relaxed, the left toying with the arm of the chair. The piece of paper at his feet helps destroy any sense of self-containment. Nor is there any suggestion of spiritual contemplation, for the cardinal looks out with great wariness through his black-rimmed spectacles. He has more in common with Holbein's "Merchant Gisze" although he is painted more freely and the emotions are much intensified. In the works of both El Greco and Holbein, like the best 16th-century portraiture after 1530, the emotions in the relationship between sitter and artist predominate.

Baroque and Rococo

The Whole Man.—The artists of the late middle ages were interested in man as a symbol; those of the early Renaissance in the facts of his appearance and position; those of the High Renaissance in him as an expression of an ideal and the Mannerist painters of the 16th century in his emotional responses. But it was not until the 17th century, in the period called the baroque, that any artist tried to embrace all these approaches in a single portrait. Certainly the Flemish Peter Paul Rubens (1577–1640) and the Dutch Frans Hals (1580?–1666) accomplished this—but it was the Spaniard, Diégo Rodriguez Velbzquez (1599–1660), who succeeded most impressively in his portrait of "Innocent X" (Pl. II, fig. 8). The pope in his dress, in his throne and in his bearing is a symbol of papal authority if not of infallibility. The facts of his appearance, no matter how ugly, are recorded here although they in no sense destroy the total impression. The ideal that Innocent X represents is far from the Renaissance ideal—but it is a magnificent expression of the physical and intellectual and moral force to which the baroque aspired. Velazquez is as much concerned as Holbein or El Greco with emotional relationships, but his are not so subtle or so strained; Innocent X challenges us with his penetrating look. Velázquez, with his remarkable ability to give the illusion of this dynamic man in space, has made a characteristically baroque effort to present the total man.

Velázquez' contemporary in Protestant Holland, Rembrandt van Rijn (1606–69), normally painted far gentler, humbler people but also tried to arrive at the synthesis of the complete man or woman. One of his late paintings, "Lady With a Pink," records the facts of his sitter's weariness and age and, by the position of her head and hands, suggests her shyness and humility (Pl. III, fig. 1). Like Leonardo, Rembrandt was interested in the spirit within such a woman, but here this radiates warmly and not coquettishly through a physical shell which in itself is a revelation of this woman's experience. Her beauty seems completely spiritual, the result of a moral life rather than of a physical ideal; Rembrandt expresses it in the gentle, worn face, the large, tender eyes and particularly in the light which seems to be the equivalent of her soul. Rembrandt's judgment of his sitters is ultimately a moral one.

One of the most influential portrait painters in Europe in the 17th century was the Flemish Sir Anthony Van Dyck (1599–1641). Like Rembrandt and Velázquez, Van Dyck was interested in an illusion of the total man revealed in a moment of contact. However, his ideal mas more like that of the early Titian whose work he admired.

As can be seen in his portrait of Charles I of England (1600–49), to whom Van Dyck was court painter, he could suggest the easy grace, the elegance and the arrogance of this man through the swing of the body, the texture of the dress, the haughty expression of the features (Pl. III, fig. 2). The casual landscape setting, the grooms with the horse, also contribute to the sense of the grace of the king, so accidentally discovered with them. Van Dyck brought this tradition of the courtly portrait from 16th-century Venice to England where it was developed in the 18th century by such painters as Sir Joshua Reynolds and Thomas Gainsborough.

The Sitter Romanticized.—France had several artists in the 18th century, including Jean Siméon Chardin (1699–1779), Maurice Quentin de La Tour (1704–88) and Jean Baptiste Perroneau (1715–83), who drew sensitive heads in pastel (*q.v.*) which show a lightness of touch which was appropriate for the period called rococo. But it was England that had the most substantial sequence of portrait painters; their names form an imposing list: William Hogarth, Sir Joshua Reynolds, Thomas Gainsborough, Joseph Highmore, Allan Ramsay, Sir Henry Raeburn and George Romney. Of these, Reynolds (1723–92) was the most verbally articulate and, before the Royal Academy of which he was the first president, he made a series of discourses about art in general with several asides on portraiture which he, like his age, regarded as a form of art inferior to history painting. During his fourth discourse he said of the portrait painter: "He cannot make his hero talk like a great man, he must make him look like one." And essentially this was the attitude of most of these English portrait painters—to emphasize, with certain visual conventions and exaggerations, the stature of the sitter. Reynolds did it himself, most convincingly in his portraits of such men as Samuel Johnson.

Gainsborough (1727–88) was perhaps the most gifted of these painters and, although many of them were influenced by Van Dyck, his style mas closest. He applied paint with the fluidity of Van Dyck. His work has a similar luminosity which seems, in itself, to give his portraits great distinction. Like Van Dyck he normally painted his sitters out-of-doors—although for the landed aristocracy of 18th-century England those parklike settings probably had more meaning in terms of prestige than they had had a century earlier. And he took certain conventions which Van Dyck had used to flatter his sitters and exaggerated them further to give the most aristocratic impression. In his portrait of "Mrs. Graham," for example, Gainsborough emphasized her proud dignity by elongating her body and by emphasizing the vertical through her long, graceful throat, the right arm and even the supporting pillar (Pl. III, fig. 3). She is spatially and psychologically sufficiently removed to remain appropriately remote. Her beauty is suggested by her exquisite features and by the shimmer of her garments, echoed in the romantic light of the sky. Finally the casualness of such an aristocratic ideal is indicated by the informal way Mrs. Graham leans on the pillar and looks without concern in another direction.

Eighteenth-century England was invaded periodically by American artists. Two talented portrait painters remained there. One of them, Benjamin West (1738–1820), became president of the Royal Academy. The other, John Singleton Copley (1737–1815), painted good, straightforward paintings which seem far removed from Gainsborough's romanticized portraits. When Copley painted "Mrs. Seymour Fort" he may have used the device of the baroque red curtain in the background and shown her in a position of considerable dignity—but with the crocheting in her hand, her solid body and good-humoured face, she represents all the most sensible middle-class virtues, presented without flattery, satire or rationalization (Pl. III, fig. 5).

19th and 20th Centuries

Realism.—In France during the first half of the 19th century there were two strains in painting comparable with those Gainsborough and Copley had represented in the 18th. Eugène Delacroix (1798–1863), when he painted his 21-year-old friend, the Baron Louis Schwiter (Pl. III, fig. 4), continued the strain in European painting which runs from the Venetians through Van Dyck to Gainsborough. Consistently he painted the full figure of this rather elegantly dressed young man, standing in a park with a poetic light breaking across the sky. However at the same time with a characteristically 19th-century realism Delacroix portrays the baron's essential vulnerability. His hands and the position of his feet, the untidy hair and collar convey his helplessness. And because he stands so simply and directly and because Delacroix has raised the horizon so that, unlike a portrait by Van Dyck or Gainsborough, the viewer is put almost on a level with him, the impression is given that this rather gentle, shy figure of Baron Schaiter has been exposed because he has been too passive to resist or to care. In the very lack of assertiveness or definition. which makes it possible for him to be such a harmonious part of the idyllic setting, the baron seems to represent at least one romantic ideal.

Just as Copley's "Mrs. Seymour Fort" is the antithesis of Gainsborough's "Mrs. Graham," so "Mme. Moitessier" (Pl. III, fig. 6) by Jean Auguste Dominique Ingres (1780–1867) is the antithesis of Delacroix's "Baron Schaiter." As substantial as Mrs. Fort and as elaborately dressed, Mme. Moitessier is decisive, assertive and meets our eyes with a challenge. Ingres, with the examples of Roman painting and of Raphael in mind, found every excuse for curves which would emphasize the firmness and roundness of her body; these combined with the relaxed pose make Mme. Moitessier essentially seductive. Throughout his career Ingres painted and drew many portraits as meticulous and direct.

The portraitist in the second half of the 19th century in France who perhaps most completely understood both Delacroix and Ingres, and learned from each, was Edgar Degas (1834–1917). His early portrait of his sister and brother-in-law, "Duke and Duchess of Morbilli" (Pl. III, fig. 8), shows an indebtedness to Ingres in the relative precision and boldness of the work but also something of the quality of Delacroix in the hesitancy of both husband and wife before the spectators. However, Degas was most conscious of the psychological complexities and tensions in the relationship of two human beings to each other—and in their relationship to the world. Although the work possesses almost the formality of a daguerreotype, Degas makes use of the positions of the figures in relation to each other and in space, their expressions and particularly their gestures to make the nature of their adjustment to each other and to society quite clear. Later Degas found a more personal visual vocabulary to convey the same kind of meaning in his portraits, which influenced such painters as Vincent Van Gogh (1853–90) and Henri de Toulouse-Lautrec (1864–1901).

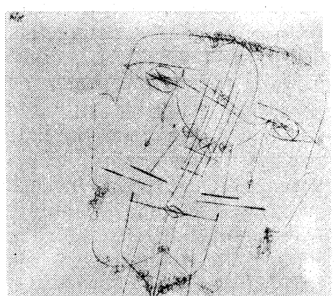
Degas' contemporary and friend Edouard Manet (1832–83) painted portraits which are psychologically uncomplicated, straightforward, but most remarkable, like all his paintings, for their sheer visual beauty (Pl. III, fig. 7). Like Manet. other painters associated with the Impressionists were less concerned with subject matter than with certain visual problems. Even Paul Cézanne (1839–1906), who painted some beautiful portraits, was only incidentally concerned with recording the appearance, personality or virtues of any particular person; his paintings had another function. It might be argued that the decline in the interest of the finest painters in portraiture was a result of the decline in patronage.

However, at the same time that Degas and his friends were receiving little encouragement, there were fashionable portrait painters throughout Europe who made fortunes from this form of art.. Perhaps the best of these was the U.S. expatriate, John Singer Sargent (1856–192j).

Sargent may have suffered somewhat from his generous patronage; indeed he eventually reacted against it and refused to paint more portraits. Whereas the most creative artists of the 19th century. Francisco Goya y Lucientes (1746–1828), Jacques Louis David (1748–1825), Jean Baptiste Corot (1796–1875), Honoré Daumier (1808–79), Jean François Millet (1814–75), Gustave Courbet (1819–77), James Abbott McNeill Whistler (1834–1903), Thomas Eakins (1844–1916) and Pierre Auguste Renoir (1831–1919) besides those already mentioned. revealed an underlying realism and a desire to present the sitter as unpretentiously as possible, Sargent fulfilled his sitters' desires to be ravishingly beautiful or forcefully handsome. In such paintings as "The Wyndham Sisters" he succeeded in giving an illusion of the most beautiful and animated of young women in a work of great brilliance and bravado (Pl. IV). Sargent has survived the criticisms of the 20th century more satisfactorily than such fashionable rivals as Giovanni Boldini (1845–1931) or Philip Alexius Laszlo de Lombos (1869–1937). However, a market for their kind of portraiture still exists.

The 20th Century.— In the first half of the 20th century, even more than during the 19th, the most penetrating portraits have not been the result of commissions of the kind Sargent received. Amedeo Modigliani (1884–1920), an Italian living a poverty-stricken and bohemian life in Paris, painted many of the most successful portraits of this period—but usually of his friends; they might pay him, but he only demanded a paltry sum. Jacques Lipchitz (1891–   ), the sculptor, has written that when he was newly married and he and his wife decided to have their portrait painted by Modigliani, the painter asked ten francs a sitting and insisted it was finished after the first. Lipchitz, in his embarrassment, persuaded Modigliani to work on it longer; however, the sculptor acquired his portrait for a modest sum (Pl. III, fig. 9).

Lipchitz has also written that the pose for this double portrait was inspired by their wedding photograph; this makes it particularly appropriate to compare it with Degas' portrait of the Morbillis which must have been based upon some daguerreotype. Probably a comparison of the photographs, as much as a comparison of the painting. would reveal how much more casually and informally the Lipchitzs were living than the Morbillis had half a century earlier. It is not just that the sculptor wears a turtle-neck sweater or has a hand cockily in his pocket or that the picture behind him on the wall is tilted precariously. It comes out in their perfect ease with the spectators, and even more tellingly in their casual intimacy with each other. Lipchitz places his hand protectively on her shoulder and she leans her head back on his chest with supreme confidence in him and in herself. None of the tensions of the Degas portrait seems to exist.


BY COURTESY OF THE PASADENA ART MUSEUM
"A FIRST SKETCH FOR THE SPECTRE OF A GENIUS" BY PAUL KLEE (1879–1940), SWISS

There is nothing photographic about this double portrait even if a photograph was the source for the composition. Modigliani makes use of visual abstractions, particularly pattern, to interpret this husband and wife. The beautiful oval of the woman's face opens up sensually whereas the features of the husband's face are smaller, cramped and more ingrown. In depending upon such abstractions Modigliani was able to eliminate irrelevant detail. to simplify the work and therefore to concentrate upon those essentials which could suggest their separate personalities, their relationships to each other and to the rest of the world more perfectly than any wedding photograph could.

Twentieth-century portraiture, like all 20th-century art, has been affected by the Freudian analysis of the personality, as is seen in "A First Sketch for the Spectre of a Genius" (see fig.) by the Swiss painter. Paul Klee (1879–1940). The work is a pathetic commentary upon the lack of balance in emotional. physical and spiritual gromth of the genius.

Of all 20th-century painters Pablo Picasso (1881–   ) has been the most creative in the discovery of new visual vocabularies to convey the character of a sitter. He has drawn and painted as meticulously and as representationally as Ingres or he has departed as far from the conventional as it seems possible for a painter to do without losing a sense of the thing portrayed His responses to people in his portraits have been sentimental, cynical, calm. analytical or morally indignant. in each case representing an attitude characteristic of a part of 20th-century society.

In his "Portrait of a Lady" (1937) Picasso continued, as he had for 30 years, to destroy the conventional integrity of the body for his own expressive purposes (Pl. I). With color, pattern, line and important allusions to anatomy, Picasso makes it apparent that a classically beautiful woman is seated. with a certain aplomb, in brilliant sunshine. She seems a typical 20th-century sophisticate in her informality, the smart dress. the lacquered nails and the hand which toys with her long hair. But Picasso was not content to describe her only socially; he designed her dress so that her jacket opens to reveal lines like stamens fanning out to her petal-like breasts; this floral motif seems carried out in the hands. It does not seem improbable that Picasso, with great restraint, is suggesting her sexual urges. But the most startling area is the face. The eye on the left is the strange and frightening red of something possessed; the quieter green eye on the right seems to have turned on itself to regard the other with disturbance and surprise. It is as if this woman, so suave externally, has suddenly become aware of the unknown world of her unconscious. Picasso, like the 20th-century novelist or psychologist, makes the accepted breakdown of the barriers between the normal and the abnormal, the unconscious and the conscious quite explicit. The Surrealists, such as Giorgio de Chirico (1888–), Max Ernst (1891–) and Yves Tanguy (1900–54) delved even more obviously into Freudian realms.

The Judgment of Quality in Portraiture.— How can the quality of a contemporary portrait be determined without the selective critical process of generations? A great portrait painting must be, first of all, a great work of art; this means that every brush stroke will have a structural role in the total painting and will, at the same time, express the attitude of artist toward sitter.

The abstract elements must have a vitality of their own which seems to be the consequence of the creative activity of a painter whose whole being is absorbed in the process. As completely different as such artists as Piero della Francesca, Velázquez or Picasso may be, every part of their work operates in producing visual relationships which make their sitters seem physically and spiritually alive. The portrait, a very difficult form of art, presents other problems about which it is perhaps rash to generalize. However. in all great portrait paintings the suggestion of the intelligence of the sitter seems to surmount the handsome costumes, elaborate settings or an unusual style. Even in Picasso's portraits from the most difficult of all his periods, analytical Cubism, the sense of the particular intelligences of sitters, as in his portraits of Ambroise Vollard, Wilhelm Uhde and Daniel Henry Kahnweiler, is finally triumphant. The great portrait. whatever the period. seems to be the product of the painter's imagination before a sitter whom this painter. because of his temperament and background, is fully able to understand. Being the product of the painter's imagination, it is thus strange to his contemporaries and impossible to anticipate.

See also PAINTING; OIL PAINTING, TECHNIQUE OF.

BIBLIOGRAPHY.—M. J. Friedlander, *Landscnpr, Portrait, Still-Life* (1949); F. Wormwald, "The Wilton Diptych," *Journal of the Courtauld and Warburg Institutes,* 17:191 (July–Dec. 1954); M. Wheeler, *Twentieth Century Portraits* (1942); *A.L.A. Portrait Index* (1906); Jacob Burckhardt, *Das Portrait* (1908); Herbert Fuerst, *Portrait Painting* (1927); Ludwig Goldscheider (ed.), *Five Hundred Self-Portraits* (1936). *See* also bibliographies of the articles on the individual painters and of PAINTING. (J. S. Bs.; X.)

PORT ROYAL, an island of Beaufort county, S.C., U.S., 50 mi. S.W. of Charleston, one of the Sea Islands. It is about 13 mi. long and 7 mi. wide. The principal city is Beaufort, a port of entry and seat of Beaufort county. The town of Port Royal is on the southern tip of the island, 5 mi. S. of Beaufort; its population is about 800. Major occupations of the area include fishing, shrimp and crab processing, cypress and pine lumbering, cattle and cotton farming and employment at nearby Parris Island. a U.S. marine corps installation devoted primarily to the basic training of enlisted personnel. Old plantation homes, vast oaks covered with Spanish moss and nearby beaches make Port Royal an exotic resort area.

The port was named Santa Elena by Spanish explorers in the early 16th century. In 1562 the French Huguenot. Jean Ribaut, seeking a haven for French Protestants and a privateering base against Spanish shipping, renamed it Port Royal and left 30 settlers on Parris Island, three miles from the present town of Port Royal. Neglected by Ribaut, after two years the settlers killed the commander he had left in charge, built a tiny ship and returned to Europe. The Spanish occupied the area more or less continuously from 1566 to 1650, maintaining garrisons and Indian missions. English claims to Carolina grew with the settlement of Charleston in 1670, and in 1684 Henry Erskin (Lord Cardross) led 51 Scottish Covenanters to Stuart's Town, 1 mi. N. of the present town of Port Royal. Charlestonians looked upon the Scots as trade rivals and ignored pleas for help when Stuart's Town was destroyed by Spanish and Indians in 1686. Gradually planters moved into the area, and in 1710 Henry Somerset (Duke of Beaufort) established the present town of Beaufort. In Jan. 1779, during the American Revolution, the British occupied the area but were dislodged the following month. After the Revolution the Port Royal environs became the centre of opulent rice and cotton plantations, and scores of magnificent ante-bellum homes attest to this golden age. Early in the American Civil War, on Nov. 6–7, 1861, a fleet of 56 Union vessels, and 12,000 men under Gen. Thomas W. Sherman, reduced the Confederate fortifications and used the port as a Union coaling and repair station for the remainder of the war. Northern abolitionists, supported by the U.S. government, conducted the Port Royal experiment during and immediately after the war, confiscating the lands abandoned by white planters and seeking, with mediocre success. to educate the ex-slaves of the area and give them control over local lands and government. (G. H. CT.)

PORT ROYAL, a celebrated Cistercian abbey, occupied a low and marshy site in the thickly wooded valley of the Yvette, at what is now known as Les Hameaux near Marly, a few miles southwest of Paris. It was founded in 1204 by Mahaut de Garlande, wife of Mathieu de Montmorenci-Marli in 1204; the church was built in 1229. During the three succeeding centuries its discipline became relaxed; reform was only attempted when Angélique Arnauld (*q.v.*) was appointed coadjutor to the abbess in 1598. Angélique's reforming energy soon brought her into contact with Jean du Vergier (*q.v.*) abbot of Saint Cyran, and chief apostle in France of the Jansenist revival.

In 1626 ague drove the nuns to Paris; they settled at Port Royal de Paris, at the end of the Faubourg Saint Jacques. The deserted buildings of Port Royal des Champs were presently occupied by "hermits," laymen, mostly relatives of the abbess, who wished for a semimonastic existence, though without taking formal vows. In 1648, however, some of the nuns returned, and the hermits retreated a short distance from the abbey. Here they set up a "little school" for the sons of Jansenist parents; and here Racine received his education. But in 1653 Innocent X condemned Jansenism and in 1656 "the hermitage" and school were broken up, and the nuns forhidden to receive new members.

In 1660 Louis XIV condemned the order and, between 1664 and 1669, the archbishop of Paris laid under an interdict those nuns who refused to subscribe to the papal censure on Jansen. In 1669, however, came the so-called "Peace of Clement IX," when the Jansenists generally were admitted to grace, and the interdict was removed from Port Royal, though the authorities broke up the convent into two distinct communities. The conformist nuns were gathered together at Port Royal de Paris, under an independent abbess, their Jansenist sisters at the original building in the country. Thereupon followed ten years of peace, through the protection of the king's cousin, Mme. de Longueville. But in 1679 she died, and Louis at once ordered the nuns to send away their novices and boarders and to receive no others. Finally, in 1705, he got from Clement XI a new condemnation of the Jansenists, which the few remaining nuns, all of whom were over sixty, refused to sign; and on the 29th of October 1709 they were forcibly removed from Port Royal by the police, and distributed among various conformist convents. In the next year the buildings were pulled down. The land on which the convent had stood was made over to Mme. de Maintenon's college of St. Cyr; in 1825 it was bought by some descendants of Jansenist families, who have done their best to restore the grounds to their original appearance, and have built a museum rich in Jansenist relics. Port Royal de Paris was secularized at the French Revolution, and is now a maternity hospital.

For a classified list of the chief hooks, ancient and modern, dealing with Port Royal, *see* the *Abrégé de l'histoire de Port Royal*, by Jean Racine, ed. by E. Gazier (Paris, 1908). *See* also C. A. Sainte-Beuve, *Port Royal*. 6 vol. and index (Paris, 1882); Charles Beard, *Port Royal*, 2 vol. (London, 1861); H. Reuchlin, *Geschichte von Port Royal*, 2 vol. (Hamburg, 1839–44); and the hooks recommended under the articles ARNAULD; JANSENISM; and PASCAL, BLAISE.

PORTRUSH, an urban district and seaside resort of County Antrim, Northern Ireland, terminus of a branch line from Coleraine. Pop. (1961) 4,263. Area 0.8 sq.mi. It is situated on the basaltic peninsula of Ramore head. with a deep bay on either side and a harbour. Out to sea lie the small rocky islands called the Skerries. The Giant's Causeway lies 7 mi. E. along the coast. Close beside Portrush the extensive ruins of Dunluce castle stand on a rock separated from the mainland by a chasm spanned by a bridge. Portrush has a salmon trade.

PORT SAID, a seaport of Egypt, at the entrance of the Suez canal, in 31° 15′ 35″ N., 32° 19′ 20″ E., and 145 mi. N.E. of Cairo by rail. pop. (1957) 212.973, lies on the western side of the canal on the low, narrow and treeless strip of land which separates the Mediterranean from Lake Menzala, the land at this point being raised and its area increased by the draining of part of the lake and by the excavation of the inner harbour. The outer harbour is formed by two breakwaters which protect the entrance to the canal; altogether the harbour covers about 570 ac. and accommodates ships drawing 28 ft. The port possesses a floating dock 295 ft. long, 85 ft. broad and 18 ft. deep, capable of lifting 3,500 tons, and a patent slip taking 300 tons and ships drawing 9 ft. 9 in. of water. On the western breakwater is a colossal statue of Ferdinand de Lesseps by E. Fremiet, unveiled in 1899, and a lighthouse 174 ft. high. Among the few buildings of note in the town are the offices of the Suez Canal company and the British barracks. the last having been built by Prince Henry of the Netherlands (d. 1879) as a dépot for Dutch trade.

Port Said dates from 1859. Originally it depended entirely upon the traffic of the canal, being the chief coaling station of all ships passing through and becoming the largest coaling station in the world. In 1902, however, a new industry was added in the export of cotton from the eastern provinces of the delta, the cotton being brought from Mataria by boat across Lake Menzala. In 1904 the opening of a standard gauge railway to Cairo placed Port Said in a position to compete with Alexandria for the external trade of Egypt generally, besides making it a tourist route to the capital from Europe.

PORTSMOUTH, EARLS OF. In 1743 John Wallop (1690–1762) of Farleigh-Wallop in Hampshire was created earl of Portsmouth. He belonged to an old Hampshire family and had been a lord of the treasury from 1717 to 1720, when he'was created Baron Wallop and Viscount Lymington. Gerard Vernon Wallop (b. 1898) became the 9th earl in 1943; he had been Unionist member of parliament for Basingstoke (1929–34) and was the author of several books, including *Alternative to Death* (1943).

PORTSMOUTH, LOUISE DE KÉROUALLE, DUCHESS OF (1649–1734), mistress of the English king Charles II, was placed early in life in the household of Henrietta. duchess of Orléans, Charles's sister. whom she accompanied during the negotiation of the treaty of Dover in 1670. Charles soon placed her among the queen's ladies in waiting. Her intrigue with him was vigorously pushed by the French ambassador, Charles Colbert de Croissy. aided by the secretary of state, Lord Arlington, and his wife. Louise, who concealed great cleverness and a strong will under an appearance of languor and a rather childish beauty (Evelyn the diarist speaks of her "baby face"), yielded only when she had already established a strong hold on the king's affections. Her son, ancestor of the dukes of Richmond (*q.v.*), was born in 1672.

The support she received from the French envoy was given on the understanding that she should serve the interests of her native sovereign. The bargain was confirmed by gifts and honours from Louis XIV and was loyally carried out by Louise. The hatred openly avowed for her in England resulted as much from her own activity in the interest of France as from her notorious rapacity. The titles of Baroness Petersfield, countess of Fareham and duchess of Portsmouth were granted her for life in 1673. Her pensions and money allowances of various kinds were enormous. In 1677 alone she received £27,300. Soon after the king's death she retired to France, where, except for one short visit to England during the reign of James II, she remained. Her emoluments were lost in her later years, which were spent on her estate at Aubigny (raised to a duchy in 1684), but she was protected from her creditors by Louis XIV. She died in Paris on Nov. 14, 1734.

See H. Forneron, *Louise de Kéroualle* (Paris, 1886).

PORTSMOUTH, a city, county and parliamentary borough, seaport and naval base of Hampshire, Eng., 70 mi. S.W. from London by road. Pop. (1961) 215.198. Area 14.5 sq.mi. The city suffered heavy air raids during World War II. About 93% of the houses were damaged and the guildhall (1890), both the main shopping centres and many public buildings were gutted.

Portsmouth owes its origin to the retreat of the sea from Portchester. No town existed there until the 12th century, when its strategical advantage induced Richard I to build one. The borough is governed by a charter granted by Charles I in 1627, modified by the municipal acts of the 19th century. The market, dating from 1194, is held on Tuesday, Thursday and Saturday.

The naval station and arsenal (known to seamen as "Pompey") is an aggregate of four towns, Portsmouth. Portsea, Landport and Southsea, and occupies the southwestern part of Portsea Island, which lies between Portsmouth harbour and Langstone harbour, two inlets of the English channel. Road and railway bridges connect the island and mainland. Portsmouth harbour opens into Spithead. the eastern end of the Solent (*q.v.*) which separates the Isle of Wight from the mainland. The harbour widens inward in bottle form, Portsmouth lying on the east shore of the neck, with Gosport (*q.v.*) opposite to it on the west side. Hayling Island is east of Langstone harbour. Portsmouth proper may be distinguished as the garrison town; Portsea as the naval station with the dockyards; Landport is occupied chiefly by the houses of artisans; and Southsea is a residential quarter and a holiday resort. There is a modern Roman Catholic cathedral. The cruciform church of St. Thomas Becket dates from about 1180 and in 193j extensions were begun consisting of the nave and aisles because in 1924 the foundation of a new diocese of Portsmouth and the Isle of Wight, taken from that of Winchester: was approved, and St. Thomas's was designated as the procathedral. The see was created in 1927. The garrison chapel originally belonged to the hospital of St. Nicholas. a foundation of the 13th century. Among interesting buildings which survived World War II is the Dickens museum (393 Commercial road) in which Charles Dickens was born in 1812. Other distinguished natives of Portsmouth are George Meredith. Sir Walter Besant and Isambard Brunel.

Passenger steamers from Portsmouth harbour serve Ryde on the Isle of Wight. A ferry and a floating bridge connect with Gosport. The civil airport is at Hilsea, immediately northeast of Portsmouth. The parliamentary borough is divided into Langstone, South, and West divisions, each returning one member. The county borough was created in 1888 and raised to the dignity of a city (1926) with a lord mayor in 1928.

Lord Nelson's flagship. H.M.S. "Victory," on which he met his death at Trafalgar in 1805, is in drydock in Portsmouth and is the flagship of the admiral of the station. The Victory museum has relics of Nelson.

The dockyard dates in its earliest form from 1496, though the town was already of importance as a naval station. Its later rise began with the building of one dry and two wet docks in 1698. Portsmouth royal dockyard covers more than 300 ac. and includes four large drydocks, 75 ac. of fitting and repairing basins and a vast conglomeration of workshops and other installations. There is a gunnery establishment on Whale Island and barracks, including those of the royal marine artillery at Eastney, beyond Southsea. Admiralty establishments provide employment for a large proportion of the population. Other industries are shipbuilding and aircraft engineering and the manufacture of corsets, cardboard boxes, brushes, refrigerators, etc. There are industrial estates at Fratton, Drayton and Farlington.

PORTSMOUTH, a city of New Hampshire, U.S., named after Portsmouth, Eng., is New Hampshire's oldest settlement, second oldest city, first capital and only seaport. Situated on the Piscataqua river near its entrance into the Atlantic ocean, it is about 60 mi. N. of Boston, Mass., and about 50 mi. S.W. of Portland, Me. Known as the Old Town by the Sea and the Queen of the Piscataqua, it is rich in historic associations and on its winding streets, tree-shaded and narrow, there are still examples of prerevolutionary architecture, ranging from the earliest simple salt-box style to the dignified 18th-century mansions, tall and square, built on the profits of the city's 18th-century shipbuilding and sailing trade.

Only three years after the Pilgrims settled at Plymouth a fishing settlement was planted 2 mi. E. of the present city. The next year (1624) settlement was made at Portsmouth proper, called successively Piscataqua and Strawberry Bank and finally in 1653 incorporated under its present name. Portsmouth was the seat of the provincial government of New Hampshire and the home of the famous Wentworth family which furnished two royal governors. Adjacent Newcastle was the scene of one of the earliest military events of the Revolution in the patriot capture of Ft. William and Mary from the British in 1774.

In the first half of the 19th century Portsmouth suffered a gradual decline of its commerce and settled down to its present status of a trading centre and home of small industry. The continuance and growth of one of the first U.S. navy yards, dating from the 1790s, has been important as a major economic support for the area. Although it is actually on Seavey's Island in the river (and so in Kittery, Me.) the establishment is known as the Portsmouth Navy yard. There in 1905 treaty negotiations ended the Russo-Japanese War. In the 20th century the yard became a centre for the building and repair of submarines. Connected with it are a naval hospital and a naval prison. The development of the large Pease air force base in Newington, just outside Portsmouth, has also been of great economic advantage to the area.

Portsmouth is located on a famous coastal highway, and for more rapid travel north and south the New Hampshire and Maine turnpikes are easily accessible. The city has a council-manager form of government, in effect since 1948. For comparative population figures *see* table in NEW HAMPSHIRE: *Population.* (A. R. F.)

PORTSMOUTH, a city of southern Ohio, U.S., on the Ohio river at the mouth of the Scioto; the seat of Scioto county. The city is protected by a $10,000,000 flood wall 27 ft. above the flood stage of the Ohio river, which was completed in 1950. Founded in 180'3 by Maj. Henry Massie, a land speculator from Goochland county, Va., Portsmouth was incorporated as a town in 1815 and as a city in 1851. While it shared in the down-river flatboat trade in agricultural produce from the beginning, its real importance dates from the opening of the Ohio and Erie canal in 1832, when it became a point of transfer from canal barges to river packets. During the remainder of the steamboat era, it was a typical river town. When steamboating declined, it became an important railway centre. From the industrial point of view, it has been noted for the manufacture of pottery, shoes and especially iron and steel. There are large sandstone quarries in nearby ravines which have supplied material for many important structures, including the Canadian parliament buildings at Ottawa. After 1952 Portsmouth's economy was greatly stimulated by the building and operation of a gaseous-diffusion plant of the Atomic Energy commission near Piketon, 25 mi. N. Some notable earthworks of the mound builders are in and near Portsmouth. There is a branch of Ohio university in the city. Portsmouth has a council-manager form of government. in effect since 1930. For comparative population figures *see* table in OHIO: *Population.* (R. L. J.)

PORTSMOUTH, a port city in southeastern Virginia, U.S., on the south shore of the Elizabeth river (an estuary of Hampton Roads), opposite the city of Norfolk (*q.v.*), with which its history has been closely associated; the seat of Norfolk county but politically independent of it. The normal annual temperature of Portsmouth is 60.7" F. It was settled in 1752 by people interested in trade but after the American Revolution the town refused to permit the settlement of British merchants. The Norfolk naval yard was established in Portsmouth by the U.S. government in 1801. In 1855 the population was decimated by yellow fever. When Federal troops evacuated the navy yard in 1861 the South fell heir to great stores of equipment and built the Confederate ironclad "Virginia" from the hull of the scuttled U.S.S. "Merrimack." The yard was recaptured by the Federals in 1862. Portsmouth received a city charter in 1858 and has a council-manager form of government, in effect since 1917.

Portsmouth, a part of the port of Norfolk, has oil and railroad terminals and enjoys steamship connections with world ports. The giant navy yard is the principal industrial employer but private shipbuilding yards and railroad shops are important. Portsmouth's manufactures include chemicals, plastics, fertilizer, machine tools, railroad equipment and peanut butter. The Intracoastal waterway runs southward past Portsmouth to the Great Dismal swamp, a haven for hunters and naturalists. The city has a Little Theatre group, a concert association, three swimming lakes, supervised public playgrounds and a naval museum, and is the site of Frederick college, a junior college for men, founded in 1958. Pop. (1960) 114,773. For comparative population figures *see* table in VIRGINIA : *Population.* (G. M. BE.)

PORTSMOUTH, TREATY OF, peace treaty that ended the Russo-Japanese War (*q.v.*). By June 1905 Japan realized that, despite an almost unbroken series of victories, it was no match for Russia in a long war. Russia, meanwhile, having suffered stinging defeats in a conflict which was unpopular with its people, was also looking for a way to end hostilities. Thus, when the president of the United States, Theodore Roosevelt, offered to mediate their differences, both sides accepted. Representatives from the warring nations met at Portsmouth, N.H., on Aug. 9, 1905, and on Sept. 5 signed a treaty providing that Russia would surrender its lease of the Kwantung peninsula and Port Arthur; that both nations would evacuate Manchuria and return it to China; that Japan's sphere of influence in Korea would be recognized by Russia; and that the island of Sakhalin would be divided at lat. 50° N. between Japan and Russia. Japan also was to have fishing rights in the Bering and Okhotsk seas. Acclaimed for his successful efforts to end the war, President Roosevelt was awarded the Nobel peace prize in 1906.

PORT SUDAN, a town and harbour of Sudan, on the west coast of the Red sea, in 19° 39' N. lat. and 37° 14' E. long., approximately 700 mi. by sea south of Suez and approximately 497 mi. by rail northeast of Khartoum and 295 mi. east of the Nile valley, which the railway joins at Atbara. Pop. (1956) 47,562. The coral reefs fringing the coast are there broken by a straight channel with deep water giving access to the harbour from which a short arm branches off westward close within the entrance. Depth 10 to 14 fathoms; at the main quays 33 ft. On the northeast side of the inlet are the main quays fitted with electric cranes, etc. There are the customs house, import clearance sheds and the warehousing area. The town proper lies on the southwest side of the inlet connected with the main quays by a causeway. Besides government offices, the public buildings include a hospital and schools.

The port dates from 1908. It owes its existence to the desire of the Sudan administration to find a harbour more suitable than Suakin for the commerce of the country. The railway (which has termini both at Port Sudan and Suakin) was opened in Jan. 1906. Port Sudan immediately attracted a large trade and became a regular port of call of British, German, Italian and other steamers. The imports are largely cotton goods, coal, oil, petroleum, provisions, machinery, timber and cement; the exports cotton lint, gum, sesame, durra, ivory, senna, coffee, sheep and goatskins, etc. Eighty miles north of Port Sudan is Mohammed

Gul, the port for the mines of Gebet.

PORT TALBOT, a municipal borough in the Aberavon parliamentary division of Glamorgan, Wales, on the Avon (Afan) near its mouth in Swansea bay, 31 mi. W.N.W. of Cardiff by road. Pop. (1961) 50.223. Area 36.6 sq.mi. Port Talbot docks were opened in 1837 and enlarged in 1898 when, after the coming of the railmays, coal from the Afan valley was carried by rail for export from the docks. With the passing of the Railways act in 1921, the Great Western Railway company took over the docks, and Port Talbot became one of the south Wales chain of ports for coal from the Rhondda and other valleys. It suffered severely in the depression of the 1930s. The docks are now used for the export of coal and coke. iron and steel, tin plate, etc., and the import of iron ore, timber and other mainly heavy-class goods. In 1947 the gigantic Abbey steel works at Margam were built by four companies as a reconstruction project for bringing up to date the sheet steel and tin plate industries of south Wales. This led, in turn, to the adaptation of the docks to meet the additional traffic. The steel works are named after Margam abbey, a Cistercian foundation of 1147, on which land they are built near the ruins of the abbey and also near Margam castle and the docks. hlargam urban district and Aberavon town were amalgamated in 1921 under the name of Port Talbot.

Besides workers in steel, oxygen, industrial solvents, etc., and on the docks. Port Talbot has a farming community. Two agricultural shows and a horticultural show are held annually as well as open and local shows of the Port Talbot Cage Birds society. The Aberavon fair (formerly a flannel fair) is held twice yearly under the 13th-century charter of Hugh le Despenser. On the beach, with its fine stretch of sand, is a pleasure fair near the promenade. A sea mall was being built in 1956. On reclaimed marshland to the west of the town the large housing estate of Sandfields was constructed. Open spaces include the Talbot and Vivian Memorial parks, each of 12 ac.

PORTUGAL, a republic of southwestern Europe, forming part of the Iberian peninsula and bounded on the north and east by the Spanish provinces of Galicia, León, Extremadura and Andalusia and on the south and west by the Atlantic ocean. For administrative purposes Portugal includes the Azores (about 700 mi. W. of Lisbon) and the Madeira group of islands. The total population amounted to 7,722,152 in 1940 and to 9,130,410 in 1960: the figures for continental Portugal were 7.185.143 in 1940 and 8,510,799 in 1960. The area of continental Portugal is 34.139 sq.mi., that of the Atlantic islands 1,201 sq.mi. In shape the country is a rough rectangle, its parallel sides running from east to west about 362 mi. apart and its breadth varying from 140 mi. in the north to about 70 mi. in the southern Alentejo.

Portugal's land frontiers are partly defined by mountains and by its four principal rivers. In the northwest the lower course of the Minho divides Portugal from Galicia, but from its middle course to Miranda do Douro the frontier usually follows mountain ranges. From Miranda to Barca de Alva the Douro marks the limit. which then drops raggedly to the level of the Tagus. The frontier follows the Tagus westward for a little way, then cuts across country to the Guadiana. ,From Mourão southward Portugal extends beyond the Guadiana and there is no natural feature to divide it from Spanish Extremadura. In its lower course the Guadiana again forms the frontier.

The Portuguese seaboard is about 500 mi. long. The only islands near the coast are the dangerous Farilhões and Berlings (Portuguese Berlengas) off Cape Carvoeiro. Most of the Portuguese coast is a series of long and gradual curves, with few indentations. Long sandy beaches are general, but Cape Rock (Cabo da Roca; *i.e.,* the Distaff) and Cape Espichel are rocky headlands north and south of the Tagus where the mountains reach the sea. Sines is another headland, and Cape St. Vincent (Cabo de São Vicente), the southwestern extremity of the country, has rough cliffs. There are sandy islands off the coast of the Algarve. The estuaries of the Tagus and Sado form considerable indentations. The former contains a small inland sea, the Mar da Palha. separated from the ocean by the narrows of the "Lisbon river"; the capital, on the north shore, is also the country's largest port. The Sado estuary lies before the port of Setúbal. The estuary of the Douro contains the great city of Oporto (though the port installations are outside the estuary at Leixões). The Mondego estuary has the small port and resort of Figueira da Foz. A number of other ports scattered round the coast are important for sardine and tunny fishing, but their harbours are almost all suitable only for small ships.

The "Atlantic Islands"—that is the Azores and Madeira (*qq.v.*) but not the Cape Verde Islands—have since 1832 formed part of metropolitan Portugal. The nine islands of the Azores have an area of 894 sq.mi. and a population (1960) of 336.933; the Madeira group. consisting of Madeira itself, Porto Santo and the uninhabited Desertas and Selvagens (Salvages) islands. has an area of 307 sq.mi. and a population of 282,678 (1960).

Physical Features.—The scenery of Portugal is rather diverse in relation to its limited area; both fauna and flora vary considerably within small distances. A broad distinction may be made between the area north of the Tagus, which is hilly (about half of it above 1,300 ft.), and that to the south, which is flat (97% of it below 1,300 ft.) except for the hills of Monchique which divide the Algarve from the Alentejo. Generally speaking, Portugal begins at the western edge of the Spanish meseta and shelves away from Spain and down to the Atlantic seaboard.

Northern Portugal comprises the provinces of Minho and Douro Litoral, which form the humid coastal region of pinewoods, maize fields and "green wine" (vinho verde), and the more mountainous interior province of Trbs-0s-Montes e Alto Douro, which includes bare ranges of mountains interspersed by forests of oak and chestnut and valleys in which cereals, olives and root crops are grown. The upper Douro valley where the river has cut through a deep stony gorge forms the celebrated wine country (*pais* do ***vinho)*** from which port wine derives its special qualities.

South of the Douro there is a coastal strip. the province of Beira Litoral. similar to the coast farther north, with fields of cereals and root crops and pinewoods; Aveiro, with its salt-water lagoon and canals. has an ancient salt industry. Inland, Beira Alta and the northern part of Beira Baixa share the Serra da Estrêla. the highest range of mountains in Portugal, which falls away in rough scrubby slopes toward the Spanish frontier. The folds of middle Beira form a transition area that produces good wine. The region of Castelo Branco in Beira Baixa is suitable for extensive agriculture with olives and cork trees. The Tagus valley, round which is formed the province of Ribatejo, is a rich alluvial region, and the flat and fertile fields known as *lezírias* bear cereals, fruits, rice and market produce, which form the wealth of the district of Santarém. To the southeast of Ribatejo is Alto Alentejo, where frontier areas of cork oaks and olives are broken by extensive stretches of sparsely inhabited heath. This country gradually merges into the extensively cultivated wheat-growing district of Beja in the province of Baixo Alentejo. The mountains and heath of Monchique divide this area from the seaboard of the Algarve, which partakes rather of the character of Andalusia or northwest Africa, being rich in fruit trees, especially the almond, fig and carob.

As has been mentioned. the highest mountains of Portugal are in the Serra da Estrêla (6,532 ft.), which forms the backbone of Beira. The next highest land is the Transmontane system on the Galician frontier. whose ranges are usually continuations of those in Spanish terrıtory. the Serra do Gerez reaches 4,944 ft.; Larouco, adjoining Gerez, j 003 ft.; Peneda. overlooking the river Minho, 4.646 ft.; Marão. betneen the Douro and Tâmega, 4,642 ft.; and Nogueira, near Braganza. 4,324 ft.

Between the Douro and the Mondego, the chief ranges are the hlontemuro (4,534 ft.). the Serra da Arada 13.661 ft.), the Serra do Caramulo (3.514 ft.) and the Serra da Lapa (3.127 ft). The Serra da Estrêla is continued in the Serra de Lousd (3,950 ft.). Betneen Lisbon and the sea rise the charming hills of Cintra (Sintra), which nith the Serra da Arrábida (1.644 ft.) form an amphitheatre round the capital, broken by the Tagus valley. South of the Tagus on the Spanish frontier there are several blocks of high land or single ridges, including Sdo Mamede (3.363 ft.), Ossa (2,142 ft) and Monfurado (1,391 ft.). The Monchique range in the northern Algarve reaches 2,959 ft.

The rivers of Portugal comprise four large streams, which have their sources in Spain, and a number of shorter ones. The Douro (Spanish Duero), Tagus (Portuguese Tejo. Spanish Tajoj, Guadiana and Minho (Spanish Miño) are the main rivers (see DOURO; GUADIANA; TAGUS). All four form for part of their courses sections of the frontier. but none of them is navigable in an international sense: Portugal is consequently not the natural port for the wares of western Spain. The Minho, 210 mi. long, can take small coasters for about 20 mi. The Lima (Spanish Limia) rises in Galicia, but its main course is in Portugal; on its estuary is the port of Viana do Castelo. The Cávado and Ave flow into the sea at Espozende and Vila do Conde. South of the Douro, the main rivers are the Vouga, rising in the Serra da Lapa and flowing into the lagoon at Aveiro; the Mondego, 137 mi. long, the longest river wholly in Portuguese territory, which rises in the Serra da Estrêla. runs first northeast, then turns back to flow through the picturesque gorge of Penacova, round the foot of the hill on which Coimbra is built and to the sea at Figueira da Foz. The Zézere, rising north of the Serra da Malcata, is a tributary of the Tagus from the north. The Sorraia flows into the Tagus estuary from the south. South of the Tagus, the Sado rises near Ourique and flows northward into a large bay on which is the port of Setúbal.

Portugal abounds in hot springs, often known as caldas (*e.g.*, Caldas da Rainha, Caldas de Monchique, etc.). These springs are used for medicinal purposes, and the resorts are much frequented.

On the Spanish frontier the scenery is rough and somewhat monotonous, rising to grandeur only in the gorge of the Douro and on the heights of Alto Alentejo; but the interior and coast are varied and pleasantly coloured. On the northern coastal area the effects of mist are attractive, and the softness of the light is in contrast with the dazzling summers of the extreme south. Where the soil is good, a wide variety of temperate and semitropical vegetation can be grown. and in Portugal the regions of palm and pine come close together. Although these favoured areas give the impression of a "garden planted by the sea," it is also true that much of the soil is poor and the rocky hillsides are often unproductive.

For the geology of Portugal, as part of the Iberian peninsula, see SPAIN.

Climate.—The climate of Portugal is usually mild, equable and temperate. The mean temperatures of the four cities of Lisbon, Oporto, Coimbra and Evora are between 60° F. and 61.5° F., and the daily variation nowhere exceeds 23° F. At Lisbon snow is almost unknown, and the heat of summer is tempered by a breeze which blows every evening (nortada). At Oporto the temperatures are a little lower and the whole year is damper, while the Algarve is sufficiently far south to experience considerable heat in August. In the interior the climate is affected by the Spanish meseta, and the northern and central frontier zones are hotter in summer than the seaboard and bleaker in winter; the deeper valleys are shielded by the mountains from cool winds and are sometimes oppressively hot in summer! while the summits of the mountains overlooking them remain fresh. The coldest place in Portugal is the high range of the Serra da Estrêla, where the annual mean temperature is less than 45° F. Heavy snowfalls lie on the mountain tops for several months of the year, but perpetual snow is unknown.

Rainfall varies considerably and reaches as much as 110 in. in the Serra da Estrêla and the northern coastal area. In the interior, drought is not uncommon and sometimes seriously affects crops, whose production may consequently vary considerably from year to year. Fog is common off the coast and is sometimes dangerous to shipping. Violent storms are infrequent, but earthquake tremors are felt from time to time. Several severe earthquakes are on record in historic times; by far the most violent was that of Lisbon (*q.v.*) of Nov. 1, 17jj.

Fauna **and** Flora.—For the fauna of the Iberian peninsula as a whole, see SPAIN. Wolves are found in the wilder and more mountainous areas, notably the Serra da Estrêla, and wild boars are preserved in certain districts. Bears existed in historic times but have long been extinct. The birds of Portugal are varied, but their distribution is often restricted to certain limited areas and they are rather inadequately protected.

A mixture of temperate and semitropical vegetation is characteristic of Portugal, where many of the plants of northern Europe flourish side by side with others introduced from Africa, the Americas and the east; thus, the slopes of Cintra are covered with pines and familiar deciduous trees, interspersed with specimens of cacti, palms, aloes and tree ferns. This is in contrast with Spain, where the vegetation, though its variety is almost equally great, is divided among zones that are rather severely demarcated. The difference is caused by the higher rainfall of Portugal, which is brought in on winds from the Atlantic and dropped before the Spanish frontier. In a number of places there are fine stretches of forest, among which the woods of Bussaco (see BUSSACO, SERRA DO) deserve to be mentioned. North of the Tagus the lime, elm, poplar and pine are common; the chestnut is grown for its fruit, and the Barbary oak (Quercus bellota, Portuguese *azenheiro*) for its acorns and charcoal, which is widely used as fuel. The cork oak is widely distributed, and the cork is of great importance in Portugal's export trade; the most important cork-bearing region is the Alentejo. The olive is also widely distributed and of no less economic importance. The carob (Ceratonia *siliqua,* Portuguese *alfarrobeira*) produces edible seed pods. Numerous conifers are grown for their timber and resin; they include the *Cupressus lusitanica*, probably a native of the Azores. Other common trees are the ilex. araucaria, myrtle and magnolia. The Australian eucalyptus flourishes, being remarkable for the rapidity of its growth. Also to be found are the agave, the Mexican opuntia, the American maple, the jacaranda and other witnesses of Portuguese enterprise in the four corners of the earth. Among specialized flora the Serra de Estrêla may be mentioned for its alpines and the lagoon at Aveiro for its aquatic plants.

HISTORY

Portugal has existed as an independent state since the 12th century, when it finally detached itself from León. Possibly even two centuries earlier there was a county of Portugal; but before this the area that is now so called had no consecutive political history independent of Spain's, nor indeed a distinctive name. An account of the common experience of the Iberian peninsula in Roman, Visigothic and Moslem times is given in the article SPAIN. but it should be remembered that the lack of independent administrative records does not disprove the ethnical and geographical dissimilarity of early Portugal from neighbouring territories. The Lusitanians, a tribe of what is now northern Portugal with relatives in adjacent Spain, fiercely resisted the Romans not only in their own tribal territory but as far afield as Andalusia. Their leader Viriatus being killed by treachery, they were subdued; but their name was later given to the westernmost of the three provinces into which M. Vipsanius Agrippa divided the peninsula (27 B.C.). The Roman Lusitania included most of modern Portugal but also spread eastward, its capital being at Mérida in Spain.

After the Germanic invasions (409–418), the Suebi maintained for a time an independent kingdom in the northwest, but this was incorporated into Visigothic Spain in 585. From this time until the Moslem invasion of 711 Portuguese history is undifferentiable from the little that is known of the Visigothic kingdom. With the fall of this power, the whole of Portugal passed under Moslem rule; but there was little Arab or Berber settlement in the north, and within half a century the expansion of the Christian kingdom of Asturias and León put an end to Moslem power north of the Douro.

The County and the Kingdom **(to 1383).**—It was in this early period of reconquest and resettlement that the phrase terra *portucalis* was first used. Derived from the name of a Roman settlement on the shore of the Douro, Portus Cale, it came to be applied to a wider area from the Douro to the Galician frontier, the Minho. This area became in the 10th century an hereditary county, when the first known governors were Dona Mumadona and her husband Mendo Gonçalves. Half a century later a member of this family was tutor and later father-in-law to Alphonso V of León, but under Ferdinand I, "the Great", of Castile and León it appears to have lost its influence. In 1064 Ferdinand carried the reconquest down to the Mondego, capturing Coimbra and appointing a separate governor there.

Under Alphonso VI of León (1065–1109) and Castile (1072–1109), the county of Portugal reappears and incorporates the district of Coimbra, to form the domain of Alphonso's illegitimate daughter Teresa and her husband Henry, brother of Duke Odo (Eudes) I of Burgundy. From 1095, therefore, Count Henry and Queen Teresa, as she sometimes called herself, governed Portugal and held the Coimbra frontier as vassals of León. On the death of Alphonso VI, when León passed to his legitimate daughter Urraca, Henry attempted to invade her domains, but little had been accomplished when he died in 1112. His son Alphonso (Afonso) I, called Henriques, was an infant; and his widow, actuated by jealousy of her half-sister, vainly endeavoured to intervene in the affairs of León and Galicia. Her association with her Galician favourite Fernão Peres, count of Trava, lost her the esteem of the Portuguese nobility and clergy. In 1128, after she had again embroiled Portugal in a futile conflict with León, supporters of her young son defeated her followers in the battle of São Mamede, and she and Fernão Peres were exiled.

Already in 1124 Urraca's son Alfonso VII had armed himself knight and been declared king of León. His cousin Alphonso Henriques similarly armed himself knight (a privilege usually confined to kings) a year later and, on the banishment of his mother, became count of Portugal. During his first years Alphonso Henriques fought vigorously on all frontiers, invading Galicia in the north and repelling the Moslems in the south. On July 25, 1139, he defeated the Moslems in the battle of Ourique (probably not the modern town of the same name). Soon after. he assumed the royal style (1140). In 1143, as a result of his campaigns and of negotiations with his cousin, his independence was admitted by León, and he placed Portugal under the direct protection of the Holy See, promising to pay an annual tribute. In March 1147 he carried the frontiers of Christian Portugal south to the Tagus with the capture of Santarém, and the arrival of a band of English, French, Flemish and German crusaders bound for Palestine enabled him to form a temporary alliance and to undertake the siege of Lisbon, which fell on Oct. 24, 1147. An English crusader, Gilbert of Hastings, became the first bishop of the restored see of Lisbon.

In Alphonso's later years, from 1179 to 1184, the Moslems, stiffened by the African Almohades, regained some ground in the south but failed to take Santarém or Lisbon; and when he died on Dec. 6, 1185, Alphonso had not only gained Portugal's independence but doubled its national territory. The military orders, especially the Templars, but also those of Santiago and Calatrava and later the Hospitallers, assisted in the defense and resettlement of the frontier areas regained from the Moslems, and the Cistercians introduced good agriculture and architecture into central Portugal, making their headquarters at Alcobaça.

Although Alphonso Henriques began to grant charters to new settlements it was his son Sancho I (1185–1211) who enfranchised many municipalities (*concelhos*), especially in eastern and central Portugal. The privileges of these communities were embodied in charters (forais). which attracted settlers from the more feudal north. Even Moslems were enfranchised, though on the other hand many of them were enslaved. Assisted by paaaing crusaders, Sancho captured Silves in the Algarve (1189); but in the folloning year an army from Africa advanced as far as the Tagus and, although Lisbon, Santarém and Tomar stood firm, the Moslems recovered Silves in 1191 together with most of the land below the Tagus. In his later years Sancho was involved in a quarrel nith the bishop of Oporto and with the papacy; but peace was made before his death, and it was left to his son Alphonso II, "the Fat", (1211–23) to endeavour to strengthen the power of the throne at the expense of the church.

Though Alphonso II himself was an unwarlike king, his followers were beside the Castilians at the great Christian victory of Las Navas de Tolosa in 1212 and, again assisted by crusaders, recovered Alcácer do Sal in 1217. Meanwhile Alphonso repudiated the bequests of large estates made by his father to his brothers and accepted those to his sisters only after a war with León. In the first year of his reign, Aiphonso called a meeting of the *cortes* at Coimbra, to which the nobility and prelates were summoned (representatives of the commoners were not to appear till 40 years later). On this occasion the barons and, especially, the clergy obtained important concessions; in fact the position of the church and the orders was now so strong that Alphonso 11 and his successors were involved in recurrent conflicts with Rome. Alphonso himself instituted *inquirições* or royal commissions to investigate the nature of holdings and recover whatever had been illegally taken from the crown. In his last years Alphonso defied the papacy and was excommunicated, but he was reconciled shortly before his death in 1223.

His son Sancho II (1223–48) succeeded as a boy of 13. Little is known of his reign, but the reconquest of the Alentejo was now completed and much of the Algarve was reduced. On his accession, Sancho found the church in full ascendancy as a result of the agreement made before his father's death. Conflicting reports exist of Sancho's own government, but in his later years the kingdom seems to have slipped into anarchy. At all events his younger brother Alphonso, who had become count of Boulogne by his marriage with the countess Matilda, was granted a papal commission to take over the government, and Sancho was ordered to be deposed by papal bull. When Alphonso reached Lisbon in 1246, he received the support of the church and of the inhabitants of Lisbon and other towns. After a civil war lasting two years, Sancho II retired to Toledo, dying there in Jan. 1248.

On his arrival the count of Boulogne had already declared himself king as Alphonso III, and the death of Sancho without issue gave his usurpation the mantle of legality. He brought together the divided kingdom, completed the reconquest of the Algarve, transferred the capital from Coimbra (*q.v.*) to Lisbon and, fortified by the support of the towns, summoned cortes at Leiria at which for the first time commoners representing the municipalities made their appearance (1254). Although still the husband of Matilda of Boulogne, Alphonso married Beatriz de Guzmán, daughter of Alphonso X of Castile, receiving the disputed territory of the Algarve as a fief of Castile. This marriage led to a dispute with the Holy See, in which Alphonso was placed under an interdict. Despite his early connection with Rome, Alphonso refused to give way, and in 1262 the bigamous marriage was legalized and his eldest son, Denis (Diniz), legitimized. Shortly afterward, Alphonso launched *inquirições*, as a result of which the church was deprived of much property. The prelates protested and most of them left the country. Although Alphonso was excommunicated and threatened with deposition, he defied the church until shortly before his death early in 1279.

The achievements of Alphonso's reign—the completion of the reconquest, the assertion of the royal power before the church and the incorporation of the commoners in the cortes—indicate important institutional advances. Under his son Denis (1279–1325) Portugal was to come into closer touch with western Europe and to acquire a university, the elements of a national literature and a navy. The chartering of fairs and the increased use of minted money bear witness to the growth of commerce, and the planting of pine forests to hold back the sand dunes near Leiria illustrates Denis' concern for shipbuilding and agriculture. In 1317 Denis engaged a Genoese admiral, Emmanuele di Pezagna (Manoel Pessanha), to build up his navy, having already adopted various measures to stimulate foreign trade. He founded the Cniversity of Coirnbra (at first in Lisbon) in 1290 and was both a poet and patron of literature. Yet he was especially famed as the "farmer king" (*rei* lavrador) for his interest in the land.

Despite his attachment to the arts of peace, Portugal was several times involved in strife during the reign of Denis. In 1297 the treaty of Alcafiices with Castile confirmed Portugal's possession of the Algarve and provided for an alliance between Portugal acd Castile. In the later years of his reign, his son, the future Alphonso IV, rebelled more than once, being persuaded to submit by the influence of his mother Isabella, daughter of Peter III of

Aragon. This remarkable woman, later canonized as St. Elizabeth of Portugal and popularly known as "a Rainha-Santa," successfully exercised her influence in favour of peace on several occasions.

Alphonso IV (1325–57) was also involved in various disputes with Castile. Isabella, who had retired to the convent of Santa Clara at Coimbra, continued to intervene in favour of peace; but on her death in 1336 war broke out, and terms were not made till 1340, when Alphonso himself with a Portuguese army joined Alphonso XI of Castile in the great victory over the Moslems on the Salado river in Andalusia. Alphonso IV's son Peter (Pedro) was married to Constance, daughter of the Castilian infante Juan Manuel de Peñafiel, but soon after the marriage he fell in love with one of her ladies, Inez de Castro (*q.v.*), by whom he had two sons. Alphonso IV was persuaded to countenance the assassination of Inez in 1355, and one of Peter I's earliest acts on his accession was to take vengeance on her murderers. During his short reign (1357–67), Peter devoted himself to the dispensation of justice; his judgments, which he executed himself, were severe and often violent, and his iron rule was tempered only by fits of revelling.

Peter's son by Constance, Ferdinand (1367–83), inherited a wealthy throne almost free of external entanglements; but the dispute between Peter the Cruel and Henry of Trastamara for the Castilian throne was raging, and on the murder of the former, several Castilian towns offered their allegiance to Ferdinand, which he was unwise enough to accept. Henry of Trastamara duly invaded Portugal in 1369, and by the peace of Alcoutim (1371) Ferdinand was constrained to renounce his claim and to promise to marry Henry's daughter. However, he instead took a Portuguese, Leonor Teles, although she was already married and in spite of the protests of the commoners of Lisbon. He also made alliance with John of Gaunt, who had married the elder daughter of Peter the Cruel and claimed the Castilian throne. In 1372 Ferdinand provoked Henry of Trastamara, who invaded Portugal and besieged Lisbon. Unable to resist, Ferdinand was forced to repudiate his alliance with John of Gaunt and to act as an ally of Castile, surrendering various castles and persons as hostages. It was only on the death of Henry that Ferdinand dared openly to challenge Castile again. In 1380 the English connection was resumed, and in the following year John of Gaunt's brother, Edmund of Langley (earl of Cambridge and afterward duke of York), took a force to Portugal for the invasion of Castile and betrothed his son Edward to Ferdinand's only child, Beatrice. In mid-campaign Ferdinand came to terms with the enemy (Aug. 1382), agreeing to marry Beatrice to a Castilian prince. She did in effect become the wife of John I of Castile, and when Ferdinand died, prematurely decrepit, Leonor Teles became regent and Castile claimed the Portuguese crown.

Leonor had long been the lover of the Galician João Fernandes Andeiro, count of Ourém, who had intrigued with both England and Castile and whose influence was much resented by Portuguese patriots. Opponents of Castile chose as their leader an illegitimate son of Peter, John, grand master of Avis, who killed Ourém (Dec. 6, 1383) and, being assured of the support of the populace of Lisbon, assumed the title of defender of the realm. The regent fled to Santarém, and the king of Castile sent an army to her aid; Lisbon was besieged for five months, but an outbreak of plague obliged the Castilians to retire.

The House of **Avis.**—The legitimate male line of Henry of Burgundy came to an end with the death of Ferdinand. and when the *cortes* met at Coimbra in April 1385 John was declared king and became the founder of a new dynasty. This result was not unopposed, for many of the nobility and clergy still considered the queen of Castile the rightful heiress; but popular feeling was strong, and John I had valuable allies in Nuno Álvares Pereira, "the Holy Constable," his military champion, and João das Regras, his chancellor and jurist.

A number of towns and castles still held out for Castile when in Aug. 1385 John I of Castile and a considerable army made their appearance in central Portugal. Although much outnumbered, the Portuguese won the great battle of Aljubarrota (Aug. 15, 1385) in which the Castilian chivalry was dispersed and John of Castile himself barely escaped. The victory, followed by secondary successes won by Nuno Álvares, assured John of Avis of his kingdom and made him a desirable ally. A small force of English archers had been present at Aljubarrota. Now the treaty of Windsor (May 9, 1386) raised the Anglo-Portuguese connection to the status of a firm, binding and permanent alliance between the two crowns. John of Gaunt duly went to the peninsula and attempted an invasion of Castile in conjunction with John of Avis. This was not successful, but the Portuguese king married Gaunt's daughter Philippa of Lancaster (1387), who introduced various English usages into Portugal and became the mother of four princes, the *inclita geração*. The truce arranged with Castile in 1387 was prolonged at intervals until peace was finally concluded in 1411.

The victory of John of Avis may be regarded as a victory of the national spirit against the feudal attachment to established order. As much of the older nobility had adhered to Castile. John rewarded his followers at their and at the crown's expense. Meanwhile, commerce prospered, and the marriage of John's daughter Isabella to Philip the Good of Burgundy was to be followed by the growth of close trading relations between Portugal and Flanders. With the conclusion of peace with Castile, John found an outlet for the activities of his frontiersmen and of his own sons in the conquest of Ceuta (1415), from which may be dated the great age of Portuguese expansion.

During the short reign of John's eldest son Edward (Duarte), "the Philosopher King" (1433–38), an unsuccessful attempt was made to conquer Tangier in 1437 by Prince Henry the Navigator and his younger brother Ferdinand, "the Constant Prince," who was held by the Moors as a hostage and died, still unransomed, in 1443. On Edward's death his son Alphonso V was still a child, and his brother Peter, duke of Coimbra, had himself made regent instead of the widow, Eleanor of Aragon. But Peter's own regency was later challenged by the powerful Braganza family, descended from John of Avis and Nuno Alvares Pereira. This family continued to set the young king against his uncle, who was forced to resign the regency, driven to take up arms and killed at Alfarrobeira (May 1449). Alphonso V (1438–81) proved unable to resist the demands of the Braganzas, who now came to own about a third of all Portugal. Having married Joan. daughter of Henry IV of Castile, Alphonso laid claim to the neighbouring throne and became involved in a lengthy struggle with Ferdinand and Isabella in the region of Zamora and Toro, where he was defeated in 1496. He sailed to France to entreat the aid of Louis XI, in which he failed, and on his return concluded the treaty of Alcácovas (1479) abandoning the claims of his wife Joan, after which she retired to a convent. Alphonso V, sometimes known as "the African" because of his Moroccan campaigns, never recovered from this reverse, and during his last years his son John administered the kingdom.

John II (1481–95) was as cautious. firm and jealous of the royal power as his father had been openhanded and negligent. At the first *cortes* of his reign he exacted a grovelling oath which displeased his greatest vassals. A suspicion of conspiracy against him enabled him to arrest Ferdinand II, duke of Braganza. and many of his followers; the duke was sentenced to death and executed at Evora, and John himself stabbed James (Diogo), duke of Viseu. In addition to his onslaught on the power of the nobility, John contrived to lessen the effects of the uniavourable treaty with Castile. Calculating and resolute, he received the epithet of "the Perfect."

John II was predeceased by his legitimate son and therefore succeeded by his cousin Manoel, duke of Beja. known as "the Fortunate" (1495–1521). Manoel I, who assumed the title of "lord of the conquest, navigation and commerce of India, Ethiopia, Arabia and Persia," inherited, thanks to the work of John II, a firmly established autocratic monarchy and a rapidly expanding overseas empire. Drawn toward Spain by the common need to defend their overseas interests as defined by the treaty of Tordesillas (*see* below), Manoel nourished the hope of joining the whole peninsula under the house of Avis; he married Mary, eldest daughter of Ferdinand and Isabella, who, however, died in giving birth to a son, Miguel da Paz. This child was recognized as heir to

Portugal, Castile and Aragon but died in infancy.

As a condition of the marriage, Manoel was required to "purify" Portugal of Jews. John II had admitted many Jewish refugees from the persecution instituted by Isabella in Castile and had exacted from them a heavy poll tax, but was also to supply ships for them to leave Portugal within eight months. This was not done, and Manoel now ordered all Jews to leave by Oct. 1497. On their assembly in Lisbon, every effort was made to secure their conversion by promises or by force. Some who resisted were allowed to go, but the rest were "converted" under promise that no inquiry should be made into their beliefs for 20 years. As "Christians" they could not be forced to emigrate, and they were indeed prohibited from leaving Portugal. In April 1506 a large number of these "new Christians" or marranos were massacred during a riot, but Manoel afterward protected them and allowed many to emigrate to Holland, where their experience of Portuguese trade was put at the service of the Dutch. It was only in 1536, again through Spanish pressure, that the Inquisition was established in Portugal; the first auto-da-fe was held in 1540.

If Manoel failed to realize his dream of ruling Spain, his son John III (1521–57) lacked the power to resist Castilian influence. A pious, dull man, he was ruled by his wife, Queen Catherine, sister of the emperor Charles V, and encouraged the installation of the Inquisition and the Society of Jesus, which soon controlled education in Portugal. In 1529 the settlement of the Moluccas dispute removed an obstacle to Portuguese-Spanish understanding, and the line of Tordesillas was matched by a similar line in the Pacific; all the new countries were in theory divided between Spain and Portugal. while the Reformation (as well as the discoveries) had come between the latter and its English ally.

John III was succeeded by his grandson Sebastian (1557–78), then a child of three. As a boy Sebastian became obsessed with the idea of a crusade against Morocco. Fanatically religious, he had no doubts of his own powers and listened only to flatterers. He visited Ceuta and Tangier in 1574 and began in 1576 to prepare a large expedition against Larache (El Araish); this departed in June 1578 and on Aug. 4 was utterly destroyed by the Moors. Sebastian himself was killed, 8,000 of his men are said to have died and 15,000 were captured. Only a handful escaped.

On the news of Sebastian's death, his great-uncle: Cardinal Henry, a brother of John III, became king. His age and celibacy made it certain that the Portuguese throne mould soon pass from the direct line of Avis. Philip II of Spain, nephew of John III and husband (by his first marriage) of his daughter Mary. had already made his preparations and, on the death of the cardinal-king (Jan. 31, 1580), summoned the authorities to obey him. An army under the great duke of Alba (*see* ALBA, FERNANDO ALVAREZ DE TOLEDO) entered Portugal in 1581, the resistance of the prior of Crato (illegitimate son of John III's brother Louis), acclaimed Antonio I at Santarém, collapsed, and Philip II of Spain became Philip I of Portugal. The claims of the duchess of Braganza (Catherine, daughter of John's brother Edward) were disregarded.

The Discoveries and the Empire.—The idea of expansion into Africa was a logical result of the completion of the reconquest in the peninsula, and the conquest of Ceuta in 1415 may be regarded as the source of the discoveries. The simple idea of fighting the hfoslems on their own soil was linked with more complicated motives: the search for a Christian ally, Prester John; the desire to explore in a scientific sense; the hope of finding a way to the rich spice trade of the Indies; and the impulse to spread the Christian faith. These purposes were gradually moulded together into a national enterprise, though at first they represented the hopes and aspirations of one man, Prince Henry (*see* HENRY OF PORTUGAL). The third son of John of Avis and Philippa of Lancaster, known rather inaccurately as "the Navigator" (he himself never went farther afield than Tangier), Henry became master of the Order of Christ, which King Denis had founded on the suppression of the Templars in 1319. The resources of the order were used to draw together skilled geographers and navigators and to provide and equip a series of expeditions that only gradually began to bear fruit. When Prince Henry died in 1460 his explorers were still about 8° short of the equator.

The date of Prince Henry's earliest expedition is not exactly known, but appears to have been about 1418, when Porto Santo was visited; the first call at Madeira probably dates from 1419. An attempt was made to settle in the Canaries, and between 1427 and 1431 the Azores were visited by Portuguese seamen. Both the Azores and Madeira were then uninhabited, and their colonization proceeded fairly rapidly from c. 1445. Sugar was exported to Europe and gave the islands great economic importance. Meanwhile, Prince Henry's ships were probing the African coast, passing Cape Bojador in 1434 and Rio de Oro (1436). The unsuccessful expedition against Tangier was followed by a break in the discoveries; but in 1439 Prince Henry was authorized to people the Azores, and from 1440 further expeditions equipped with a new and lighter ship, the caravel, reached Arguin, Senegambia (1444), Cape Verde and a point 100 leagues beyond (1446). This last point, near Sierra Leone, seems to have been the limit of the discoveries at the time of Prince Henry's death.

Under Alphonso V three military expeditions were sent against Morocco (1458, 1461 and 1471); by the last of them Tsngier and Arzila were captured. The African explorations were not entirely neglected, but it remained for John II. with his sharp sense of the national interest, to found a fortress and trading post in the Gulf of Guinea at Elmina (São Jorge da Rfina, 1481–82). Diogo Cam (Cão) discovered the mouth of the Congo in 1482 and then advanced to Cape Cross, 200 leagues beyond (1486). In 1488 Bartholomeu Diaz de Novaes at length rounded the Cape of Good Hope and reached the East African coast, and the seaway to India lay open. His return was followed in 1492 with the surprising news that Christopher Columbus had, as he thought, discovered the Indies by sailing west across the Atlantic. Much as this news must have perturbed the Portuguese, Columbus brought no news of the spiceries or the cities of the east, and John II ordered the preparation of an expedition to India by way of South Africa, though this, as it turned out, sailed only after his death, by order of Manoel I. John also contested the Spanish claim to all lands discovered beyond the Atlantic, and by the treaty of Tordesillas (June 7, 1494) Spain's rights were limited to what lay more than 370 leagues west of the Cape Verde Islands. By reason of this the territory that was to become Brazil was reserved for Portugal.

The treaty of Tordesillas had confirmed Portugal's rights to the exploration of Africa and the seaway to India. In July 1497 Vasco da Gama set sail with four ships on the first expedition to India. They reached Calicut the following spring, and the survivors put into Lisbon in the autumn of 1499 with specimens of oriental merchandise. A second fleet was at once prepared under Pedro Álvares Cabral, who touched the Brazilian coast (April 22, 1500) and claimed it for Portugal. One of Cabral's ships. under Lourenço Marques, discovered Madagascar in 1501; João da Nova discovered Ascension in the same year, and St. Helena in 1502. Tristão da Cunha sighted the islands named after him in 1506 and went on to explore Madagascar. Meanwhile, trading posts had been established by Cabral at Cochin and Calicut (1501) and by João da Nova at Cannanor. In 1502 Vasco da Gama made tributary to Portugal the ruler of Kilwa in East Africa.

In 1joj Francisco de Almeida arrived as viceroy of India, strengthening the African station at Kilwa and supporting the ruler of Cochin against the *samorin* of Calicut. The control of sea trade now instituted became the chief source of Portuguese wealth in the east. It nas assured by the defeat of Moslem naval forces off Diu in 1509. Almeida's successor Alphonso d'Albuquerque conquered Goa (1510), nhich he made the seat of Portuguese poner, and Malacca (1511); sent two expeditions to the Moluccas (1512 and 1514); and captured Ormuz in the Persian gulf (1515). Soon after Ferniio Pires de Andrade reached Canton; in 1542 Portuguese merchants were permitted to settle at Liampo and in 1557 they founded the colony of Macao (Macau).

Alphonso d'Albuquerque (q v.) was responsible for the establishment of Goa as the capital of the Portuguese east and to a large extent for the conception of a system of strong points which secured the trade of the orient to Portugal for nearly a century. Goa. seized from the sultan of Bijapur. soon became the chief port of western India; Ormuz controlled the Persian gulf and Malacca the gateway from the Indian ocean to the South China sea. while a string of fortified trading posts secured the coast of East Africa, the gulf and the shores of India and Ceylon. Farther east, less fortified settlements were set up with the consent of the native rulers from Bengal to China, and the trade of the principal spice islands nas in Portuguese hands. The preservation of the whole system was entrusted to a governor, who sometimes held the rank of viceroy. at Goa; and although Portuguese arms liad both triumphs and reverses, their control of the oriental trade remained substantial, if never complete, until the 17th century, when the Dutch. at war with the joint crown of Portugal and Spain and deprived of their traditional trade with Lisbon, began to seek spices from their source and effectively demolished the Portuguese monopoly.

The "Captivity," 1580–1640.—After Philip II had occupied Portugal, the island of Terçeira in the Azores held out for Antonio of Crato. who himself sought alliances in England and France. In 1582 a French expedition to establish him in the Azores was defeated, and in 1589 an English attempt upon Lisbon, led by Sir Francis Drake and Sir John Norris, failed dismally. But although Antonio died in Paris in 1594, the true symbol of Portuguese independence was not the prior of Crato but Sebastian himself. The Portuguese populace refused to believe that he was dead and nourished a messianic faith in his reappearance, of which no fewer than four pretenders sought to avail themselves, the last as late as 1600 and as far afield as Venice.

Meanwhile, Philip II arrived in Portugal, was crowned king and, by virtue of the *cortes* of Tomar (1581), undertook to preserve Portuguese autonomy, to consider the union as a personal one like that of Aragon and Castile under Ferdinand and Isabella, to appoint only Portuguese to the administration, to summon *cortes* frequently and to be accompanied by a Portuguese council in Madrid. These undertakings were adhered to by Philip II (I of Portugal, 1580–98), neglected by Philip III (II, 1598–1621) and completely violated by Philip IV (III, 1621–40).

The resentment of the Portuguese against Spanish rule was increased by the failure of the kings to visit Portugal, lack of redress, the appointment of Spaniards to Portuguese offices, the loss of trade consequent on Spain's foreign wars and the levying of taxation to sustain these. The final straw was the count of Olivares' policy of setting the Portuguese against the equally discontented Catalans. Two Portuguese insurrections in 1634 and 1637 failed to attain dangerous proportions, but in 1640 Spain's powers were extended to the utmost by war with France and revolt in Catalonia. Richelieu already had agents in Lisbon, and a leader was found in John, duke of Braganza, a grandson of the duchess Catherine whose claims had been overriden by Philip II. Taking advantage of the unpopularity of the governor, Margaret of Savoy, duchess of Mantua. and her secretary of state Miguel de Vasconcelos, the leaders of the party of independence carried through a nationalist revolution on Dec. 1, 1640. Vasconcelos was almost the only victim of the movement; the Spanish garrisons were driven out; and on Dec. 15 the duke of Braganza was crowned as John IV.

The House of Braganza.—Although the *cortes* confirmed the accession of the dynasty of Braganza and John's coronation on Jan. 28, 1641, the success of the new regime was not finally assured till 1668, when Spain at last recognized Portuguese independence. Faced with the threat of a Spanish invasion, John had at once sent missions to the courts of Europe in quest of alliances. France now refused a formal treaty. The Dutch, having seized Brazil, accepted a truce in Europe and proceeded to capture Angola. In England John made a treaty with Charles I, which was almost at once voided by the regicide. Meanwhile, the Portuguese defeated the Spaniards at Montijo (May 26, 1644) and warded off several invasions. In 1654 they negotiated a treaty with the English commonwealth, obtaining promises of aid in return for very considerable commercial and other concessions. By a secret article of the treaty of the Pyrenees (1659) France promised Spain to give no further aid to Portugal, but in 1661 negotiations began for a treaty with the restored English monarchy. In 1662 Charles II of England married John's daughter Catherine of Braganza and, in return for a large dowry, including the cession of Bombay and Tangier. provided arms and men for the war with Spain. Portuguese defense was organized by the count-duke of Schomberg; in June 1663 Sancho Manoel, count of Vila Flor. defeated Don John of Austria and on June 17, 1665. António Luis de Meneses, marquis of Marialva, won the important victory of Montes Claros. Peace was negotiated by Sir Robert Southwell and Sir Richard Fanshawe (the translator of the *Lusiads*) and signed on Feb. 13, 1668.

On the death of John IV his second son Alphonso VI (1656–83) was 13. His mother, Luisa de Gusmão, acted as regent until on June 23, 1662, he began to rule. Alphonso himself was feeble-minded, but the country was capably governed by Luis de Vasconcelos e Sousa, count of Castelo-Melhor, until 1667. The French princess Maria-Francisca of Savoy, who had married Alphonso in the previous year, now entered into an intrigue with his more personable brother Peter. They contrived to dismiss Castelo-Melhor and to have Maria-Francisca's marriage annulled. She at once married Peter, who was declared regent. Alphonso was imprisoned until his death in 1683.

During the reign of Peter II (1683–1706), Portugal recovered from the strain of the Spanish wars and began to feel the effects of the discovery of gold and precious stones in Brazil. The first strike of gold in Minas Gerais took place in 1692, and in the last years of the 17th century considerable wealth was being extracted; however, it was not until 1728 that diamonds were discovered and the wealth of Brazil came to form an appreciable part of the revenue of the Portuguese crown.

The struggle for the Spanish succession saw Portugal's recent friends, England and France, on opposing sides; and although Peter sought at first to remain neutral, Portugal joined the Grand Alliance in 1703, by which it afforded a base for the archduke Charles to conduct his war for the Spanish throne. In the same year (Dec. 27) John Methuen also concluded the brief treaty which bears his name, by which the exchange of port wine for English woollens became the basis for Anglo-Portuguese trade. Although the treaty of 1654 had secured great privileges for English merchants in Lisbon, neither it nor the treaties of 1642 and 1661 by which the traditional alliance was restored had created trade. This was now done, and by reason of the wealth that soon poured into Lisbon from Brazil, the English merchants gained a commanding position in the trade of Portugal. The political treaties of 1703 proved less fruitful. The marquês das Minas (Antonio Luis de Sousa) entered Madrid in 1706, but French and Spanish forces were victorious at Almansa, and in 1711 the French admiral René Duguay-Trouin sacked Rio de Janeiro. At the end of the war Portugal was not included in the peace of Utrecht, but at length in Feb. 1715 Portugal concluded peace with Spain at Madrid.

Under Peter's son John V (1706–50) Portugal attained a degree of prosperity unknown since the restoration. The royal fifth levied on the precious metals and stones of Brazil gave the monarchy an independent source of wealth. *Cortes*, which had met irregularly since the restoration, were no longer summoned, and government was carried out by ministers appointed by the king. John V himself showed little interest in administration, though he did not fail to convert his wealth into papal and other dignities. The archbishop of Lisbon became a patriarch and the king of Portugal "his most faithful majesty"; and royal academies, palaces and libraries made their appearance. But in the second half of the reign the ministers proved inadequate and the kingdom sank into stagnation. However, on John's death his son Joseph (1750–77) appointed as minister Sebastião José de Carvalho e Mello, later count of Oeiras and marquis of Pombal (*q.v.*), who soon gained a complete ascendancy over the king and endeavoured to replace the stagnant absolutism with a more active type of despotism which, with some qualifications, deserves the epithet "enlightened." His full powers date from his efficient handling of the crisis caused by the disastrous Lisbon earthquake of Nov. 1755; but even before this he had reformed the sugar and diamond trades, set up a national silk industry (1752) and formed one chartered company to control the sardine- and tunny-fishing industry of the Algarve and another to trade with northern Brazil.

In 1756 he founded a board of trade with powers to limit the privileges enjoyed by the English merchants under the treaties of 1654 and 1661 and set up the General Company for Wine-Culture to control the port wine trade. Industries for the manufacture of hats (1759), cutlery (1764) and other articles were set up with varying success; the University of Coimbra was reformed (1772), and the royal board of censorship (1768) directed lower education from 1771.

Pombal's methods were arbitrary and his enemies numerous. His reform of the wine industry provoked a riot in Oporto (1757) which was savagely repressed; but his principal victims were the Jesuits, expelled in 1759 from all the Portuguese dominions, and the nobility, in particular José Mascarenhas, duke of Aveiro, and the Távora family, who were accused of an attack on the king (Sept. 3, 1758), condemned and executed (Jan. 12, 1759).

While Pombal succeeded in modifying the ascendancy of the British merchants in Portugal, he invoked the alliance in 1762 when Spain, prompted by the Family Compact, invaded Portugal. The Portuguese army was reformed by Count William of Lippe-Bückeburg, under whom John Burgoyne served as brigadier general, and an English force was led by James O'Hara, second Lord Tyrawley, and John Campbell, fourth earl of Loudoun. Peace was signed in Feb. 1763 at Fontainebleau. Only the death of Joseph (Feb. 24, 1777) ended Pombal's regime. After the accession of Joseph's daughter Maria I (1777–1816), who had married his brother, her uncle Peter III, the aged dictator was dismissed and eventually condemned on several charges. His successors restored the Jesuits and made peace with Spain by the treaty of San Ildefonso (1777).

Maria I suffered from fits of melancholia after the loss of her consort (1786) and eldest son. In 1792 her mental balance was further disturbed, probably by the news of the French Revolution, and she ceased to reign. Her son, who on her death was to ascend the throne as John VI (1816), became prince regent. In 1793 Portugal joined England and Spain against France, sending a naval division to assist the English Mediterranean fleet and an army to the Catalan front. The peace of Basle (July, 1795), by which Spain abandoned its allies, left Portugal still at war. Although subjected to pressure from the Directory and from Manuel de Godoy, Portugal remained unmolested until 1801, when an ultimatum was delivered and Godoy invaded the Alentejo. By the peace of Badajoz (June 6, 1801) Portugal lost the town of Olivenza and paid an indemnity. From the peace of Amiens (1802) until 1807 Portugal was once more immune from attack, though subjected to continuous pressure to break off the English connection. By the Berlin decree of Nov. 21, 1806, Napoleon sought to close all continental ports to British ships. Portugal endeavoured to maintain neutrality, but the secret treaty of Fontainebleau (Oct. 1807) provided for its eventual dismemberment by Napoleon and Godoy. Already Gen. Andache Junot was hastening across Spain with a French army, and on Nov. 27 the prince regent and the royal family and court embarked on a fleet lying in the Tagus and were escorted by British vessels under the command of Sir Sidney Smith to Brazil. Junot declared the Braganzas deposed. but his occupation of Portugal was challenged in Aug. 1808 by the arrival of Sir Arthur Wellesley (later duke of Wellington) and 9,000 British troops at the mouth of the Mondego. Winning the victories of Roliça (Aug. 17) and Vimeiro (Aug. 21), Wellesley enabled his superiors to negotiate the so-called convention of Cintra (Xug. 30) by which Junot was allowed to evacuate Portugal with his army. A second French invasion threatened early in 1809, when Sir John Moore's force uithdrew to Corunna to re-embark. In February William Carr Beresford was placed in command of the Portuguese army, and in March Marshal Soult advanced from Galicia and occupied Oporto. Wellesley returned in April, drove Soult from northern Portugal and cleared the Tagus valley with the victory of Talavera de la Reina at the end of July. The third French invasion followed late in Aug. 1810 when Marshal André Masséna with Marshal Michel Ney and Junot entered Beira. Defeated by Wellington at Bussaco near Coimbra, the French found themselves facing the prepared lines of Torres Vedras, where they wintered amid great privations. By the spring of 1811 they could only retreat and, on March 5, began the evacuation of Portugal, beset all the way by English and Portuguese attacks and crossing the frontier after ihe defeat of Sabugal (April 3).

Portugal made peace with France on May 30, 1814. It was represented at the congress of Vienna but did not play a prominent part in the settlement. However, the series of Anglo-Portuguese treaties concluded between the years 1809 and 1817 was important in so far as it extended many of the conditions of the Anglo-Portuguese alliance to Brazil and had an influence on the future of Africa. England's efforts to get Portuguese collaboration in suppressing the slave trade resulted in the treaty of Jan. 22, 1815 (signed in Vienna), and in the additional convention of 1817, by reason of which Portugal's claims to a considerable part of Africa were admitted. Although England had agreed in 1809 and in 1810 to try to recover Olivenza for Portugal and was to receive part. of Portuguese Guinea should it succeed, Spain nevertheless held and continues to hold this frontier town.

Constitutionalism.—The Napoleonic campaigns had caused great devastation in Portugal, and the absence of the royal family and the presence of a foreign commander (Beresford) combined with revolutionary agitation and the influence of Spanish liberalism to produce an atmosphere of discontent and restlessness. On Dec. 16, 1815, Brazil was raised to the rank of a kingdom united with Portugal, and John, who succeeded to the throne in March 1816, showed no desire to return though in anticipation of his arrival George Canning was sent as ambassador to Lisbon to welcome him. In 1817 Beresford suppressed a conspiracy in Lisbon, and the Masonic leader Gen. Gomes Freire de Andrade was executed. Unrest increased, and when Beresford himself went to Brazil to press John to return, a constitutionalist revolution began in Oporto (Aug. 24, 1820), spread over the country and led to the formation of a junta in Lisbon (Oct. 4). On Beresford's return he was not allowed to land, and British officers were expelled from the army. A constituent assembly was summoned which drew up a very "democratic" constitution. thus confronting John VI with an accomplished fact. His reluctance to return was at last overcome, and he left his elder son Pedro to govern Brazil, landing at Lisbon on July 4, 1821. He swore to uphold the constitution, but his wife, Carlota Joaquina, and their second son, Miguel, refused to take the oath and were duly sentenced to banishment, though this was not carried out. The Portuguese constitutionalists, not appreciating the determination of Brazil not to yield up its status as a kingdom, sought to compel Pedro to return; but he, rather than sacrifice the rule of the Braganzas in Brazil, declared for Brazilian independence (Sept. 7, 1822) and became emperor of Brazil as Pedro I. This enabled his brother Miguel to appeal to absolutist forces in Portugal to overthrow the constitutionalists, and an insurrection led by the prince almost succeeded (April 30, 1824); but through the action of the foreign ministers John VI was restored and Miguel went into exile in Vienna (June 1824).

John VI acknowledged the independence of Brazil in 1825, assuming pro *forma* the imperial title and then yielding it to Pedro, but when he died (March 10, 1826) no provision had been made for the succession except that his daughter Isabel Maria was now named regent. Pedro, as Peter IV of Portugal, issued a constitutional charter, drawn up by himself, providing for a parliamentary regime by the authorization of the monarchy and not based on the sovereignty of the people. He then made a conditional abdication of the Portuguese throne in favour of his daughter Maria da Gloria, aged seven, provided that she should marry her uncle Miguel and that he should swear to accept the charter. This compromise could not be effective. The absolutists had hoped that Pedro would resign all rights to the Portuguese crown, and the council of regency hesitated to publish the charter until Gen. João Carlos de Saldanha, later duque de Saldanha, forced their hand. In October Miguel took the oath and was appointed regent, landing in Lisbon in Feb. 1828. His supporters at once began to persecute the liberals. A form of *cortes* met in Lisbon, and in July 1828 repudiated Pedro's claims and declared Miguel rightful king.

Only the island of Terceira in the Azores sustained the liberal cause, but when the liberal refugees in England tried to repair there they were intercepted by a British ship (Jan. 1829). In June 1829, however, a regency on behalf of Maria da Glória was set up in Terceira, and in 1831 Pedro, having abdicated the Brazilian throne, came to Europe and began to raise money and men for the conquest of Portugal. In Feb. 1832 the expedition sailed to the Azores, and in July the liberals disembarked at Mindelo near Oporto, which city they soon occupied. However, the rest of the country stood by Miguel, who besieged the liberals in Oporto for a year (July 1832–July 1833). 'By now Miguelite enthusiasm had waned, and António José de Sousa Manoel, duke of Terceira, and Capt. Charles Napier, who had taken command of the liberal navy, made a successful landing in the Algarve. Terceira advanced on Lisbon, which fell on July 24, 1833, and Miguel capitulated at Evora-Monte on May 26, 1834.

The War of the Two Brothers ended with the exile of one and was soon followed by the death of the other (Sept. 24). Maria da Glória (Maria II) was now queen at the age of 15. She was twice married: to Augustus, duke of Eeuchtenberg, in Jan. 1835; and to Ferdinand of Saxe-Coburg in April 1836. While Maria necessarily came under the influence of the successful generals of the civil war, her chief aim was to defend her father's charter (which had been octroyke) from those who demanded a "democratic" constitution like that of 1822, asserting the sovereignty of the people. In Sept. 1836 the latter, thenceforth called Septembrists, seized power. The chartist leaders rebelled and were exiled, but by 1842 the Septembrist front was no longer united and António Bernardo da Costa Cabral restored the charter. In May 1846 the movement of Maria da Fonte, a popular rising in which almost all parties joined, put an end to Costa Cabral's government but left Portugal divided between the Septembrists, who held Oporto, and Saldanha, now in Queen Maria's confidence, in Lisbon. Saldanha negotiated for the intervention of the Quadruple Alliance, and a combined British and Spanish force received the surrender of the Oporto junta in June 1847 and ended the war with the convention of Gramido (June 29, 1847). Saldanha governed until 1849, when Costa Cabral resumed office only to be overthrown on April 7, 1851. Saldanha then held office for five years (1851–56), and the period of peace at length permitted the country to settle down.

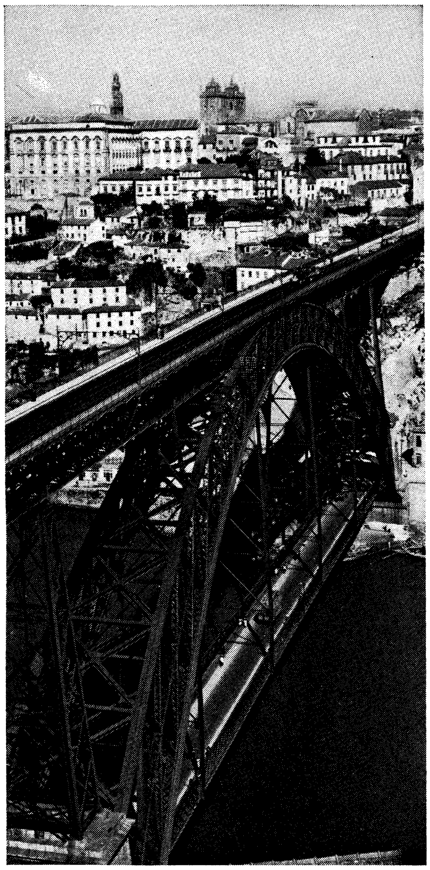
When Maria II died she was succeeded by her eldest son, Peter V (1853–61), who married Stephanie of Hohenzollern in 1857. He promised to be a capable and conscientious monarch, but died of cholera on Kov. 11, 1861. His brother Luis (1861–89) seemed to have inherited a country that had recovered from the Napoleonic invasions and from civil wars, political strife and pronunciamentos. But although the main parties were now defined as Historicals (*i.e.,* radicals) and Regenerators (or moderates), the alternation of governments gradually ceased to reflect popular feeling, and in the last years of Luis' reign republicanism was already gaining ground. With the accession of Carlos (1889–1908) there occurred a serious dispute with Great Britain. Portugal's possessions in Africa had been recognized by Great Britain in the treaty of 1815; but more recently the entry of Germany and Leopold of the Belgians into the colonial field had led to the definition of effective occupation as the basis for possession of colonial territories (conference of Berlin, 1885). A colonial movement had gained momentum in Lisbon, and Portuguese claims to the "Rose-Coloured Map," a colony stretching across Africa from Angola to Mozambique. were recognized by France and Germany (1886). Although Lord Salisbury registered a protest (1888), the Portuguese foreign minister Henrique de Barros Gomes sent Maj. Alexandre de Serpa Pinto to the Shiré highlands with a view to their annexation. He became involved in a fight with the Makololos, who were under British protection, and a series of communications between London and Lisbon ended in the dispatch of the British ultimatum of Jan. 11, 1890, demanding the withdrawal of all Portuguese from the Shiré. Amid great popular excitement Barros Gomes had no alternative but to comply, and the government resigned. The incident caused the deepest resentment in Portugal, not only against the ancient ally but also against the monarchy, which was menaced by a republican revolution in Oporto (Jan. 31, 1891).

During the following years, the Portuguese African colonies were defined as a result of the treaty of May 1891, but the financial position of the country was so bad that it seemed unlikely that the efforts to consolidate the African colonies would succeed. In 1897 it became clear that Portugal would require a considerable loan, and Germany demanded to partake in any assistance that was offered. On Aug. 30, 1898, Lord Balfour concluded an Anglo-German convention assigning spheres of influence in the Portuguese colonies to Great Britain and Germany in the event of such a loan. In 1899 the Germans endeavoured to persuade the Portuguese to accept a loan, and this and the imminent danger of a conflict in the Transvaal caused an Anglo-Portuguese approximation. On Oct. 14, 1899, the ancient treaties of alliance were reaffirmed in a secret declaration, later made public.

Meanwhile, the financial situation showed little improvement, and the republicans continued to progress. In 1906 João Franco, formerly a Regenerator, came to power as champion of the failing monarchist cause. Unable to obtain the support of the other monarchists, he began to govern by decree (May 19, 1906). Although Franco bravely undertook to reform the finances and administration, he was accused of illegally advancing money to the king. These scandals were followed by rumours of plots, and on Feb. 1, 1908, Carlos and his heir, Luis Felipe, were assassinated as they rode in an open carriage in Lisbon. Whether or not the regicides were isolated fanatics or agents of a wide organization such as the *Carbonários,* the deed was applauded by the republicans, who now prepared for a final attack on the monarchy. King Manoel II (1908–10) found no unity among the monarchist politicians, who continued to squabble till the last minute. The general election of Aug. 1910 showed republican majorities in Lisbon and Oporto, and on Oct. 3 the murder by a madman of one of the republican leaders, the distinguished physician Miguel Bombarda, offered the pretext for a rising that was already organized. Armed civilians, soldiers and the men aboard some ships in the Tagus began the republican revolution on Oct. 4 and, after faltering, their movement succeeded on Oct. 5. Manoel escaped to Ericeira and thence by sea to Gibraltar and to England, where he resided at Twickenham. On his death in 1932 his body was returned to Portugal.

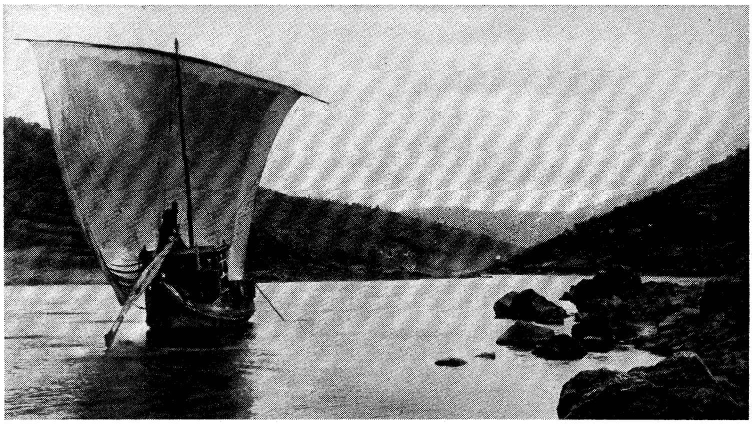
The Republic. — The new regime formed a provisional government under the presidency of Theophilo Braga, a well-known writer. This in turn issued a new electoral law giving the vote to all adult Portuguese and presided over the election of a constituent assembly which opened on June 19, 1911. The constitution was passed on Aug. 20, and the provisional government surrendered its authority on Aug. 24 to the new president, Manoel José d'Arriaga.

Although a monarchist invasion was unsuccessfully attempted by Henrique de Paiva Couceiro in Oct. 1911, the main danger to the new regime came from its internal divisions. For the moment, it was fairly united in denouncing monarchism and persecuting the church. The religious orders were expelled (Oct. 8, 1910) and their property confiscated. The teaching of religion in primary schools was abolished, the marriage of priests legalized and the Roman Catholic Church disestablished. The conditions under which Catholics and monarchists were imprisoned attracted attention abroad, and it was only gradually that this legislation was modified. New universities were founded at Lisbon and Oporto, but the task of destruction proved easier than that of construction, and before long the republicans were divided into Evolutionists (moderates), led by Antonio José de Almeida; Cnionists (centre party), led by Manoel Brito Camacho; and Democrats (the left wing), led by Afonso Augusto da Costa. A number of prominent republicans had no specific party. The whirligig of republican political life offered little improvement on the monarchist regime, and in 1915 the army showed signs of restlessness. Gen. Pimenta de Castro formed a military government and permitted the monarchists to reorganize, hut a Democratic revolution (May 14) led to his arrest and consignment to the Azores. President Arriaga resigned and was succeeded by Braga ad interim and then by Bernardino Machado (Oct. 5, 1915–

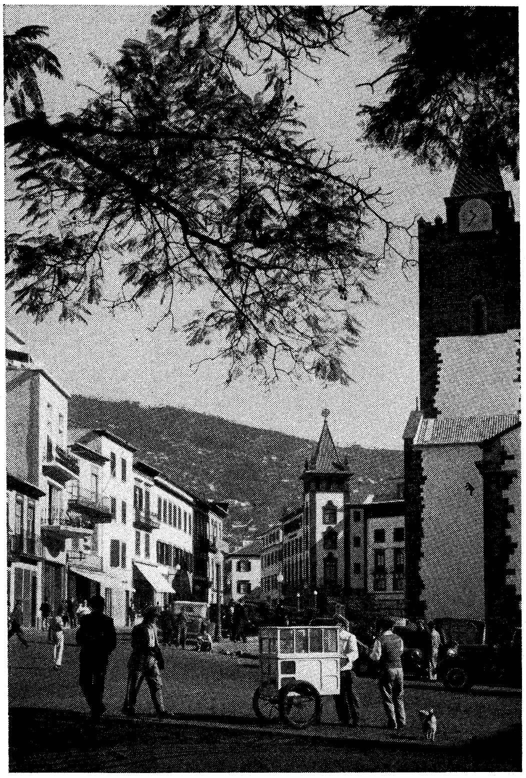


Dom Luís I bridge (1881–85) spanning the Douro river, Porto (Oporto)

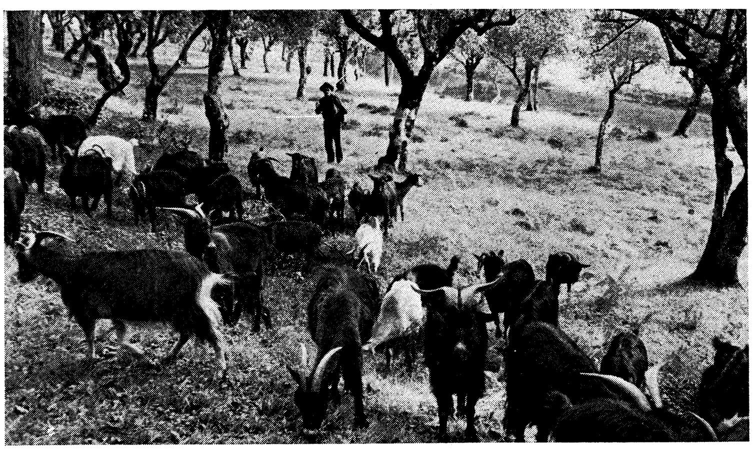
Terreiro do Paço, Black Horse square, the entrance to Lisbon. The statue of King Joseph I was erected in 1775



A *rabelo* on the Douro river, carrying casks of wine. Terraced vineyards line the river's banks



Street in Funchal, capital of Madeira Island

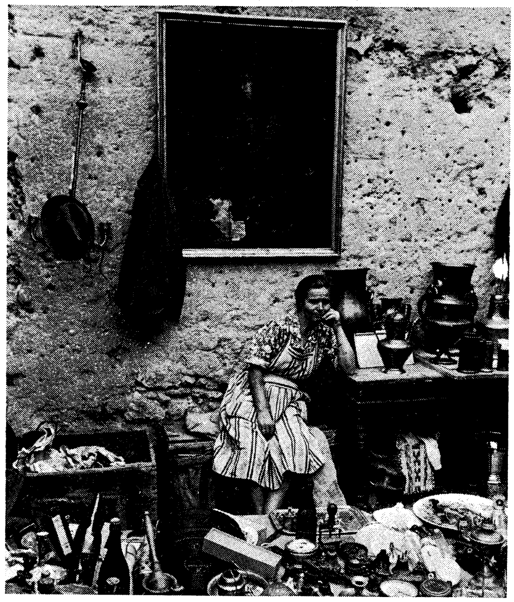


Shepherd of northern Portugal with his flock of goats

VIEWS OF PORTUGAL AND MADEIRA ISLAND

BY COURTESY OF (TOP LEFT) PORTUGUESE STATE OFFICE, (TOP RIGHT) BRITISH EUROPEAN AIRWAYS, (CENTRE RIGHT) PORTUGUESE EMBASSY, LONDON; PHOTOGRAPHS, (BOTTOM LEFT) W. SUSCHITZKY, (BOTTOM RIGHT) STURE JOHANNESSON

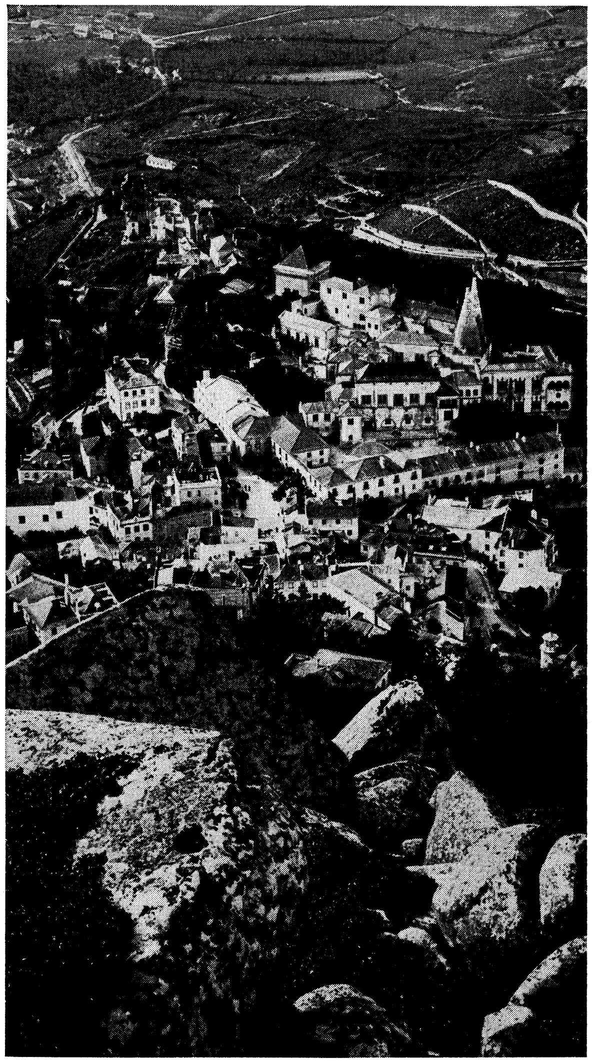
Shepherd driving his flock past a Portuguese windmill, near Sintra



Portuguese woman sitting amid her wares in the *Feira da Ladre,* the "Market of Thieves," Lisbon

Peasants of south central Portugal riding their donkeys to market

Fishermen waiting to sell their catch along the beach of **Sezimbra,** fishing village south of Lisbon



Aerial view of Sintra, on the northern slope of the Serra de Sintra. In the right background is the royal palace (12th–15th century)

SCENES OF SOUTHERN PORTUGAL

BY COURTESY OF (CENTRE LEFT) PORTUGUESE EMBASSY, LONDON, PHOTOGRAPHS, (TOP LEFT) ARMIN HAAB FROM BLACK STAR, (TOP RIGHT, BOTTOM LEFT) STURE JOHANNESSON, (BOTTOM RIGHT) EWING GALLOWAY

Dec. 8, 1917). The Democratic regime, in which Costa was paramount, was ended by the revolution of Maj. Sidónio Pais, who established a "New Republic" of a right-wing tendency, supported at first by the Unionists, but on their separation driven to found its own National Republican party. Sidónio Pais' "presidentialist" regime was abruptly ended with his assassination on Dec. *14. 1918,* when, after the provisional presidency of Adm. João de Canto e Castro. power passed gradually back to the Democrats.

Meanwhile, on Aug. *7.* 1914, Portugal had proclaimed its adhesion to the English alliance, and on Nov. *23* committed itself to military operations against Germany. On Sept. 11 a first expedition left to reinforce the colonies, and there was fighting in northern Mozambique, on the Tanganyika frontier and in southern Angola, on the frontier of German South-West Africa. In Feb. *1916* Portugal seized German ships lying in Portuguese ports and Germany declared war (March 9). A Portuguese expeditionary force went to the western front in 1917, under Gen. Fernão Tamagnini de Abreu; on April *9, 1918,* they mere under heavy German attack in the battle of the Lys. In the peace treaty Portugal received 0.75% of the indemnity payable by Germany and the Kionga area captured by Portuguese forces in East Africa.

Almeida completed his term of office as president (Oct. 5, 1919–Oct, 5, 1923), but ministries succeeded one another in rapid succession. In *1921* the founder of the republic, António Machado Santos, was among those murdered by enemies of Sidónio Pais; and although António Maria da Silva contrived to govern in the Democratic interest for a year and nine months, his fall in 1923 was followed by a number of short-lived ministries.

Revolutionary movements grew more frequent as the Democratic party lost its cohesion, and there were signs of impatience with the political turmoil on the part of the army. Although the Democrats obtained a clear majority in *1925* and Manoel Teixeira Gomes (1923–25) yielded the presidency to Bernardino Machado without incident, a military revolt occurred in Lisbon on Feb. 2, 1926. It was quelled. but on May 28 Commander Joaquim Mendes Cabeçadas and Gen. Manoel de Oliveira Gomes da Costa rebelled at Braga. Machado was deposed, and a provisional government was formed.

The "New State." — At first Cabeçadas was head of the provisional government and Gomes da Costa minister of war; but the former was regarded as too close to the politicians, and Gomes da Costa unseated him. Within a few weeks he too was deposed and his place taken by his foreign minister. Gen. António Oscar de Fragoso Carmona (July 9, 1926). Carmona was elected president of the republic in March *1928* and re-elected in *1935, 1942* and *1949,* in each case without opposition; he remained president until his death in April *1951.* After an attempt at revolution in Feb. *1927.* which resulted in considerable bloodshed, Carmona's government was not seriously interrupted. The program of the military regime was merely to restore order. To remedy the financial plight of the country, it had been proposed to borrow money from the League of Nations. but the conditions offered included supervision of the finances. which was regarded as offensive to national sovereignty. The loan was therefore rejected. and Carmona called on António de Oliveira Salazar to take the ministry of finance. Salazar (born at Santa Comba Dão, *1889).* professor of law at Coimbra. obtained full powers over all expenditure and revenue and embarked on a complete overhaul of the administration. As minister of finance from *1928* to *1940* he produced an unbroken series of budgetary surpluses. which restored Portugal's financial credit. As prime minister from *1932* he ushered in the new constitution of *1933;* as minister of colonies in *1930* he prepared the Colonial act governing the administration of Portugal's colonial empire; and as minister for foreign affairs from *1936* he guided Portugal through the difficulties caused by the Spanish Civil War and practised a form of neutrality compatible with the Anglo-Portuguese alliance during World War II On the death of Carmona in *1951,* Salazar assumed under the constitution the attributes of the presidency, until Gen. Francisco Craveiro Lopes mas snorn in as president on Aug. 9. *1951.*

By *1953* Salazar had been a member of the government for 25 years. His "New State," as defined by the constitution of 1933, provided for a president, elected for a period of seven years, who appointed a prime minister and a variable number of ministers; a national assembly of deputies elected quadrennially as a block, meeting for at least three months annually; and a corporative chamber consisting of representatives of trades and professions and acting as a consultative assembly. At the general elections of Nov. *1953* there were *28* opposition candidates, but all *120* seats went to the government (National Union) party. India's attempts to absorb Goa having been rebufied throughout 1954, the Indian government severed diplomatic relations with Portugal in July *1955.* This was followed, in August, by mass invasions of the Portuguese colonies in India by "passive resisters" These were repelled, with some losses. In Dec. *1955* Portugal became a member of the United Nations and in Feb. *1956* referred the question of free access through Indian territory to the enclaves of Dadra and Nagar Havili (Aveli) to the International Court of Justice which, in April *1960,* recognized Portugal's right to the enclaves and also recognized India's right to control access to them through Indian territory Finally on Dec. *18, 1961.* India sent troops into Goa. Diu and Damão, and the next day the Portuguese surrendered. Rear Adm Américo Deus Rodriguez Tomás succeeded Craveiro Lopes as president in *1958.*

On Jan *22, 1961,* the Portuguese cruise ship "Santa Maria" was seized in the Caribbean sea by insurgents who had embarked as passengers The seizure was said to have been planned to coincide with the uprisings against the Salazar government in Angola and other Portuguese colonies. No uprisings occurred, however. and after cruising about the Atlantic for nearly two weeks the "Santa Maria" put into Recife. Braz., where its passengers were released. The ship was returned to its owners and the rebel crew. led by Henrique M. Galvão, was granted political asylum in Brazil.

POPULATION

The population of continental Portugal was 8,510,799 in *1960;* it was 7,185,143 in *1940* and *6.360.347* in *1930.* With the Azores and Madeira it was 9,130,410 in *1960* and 7,722,152 in *1940.* The colonies with an area of 803,835 sq mi, have a population of 11 *861 591* (1950) A decrease in the rate of emigration in the early years of World War II was reflected in a rather steep increase of population and the urban population grew more rapidly than the rural because of internal migration In 1960 the population of the chief towns was: Lisbon 818,382; Oporto 310,474; Setúbal 59,024 (mun); and Coimbra 112,199 (mun).

The Portuguese population increased rapidly in relation to the size of the country. The birth rate, at 23.6 per 1,000 in 1961, is one of the highest in western Europe. The death rate (10.7 per 1 000) is also high. The population is unevenly distributed, all but one-seventh inhabiting the provinces north of the Tagus. The density of population (1960) in continental Portugal reaches 1 380.2 per square mile in the district of Oporto but only 71.6 in that of Beja. The average for the whole country is *258* 4 per square mile. The island of Madeira is more thickly peopled than the mainland (except for the districts of Oporto and Lisbon), with 920 8 per square mile; the Azores have 376.9 per square mile.

Areas such as the Minho are seriously overpopulated. The division of land has proceeded so far that it is often uneconomically cultivated. The less populated areas, on the other hand, will not bear any very considerable increase because of poor soil. There has long been a considerable emigration of Portuguese, principally to Brazil but also to the United States, other parts of Latin America and Africa The emigrants are hard-working and vigorous. but nhile their unskilled labour commands a ready market in Brazil they find little opportunity in the Portuguese colonies, where unskilled work can be done by the natives

Religion and Education. — Roman Catholicism is the religion of the majority of the people. though other creeds compatible with good order are tolerated. The position of the Roman Church in Portugal is determined by the concordat of May *1910.*

Statistics of the school year *1952–53* for continental Portugal showed that there were *12.481* state-run establishments giving primary education, *40* giving secondary. *78* giving technical. *5* giving artistic and *22* giving advanced. as well as *11* training teachers; at the same time there were 9jj private or ecclesiastical establishments giving instruction of various grades. Pupils at these establishments, both state-run and private or ecclesiastical, in continental Portugal numbered 3,657 in infant schools, 859,468 in primary. 50,894 in secondary. 38,393 in technical and 1.028 in artistic, as n-ell as 10,440 receiving advanced education. 1,824 being trained to teach in state schools and 5,040 seminarists.

Racial Composition. — The original Portuguese stock has received transfusions of blood from many races: Romans, Goths, Arabs and Berbers, settlers from northern Europe. Jews, Negroes, etc. In general, however, the typical Portuguese stock is rather short, dark and sturdy, and among the peasantry the strain seems to be remarkably pure. The type is thought by some to be characteristically Iberian and by others to represent Mediterranean man. It is in any case not dissimilar from the prevalent type in Galicia or Asturias.

Although the Romans stamped the country with their language, institutions and civilization, they appear to have had little influence on the racial composition of the people. which may have been fairly constant from their arrival until their departure. The Suebi and Visigoths, who arrived in the jth century A.D.. left traces of more northern physical characteristics. which are especially common in the north. A number of Gothic place names indicate settlements or colonies of these people.

The overthrow of the Visigothic kingdom by the Moslem invasion of 711 introduced a new stock and a new religion. The so-called Moors included Arabs (some from Syria') and Berbers, and they deeply influenced the language, life. architecture and handicrafts of the Portuguese. This influence varied from region to region. North of the Douro it was negligible. since this region was shortly reconquered by the Christians. South of the Douro there was a Mozarabic civilization centred on Coimbra, in which Portuguese stock, still professing the Christian faith. adopted Arab ways and, to some extent, the Arabic language; mixed proper names are common. and it is not unusual to find records even of priests bearing Arab names.

With the reconquest, the Mozarabic civilization was again gothicized, but farther south the Arabic element persisted and is strongest in the Algarve. There were Jews in Portugal in Visigothic times, and they flourished under the Moslems. During the middle ages there were many Jewries, some of them extremely prosperous. Under the influence of Queen Isabella of Spain. King Manoel I (1495–1521) was persuaded to expel the Jews. Many were forcibly converted and. in some cases, intermarried into the population, but others retained their racial and cultural traits. From the foundation of the kingdom to modern times there has been a gradual introduction of other European stocks by settlement. Negroes from Africa were introduced as slaves in fairly considerable numbers after 1450 and left their mark especially in the south, where they were employed on the land, and in such towns as Lisbon, where they were drawers of water or performed similar tasks.

Customs. — The staple diet of the Portuguese people is one of fish, vegetables and fruit; the fish includes dried cod (*bacalhau*), which is prepared in many ways. Cooking is usually done in olive oil, and meat is rarely eaten by the labouring classes. Rice, maize bread and beans are characteristic of the popular diet. Wine is consumed generally but sparingly.

A great variety of picturesque costumes are worn. These may be seen at their best at the *romarias*, or pilgrimages. which combine religion with the attractions of a fair. A characteristic male dress is a white shirt and black trousers with a red sash. In the Alentejo this is accompanied by a stocking cap. and a copper-tipped quarterstaff is carried. Elsewhere a broad-brimmed hat is worn. In the north an umbrella is usually carried by countrymen. and in places short capes are made of reeds. Fishermen may wear a check or tartan shirt.

The female peasant dress is extremely varied, though above a certain age black is usually worn. A white blouse and a full black skirt is a common dress, and a daily clean apron is a general practice. On holidays girls wear brightly coloured cotton dresses decorated with gold or silver filigree ornaments. Headgear ranges from kerchiefs, to round felt or straw hats according to the season and locality.

The sport of bullfighting is conducted without the bull's being killed. Duelling with staves and rowing are other sports; football is popular. Dancing and singing play a prominent part in the life of the people. Almost every village has its *terreiro*, or dancing floor of beaten earth, and band. The traditional songs are of a slower rhythm than the Spanish. but the melody is robust and generally lyrical. The usual popular instruments are the gaita or bagpipe (commonly used in the north for dancing), the pipe, fiddle and drum. The gaita has been to some extent ousted by the accordion. but the Portuguese guitar, which is quite distinct from the Spanish guitar (known in Portugal as the *viola*), maintains its popularity. In Lisbon the *fado* is a ballad of crime or jealousy; a more lyrical form comes from Coimbra. Genuine popular ballads are still composed and recited to celebrate or commemorate local events.

Many curious superstitions survive in rural Portugal. Some are concerned with witches (*bruxas* or *feiticeiras*); there are also enchanted Moors (*mouras* encantadas), mermaids (sereias) who lure fishermen to destruction and werewolves (*lobis-homens*).

There are considerable regional variations in Portugal, and local differences are quite strongly preserved: but regionalism is less pronounced than in Spain and is almost devoid of political implications.

ECONOMICS, DEFENSE AND COLONIES

Agriculture, Livestock and Fishing. — Portugal is primarily an agricultural country, and 60% of the population of continental Portugal is engaged in agricultural pursuits.

Approximately two-fifths of Portugal is arable, and the main cereal crops are maize; wheat, rye, oats, barley and rice. Maize is grown especially in the north (districts of Oporto and Braga) and the coastal zone, while wheat, the most valuable crop, is produced in large quantities in the districts of Beja, Évora and Portalegre (Alentejo).

The consumption of wheat increased considerably in the 20th century, and Portugal can rarely grow enough to meet its needs. An energetic wheat campaign led to a year or two of self-sufficiency in the early 1930s, but thereafter importation again became normal as it seems to have been for centuries, though on a smaller scale than before. The olive tree is widely distributed, and olive oil is Portugal's second most valuable crop; Portugal is the world's third largest producer.

Grapes are grown over most of northern and central Portugal. The most valuable part of the vintage is port wine, which has been Portugal's principal export, but table wines are exported in considerable quantities to the colonies and to some extent to Brazil and other markets. Rice is grown in the valleys of several rivers. Fruit. abundant almost everywhere, is exported in its natural state, or dried or candied. The Algarve is famous for almonds and figs, Setúbal for oranges and Elvas for plums. (See Table I for some principal crops.)

TABLE I.—Agricultural Production
(in 000 metric tons; for olive oil and wine in 000 hl.)

Crop	1930–34	1948–50	1952–54	1955
Wheat	493	445	673	394
Barley	43	94	101	69
Oats	92	112	130	71
Rye	118	148	177	131
Maize	381	360	370	342
Rice	36	97	138	180
Potatoes	604	979	1,075	1,034
Olive oil	513*	722†	820	...
Wine	7,888*	8,030‡	11,410§	...

*1934–38. †1947–50. ‡1948–52. §1953–54.

Other important rural products are cork, of which Portugal is the world's largest producer and which is exported either crude or manufactured, and the products of the country's pine forests, including resin, turpentine. pit props and sann wood. Resin, a comparatively recent industry, had risen to be Portugal's fourth most important export by the end of World War II.

Oxen are widely used for plowing, especially in the north.

Sheep are numerous in eastern Portugal. The donkey is the usual beast of burden. Pigs and mules are bred in the Alentejo, as are bulls for the ring.

In 1955 cattle numbered 903.562: sheep 4,796,675; pigs 1,418,-615: goats 707,107; donkeys 232,497; mules 126,286; and horses 68.175.

Fishing villages are found at frequent intervals along almost the whole Portuguese coast. A fleet sails annually from Lisbon to the Newfoundland banks to procure the cod from which the staple *bacalhau* is made. The most valuable catch is the sardine, always a main export and occasionally the leading one. The centres of the sardine industry are at Setubal and at Matozinhos (near Oporto). The tunny is fished off the Algarve.

Industry and Mining.— Much of Portugal's industry is connected with the preparation of export products—the manufacture of cork and of glass for wine bottles, the canning of sardines. the extraction of resins and turpentine. etc. In addition, textiles of good quality are manufactured with home-grown wool or colonial cotton: other industries include cement and other construction materials. paper, soap, fertilizers. etc.

Various minerals occur in Portugal. including tin. wolfram, copper. sulphur. uranium, titanium, manganese. lead, zinc and kaolin. Tin. wolfram and copper are exported. Coal is found in a few places, but production is insufficient for domestic consumption. Iron ore exists in considerabie quantities but is little exploited.

Foreign Trade.— Portugal's principal exports are cork and cork manufactures (representing 18% of the total value of exports for the years 1951–54), fish, canned and in brine (10%), cotton fabrics (10%) and wine (8%). During World War II a great boom was produced by the competitive buying of rare ores by both belligerents. Wolfram was in especially great demand and remained so in the post\\-ar decade. Pyrites constitute another valuable mineral. Wood and wood products and fruit (principally almonds) are also exported in considerable quantities.

The principal imports are machinery. vehicles, etc. (26% of the total value for the years 1951–54), coal and petroleum and their products (11%), iron and steel and their manufactures (9%) and raw cotton (8%). In these circumstances, as other foodstuffs and raw material have also to be imported, there is normally an unfavourable balance of trade. The true extent of the gap, however, nas exaggerated by official figures until World War II. when the method of evaluation was altered. The deficits were met by agiotage on colonial goods, remittances from emigrants, services to shipping, etc. (See Table II.)

TABLE *11.—Foreign Trade*
(in 000,000 escudos)

Item	1948	1950	1952	1953	1954	1955
Imports (c.i.f.) . .	10,362	7,882	9,991	9,547	10,085	11,445
Exports (f o b) . .	4,295	1	6	6,284	7,297	8,144

The overseas territories together constitute the largest customer and supplier of continental Portugal. Between 1951 and 1954 the proportion of Portuguese exports to them increased from 23% to 25.1%, while the proportion of Portuguese imports from the overseas territories rose from 11.7% to 17%. Among other countries the main destinations of exports are the United States. the United Kingdom and the German Federal Republic. Main sources of imports, after the overseas territories, are the Cnited Kingdom, the German Federal Republic and the United States.

Finance.——Until Salazar became minister of finance in 1928. the Portuguese budget showed a deficit regularly. the only surplus for generations having occurred in one of the early years of the republic. Foreign indebtedness was high, and between 1917 and 1923 the escudo had dropped in value from 4*s*. to 2½*d*. When Salazar came to power, he applied a severe system of financial orthodoxy and produced a balanced budget in his first year. This feat was repeated annually, and the considerable surpluses garnered were used to promote public works. education, colonial development, equipment of the armed forces, etc. The foreign debt was greatly reduced. Revenue and expenditure are shown in Table III.

TABLE III.—*National Budgets*
(in 000,000 *escudos*)

Item	1951*	1952*	1953*	1954†	1955†	1956†
Revenue	5,653	5,906	6,488	7,076	7,335	7,680
Expenditure . . .	5,605	5,855	6,407	6	7,331	7,671

*Actual. †Estimated.

Communications.— The Portuguese roads were greatly improved and extended by Salazar's government and are usually well maintained. There are about 2.250 mi. of railway line, mostly of the broad or Spanish gauge. Part of this is state-owned, part privately owned. The Companhia dos Caminhos de Ferro Portugueses administers some private and some state-owned lines. The principal line is that running from Lisbon to Oporto via Coimbra. Lisbon is connected with Madrid by the Tagus valley. with Seville and Madrid via Elvas and Badajoz and with northern Spain and France by Guarda and Salamanca. From Oporto one can go to Salamanca via the Douro valley and into Galicia by the line crossing the Minho at Valença-Tuy.

Defense.— In peacetime, the ministry of defense co-ordinates the activities of the ministries for the army and the navy through a general secretariat for national defense under the direction of the chief of the general staff of the armed forces.

There is a supreme national defense council whose ex-officio president is the president of the cabinet of ministers. but which may be presided over by the president of the republic when necessary.

The Portuguese army consists of 16 infantry regiments. 3 independent battalions. 10 battalions of chasseurs and 3 machine-gun battalions; j motorized regiments of light artillery. 3 of heavy artillery and 1 of coastal artillery; 1 regiment and 3 independent groups of anti-aircraft artillery; 1 regiment of mountain artillery; 4 mechanized regiments; 2 regiments of engineers, each with telegraphists and sappers; 1 railway battalion: and 1 group of motor convoy companies, pontoon units and other services. The permanent effectives, including officers. total about 30.000 men in peacetime.

The national republican guard. comprising infantry and cavalry, has a total effective of about 7,000 men. The total effective of the fiscal customs guard is 5,400 men. The Portuguese legion (Legião Portuguesaj is a voluntary patriotic organization nith about 50,000 men. Military service is compulsory and involves 18 months' preliminary training, a period of 8 years on the active strength and a period of 12 years in the reserve, followed by 5 years in the territorial army. Service normally ends at the age of 45. In the colonial forces; service is normally for ten years in the active army and five in the territorial reserve. Members of the home army can be seconded to the colonial army for shorter periods, and reductions are made for volunteers.

Continental Portugal is divided into five military regions: Oporto. Coimbra, Tomar. Évora and Lisbon. There are separate commands in Madeira and the Azores. In the colonies there are commands in Angola. Rlozambique and Cape Verde and military departments in Guinea. India. Macao and Timor.

The air force consists of offensive and defensive groups, a bombing and an observation group and a training and depot squadron. The air service includes a command headquarters and inspectorate, aeroplane and balloon departments, anti-aircraft defense and flying schools.

The Portuguese navy in 1954 consisted of five destroyers, eight frigates and escort vessels and three submarines. with numerous auxiliary craft. The normal complement is 860 officers and 6,37j ratings.

Colonies.— The Portuguese colonial empire consists of seven separate colonies of which five are in Africa, one in Asia and one in Oceania. The two large colonies of the African mainland. Angola (Portuguese West Africa) and Mozambique (Portuguese East Africa). represent more than 90% of the empire by area. Third in size is Portuguese Guinea. Almost opposite Guinea lie the Cape Verde Islands. while in the Gulf of Guinea the tropical islands of St. Thomas (São Tome) and Prince's (Principe) form the fifth of the African colonies. The Portuguese "state of India," which consisted of Goa, Damão and Diu, was forcibly taken over by India in Dec. 1961. In China, the promontory of Macao (Macau) on the Pearl river lies between Canton and Hong Kong. Timor, the largest of the Lesser Sunda Islands, is divided between Portugal and Indonesia (formerly Dutch). All these are described in separate articles.

The Colonial act of 1933 formulated the rights and duties of the colonies and the main outlines of colonial policy. The minister for colonies in Lisbon is assisted by a supreme colonial council and other advisory committees. The governor of each colony has a colonial council, and there are periodical meetings of governors in Lisbon. For a time after 1921 there were parliamentary institutions in the colonies, but under the corporative regime these organs of sovereignty disappeared and colonial policy was coordinated in Lisbon.

BIBLIOGRAPHY.—For geography *see* A. Amorim Girão, *Geografia de Portugal* (Coimbra, 1942); H. Lautensach, *Portugal,* 2 vol. (Gotha, 1932–37); Américo Costa, *Dicionário corográfico de Portugal continental e insular,* 10 vol. (Oporto, 1949).

General histories of Portugal in English are Charles E. Nowell, *A History of Portugal* (New York, 1952); H. V. Livermore, *A History of Portugal* (Cambridge, 1947), and H. Morse Stephens, *Portugal* (London, 1891; with additional chapter, 1908). In Portuguese the most complete modern history is the monumental *História de Portugal,* ed. by Damião Peres and others, 8 vol. (Barcelos, 1929–38); Fortunato de Almeida's *História de Portugal,* 6 vol. (Coimbra, 1922–27), is valuable for its bibliography.

Other general works covering various aspects of Portuguese history are: Fortunato de Almeida, *História da Igreja em Portugal,* 4 vol. (Coimbra, 1910–22), and Padre Miguel de Oliveira, *História eclesiástica de Portugal* (Lisbon, 1940); J. Lúcio de Azevedo, *Épocas de Portugal económico* (Lisbon, 1929); the *História da expansão portuguesa no mundo,* 2 vol. (Lisbon, 1937–42). *See* also E. Prestage, "The Anglo-Portuguese Alliance," in *Transactions of the Royal Historical Society* (1934) and *Chapters in Anglo-Portuguese Relations* (Watford, 1935).

Early and Mediaeval Portugal: José Leite de Vasconcelos, *Religiões da Lusitania* (Oporto, 1924); Adolf Schulten, *Viriato,* Port. trans. by A. Ataíde, 2nd ed. (Oporto, 1940); A. A. Mendes Corrêa, *Raizes de Portugal,* 2nd ed. (Lisbon, 1944); Damião Peres, *Como nasceu Portugal,* 2nd ed. (Coimbra, 1942).

For the early monarchy, *see* Alexandre Herculano, *História de Portugal,* 4 vol. (Lisbon, 1846–73), 7th ed., 8 vol. (Lisbon, 1914–16), going to the death of Alphonso III in 1279; Padre Luis Gonzaga de Azevedo, *História de Portugal,* 5 vol. (Lisbon, 1935–42). For the documents of Alphonso Henriques' chancery *see* Abiah E. Reuter, *Chancelarias medievais portuguesas,* vol. i (Coimbra, 1938). The English narrative of the conquest of Lisbon is edited and translated by C. W. David, *De expugnatione Lyxbonensi* (1936). Carl Erdmann, *Papsturkunden in Portugal* (Berlin, 1927), deals with early relations between Portugal and Rome. Sources are dealt with by Gonzaga de Azevedo.

E. Prestage, *Royal Power and the Cortes in Portugal* (Watford, 1927), and Visconde de Santarém, *Memórias para a história e theoria das cortes geraes . . .* (1827; Lisbon, 1924), deal with early institutions. H. da Gama Barros, *História da administração pública em Portugal nos séculos XII a XIV,* 4 vol. (Lisbon, 1885–1922), new ed. by T. de Sousa Soares (1945 *et seq.*), deals with administration. *See* also A. de Sousa Silva Costa Lobo, *História da sociedade em Portugal no século XV* (Lisbon, 1903); Virgínia Rau, *As sesmarias medievais portuguesas* (Lisbon, 1946).

The Age of the Discoveries: For the domestic history of Portugal, *see* the general histories already mentioned and the chronicles of John II by Rui de Pina, Damião de Gois and Garcia de Resende; of Manoel by Damião de Gois; of John III by Frei Luiz de Sousa and Francisco de Andrade; and of Sebastian by Frei Bernardo da Cruz. *See* also Alfredo Pimenta, *D. João III* (Oporto, 1936); J. D. M. Ford (ed.), *Letters, 1521–1557* of the court of John III (1931); J. M. de Queiróz Veloso, *D. Sebastião* (Lisbon, 1935), and *A Perda da independência,* vol. i, *O Reinado do Cardeal D. Henrique* (Lisbon, 1946).

Alexandre Herculano, *História da origem e estabelecimento da inquisição em Portugal,* 3 vol., 10th ed. by David Lopes (s.d.), can be consulted in translation (1926). Mário Brandão, *O Colégio das Artes,* 2 vol. (Coimbra, 1924–33), and Cardinal M. Gonçalves Cerejeira, *Clenardo* (Coimbra, 1926), afford useful introductions of the Renaissance in Portugal.

For the Portuguese in the east, *see* C. R. Boxer, *Fidalgos in the Far East, 1550–1770* (The Hague, 1948), *The Christian Century in Japan, 1549–1650* (1951) and chapter in *Portugal and Brazil,* ed. by H. V. Livermore and W. J. Entwistle (Oxford, 1953).

The Late 16th, 17th and 18th Centuries: J. M. Queiróz Veloso, *Reinado de D. Henrique;* Dánvila, *Don Cristóbal de Moura* (Madrid, 1900); Miguel das Antas, *Les Faux Sébastian* (Paris, 1866); J. Lúcio de Azevedo, *A Evolução do Sebastianismo,* 2nd ed. (Lisbon, 1947).

For the restoration *see* E. Prestage, *Diplomatic Relations of Portugal: 1640–1668* (Watford, 1925), and contemporary authorities such as Luis de Meneses, *História de Portugal restaurado,* 2 vol. (1679–98). For the life of D. Luisa de Gusmão *see* Hipólito Raposo's biography (Lisbon, 1947). António Baião studied the marriage of Alphonso VI in his *Causa de nulidade* (Coimbra, 1925), and Virgínia Rau has written on Catherine of Braganza in *O Instituto,* vol. 98 (Lisbon, 1941). Damião Peres, *A Diplomacia portuguesa e a sucessão de Espanha: 1700–14* (Barcelos, 1931), deals with Portugal in the War of the Spanish Succession; Eduardo Brazão, *Relações externas de Portugal: reinado de D. João V,* 2 vol. (Oporto, 1938), with the reign of John V. For the age of Pombal *see* Marcus Cheke, *Dictator of Portugal* (London, 1938); the most convenient introduction in Portuguese is J. Lúcio de Azevedo, *Marquês de Pombal e a sua época* (Lisbon, 1909 and 1922). *See* also Caetano Beirão, *D. Maria I: 1777–92,* 2nd ed. (Lisbon, 1934).

The 19th and 20th Centuries: C. K. Webster (ed.), *Britain and the Independence of Latin America, 1812–1830,* 2 vol. (Oxford, 1938); M. de Oliveira Lima, *D. João VI no Brasil,* 3 vol., 2nd ed. (Rio de Janeiro, 1945); Marquês do Lavradio, *D. João VI e a independência do Brasil: últimos anos do seu reinado* (Lisbon, 1937); Oliveira Lima, *D. Miguel no trono 1828–1833* (Coimbra, 1933); Maria Amélia Vaz de Carvalho, *Vida do duque de Palmela,* 3 vol. (Lisbon, 1898–1903); W. Bollaert, *Wars of Succession in Portugal and Spain,* vol. i (London, 1870); John Smith, *Memoirs of Field-Marshal the Duke of Saldanha,* 2 vol. (London, 1880), a rather flattering portrait; Júlio de Vilhena, *D. Pedro V e o seu reinado,* 3 vol. (Coimbra, 1921); Luis Vieira de Castro, *D. Carlos I,* 3rd ed. (Lisbon, 1943); Jesús Pabón, *La Revolución Portuguesa,* 2 vol. (Madrid, 1941–45).

For the regime of Salazar, *see* F. C. C. Egerton, *Salazar, Rebuilder of Portugal* (London, 1943); Antonio Ferro, *Salazar: Portugal and Her Leader,* Eng. trans. (London, 1939); Luis Teixeira, *Perfil de Salazar* (Madrid, s.d.); also Salazar's own *Discursos* and *Doctrine and Action,* Eng. trans. (London, 1939). Michael Derrick, *The Portugal of Salazar* (London, 1938), is a general account.

For official information and statistics, see *Anuário Estatístico de Portugal* (Lisbon); *Estatística comercial* (Lisbon); *Anuário demográfico* (Lisbon); *Boletim Mensal do Instituto Nacional de Estatística* (Lisbon); *Anuário Colonial* (Lisbon); *Boletim da Agência Geral das Colónias* (Lisbon, monthly). *See* also P. Descamps, *Le Portugal* (Paris, 1935); F. Cotta, *Economic Planning in Corporative Portugal* (London, 1937). (H. V. L.)

PORTUGUESE EAST AFRICA or MOZAMBIQUE (officially PROVINCIA DE MOÇAMBIQUE), the most populous and second largest of the five Portuguese African possessions, is bounded on the east by the Indian ocean, on the north by Tanganyika, Nyasaland and Northern Rhodesia, on the west by Southern Rhodesia and the Transvaal and on the south by Natal (Tongaland). Its area is 297,846 sq.mi., and its length from north to south about 1,300 mi. Because of the great irregularity of the frontier the territory varies in width from 56 mi. in the south to 480 mi. It takes its name from the town and island of Moçambique or Mozambique (*q.v.*), formerly the capital and a way station on the voyage to India.

Physical Features.—The coast line extends from 10° 40′ S. to 26° 52′ S. and makes a double curve on a northeast-southwest axis. Its length is about 1,600 mi. In the extreme south, about 40 mi. N. of the Natal frontier, is the great basin of Delagoa bay (*q.v.*) on which stands the capital, Lourenço Marques. North of this the coast is low-lying and sandy or swampy as far as the deep indentation of the Zambezi delta. From the Zambezi northward the coast is studded with small islands, mainly of coral formation, on one of which is Mozambique. North of this there are high rocky headlands and rugged cliffs. Pôrto Amélia stands on the great natural harbour of Pemba bay. The territory is rich in rivers, about 50 of which flow into the Indian ocean. The Zambezi divides the province in two: to the south the coastal plain is much deeper and only a small part of the high plateau falls in Portuguese territory. In the centre the Gorongoza reaches 6,600 ft., and farther north there are several ranges: Nampula district has more than 20 groups of mountains more than 4,000 ft. high and Namuli peak is 8,858 ft. high. Southeast of Lake Nyasa there is a high range which drops 3,000 ft. in 6 mi. to the level of the lake. The highlands along the Southern Rhodesian border reach about 9,000 ft.

Geology.—The central plateau consists of gneisses, granites and schists of the usual East African type which in part or in whole are to be referred to the Archaean system. Rocks of the Karroo period occur in the Zambezi basin, where at Tete they contain workable seams of coal and have yielded plant remains of Upper Carboniferous age. Sandstones and shales, possibly of Upper

Karroo age, form a narrow belt at the edge of the foot plateau. Upper Cretaceous rocks crop out from beneath the superficial deposits along the coast belt between Delagoa bay and Mozambique. The highest Cretaceous strata occur in Conducia, where they contain the huge ammonite *Pachydiscus conduciensis.* The Eocene formation is well represented in Gazaland by the nummulitic limestone which have been found to extend for a considerable distance inland. Basalts occur at several places in the Zambezi basin. On the flanks of Mt Milanje there are two volcanic cones which seem to be comparatively recent; but the most interesting igneous rocks are the rhyolitic lavas of the Lebombo range.

Climate and Health. — In most parts of Mozambique there is a hot, wet season (October–March) and a cooler, dry season (April–September), though rainfall is irregular. The climate of Lourenço Marques resembles that of Durban, South Africa, with an average temperature of 72° F. In the centre Quelimane on the coast has an annual mean temperature of 85.1°, with a maximum of 106.7° and a minimum of 49.1°. At Tete, about 260 mi up the Zambezi, the annual mean is 77.9°, the hottest month being November, 83.3°, and the coldest July, 72 3°. The range is similar in the north. On the uplands and plateaus the climate is more temperate. Rainfall (average over many years in inches) is: Lourenço Marques 30.6; Beira 60.4; Quelimane 56.4; Mozambique 31 4; Tete 21 2; Shiré 72 2.

Malarial and other diseases occur in Mozambique. especially on the lower ground. Great progress has been made in making Lourenço Marques and the other main centres healthful. and medical and preventive services have been much extended, especially in combating the malarial mosquito at its breeding grounds. Endemic focuses of sleeping sickness have been verified at various places. and the tsetse fly is found in several districts.

Flora and Fauna. — The coconut is common in the coast regions and often attains 100 ft.; the date palm, mostly in marshy ground and near rivers, is seldom more than 20 ft. in height; four other palms occur A kind of cedar is found in the lower forests; ironwood and ebony are common. The large *Kkaya senegalensis,* found in ravines and by riverbanks, affords durable and easily worked timber; there are several varieties of *Vitex* and of *Ficus,* notably the sycamore fig *(Ficus sycomorus).* which bears edible fruit and is the "sycamore" of the Bible.

Excellent hardwood is obtained from a species of *Grewia.* Other characteristic trees are the mangrove (along the sea shore), sandalwood, gum copal, baobab and bombax, and, in the loner plain, dracaenas (dragon trees), and many species of creepers and flowering shrubs, and several prickly shrubs. Acacias are numerous. including the gum-yielding variety, while *Landolphia* rubber vines grow freely in the forests Coffee, cotton indigo and tobacco plants, castor oil, bananas, mangoes and pineapples are found. The bamboo is common and spear grass with its waving, snowy plumes grows to 12–14 ft. and is abundant along the river banks and along the edges of the marshes.

The lion, of both the yellow and the black-maned varieties, leopard spotted hyena, jackal, serval. civet cat, genet, hunting dog and mongoose occur in the Rfozambique district. The elephant and the black rhinoceros are common, and south of the Zambezi are a few specimens of white rhinoceros (*Rhinoceros simus*). The rivers and marshes are the home of hippopotamuses, which have however deserted the lower Zambezi. The wart hog and the smaller red hog are common. A species of zebra is plentiful, and herds of buffalo are numerous in the plains and in open woods. Many antelopes are found, but the giraffe does not occur. Scaly anteaters are fairly numerous, and rodents are common. There are several kinds of monkeys and lemuroids, but the anthropoids are absent.

Crocodiles, lizards, chameleons. land and river tortoises are all very numerous, as are pythons (about 18 ft. long). cobras, puff adders and vipers. Centipedes and scorpions and insects are innumerable. Among insects mosquitoes, locusts, the tsetse fly, the hippo fly, cockroaches, phylloxera. termites. soldier ants and flying ants are common plagues. As has been indicated. the Zambezi forms a dividing line not crossed by certain animals, so that the fauna north of that river presents some marked contrasts with that of the south.

Flamingoes are common in the Mozambique district. Cranes, herons, storks. pelicans and ibises are numerous. including the beautiful crested crane and the saddle-billed stork (*Ephippiorhynchus senegalensis)*; the last-named is comparatively rare. The eagle, vulture, kite, buzzard and crow are well represented, though the crested eagle is not found. The guinea fowl. partridge, bustard, quail. wild goose, teal, widgeon. mallard and other kinds of duck are all common. A small green parrot is found.

HISTORY

Between the 11th and 1 jth centuries the east coast of Africa as far south as Sofala was linked politically with Arabia and India. Although the main centre of Arab influence was to the north of what is no Mozambique, Arab trade and to a lesser extent civilization had influenced the coastal peoples down to the Zambezi. Mozambique was first opened to European influences by Vasco da Gama who, on rounding the Cape of Good Hope in 1497, put in at what he called the Rio dos Bons Sinaes (River of Good Tokens). where he first found signs of oriental influence: this is now the Quelimane river, the northern outlet of the Zambezi, discovered on Feb 25. 1498.

Gama also put in at Mozambique (March 1), before sailing north for Malindi Mombasa and India. Sofala was seen in July 1500 by Pedro Álvares Cabral on his way to India, and on his return it was visited by one of his ships under Sancho de Toar, who made inquiries about the legendary gold trade of the place. Soon afterward. António de Campo visited Delagoa bay. A Portuguese settlement was made at Sofala in 1505. Despite its supposed commercial attractions Sofala was difficult to maintain and unsuitable as a way station for the Portuguese Indiamen, and the port of Mozambique was therefore annexed and fortified soon after. Within a few years the Portuguese had ended Arab influence in the area. Attempts to reach the *monomotapa,* the potentate who owned the supposed gold and silver mines of the interior, were disappointing. though a convict named Antonio Fernandes explored much of Monomotapa (Mashonaland) before 1514. The desire to find an easier route to the interior led to the founding of a settlement near Quelimane in 1544. In the same year Lourenço Marques explored the Delagoa bay area, and a station was set up near Catembe.

As a result of Fernandes' explorations the Zambezi was adopted as the main route into the interior. Sena. 160 mi. from the sea, was established in 1531, and Tete. 321 mi. upstream, soon after. In 1560 the Jesuit father Gonçalo da Silveira set out to convert the *monomotapa,* and guided by a Portuguese trader reached the chief's kraal in a year Although he found a compatriot living with the chief, he himself and his converts were strangled in March 1561.

The death of Silveira was followed by the dispatch of an expedition from Lisbon to seize the *mononzotapa's* mines. Its leader, Francisco Barreto, after losses from disease turned back and himself died. Barreto was followed by \-asco Fernandes Homem who travelled from Sofala to Manica and negotiated with the *monomotapa* near Umtali: he was disappointed with what he saw. and, although the great amount of valuable information about the interior he and his predecessors had collected was incorporated in João dos Santos' *Ethiopia oriental* (1609), the idea of conquering it for the crown of Portugal seems to have been abandoned in view of the limited possibilities of trade.

In the 17th century the Dutch wrested control of the eastern seas from the Portuguese. but. though they thrice attempted to seize the port of Mozambique, they were beaten off. The Portuguese settlers had now come to rely largely on the slave trade, which played an essential part in the development of Brazil. When the Dutch for a time seized the main sources of slaves in Angola, the Portuguese fell back on Mozambique, among other places. The slave trade continued until the middle of the 19th century, slavery was abolished in the colony in 1878.

In the early part of the 18th century the Arabs again expanded in east Africa and the northern limits of Portuguese influence were fixed at roughly the modern frontier of Mozambique. In

1752, Portuguese East Africa, after being subordinated to the Portuguese administration at Gba, was separated and given an independent governor.

The most remarkable of the colonialists of Mozambique was Francisco José Maria de Lacerda e Almeida, a Brazilian, who had explored the interior of his own country and Angola. He was made governor of Rios de Sena in 1797, and carried out the expedition to Cazembe on which he died in the following year. The distress caused in Portugal by the Peninsular War and the separation of Brazil left their mark on the administration of Mozambique, whose inhabitants felt their whole existence threatened by the abolition of slavery. Much of the country was also threatened in the 19th century by the raids of savage tribes of Zulu origin.

In the partition of Africa Portugal maintained rights based on the discovery of most of the African coast in the face of the doctrine of effective occupation. Cntil the Congress of Berlin Portugal hoped to preserve a continuous belt of territory from coast to coast uniting modern Angola with Mozambique. The acquisition of British rights in this area, especially to the south of Lake Nyasa and in the Shiré highlands, caused the Portuguese to prepare a counterexpedition. but when Maj. A. de Serpa Pinto came into conflict with peoples under British protection, the marquess of Salisbury, then British prime minister, delivered an ultimatum in Lisbon (1890). This was followed by a treaty defining the frontiers of British and Portuguese possessions and the creation of the Mozambique and Niassa companies for the development of the area. Under the Portuguese republic a measure of autonomy was granted to the colony, and this was extended in 1920. After the Portuguese revolution of 1926 this system was ended, and within the provisions of the Colonial act a much more centralized system mas adopted.

The building of the railways led to a rapid expansion of Mozambique's economy, and conventions with the countries of the hinterland were signed governing the question of transit trade, the recruitment of natives from Portuguese territory for work in the Rand mines and other matters. The original Mozambique convention which had been concluded with the Transvaal government in 1909, lapsed in 1923 and was replaced in 1934 by a new treaty that ran until 1939; thereafter it remained in force subject to 12 months' notice of termination of either party. The Companhia de Moçambique was wound up in 1942 and Mozambique was designated as an oversea province of Portugal in 1951.

THE PEOPLE

Populations and Towns. — The population of Portuguese East Africa shown in the census of Sept. 1950 was 5,732,317 as compared with 5,085,603 at the census of 1940. The number of civilized inhabitants was given as 92,404, of whom 48,910 were whites and 24,898 half-castes; there were small numbers of Indians and Chinese, and 4,377 Negroes were described as "assimilated"; *i.e.*, living as whites.

All the natives are Bantu-speaking, and the main tribal groups from north to south are: in Niassa, the Yao (*q.v.*); in Pbrto Amélia, Nampula and Quelimane, the Makwa or Macua; in Beira and Quelimane, the Basenega; in Tete, the Baangoni and Basenega; in Lourenço Marques and Inhambane, the Baronga, Batonga and Bachopi. The Yao occupy the area between Lake Nyasa and the Msalu river. The Makwa are divided into four groups — the lower Makwa, the Lomwe or upper Makwa, the Maua and the Medo. They have come into contact with Arabs, Banyai and Battia in the coastal districts, and their language has been much altered, though they have kept their purity of race. Between the Zambezi and the Mazoe most of the tribes are of Zulu origin, and in the area south of the Pungwe river, known as Gazaland, the ruling peoples are of Zulu origin, and all other tribes of difierent stock are known as Tsonga (Thonga). They include the Batonga (Inhambane) and Baronga (Lourenqo Marques), peaceful stock raisers and farmers akin to the Basuto. The Bachopi are a Bantu-speaking people of different origin and language.

The most important towns are: Lourenco Marques (*q.v.*), the capital, where about half the white population lives; Beira (*q.v.*), the headquarters of the former Mozambique company's territory; Mozambique (*q.v.*), established as a Portuguese post in 1508 and the capital of the territory until 1897; Quelimane, Inhambane and Chinde (*qq.v.*). Sofala (*q.v.*) is now of little importance, and its fort, founded in 1505, has collapsed into the sea. Other European settlements are (from north to south) Ibo, Pbrto Amélia, Vila Cabral, Nampula. António Enes (Angoche. formerly Parapato), Tete, Sena, Zumbo, Macequece (Masikesi, Vila Manica) and Vila João Belo. Ibo is a small port on one of the many Cabo Delgado islands and was formerly the capital of the district. It is picturesque and has ancient fortifications. Pôrto Amélia, the port for the districts of Cabo Delgado and Niassa, stands on the natural harbour of Pemba bay, which is 1½ mi. wide at the entrance and covers an area 7 mi. long by 5 mi. broad. Nampula, the capital of Niassa and seat of a bishopric, has a European population of about 300 and is the centre of a native population of 100,000. António Enes, 95 mi. southwest of Mozambique, dates from the 17th century and was rebuilt after suffering severely from cyclone damage in 1939. It exports copra. peanuts, sisal, etc., from an important area.

The Zambezi towns, some of which date from the 16th century, represent the limits of Portuguese penetration into the interior until the 20th century. They had considerable economic importance until the 18th century after which they declined. The development of the Rhodesias and the consequent building of railways restored their former importance. Tete, founded in 1531, is the centre of a mineral-bearing district and of an important transit trade with the British territories, since it is on the main road from Salisbury (Southern Rhodesia) to Blantyre (Nyasaland). Its district covers 65,000 sq.mi. and has a population of 336,000. Sena, halfway between Tete and the sea, is an ancient town, now about 2 mi. from the Zambezi. From it the Trans-Zambezi bridge crosses the river to Dona Ana on the north bank.

Macequece, on the railway line from Beira to Rhodesia, is 15 mi. from the frontier. It is pleasantly situated at 2.300 ft. and as it is healthful for most of the year it is a resort for those who live on the coast. It is the capital of Manica district and the centre of the small Manica gold fields. Vila Pery and Vila Machado are other settlements on the same line. Vila João Belo, 23 mi. from the mouth of the Limpopo, the chief town of the district of Gaza, is the centre of a rich farming area producing sugar, rice, maize and timber. A group of settlements in the neighbourhood of Lourenço Marques includes Moamba and Ressano Garcia, both on the railway from the capital to the Transvaal.

Education and Religion. — The predominant faith is Roman Catholic; the position of the church is defined by the Portuguese concordat and missionary agreement of 1940. This created a metropolitan see at Lourenqo Marques, to which two dioceses of Beira and Nampula are suffragan. There is freedom of worship and in addition to the modern Roman Catholic cathedral Lourenço Marques has an Anglican procathedral, a Methodist church, a synagogue, a mosque and a Chinese temple. Anglicans in Portuguese East Africa are subject to the archbishop of Cape Town: the Delagoa bay region and the district of Sul do Save form the Lebombo diocese with see at Lourenço Marques; Anglicans in the north come within the diocese of Southern Rhodesia. Other Christian missions are the Church of Scotland, Swiss and American Free Methodist.

The educational system of the colony is supervised by the department of education in collaboration with that of health. There is no university in Mozambique and students who wish to work for a degree usually go to Portugal. A large new secondary school, the Liceu Salazar, was built in Lourenco Marques in 1951 to serve the whole province.

There is a school for training native teachers run by the Roman Catholic Church and a special school for the children of native chiefs. The usual school for natives provides a primary education lasting four or five years. The age of entry varies greatly, and the subjects are reading, writing and arithmetic. There are also three arts and crafts schools for natives. Under the agreement of 1940 most of the native primary schools are entrusted by the state to Roman Catholic missionaries. There are also several foreign missionary schools. All instruction is given in Portuguese. Lourenqo Marques has various private and community schools for the English-speaking community. and for Hindus. Moslems and Chinese. In 1952 the number of primary schools was given as 1,261 with 174,320 pupils. There were 21 lyceal and other secondary schools (1950) with 1,885 pupils; and 3 teachers training colleges (1951) with 21 j students.

Administration. — The head of the province's government is the governor general who is appointed by the council of ministers in Lisbon for a four-year term, subject to reappointment, and who is directly responsible to the minister for overseas provinces in Portugal. Although he may be overruled in Lisbon on important matters, the governor general exercises wide powers in the province. He resides in Lourenqo Marques. He is assisted by an advisory government council.

There are no representative institutions, the only elected officials being the five unofficial members of the government council. who are elected by certain economic organizations such as the chambers of commerce, and the elected members of the town councils in the few municipal areas designated as communes. The five unofficial members of the government council are more than offset by the seven official members who sit on the council by reason of their position in the local administration. The council normally holds but one short session each year and is strictly consultative. The administration of the province is carried out through four lesser provinces and nine districts as follows (from south to north): province of Sul do Save, consisting of the districts of Lourenqo Marques, Gaza and Inhambane; province of Manica and Sofala, districts of Beira and Tete; province of Zambézia, district of Quelimane; province of Niassa, districts of Nampula. Cabo Delgado and Lago. The provincial capitals are Lourenqo Marques, Beira. Quelimane and Nampula respectively.

The districts are in turn divided into subdistricts (*circunscrições* civis) each under an administrator, and each subdistrict is redivided into one to four administrative posts, in which are the post offices, police stations, etc. The provinces are headed by provincial governors who can be overruled by the governor general. An administrator heads each district. A judicial system, comprising a court of appeals and courts of preliminary investigation in ten judicial divisions, maintains separate sections for native cases and applies the Portuguese law (cddigo civil).

The Mozambique company (Companhia de Moçambique) was incorporated by royal charter in 1891 for a term of 50 years. Much of its capital of £1,500,000 was foreign, and it exercised sovereign rights over the territories of Manica and Sofala, an area of 59,315 sq.mi., until its rights reverted to the Portuguese government in 1941, when they were not renewed, and the territory was formally restored to direct Portuguese administration on July 19, 1942. In this territory the company had control of agriculture, commerce, industry, mining, communications and transport, taxation and customs. and issued its own currency and postage stamps. The main interests of the company were in agriculture and transport, and after the restoration of the territory to the provincial government extensive schemes were adopted for developing it.

The Niassa company (Companhia do Niassa) acquired a charter for the administration of territories north of the Lurio river in 1894. Its capital was at Pôrto Amélia. Development under the company was comparatively slow, and in 1929 the Portuguese government resumed administration of the area.

ECONOMY

Agriculture. — Although much of the province consists of thinly populated bush country, it has also areas of high fertility. The most important of these are the southern lowlands between Catuane and Inhambane. which contain the lower reaches of the Limpopo and other rivers; the valleys of the Save and Zambezi; Quelimane; the coastal area of Mozambique and Nacala and its hinterland; and the Macondes highlands on the Tanganyika frontier. These include the main areas of native population. The main types of agriculture are the indigenous; the native-produced cash crop; and the European-owned plantation. There are few white small farmers, though it was hoped in the 1950s that the drainage and irrigation of the Limpopo valley would provide suitable soil for the settlement of Portuguese immigrant small holders.

The main crops gro n by European (and other non-native) cultivators are: copra, sisal, sugar cane, tea, rice. potatoes, sunflower, maize. tobacco and wheat — together contributing one-third of the province's exports. Sugar is grown on estates in the Zambezi, Sul do Save and Manica areas; and there are very extensive plantations of copra-producing coconut palms in the coastal area of Zambézia, with about 6,000,000 trees. Sisal is produced as a plantation crop in Zambézia, Niassa and Manica. Tea is an increasingly valuable plantation crop.

The most valuable single export of the province is raw cotton, which accounted for between one-fifth and one-quarter of total exports between 1946 and 1950. It is produced by the natives, and its development has been accomplished to some extent by sacrificing staple crops. Both cotton and rice, which latter meets the territory's needs and leaves a surplus for export, are cultivated under European supervision, under a concessionary system.

Native-produced crops include cashew nuts, which are collected all over Mozambique. copra, peanuts. sesame (all of which are usually exportable), maize, tobacco and vegetables. Maize normally suffices for consumption in Mozambique, but in 1949, 1950 and 1951 crops were poor, and imports were necessary. Tobacco, which is grown in the north, and coffee, which has a rather bitter taste popular in Mozambique, are produced for local consumption.

Forestry, Stockraising and Industries. — There are considerable resources of timber, including a large area of forest behind Beira.. The export of timber and wood-products increased greatly during World War II, from 10,960 tons in 1939 to 80,596 in 1946.

The most important timbers produced are: African mahogany (Khaya senegalensis) ; ebony or grandilha; mussacossa or pod mahogany (Afzelia quanzensis), called *chanfuta* in the south of the province, used for furniture, vehicles, etc.; m'bila (*Pterocarpus*) or bloodwood; *pau-ferro* (Swartzia), suitable for high-class furniture; African sandalwood for furniture and wagon work, etc.; ziba, a valuable hardwood; *moanjwa* (Cordyla); *m'zimbiti* (*Andro*-stachys), impervious to white ants, and used for railway sleepers and piles; *panga-panga* (Lonchocarpus), suitable for furniture; muanga or chuanga (Ormosia), used for bridge building, being impervious to white ants; *monhé* or gone (Adina), similar to teak; and messanda (Erythrophloeum), a very hard red wood, suitable for railway sleepers.

There is little industrial development in the province, but the government's policy is to encourage local production by the use of protective tariffs and the concession of monopolies for the manufacture of certain products. A textile factory has been built at Vila Pery, and cement is made near Lourenqo Xarques, where production is nearly 50,000 tons a year, and Beira. A large fibrous cement factory at Dondo, near Beira, makes irrigation pipes and prefabricated houses. Bricks, ceramics and other construction materials are produced in the province. A rubber factory makes rubber-soled footwear from the latex of a wild tree, and jute sacks and bags are also manufactured. In 1955 there were 6 tobacco factories and 32 producing oils and soaps. There are factories for the preparation of foodstuffs. including milling and the decortication of rice and cashew nuts. There are several breweries and mineral-water factories.

Minerals and Mining. — The mineral resources of the province are still inadequately known, though the mines department was undertaking a full survey in the mid-1950s. Although the region of Sofala was according to legend rich in gold and was identified with Ophir (*q.v.*), the quantity now extracted is small. It is mined near Vila de Manica and Tete, and there are alluvial deposits near Vila de Manica and Alto Zigonha (Quelimane). Coal is mined, though not on a large scale, in the Zambezi valley near Tete, and surveys confirm the existence of an extensive basin estimated to contain 700,000,000 tons. The Companhia Carbonifera de Mocambique. uith Belgian capital, supplies the railways and the port of Beira and exports some coal to Nyasaland. Southern Mozambique imports coal from South Africa.

The Alto Ligonha company, with exclusive rights over part of Zambézia, mines beryl, mica, colombite and bismuth. Quantities of graphite exist near Nacala and in Angónia, but extraction is irregular. Prospecting for petroleum was undertaken in Sul do Save under a contract for ten years (1948–58) between the Portuguese government and the Moçambique Gulf Oil company. Radioactive minerals exist in the Tete district; prospecting concessions are granted only through the Portuguese government and independent prospecting is prohibited.

Finance and Trade. — Unlike Angola, which for several years absorbed large quantities of capital without any return, Mozambique has enjoyed a long period of prosperity, largely as a result of a steady income from the supply of services and native labour to the territories to its west. At the end of 1951 the province's exchange account shoued reserves of about £3,500,000 in foreign currencies and £4,500,000 in gold. There was a surplus of income over expenditure after 1937, so that large sums were devoted to extraordinary public works, amounting to nearly £7,000,000 between 1946 and 1950. In 1947 the Portuguese government made a loan of 1,000,000,000 escudos to Mozambique.

The chief sources of revenue are customs duties. income tax and licence and stamp duties. The monetary unit is the Mozambique escudo of 100 centavos, equal in value to the Portuguese escudo. The Banco Nacional Ultramarino is the bank of issue.

The development of the province has been greatly facilitated by the profitable transit trade of the Transvaal, the Rhodesias, Nyasaland and Belgian Congo, though this has in some ways hindered the growth of internal communications within Mozambique. The hiring of a large number of native labourers to the Rand mines has similarly contributed very greatly to the territory's prosperity, though the absence of so large a proportion of its labour is unfavourable to its own agriculture. However, the advantages of these arrangements far exceed the disadvantages, and the construction of railways to the interior has led to the appearance of new townships in the hinterland of the capital and of Beira.

The requirements of the transit trade have led to a continuous development of the railways and port installations, while agricultural production has steadily increased. and Portuguese industrialists have introduced a number of manufactures. British and South African interests are represented in transport services, distribution. agriculture, etc. There is also U.S., French, Belgian and German capital.

The foreign trade of the province normally shows an excess of imports over exports. In 1950 imports were valued at 1,654,000,000 escudos and exports at 944,000,000 escudos. Re-exports, largely minerals from South Africa, were 604,000,000 escudos and transit traffic 7,936,000,000 escudos. Nearly 30% of both imports and exports were trade with Portugal. Twenty per cent of the province's imports came from the United Kingdom, but only 2% of its exports were sent there. Thirteen per cent of imports came from the United States which took 6% of Mozambique's exports. and the corresponding figures for South Africa were 13% and 18%.

The chief imports are cotton textiles (about one-sixth of the whole), railway material, agricultural and other machinery, table wines and vehicles. Other main items are iron and steel, wheat flour, gasoline and milk.

The cost of living in Mozambique doubled between 1939 and 1950.

Communications. — The province is served by some 40 shipping lines, which link Lourenço Marques with the main south and east African, European. Indian and American ports. In 1953, 1,197 ships with a net tonnage of 7,932,985 were handled at Lourenqo illarques. At Beira 669 ships of 2,582,979 tons entered in 1952. In each case more than half were English. The number of entries by coastal shipping in 1949 was 1,042, of which Lourenço Marques accounted for 171, Beira 179, Quelimane 136, Inhambane 112, Chinde 86, Mozambique 80, António Enes 79 and Pôrto Amélia j6.

The road system is satisfactory in the settled areas. though many parts of the province are still inaccessible by road, and much surfacing and bridge-building is necessary to make the existing roads suitable for use all the year round. Of 23,200 mi. of road in the province in 1952, 2,560 mi. were described as main roads. Metalled roads are limited to the capital and Beira, but the main towns are linked by good gravel roads. The following roads are the main international routes: Lourenço Marques to Goba for Swaziland; Lourenqo Marques to Ressano Garcia for Johannesburg; Beira to Macequece for Salisbury; Tete to Zôbué for Nyasaland; Tete to Vila Gamito for Fort Jameson (Northern Rhodesia); Quelimane to Milanje for Blantyre (Nyasaland); Mozambique to Nampula and Mandimba for Blantyre: and Mandimba to Vila Cabral and Côbué (Kabué) for Tanganyika.

The province's railway system owes its existence to the transit trade of the neighbouring English-speaking territories, and although these lines have contributed much to the opening up of Mozambique. there is still no rail connection between the chief centres of the province. From Lourenço Marques there are lines to Ressano Garcia (for the Transvaal frontier and Johannesburg), to Goba (for Swaziland); to Xinavane for the Komati (Incomati) valley; and to Marracuene (Vila Luisa) and the Limpopo valley. There is a short line from Vila João Belo to its hinterland (85 mi.), and from Inhambane to Inharrime (55 mi.). In central Mozambique the port of Beira is connected with Blantyre by the Trans-Zambezi railway, while a branch goes up to Moatize, near Tete. The line from Beira to Umtali for Salisbury (190 mi.), also connects Macequece, Vila Pery and Vila Machado with the coast. Quelimane has a port railway to Mocuba (go mi.); and a line from the port of Lumbo (Mozambique) connects with the new port of Nacala and runs through Nampula and up toward the Nyasaland frontier at Cuamba (335 mi.).

The Lourenqo Marques-Transvaal line carried 449.892 passengers and 3,455,945 tons of freight in 1950, and the Beira-Umtali line 237,710 passengers and 1,724,736 tons of freight.

The Zambezi is navigable by light-draught steamers throughout its course in Portuguese territory with a break at the long Kebrabasa (Quebrabaqa) rapids, 400 mi. from its mouth. There is direct steamer and railway connection with Lake Nyasa by the Shiré (Chire) river (*q.v.*).

The province belongs to the South African postal union. It is connected with Europe by telegraph via South Africa and via Zanzibar. A cable connects Mozambique with Madagascar, and it is linked with the British-owned Aden-Durban cable. There are land lines between Lourenqo Marques and Johannesburg, and Beira and Salisbury, an internal radio system for communication between the main administrative centres, and an external radio system for Lisbon and other towns in Portugal. The Radio Club of Mozambique controls five transmitters which broadcast in Portuguese, and also in English for South Africa. (H. V. L.)

BIBLIOGRAPHY.—F. J. M. de Lacerda e Almeida, *Lands of Cazembe* (London, 1873); G. M'C. Theal, *The Portuguese in South Africa* (London, 1896), *Records of South-Eastern Africa, 9* vol. (London, 1898–1903); Foreign Office, London, *Mozambique* (London, 1918); Admiralty, London, *A Manual of Portuguese East Africa* (London, 1920), *Portuguese Nyasaland* (London, 1920); E. Axelson, *South-East Africa, 1488–1530* (London, Toronto, 1940).

PORTUGUESE GUINEA, a Portuguese overseas province on the Guinea coast of west Africa, extending from just south of Cape Roxo to the Cajet river (the northern arm of the Cogon estuary). Its coastline is extremely indented but extends about 150 mi. as the crow flies. Its area is 13.948 sq.mi. It is enclosed by Senegal on the north and Guinea on the southeast.

Physical Features. — Almost all the country is lowland. Off the coast there are many islands separated from the mainland only by creeks. although the Bijagós (Bissagos) archipelago consists of about 25 islands and islets lying 15 to 30 mi. offshore. The main rivers are the Cacheu (upper course called Farim), the Mansôa, the Geba and the Corubal (Rio Grande; upper reaches in French territory called Komba). the two last uniting in the deep inlet of the Rio Grande or Geba estuary. Other deep inlets are the Rio Tombali, the Rio Grande de Bolola and the Rio Cacine (which are not rivers but gulfs). There are fairly numerous swamps and pools. except in the southeast, the only high ground in the territory (328 ft.).

Climate. — There are two seasons, the dry from December to

May, and the wet from June to November. During the former the hot northerly harmattan (*q.v.*) blows from the desert, and the maximum monthly mean temperature is 85° F. in May. There is no rain at all between January and April, and the whole rainfall of up to 75 in. is therefore confined to the wet season, about one-third of the total occurring in August. The minimum mean monthly temperature occurs in January (77°). The difference between the two seasons is less marked in the interior.

Flora and Fauna. — The coastal region and the islands are covered with palm trees; the rest of the country, interspersed with swamps, is only lightly forested. The chief trees are the cotton tree, the African mahogany (Khaya senegalensis), the great ironwood or balsam tree (*Copaifera*), the baobab and innumerable varieties of acacia. Fruit trees include the papaw. guava, mango, banana and orange. Coffee trees, cotton bushes and indigo may be found. Peanuts, rice and millets are cultivated and are, besides the products of the palm. the chief staples of the native population. The fauna includes water buffaloes, deer, antelopes, lions, leopards. monkeys and many varieties of snake; occasionally elephants stray in from French territory; crocodiles and sharks abound in the estuaries. Birds include the pelican, heron, marabou, egrets, the trumpet bird and yellow parrots.

History. — According to João de Barros, Portuguese Guinea was first reached by Nuno Tristão in 1446, though it is still uncertain whether in fact Nuno Tristão passed the Gambia river. It was next visited by Diogo Afonso, Alonso Fernandes and Alvise Cadamosto (1456), who described it at some length. The colonists of Santiago in the Cape Verde Islands were later granted trading rights in Guinea, but the only settlers seem to have been isolated traders living among the natives. In the middle of the 16th century foreign interlopers began trading in Guinea: by 1588 the Cape-Verdeans had established a village at Cacheu, and in 1624 the overseas council decided to send royal officials there and to other parts with instructions to administer and defend them. Some of the early settlements such as São Felipe and Porto da Cruz were later abandoned, but others still exist, among them Farim, Geba and Buba. With the Portuguese restoration of 1640, a captain-major and factor was appointed to Cacheu from Lisbon, and the old dependency on the Cape Verde Islands gradually declined, till in 1879 all formal connection was dissolved. In 1676 the Cacheu company was given a virtual monopoly of the Guinea trade, but it was soon dissolved.

The expansion of the French Senegal company led to the building of a Portuguese settlement at Bissau in 1687, and this was created a captaincy in 1692, the duty of maintaining it being transmitted to the second Cacheu company. The main export of Guinea was slaves for Spanish America, and the second Cacheu company won the Spanish asiento or monopoly from the French Senegal company. However the company's contract was terminated in 1703, and Bissau was abandoned to be refounded in 1753 under the influence of the marquess of Pombal's Graõ-Pará company. In 1792 an English expedition led by Lieut. Philip Beaver tried unsuccessfully to establish a settlement at Bolama. This attempt led to a dispute between Portugal and Great Britain about the possession of Bolama, which was finally awarded to Portugal by the arbitration of Pres. Ulysses S. Grant of the United States (April 21, 1870). Bolama was then made the capital of the colony. The Franco-Portuguese frontier was defined in 1886. when the Portuguese lost the southern bank of the Casamance estuary in the north in return for the Cacine district in the south. The demarcation was completed in 1902–05.

Until the 19th century the colony had been at once dependent on the slave trade and unable because of it to attain orderly development. It was only after its abolition that the Portuguese were able to reduce the interior, between 1890 and 1915, in which year Capt. Teixeira Pinto finally pacified it. Even after this there was some resistance by the Bissagos, but after 1936 the colony developed steadily and peacefully. It was designated an overseas province in 1951.

Peoples. — The population of Portuguese Guinea at the 1950 census was 510,777 (including 502,457 Negroes. 4,568 *mestiços* [mixed], 2.263 Europeans).

The African inhabitants of the province consist of about a dozen peoples. Some of the tribes of the interior are Moslems, while those of the coastal regions (the majority) have retained their traditional religions. The first group includes the Fula or Fulani (*q.v.*), the Mandingo (*q.v.*) and the Biafada or Biafar; the first two of these groups are among the most industrious and intelligent peoples of the territory. Of the non-Moslem peoples, the Balante are the largest group in the province and are regarded as hard-working and shrewd, but litigious. The Manjako or Mandjak have proved readiest to accept Portuguese ways and the Palel most recalcitrant. Other non-Moslem peoples are the Fulup or Felupe north of the Cacheu river, the Bissago or Bijago of the islands and the Nalu in the extreme south. All the native peoples are agriculturists. although the Fula are also cattle breeders. Several thousand urbanized Africans live in the towns of Cacheu, Bolama and Bissau. There are about 2.500 whites and appreciably more half-breeds, including a large proportion of creoles from the Cape Verde Islands, who act as minor officials and storekeepers.

Education. — Native education is left largely to the natives themselves and the missions. There were in 1950 a small central (secondary) school in Bissau, four vocational schools and 59 primary or rural schools, with 3,295 pupils.

Administration. — The capital was shifted to Bissau from Bolama in 1942. It is the seat of a governor appointed from Lisbon and responsible to the minister for overseas; he is aided by a small cabinet of officials. The whole province is divided into ten *circunscrições* (subdistricts), which are in turn subdivided into *postes*. Native administration is left in the hands of dependable tribal chiefs.

Economy. — The currency is the Portuguese escudo, and the Banco Nacional Ultramarino is the bank of issue within the province. A gradual development of the province's economy has taken place, and the total value of exports rose from 64,000,000 escudos in 1941 to 118,000,000 escudos in 1950. The chief products are native crops, such as peanuts, palm oil, and rice; hides, wax and timber are other exportable commodities. A wide range of consumer goods, including especially cotton piece goods, wines and foodstuffs and equipment, is imported; imports were valued at 128.000.000 escudos in 1950. Bissau is the leading port, followed by Bolama and Cacheu. The deep estuaries provide easy communications with parts of the interior. (H. V. L.)

BIBLIOGRAPHY.—*Anuario da provincia da Guiné* (annually, 1925 ff.) ; J. Teixeira Pinto, *Teixeira Pinto, a ocupação militar da Guiné* (1936) ; H. A. Bernatzik, *Äthiopen des Westens,* 2 vol (1933) ; A. Lyall, *Black and White Make Brown* (1938) ; J. Barreto, *Histdria da Guiné* (1938) ; L. A. de Carvelho Viegas, *Guiné Portuguesa,* 3 vol. (1936–40) ; Teixeira Matos, *Guiné* (1954).

PORTUGUESE LANGUAGE, one of the Romance languages (*q.v.*), is the language of Portugal, including the Madeiran and Azorean archipelagos, and of Brazil. It is also the official language of Portugal's overseas provinces in Africa and the east. Spoken by about 70.000.000 persons, it is the end product of the evolution of the Romance dialect that was spoken in the county of Portugal, awarded by the king of León and Castile at the end of the 11th century to County Henry of Burgundy. Henry's son became the first king of an independent Portugal and advanced the area of his rule southward at the expense of the Moslem Moors who then governed the region. The language spoken by the Portuguese displaced the Mozarabic presumably spoken by Christians or their descendants who were living under Moorish domination; displaced, the Mozarabic undoubtedly influenced the emerging Portuguese to such an extent that the new national language is perhaps better considered the resultant of a Portuguese force from the northwest and a Mozarabic force from the south. By the middle of the 13th century Portugal had attained boundaries that are substantially those of the present day, and Portuguese became the language of the entire country. There is slight dialectal differentiation. Except for an occasional border dialect on the Spanish frontier, however, the *falares regionais* portugueses, as they are now called, are mutually comprehensible. The language of the nation's capital, Lisbon, and of the ancient university city, Coimbra, has provided the basis of the standard national language.

Portuguese was first written at the end of the 12th century. A standard written language was quickly formulated. It has changed little since the 13th century, virtually not at all since the 16th.

Portuguese was established as the official language of Brazil soon after Pedro Álvares Cabral's discovery of the continent in 1500. In its subsequent development it proved to be, on the whole, more conservative than the language of Portugal. Although regional pronunciations have developed, they do not hinder intercommunication. Moreover, the Brazilians and Portuguese communicate with ease despite an instantly recognizable accent. The influence on the Portuguese of Brazil of native American languages, African languages of imported slaves and Spanish of adjacent countries to the south has probably been negligible except for certain items of vocabulary.

Vasco da Gama initiated the Portuguese influence in the orient. The language of the Portuguese discoverers, colonizers, merchants and missionaries spread rapidly and Portuguese words are today far more disseminated than the area of Portugal's political control would suggest. They are found on Ceylon, for example, and even in Japan. Thus in the latter country the Portuguese *têmporas* "Ember days" is used for fried seafood.

In its evolution since the establishment of the Portuguese monarchy, Portuguese has developed more or less independently of the Romance dialects that ultimately became the language of Spain. In Galicia, however. the local dialect was originally very similar to Portuguese and has occasionally been used as a literary language. Several features of Portuguese distinguish it markedly not only from Spanish but also from other Romance languages.

Phonology.— There are five distinctive nasal vowels. as in *sim, lenço, sã* and *lanço, som* and *dom,* and *durn,* and a series of nasal diphthongs, as in *pão, põe* and *bem.* Final *em,* as in the latter word, is pronounced [ẽĩ] in standard Portuguese but as [ẽ] in many regions of Portugal and in Brazil. Among the oral vowels the distinction between closed and open *e* and *o* is meaningful: *sê-sé, pôde-pode,* the circumflex indicating closeness. the acute accent openness. Final unstressed vowels are weak and tend to disappear, especially in Portugal. In most regions *s* before a consonant is [ʃ] or [ʒ], depending on whether the consonant is voiceless or voiced (*casta, Lisboa);* intervocalic *s* is [z]. In the Rio de Janeiro area *t* and *d* before [i] become affricates approaching [tʃ] and [dʒ]. Historically, Latin intervocalic *l* and *n* have in many situations disappeared (*só,* Spanish *solo; lua,* Sp. *luna*). Because of the history of *l* and *ll,* the Portuguese definite article is simply *o, a, os* or *as.* Although the intervocalic *n* tended to disappear as a consonant, it often nasalized a preceding vowel. Thus, the singular noun ending *ão,* as in *mão, alemão, nação,* corresponds to three plural endings. *mãos, alemães, nações.* Comparison with Sp. *manos, alemanes, naciones* clarifies the endings and confirms that today's *ão* represents a convergence of earlier *ão, am* and *om.* Latin stressed *e* and *o* did not diphthongize *(pi, terra, roda, porta,* contrasted with Sp. *pie, tierra, rueda, puerta*), nor has initial *f* disappeared (*filho,* Sp. *hijo*).

Forms.— Portuguese is most different from Spanish in the verb system. It retains the Latin pluperfect as a pluperfect (1st and 3rd sg. *cantara,* used alternatively with a compound *tinha cantado).* It has a conjugated or personal infinitive and a future subjunctive. They have identical endings, those of the former being added to the infinitive, those of the latter to the preterite stem (3rd pl. *cantarem,* but *fazerem-fizerem*). Portuguese has two forms for "two," masc. *dois* and fem. *duas,* and maintains vow-el harmony in such groups of words as demonstrative *isto,* a neuter pronoun, and *êste* and *esta,* masculine and feminine demonstrative adjectives, respectively, the *e* of *esta* being [ɛ].

Syntax.— As suggested above, *ter* (Lat. *tenere*) is today the normal verbal auxiliary, and not *haver* (Lat. *habere*). Object pronouns are normally placed after the verb in Portugal, although in spoken Brazilian they usually precede. In the future tense. today used chiefly in the written language, they are inserted between infinitive and ending (*dar-lhe-ei o livro* "I shall give the book to him"). The combination of preposition and article is common *(do, da, dos, das,* for *de* + *o,* etc., and similarly *no, em* + *o,* and *pelo, por* + *o*). Forms of direct address are elaborate, ranging from *V.ª Ex.ª* (*Vossa Excelência*) through *o Senhor* and *a Senhora* and a more familiar *Você* to *tu;* all but the latter take the so-called "third-person" verb forms. In Brazil *V.ª Ex.ª* is restricted to the most formal discourse, its use otherwise being considered distinctly Portuguese.

Vocabulary.--An outstanding feature of Portuguese is the use of the church's designations for the days of the week, Monday *segunda-feira,* Tuesday *têrça-feira,* Wednesday *quarta-feira,* Thursday *quinta-feira* and Friday *sexta-feira.* Saturday and Sunday are the common *sábado* and *domingo.* Portuguese shares with Spanish many words of Arabic origin, yet also has several not found in standard Spanish, such as *alface* "lettuce," *alfaiate* "tailor." The language of Brazil contains many words. particularly designations for native animals, flowers, foods and the like, that have not entered the language of Portugal or other Romance languages.

BIBLIOGRAPHY.—*General statement with basic bibliography not repeated below:* William J. Entwistle, "The Portuguese and Brazilian Language" in H. V. Livermore (ed.), *Portugal and Brazil* (1953). *Additional general works:* Manuel de Paiva Boléo, *Introdução ao estudo da filologia portuguesa* (1946); Serafim Silva Neto, *Introdução ao estudo da língua portuguêsa no Brasil* (1950); *Manual de filologia portuguêsa* (1957); *Histdria da lingua portuguêsa* (in iascicules, 1952 ff.); Antenor Nascentes, *Dicionario etimológico da lingua portuguêsa,* 2 vol. (1932–52). *Miscellaneous works:* Kimberley S. Roberts, *An Anthology of Old Portuguese* (1956); F. M. Rogers, "Gonçalves Viana and the Study of Portuguese Phonetics," *Bol. de Filol.,* vii, 17–29 (1940); Armando de Lacerda, *Caracteristicas da entoação portuguesa,* 2 vol. (1941–47); J. Mattoso Camara, Jr., *Para o estudo da fonêmica portuguêsa* (1953); Helmut Ludtke, "Fonemática portuguesa," *Bol. de Filol.,* xiii, 273–288 (1952), xiv, 197–217 (1953); Sebastião Rodolfo Dalgado, *Influência do vocabulário português em línguas asiáticas* (1913), English trans., "Gaekwad's Oriental Series," lxxiv (1936); David Lopes, *A expansão da língua portuguesa no Oriente durante os séculos XVI, XVII e XVIII* (1936); Leo Pap. *Portuguese-American Speech: an Outline oj Speech Conditions Among Portuguese Immigrants in New England and Elsewhere in the United States* (1949). *Current periodicals: Boletim de Filologia* (1932 ff.); *Revista de Portugal,* series *A, Lingua portuguêsa* (1942 ff.); *Revista Portugtiesa de Filologia* (1946 ff.); *Revista do laboratório de fonética experimental* (1952 ff.); *Revista Brasileira de Filologia* (1955 ff.). (F. M. R.)

PORTUGUESE LITERATURE. The literature of Portugal is distinguished by the wealth and variety of lyric poetry which have characterized it from the beginning, by the mediaeval lack of and later achievement in the national epic. the nealth of historical writing. and the relative slightness in drama, biography and the essay The early *cancioneiros* evidence a school of love poetry which spread, with the language. to Spain at a time when Spanish was as yet undeveloped for lyrical purposes. The *romanceiro* or balladry on the other hand was much influenced by that of Spain, though not sharing the latter's predilection for the heroic. *Amadís de Gaula,* prototype of the romance of chivalry, was in its primitive version almost certainly Portuguese, as was, later, the *Diana* of Jorge de Montemor (Montemayor), the masterpiece of the pastoral novel.

The *Lusíadas* may be held at once the most successful of the many Renaissance epics cast in the classical mould and the most national of great poems in any modern literature, and the many outstanding works of history and travel of the 16th and 17th centuries are worthy of a race of explorers who carried their flag. their faith and their speech to the ends of the earth. Gil Vicente, in the early 16th century. was a dramatist of great gifts. but no other appeared until Almeida Garrett in the 19th, and Portugal never developed a national drama.

This literature. which until the 19th century lay largely unstudied and unknown. has from the beginning been much exposed to foreign influences. The earliest was Provençal, and Provencal taste ruled for more than a century. Then came Castilian. with a court poetry which provided models until the Renaissance saw triumph that of Italy and the classics of antiquity. In the 17th century with political domination Spain again imposed its literary standards. followed in the 18th century by France. The Romantic movement reached Portugal from both France and England. two countries whose influence, joined in a lesser degree by that of Germany. persisted long after. The closeness of contacts with Spain, reinforced by dynastic marriages which often brought to the court at Lisbon a predominantly Spanish atmosphere, explains why for two centuries and more from 1450 nearly every Portuguese writer of note was bilingual and wrote also in Spanish. so that some, like Montemor and Manuel de Mello. are numbered among the classics of Spanish letters. Portuguese literature retains nonetheless a distinct individuality which contrasts strikingly with that of Spain alike in the nature of its development and in the divergent kinds where lie its major achievements; in it may be seen reflected the differing ethnical constitution of its people and the distinctive paths along which their lot has been cast. The mediaeval lyric! the chronicles of Fernão Lopes, the plays of Gil Vicente. the *Histdria trágico-marítima*, the bucolic verse and prose of the 16th century and. above all. the *Lusíadas*, are several expressions of a clearly defined national temperament which early carved out for itself original expression.

Early Period.— Though no literary documents belonging to the first century of Portugal's history as a nation have survived. there is evidence of the existence of an indigenous popular poetry both sacred and profane. Provencal influences were for a long time to mould the manifestations of poetical talent. but they did not originate them. A few compositions dating from before the year 1200 survive: one. attributed to Sancho I, is the earliest extant *cossante,* the name now given to brief lyrical poems, parallel-strophed, almost immobile in their repetitiveness and instinct with that *saudade* or wistful sadness which is never wholly absent from Portuguese literature. The accession in 1248 of Alphonso (Afonso) III. who had lived 13 years in France and returned home, bringing poets in his train, to play the role of patron of letters, inaugurated a period of poetic activity illustrated in the *Cancioneiro do Ajuda*, the oldest collection of Peninsular verse. Soon all the forms of Provence and of northern France were current, subtlety of form and device taking precedence in them over thought or emotion. Three main types of *cantiga* were recognized. all often practised by the same poet: *de amor*, *de amigo* and *de maldizer*. The second, put into the mouth of the lady lamenting her lover's absence. commonly betrays a truer feeling than the first; in the third the poet vents satire on his rival or enemy.

The apogee of this palace poetry dates from the early years of the reign of Dinis (1279–1325). who had been educated by a Frenchman, Aymeric of Cahors. Dinis. grandson and imitator in his services to culture of Xlphonso the Learned of Castile, founded his country's first university in Lisbon (later to be removed to Coimbra) in 1290. and stimulated the translation into Portuguese of outstanding works from Spanish, Latin and Arabic. He thus ranks as the founder of vernacular prose in Portugal; but he was also a true poet, technically accomplished and endowed with genuine feeling and esteemed the best poet of his age in the peninsula. To his court came troubadours and *jograis* from Leon. Castile and distant Aragon to enjoy the last afterglow of a cult already dying or dead elsewhere. and about 2.000 poems by its 200 poets are preserved in the three great *Cancioneiros da Ajuda, da Vaticana* and *Colocci-Brancuti*. In the main this poetry forms monotonous reading today, because of its poverty of ideas and conventionality of metrical form and expression: in it poets served an apprenticeship to their craft. and the language developed its rare musical qualities against the birth of more individual inspiration.

In contrast with the restricted horizons of courtly verse, themes of adventure. war and chivalry mingled with love, religion and the sea in the considerable collection of ballad poetry known as the *romanceiro*. Differing in subject matter from the ballad in Spain, which drew heavily on the native epic tradition. the *ronzanceiro* still derived in all probability from across the border and exploited the popularity of the form — the octosyllable with assonance in alternate lines — in more congenial directions. Few if any *romances* can be dated earlier than the 1jth century; they belong to the close of the middle ages, an anonymous collective poetry kept alive by oral transmission. with a late artificial flowering, from the pens of known poets. in the 16th and 17th centuries. Heroes and incidents of the French and Spanish epos were reflected in numerous derivative ballads: of native Portuguese epic we can point at most to a *Poema da batalha do Salado* (1340) by one Alphonso Giraldes concerning which the brief surviving fragment allows no firm inferences.

Prose literature took much longer than verse to perfect its instrument. Religious writings — fragments of the Bible: lives of saints and monastic rules — brief annals of the early kings and *livros de linhagens* or books of descent constitute the earliest texts; they date from the late 12th century onward and interest the student of language rather than of literature. The *Livro de linhagens* of Pedro, count of Barcelos (1289–1350), raised the last-named kind to the confines of literature. and therein constitutes a landmark, by a concern that went beyond genealogy to history and legend. The early popularity of the *matière de Bretagne* is attested both here and elsewhere, as in the five songs based on Breton *lais* with which the *Cancioneiro Colocci-Brancuti* opens: the ideals of chivalry and the spirit of sentimental adventure associated with the knights of the Round Table clearly made strong appeal to the Portuguese temperament. The *Histdria dos cnvaleiros da Mesa Redonda e da demanda do Santo Graall,* an adaptation from the French dating from the early 14th century. is the chief relic of a considerable activity in this field. out of which derived *Amadís de Gaula,* progenitor of a long succession of romances of chivalry in Spain and Portugal. While the authorship and country of this are still in debate, the balance of probability inclines to a Portuguese original. at least for the first three books of *c.* 1350, from the pen possibly of one Vasco de Lobeira.

The 15th Century.— Under John (João) I (1385–1433), founder of the new dynasty of Aviz. the court became once again a centre of literary culture. The king himself wrote a *Livro da montaria* or treatise on the chase. His son Duarte collected a rich library of the ancients. some translated by his order. as was also John Gower's *Confessio amantis,* and of mediaeval poems and histories. and composed a moral treatise. *Leal Conselheiro, c.* 1430, which revealed a great and conscious stylist. His brother Pedro's *Trauctado da Uirtuosa Benfeyturia* was a version of Seneca's *De beneficiis;* Cicero and Vegetius were among other authors translated by this much-travelled prince or at his instance. But the great distinction of the age was its chronicles, for which much credit falls to Duarte who as king created in 1434 the office of Cronista Maior do Reino and appointed to it Fernão Lopes (*q.v.*), the father of Portuguese historiography — Robert Southey called him the best chronicler of any age or nation — and author of chronicles of the first ten kings of Portugal, of which only those of Peter (Pedro) I. Fernando and John I survive. Earlier he had written the biography of the hero of Aljubarrota. the Constable Nun' Álvares Pereira. Vividness of style and character portrayal combined with serious documentation and a high sense of principle and responsibility to produce in Lopes the finest achievement of mediaeval Portuguese prose.

His successor in office, Gomes Eanes de Zurara (*q.v.*), adding to the seriousness a constant parade of erudition, continued the chronicle of John I on a lower level of artistry with an account of the 1415 expedition to Ceuta and the early period of expansion in North Africa. His chief work, born of admiration for Prince Henry the Navigator, was his *Crdnica do descobrimento e conquista da Guiné*. Rui de Pina (*c.* 1440–*c.* 1523), if likewise not of the stature of Lopes either as historian or as artist, was free from the rhetorical defects of Azurara. and his chronicles of Duarte, Alphonso V and John II were characterized by a notable frankness: the people. who in Lopes had occupied the foreground, here yielded pride of place to the monarch. To Pina's reworking of Lopes' narratives of the six reigns from Sancho I to Xlphonso IV is owed the irreparable loss of the original text; his own chronicle of John II was in its turn reworked, and spiced with much anecdotal gossip, by Garcia de Resende (*q.v.*).

Poetry had suffered a long eclipse after the spate of activity reflected in the *cancioneiros,* and when in the mid-15th century it was once more cultivated, much had changed. The dominant influence came now from Spain. and where once Spanish poets had, written in Galician-Portuguese, Portuguese poets initiated the long chapter of fealty. in theme and language alike, to Spain. Apart from the *romances,* popular poetry had disappeared along with that of the troubadours, whose legacy stood reduced to a set of metrical devices and another of conceits on the topic of courtly love. The constable Dom Pedro de Portugal (1429–66), son of the prince of that name already referred to, was led by the accidents of his own storm-tossed life—he lived for seven years in exile in Castile and died as king of Aragon—to imitate the fashion of writing in Castilian. As one of the first likewise to adopt the new Spanish trend away from the Provençal manner in favour of allegory and the cult of classical antiquity derived from Italy, his influence on his compatriots was doubly important. His own poems were inspired by deep feeling and much reflection on life. It was to him that the marques de Santillana addressed, *c.* 1449, his historic letter dealing with the origins of Peninsular verse. The constable was one of almost 200 poets represented in the *Cancioneiro geral* (1j16) of Garcia de Resende, covering the preceding three-quarters of a century. The main subjects of these 1,000-odd poems, in Portuguese and Castilian, are love, satire and epigram. Discovery and conquest in the east hardly find an echo, even in the verse of those who had taken part in them. Instead theme and tone are predominantly trivial and treatment artificial; the compositions that reveal genuine feeling or serious intent are very few. Resende was himself a better poet than most of his contributors. notably in his stanzas on the death of Inês de Castro. Some names were destined notwithstanding to count among the foremost in Portuguese literature: Bernardino (Bernardim) Ribeiro, Cristóvão (Christovam) Falcão, Gil I'icente, Francisco de Sá de Miranda (*qq.v.*). These typify the transition from the 1jth-century Spanish school to the Italianate school of the 16th. Ribeiro and Falcão, introducers of the bucolic style. proved successful in pouring new life into old forms and by their eclogues and *redondilhas* gave models which later writers worked by but rarely equalled.

Gil Vicente and Early Drama.— The emergence of the drama from its mediaeval swaddling-clothes to the threshold of the modern play may be traced in the works of Gil Vicente (*q.v.*), court dramatist and greatest name in the Portuguese theatre, who, having no forerunners in Portugal. drew for his first pastoral-religious *autos* on Spain. chiefly on Juan del Encina (*q.v.*). Eleven of his 44 plays were written wholly, and another 17 partly, in Spanish. The trilogy of the *Barcas* revealed his dramatic power in serious vein. but even here can be seen his fondness for comic relief, by way of which he arrived at pure comedy and the study of character. In this lay his strength, in construction his weakness; and the latter consideration, not remedied by his successors, had its bearing on the phenomenon of a potential national theatre that may be said to have died with its founder. His real influence was felt in Spain. In centres where Yicente's plays were known and acted writers for the stage did spring up, in number sufficient to allow afterward the term *Escola Velha* or old school of Gil Vicente, but none had the talent to compare with his achievement. The best known were Afonso Álvares in the religious vein, António Ribeiro Chiado, an unfrocked friar who wrote farces with a strong satirical bent, and his brother Jerónimo Ribeiro, likewise a satirist. António Prestes evinced in his plays more knowledge of folklore than dramatic competence. Baltasar Dias, a blind poet from Madeira. wrote simple religious *trutos* which for long retained their popularity. One of the last of the school was Simão Machado, whose *Comidia de Dio* and *Comédia da pastora Alfea* possessed something of Vicente's lyrical facility and skill in portraying peasant scenes.

By the time of Vicente's death, *c.* 1536, court favour had been withdrawn from the stage. The Inquisition. introduced into Portugal in that year, early declared war on the popular theatre on the charge of grossness, to counter which the Jesuits encouraged the writing of Latin tragicomedies or dramatized allegories for performance at religious or scholastic festivals. Vicente's own plays, which figure on the Spanish Index of 1559, were reduced in number to 35 and sadly mutilated in the second edition of 1j86, and no new edition appeared for another 250 years.

The Renaissance.— The movement commonly called the Renaissance reached Portugal both indirectly through Spain and directly from Italy. with which country there had been close cultural relations through the 1jth century. Xlphonso V had Matthew of Pisa as tutor and summoned Justui Balduinus to his court to write the nation's history in Latin. while John II corresponded with Politian. In the following century many famous humanists took up their abode in Portugal, Nicolas Cleynaerts taught Prince Henry. later cardinal and king. and lectured on the classics at Braga and Evora; Vassaeus directed a school of Latin at Braga: and George Buchanan accompanied other foreign professors to Coimbra when in 1547 John III reformed the university. Many distinguished Portuguese teachers returned from abroad to assist the king in his task. among them Aires Barbosa from Salamanca, André de Gouvêa of the Parisian college of St. Barbe, whom Montaigne called "sans comparaison de plus grand principal de France." Aquiles Estaço and Diogo de Teive.

At home Portugal produced its scholars of note, André de Resende (*q.v.*), author of *De antiquitatibus Lusitaniae,* Francisco de Holanda, painter, architect and author of *Quatro Diálogos da pintura antiga,* and many another. Women took a share in the intellectual movement of the time. The sisters Luisa and Angela Sigêa, Joana Vaz and Paula Vicente, daughter of the dramatist, constituted an informal female academy under the presidency of the infanta Maria. daughter of King Manoel. Luisa Sigêa was both orientalist and poetess in Latin; Lianor de Noronha, of noble family, served letters by her encouragement of translations.

The Italianate School.— The return in 1526 of Francisco de Sá de Miranda (c. 1485–1558) after a six years' stay in Italy initiated a literary reform of far-reaching effect, though his *Obras* only appeared posthumously in 1595. Like his contemporary Garcilaso in Spain. he introduced and acclimatized the new poetic forms of sonnet. canzon. ode and epistle in hendecasyllabic *ottava rima* and in tercets. At the same time he gave fresh vigour to the national octosyllable or *medida velha* through his *Cartas* and *Sátiras* which, with the *Églogas,* some in Portuguese, others in Castilian. are perhaps his most successful compositions. His chief disciple, António Ferreira (*q.v.*), a convinced classicist. wrote sonnets superior in form and style, along with odes and epistles too obviously reminiscent of Horace. Pero de Andrade Caminha. Diogo Bernardes, Frei Agostinho da Cruz and André Falcão de Resende continued the erudite school which, after some opposition, definitely triumphed with Luiz Vaz de Camdes (*q.v.*). The *Lima* of Bernardes (1596) contains beautiful eclogues while the religious poems of his brother Frei Agostinho are full of charm. Camdes, for all his eminence in the epic. was greater still as' a lyric poet: were the *Cem melhores Poesias líricas da lingua portuguesa* true to its title, wrote the compiler. D. Carolina Michaëlis de Vasconcelos, it would contain no other name. Here a profound classical education combined with perfect mastery of his instrument and a lifetime of checkered experience on which the poet had reflected deeply to produce in sonnets, eclogues, odes, elegies and *canções* the greatest poetry in the language. *Os Lusíadas* ("The Portuguese"), his epic narrative of Portuguese achievement in the east. with which was interwoven the whole story of the nation and much else, took rank on its appearance in 1572 as the national poem par excellence and the greatest of all Renaissance epics after the Virgilian pattern. Of the many who were moved to emulation by its success none approached Camdes in inspiration or poetic gifts. The least unsuccessful was perhaps Jerónimo Côrte-Real (Jeronymo Corte-Real; *q.v.*) with his long prosaic accounts of the *Segundo Cêrco de Dio* (1574) and the *Naufrágio de Sousa de Sepúlveda* (1594). Most of these poems, like the *Eleginda* of Luis Pereira Brandão (1588) on the disaster of Al Kasr al Kebir, the *Primeiro Cêrco de Dio* of the chronicler Francisco de Andrade (1589) and even the *Afonso Africano* of Vasco Mousinho de Quevedo (1611), for all their futile allegory. contain vigorous descriptive passages.

In the drama Sá de Miranda and his followers protested against the name *auto,* restored that of comedy and subitjtuted prose for verse. Taking Terence commonly as their model, they produced not Portuguese characters but conventional Roman-Italian types. This revived classical comedy, artificial alike in subject and style, won the favour of humanists and the nobility, though its influence was to be short-lived. Plautus and Ariosto were present as well to Sá de Miranda when, avowedly to combat the school of Vicente, he wrote *Os Estrangeiros,* the first prose comedy, and *Os Vilhalpandos,* both actions being set in Italy. His *Cleópatra,* a first classical tragedy. is lost. António Ferreira (*q.v.*), a greater dramatist, likewise attempted both kinds: *O Cioso,* Italian even to the names of the personages. came nearer to being a comedy of charatter, but his fame rests chiefly on *Inês de Castro,* which treated the most moving tragic theme in the nation's history by reference not to Seneca but to Sophocles and Euripides. From Jorge Ferreira de Vasconcelos *(c.* 1515–8j) came a "new invention" of another kind with *Eufrosina:* written under the influence of the *Celestina,* which enjoyed a great vogue in Portugal, it was close kin to the Spanish school though essentially Portuguese in characters and general atmosphere. This and his other plays, *Ulissipo* and *Aulegrafia,* resemble novels in dialogue and contain a treasury of popular lore and wise and witty sayings introduced with a moral purpose.

Sixteenth-century History. — Discovery and conquest in Africa, Asia. America and on the ocean inspired historians as well as poets. and many achieved distinction in narrating these events. The best had themselves seen Portugal's new greatness in the building and were moved by patriotism to write of it, so that their records gain in vividness what they may lose in scientific detachment. In the three "Decades" of his *Ásia* (1 jjz–63) João de Barros *(q.v.),* the Livy of his country, told in simple, vigorous language the deeds of his compatriots overseas down to 1526. His first decade undoubtedly influenced Camões, and together, one by his prose, the other by his verse, the two fixed the written language. This work. continued by the more critical and incisive Diogo do Couto (1542–1616), may claim to rank as the noblest historical monument of the century. The manuscript of do Couto's *Décadas 4–12,* carrying the story to the end of the century, suffered shipwreck, fire, theft and official delays and reached publication piecemeal in partial and very unequal form. In his *Soldado prático* he added some acute observations on the causes of Portuguese decadence in the east. Ten years of investigation in India underlay the *Histdria do descobrimento e conquista da Índia* (1552–54 and 1 j61) of Fernão Lopes de Castanheda, covering the first 40 years, a work which ranks close to those of Barros and do Couto. António Galvão, a governor of the Moluccas who died at home a pauper. left a brief *Livro dos descobrimentos das Antilhas e fndia* (1563) full of curious observations cast in the form of annals. Gaspar Correia likewise embodied intimate knowledge of the manners and customs of India in the picturesque prose of his *Lendas* or *Crdnica dos feitos da Índia* (1551), a work remarkable for the vividness of its effects. Among other historical works dealing with the east were the *Comentcirios de Afonso d'Albuquerque* (1557), an account of the great captain and administrator by his son, and the *Tratado das cousas da China e de Ormuz (* 1570) of the missionary Frei Gaspar da Cruz.

From this spate of writing on expansion overseas attention returned, by way of chronicles of the monarchs who presided over it, to the history of Portugal itself. Damião de Gois *(q.v.),* diplomatist, traveller, humanist and intimate friend of Erasmus, possessed an encyclopaedic mind and one of the most critical spirits of the age: his *Crdnica* (1566–67) of Manoel the Fortunate, preceded by one of his son, later John II, is most valuable where the author's oun feelings or experience come into play. Like Francisco de Andrade's uncritical *Crdnica de D. Jocio III* (1613), it still allowed eastern affairs to overshadow events at home; so too did Jerónimo Osório "the Portuguese Cicero," whose *De rebus Emmanuelis regis Lusitaniae* (1571), based on Goes and written in Latin in order to make the story known *per omnes reipublicae Christianae regiones,* achieved considerable fame abroad. Frei Bernardo da Cruz, who was with his king at the disaster of Al Kasr al Kebir. told the story of the reign in a *Crdnica de D. Sebasticio,* while Miguel Leitão de Andrade, taken prisoner in the battle, related his experiences along with many popular traditions and customs in his wide-ranging *Miscelânea.*

Works of travel likewise abounded and derive a particular importance from the fact that their authors were often the first Europeans to visit or at least to study the countries in question. Among the more noteworthy were the *Verdadeira informação das terras do Preste Jocio* by Francisco Álvares (Alvarez) (1540), the *Itinerários* (1560) of Antonio Tenreiro and Martim Afonso (1565), the *Itinerário da Terra Santa* (1593) by Frei Pantaleão de Aveiro, the *Etiopia oriental* by Frei João dos Santos (1609), and a much-translated classic, the *Histdria da vida do padre Francisco Xavier* (1600) by Padre João de Lucena. Important both as history and as human documents were the *Cartas* written home by Jesuits in China and Japan, of which collections were published in 1570 and 1598. An anonymous *Descobrimento da Frolida* or Florida and the *Tratado descritivo do Brasil em 1587* of Gabriel Soares de Sousa are reminders that Portugal was also present and active in the new world to the west. In all this literature of travel the palm is still held for curious interest by the *Peregrinação* (1614) which Fernão Mendes Pinto *(q.v.),* prince of adventurers throughout the east, composed in his old age for his children's reading, and for tragic pathos by the *Histdria trágico-marítima,* a collection first printed as such in 1735–36 of 12 contemporary narratives, told by survivors or based on their accounts, of the more notable disasters which befell Portuguese ships between 1552 and 1604, among them the stories of the "São João" wrecked on the Natal coast in 1552, which inspired Côrte-Real's epic poem as well as some poignant stanzas in the *Lusiadas,* and of the "São Bento" which foundered when homeward bound in 1554 after carrying Camões to India.

The Novel and Other Prose. — Bernardim Ribeiro (1482–1 j52), whose five eclogues introduced pastoral poetry to Portugal, was equally an innovator in the pastoral novel with his *Saudades,* better known by its opening words *Menina e moça* (published 1554–57). This tale of rustic love and melancholy, chivalresque elements mingling with the pastoral and lyric songs with the prose, transferred themes and emotions previously held the preserve of poetry to a new medium and explored them with scant concern for plot. From it Jorge de Montemor (Montemayor; *q.v.*) drew some part of his inspiration for the *Diana* which, written in Spanish, started a fashion subscribed to by Cervantes and Lope de Vega among many others and represents one of the outstanding contributions of Portugal to the neighbouring literature. Both countries shared in the new enthusiasm of the 16th century for the romance of chivalry, in an age when imperial enterprise to east and west was such as to blur the dividing line between fact and the most improbable flights of the imagination. . The first work of João de Barros, historian of empire, was in fact his *Histdria do Imperador Clarimundo* (1520), written purposely to develop his style for more serious tasks and serving, through the adventures of this fictitious progenitor of the kings of Portugal, his consistent aim of glorifying his native land. In the *Palmeirim de Inglaterra* (1544) Francisco de Morais *(q.v.)* naturalized one branch of the Spanish descent of Amadís with an imaginative luxuriance and a purity of style which caused Cervantes to bracket it with the works of Homer. Its own Portuguese progeny, the *Dom Duardos* (1587) of Diogo Fernandes and Baltasar Gonçalves Lobato's *Dom Clarisol de Bretanha* (1602), were of an inferior order. The dramatist Ferreira de Vasconcelos kept alive memories of the Arthurian cycle with his *Sagramor* or *Memorial da segunda Tdvola Redonda* (1567). A very different type of fiction entered with the *Contos de proveito e exemplo* of Fernandes Trancoso, containing 38 tales derived from tradition or imitated from Boccaccio and others, which won and held favour for over a century.

Among moralists three at least rank as masters of prose style: Frei Heitor Pinto for his *Imagem da vida christã* (1563), Bishop Amador Arrais for his ten *Diálogos* (1589) on religious and other topics and Frei Tomé de Jesus for his mystic and devotional treatise *Trabalhos de Jesus* (1602–09). The maxims of Joana da Gama entitled *Ditos da freira* (1 j55) form a curious if unsubtle psychological document. The roll of scientists includes the cosmographer and mathematician Pedro Nunes (Nunez), inventor of the nonius, and the botanist Garcia da Orta, whose *Coldquios dos simples e drogas* (Goa, 1563) was the first book to be printed in the east, while the form of Aristotelian scholastic philosophy professed at Coimbra had a succession of learned exponents, mainly in Latin, in which language also Francisco Sanches wrote his notable treatise *Quod nihil scitur* (1581).

The 17th Century. — From a literary as from a political point of view the new century found Portugal in a lamentable state of decadence. Long before the loss of independence to Spain in 1580 Spanish influence had brought about the introduction of the Inquisition, and with it censorship of books and the preparation of an Index; among its early victims was George Buchanan, at the instance of the Jesuits, into whose hands passed between 1552 and 1j55 control of higher education. Cultism. inseparable at bottom from classical education. was already present—as in Camões and Ferreira de Vasconcelos—before Luis de Góngora y Argote; but with the exhaustion of the national spirit that underlay political eclipse the influence of Gongora penetrated deeply. Its extent may be seen in the five volumes of the *Fenix renascida* (1716–28), which anthologizes the poetic production of the preceding century and reveals in the very titles of poems the emphatic futilities to which good talents could devote themselves. The trend. reiniorced by the new fashion out of Italy of literary academies. survived the throwing-off of the Spanish yoke in 1640; Portuguese editions of Góngora appeared in 1646, 1647 and 1667. In 1649 there was founded the Academia dos Generosos, numbering many illustrious by rank and learning. in 1663 the Xcademia dos Singulares.

In the bucolic vein a worthy disciple of Bernardim Ribeiro arose in Francisco Rodrigues Lobo (*q.v.*), whose long pastoral romance *A Primavera* (3 parts. 1601–14) showed. with the same delicate perception of nature. a gentler melancholy still and even more sluggish action. interspersed with songs which, with his *Églogas* (160j). earned him the title of the Portuguese Theocritus. Livelier and more varied interest attaches to the same author's *Côrte na aldeia e noites de inverno* (1619), a late flowering of Castiglione's *Cortegiano.* The foremost literary figure of the age was the encyclopaedic Francisco Manuel de Melo (*see* MELO, FRANCISCO *MANUEL* DE), at once a classic of Spanish and—with his *Epanáforas de vária história portuguesa* and *Apólogos dialogaes* —of Portuguese literature. who strove hard, more successfully in prose than in verse. to free himself from subservience to Spanish form and style. Most lyricists of the period remained steeped in Gongorism or, writing in Spanish. have no place here. It suffices to mention Soror Violante do Ceo, an exalted mystic praised as "the tenth muse," or the poems of Frei António das Chagas. who is better represented by his *Cartns espirituais* (1684–87). Satirical verse had two cultivators of merit in Tomás de Noronha and António Serrão de Castro, author of *Os Ratos da Inquisição,* a facetious fruit of his imprisonment by the Holy Office; the adherents of Gongorism were pilloried by Diogo de Sousa Camacho. Epic poets continued active! but few of their productions were more than rhymed chronicles. Their works span the century. from the *Condestabre de Portugal* (1610) of a poet already mentioned. Rodrigues Lobo, to the *T'iriato trdgico* of Brbs Garcia de Mascarenhas, published posthumously in 1699; those falling between include the *Ulissea* of Gabriel Pereira de Castro (1636), the *Malaca conquistada* of Francisco de Sá de Meneses (1634) and the *Ulissipo* of Sousa de Macedo (1640).

History, Oratory and Drama.—Frei Bernardo de Brito, beginning his ponderous *Monarquia lusitana* (1597–1606) with the creation, reached only to the founding of the monarchy. His work is a mass of legends lacking in foundation or critical sense, but both here and in the *Crdnica de Cister* (1602) he proved himself a great stylist. Of the four continuers of the former work, the last three were no better equipped: the first, Frei Antonio Brandão, who covered the period from Afonso Enriques to John II, wrote as a man of high intelligence and a learned and conscientious historian; his parts three and four appeared in 1632, parts five to eight between 1650 and 1727. Other historical works deserving of mention are the *Discursos vários politicos* of Manuel Severim de Faria (1624), the *Crdnica da Companhia de Jesus* of Padre Baltasar Teles (1645–47) and the *Portugal restaurado* of Luis de Meneses, conde de Ericeira (1679–98). Baltasar Teles also edited in 1660 an *Histdria geral da Etiopia a alta ou Preste João* of his fellow-Jesuit, the missionary Manuel de Almeida; and, although travel literature compares ill with that of the preceding century. note should be made of the *Itinerário da fndia por terra* (1611) of Frei Gaspar de S. Bernardino and of the *Relação do novo caminho através da Arabia e Siria* (1665) of Padre Manuel Godinho. Frei Luis de Sousa, a typical monastic chronicler, won lasting fame as a stylist with his *T'ida de Frei Bertolomeu dos Mártires* (1619) and the *Histdria de S. Domingos* (1623). Another notable biography, one of the best-known works of the century, was Jacinto Freire de Andrade's *Vida de D. Jocio de Castro* (1651). Manuel de Faria e Sousa, a voluminous writer on Portuguese history and commentator of Camões, wrote in Spanish, as did Melo in his classic account of the 1640 *Guerra de Cataluña.*

The Jesuit António Yieira (*q.v.*), missionary and diplomatist and held in his *Cartns* one of the greatest of all writers in Portuguese, repeated his triumphs of Bahia and Lisbon in Rome. which proclaimed him the prince of Catholic orators. Dying, Yieira considered the language safe in the hands of Padre Manuel Bernardes (1644–1710), a humble priest and recluse whose sermons and oratorical works *Luz e calor, Nova Floresta* and *Exercícios espirituais* breathed a calm serenity and naturalness alien to the other and exerted a powerful influence in freeing the language from the now outworn conceits of the *culteranos.* Among the most human documents of the age were the *Letters of a Portugese Nun,* which first appeared in French in 1669 and were long attributed to Mariana Alcoforado (*q.v.*). Padre Ferreira de Almeida's translation of the Bible (*Novo Testamento* [1681], *Velho Testamento* [1748–53]) has considerable linguistic importance.

The popular theatre lived on obscurely in the *comédias de cordel,* mostly anonymous and never printed. Such *autos* as have survived are mainly religious and show the common Gongoristic abuse of metaphor and conceit. All through the century dramatists who aspired to be heard wrote, like Jacinto Cordeiro and João de Matos Fragoso. in Castilian. with an occasional exception such as Melo's witty *Auto do fidalgo aprendiz* (1646). The court after 1640 preferred Italian opera, French plays and Spanish *zarzuelas* to dramatic performances in the vernacular, to. the detriment alike of native drama and of acting.

The 18th Century.—The new century, in Portugal as in Spain, was to be predominantly prosaic, even in poetry. In the opening decades bad taste was still rampant, but gradually signs appeared of a literary revolution which developed eventually into the Romantic movement. Men of liberal ideas went abroad to France and England. and to their exhortation and example were largely due the reforms which by degrees invaded every branch of letters. Of such were Alexandre de Gusmão, Xavier de Oliveira, Ribeiro Sanches. Correia da Serra. Avelar Brotero and Manuel do Nascimento (*see* NASCIMENTO, FRANCISCO MANOEL DO). Earlier, Luis Antonio Verney had poured scorn on prevailing methods of education in his *Verdadeiro método de estudar* (1746). New literary societies. variously called academies or arcadias. co-operated in the task of reform. In 1720 John V, an imitator of Louis XIV, established the Academia da História; in its *Memórias* (15 vol., 1721–36) may be seen the excellent work done by its members. who included Manuel Caetano de Sousa. author of a colossal *Histdria genealógica da casa real portuguesa* (1735–49), Barbosa Machado, compiler of the invaluable *Biblioteca lusitana* (1741–58), and Soares da Silva, chronicler of the reign of John I. The Academia Real das Ciências, founded in 1779 by the duque de Lafões, showed particular interest in language and literature and initiated specialized research and the study of Portuguese literary history (*Memórias de literatura, 8* vol. [1792–1812]). In its ranks were found nearly all the scholars of note at the end of the century. such as the ecclesiastical historian Frei Manoel do Cenbculo. the scientist of many parts Ribeiro dos Santos, Caetano do Amaral, a patient investigator into the origins of Portugal. João Pedro Ribeiro, who has been called his country's first modern historian, and the critics Francisco Alexandre Lobo, bishop of Vizeu, Cardinal Saraiva, and Frei Fortunato de S. Boaventura.

The **Arcadias.**—In 1756 António Dinis da Cruz e Silva (*q.v.*) established with others the Arcádia Clissiponense, its first aim being the uprooting of Gongorism and Spanish influence generally; an indifferent poet himself in odes, elegies and sonnets: his mock-heroic *O Hissope,* inspired by N. Boileau's *Le Lutrin,* was a telling satirical document. Antonio Correia (Correa) Garção, the most prominent Arcadian. was a devotee of Horace and technically accomplished rather than inspired. The bucolic verse of Domingos dos Reis Quita signified a return to the native tradition of two centuries earlier. Sincerity and suffering spoke in the justly more famous *Marília,* a volume of love lyrics in a pastoral setting, of Tomás (Thomaz) António Gonzaga (*q.v.*). In 1790 a Tova Arcádia came into being, its two most distinguished members the rival poets Manuel Maria Barbosa de Bocage (*q.v.*), a would-be second Camões in his life and in his lyrics who overspent himself and lives by a few sonnets, and José Agostinho de Macedo (*q.v.*), in whom inspiration fell below a notable industry, chiefly in the epic. Curvo Semedo was the only other New Arcadian of merit. Outside the Arcadias stood the "Dissidents," who numbered at least two writers of distinction. Few Portuguese satirists have possessed such equipment for the office as Nicolau 'Tolentino de Almeida (1740–1811), who painted the customs and follies of his day with devastating accuracy and distributed attacks or begged favours in the same sparkling verse. Francisco Manuel do Nascimento addressed himself perseveringly. at home and through 40 years of exile, to the purifying and enrichment of the language and to restoring the cult of the *quinhentistas*. 4 convert to romanticism shortly before his death, he prepared the way for its triumph in Portugal.

Early in the century authors sprung from the people attempted a revival of the drama at the Bairro Alto and Mouraria theatres in Lisbon. where numerous pieces of low comedy were staged. The Operas *portuguesas* of António José da Silva (*q.v.*), produced between 1733 and 1741, owe the name to the interspersing of the prose dialogue with arias. minuets and modinhas; if unremarkable in plot, style or language. they have a certain comic force of invention. Nicolau Luis was a fertile adapter from the Spanish and Italian. his best play. on the ever-appealing tragic theme of D. *Inês* de Castro (1772), being an imitation of Vélez de Guevara; lifeless characters and conventional passions notwithstanding, his comedies long held the stage. Meanwhile the Arcadia sought to raise the tone of the stage. finding its ideals in the classics of antiquity or of the 16th century but immediate inspiration in the contemporary French theatre. Its efforts failed from lack of dramatic talent and of popular appeal. Correia Garção led the way with two satirical comedies in blank verse. Teatro *novo* and *Assembléa* ou *partida*, but did not persevere. Manuel de Figueiredo. setting out to write pieces "morally and dramatically correct," produced 14 volumes of plays in prose and verse (Teatro, 1804–15) on national subjects; utterly lacking in life. they were never acted. The three Greek tragedies of the bucolic poet dos Reis Quita, *Astarto, Megara, Hermione*, proved likewise stillborn; to them he added yet another *Inês* de Castro, reduced to the three unities, and a pastoral drama Licore.

Romanticism and After.—The 19th century witnessed a general revival of letters; again the initial stimulus came from abroad, but this time it proved more congenial to the native temperament. The chief exponents of rpmanticism were in poetry and the drama João B. de Xlmeida Garrett (*q.v.*) and in prose Alexandre Herculano (*q.v.*), both formed in exile, the price of their political liberalism. Almeida Garrett read contemporary foreign literature in England and France and. imbued with patriotic fervour, introduced his fellow-countrymen to the new movement through two epics, *Camões* (182j) and *Dona Branca* (1826). His poetry, subjective in the short lyric. historical in longer compositions, remained always sincere and natural. António Feliciano de Castilho (*q.v.*), a gentle romantic who still looked back to the Arcadias and beyond. exercised much influence over a younger generation of poets: João de Lemos and the group associated with him in *O trovador* (1848), Soares de Passos and Tomás Ribeiro. who won fame with his ardently patriotic D. Jaime (1862). Mendes Leal, outstanding in the heroic vein. Francisco Gomes de Amorim and Raimundo António de Bulhão Pato belong more or less to the same school.

In 1865 romanticism received a frontal attack in a revolt against the primacy of Castilho led by Antero (Anthero) de Quental (*q.v.*), a student of German philosophy and poetry, and Teofilo (Theófilo) Braga (1843–1924), disciple of Auguste Comte and author already of an epic of humanity. *Visão* dos *tempos* (1864). Literature gained considerably therefrom. and especially poetry. Quental enshrined his metaphysical pessimism and agony of thought in finely wrought sonnets. *Odes modernas* (1865), Sonetos (1881), which place him near to Heinrich Heine and Giacomo Leopardi. The *Campo* de pores (1893) of João de Deus (*q.v.*) contains some of the finest short poems in the language, of a spontaneous simplicity. Abílio Manuel Guerra Junqueiro (1850–1923), heir to Victor Hugo, was a would-be social revolutionary swayed by grandiose ideas and overprone to grandiloquence (A *Morte* de D. *João*, A *Velhice* do Padre *Eterno*, Finis *patriae*); in *Os* Simples (1892) he turned to the portrayal of peasant life in sonorous stanzas that, lit by his powerful imagination and pantheistic tendencies, constitute his finest poetry. Akin to him on a lower level was Duarte Gomes Leal (1848–1921), a militant anti-Christian in *Claridades* do *sul* and antimaterialist in *O anti-Cristo*, whose declamatory excesses could likewise yield to a quiet sincerity on humble themes. Cândido Gonqalves Crespo (1846–83), in his slender harvest of delicately chiselled verse, *Miniaturas* and *Nocturnos*, stood out as the first of his country's Parnassians. By contrast Cesário Verde (1855–86) addressed himself in unaffected style to surprising the poetic essence of common realities; through the posthumous Livro de *Cesário Verde* he became one of the rediscoveries of a later generation. The *Só* (1892) of António Nobre (1867–1900) was intensely Portuguese in themes. mood—an all-pervading *saudade*—and rhythms; he typifies. with the sincere but nebulous pantheist Teixeira de Pascoais (1877–1953), a cult of *saudosismo* that was to inspire a whole school of northern poets, and his influence went deep. French Symbolism found an enthusiastic adept in Eugénio de Castro (1869–1944); in a long series of volumes from Oaristos (1890) to *Camaféus romanos* (1921) and beyond he sought to fill his verse with imagery and colour while emptying it of all personal element, and was admitted for a period, after the death of Junqueiro. as the greatest of contemporary poets. Afonso Lopes Vieira (1878–1946) brought the rhythm of the sea as well as many traditional notes into his *Ilhas* de *bruma* (1918) and showed a rare artistry in his retellings of two earlier classics, *Amadís* and Diana.

Drama, the Novel, and History.—Almeida Garrett, seeking early to reinvigorate the drama. found that he had to create alike theatre. plays. actors and audience. In *Um Auto* de Gil *Vicente, O Alfageme* de *Santarém* and especially *Frei Luís de Sousa*, a tragedy of fatality and pathos. all written in prose as admirable as his poetry, he proved himself. after Vicente, his country's most notable dramatist. The historical bent was continued by José Mendes Leal (1818–86), Gomes de Amorim (1827–91) and Manuel Joaquim Pinheiro Chagas (1842–95), all three inclined to ultraromanticism. António Enes (1848–1901) dramatized questions of the day in a spirit of combative liberalism, Ernesto Biester (1829–80) wrote social drama and Fernando Caldeira (1841–94), also no mean lyric poet, comedy. Good dialogue and sparkling wit marked the comedies of Gervásio Lobato (1850–9j), some of the most popular of them written in collaboration with João da Câmara (1852–1908), who for his plays historical, social and fanciful—Afonso *VI, A Rosa* engeitada, *Os Velhos*—was accounted the outstanding dramatist of his day. Other historical playwrights include Henrique Lopes de Mendonça, Marcelino Mesquita and the admirably gifted Júlio Dantas (1876–1962), remarkable for the wit, lightness of touch and sense of atmosphere with which he reconstructed the past (A *Severa*, Santa *Inquisição*, A Ceia dos cardenis, Rosns de *todo* o *ano*). With these plays of the early 20th century may be mentioned António Patrício's *Dinis e* Isabel (1919) and D. *João e* a *máscara* 11024), the *Egas Moniz* (1918) of Jaime Cortesão, and *O Gebo e a sombra* (1923), a tragedy of unrelieved gloom and considerable power by Raúl Brandão.

Herculano. returning from exile with an enthusiasm for the *Waverley* Novels, launched the historical romance with *O Monástico* (1844–48) and *Lendas* e *narrativas* (1851). Many took up the kind. Oliveira Marreca, Arnaldo da Gama, Pinheiro Chagas, the most popular successes being A *última* corrida de *touros em Salvaterra* and *A Mocidade de* D. *João V* by Rebelo da Silva and João de Xndrade Corvo's *Um* Ano *na côrte*. This was the great age of the novel: Camilo Castelo Branco (see CASTELO BRANCO. CAMILLO), J. G. Gomes Coelho (1839–71), Jose Maria Eça de Queiros (*q.v.*) are names which would stand high in any country. The first, a great impressionist, described to perfection the domestic and social scene (*Amor* de *perdição, Amor* de *salvação*, the various *Novelas* do *Minho*). Gomes Coelho. better known by his pseudonym Júlio Dinís, depicted country life and scenery with much charm, as in *As Pupilas do Snr. Reitor; Uma família inglesa* describes English society in Oporto with a detail suggestive of Charles Dickens. Eça de Queirós introduced naturalism with his powerful novel *O Crime do Padre Amaro,* followed by *O Primo Basílio* and *Os Maias;* he was the greatest of the realists, though materialism was always tempered by a sensitive imagination, and his last novels, *A ilustre Casa de Ramires* and *A Cidade e as serras,* place him rather with the regionalists. Naturalism claimed too Lourenço Pinto, Luís de Magalhães and the much greater Francisco Teixeira de Queirós (1849–1919), who sought to lay bare contemporary society in the 15 volumes of his two series *Comddia do campo* and *Corne'dia burguesa.* Antero de Figueiredo, a stylist who excelled in regionalist sketches *(Jornadas em Portugal, Senhora do Amparo),* showed historical imagination of a high order in his fictionalized biographies *D. Pedro e D. Inês* (1913), *Leonor Teles* (1916), *D. Sebastiiio* (1925). Raúl Brandão in *Os Pobres* (1906) and *Os Pescadores* (1923) brought a poignant realism to the description of the sufferings of humble folk.

With his magnum opus the *Histdria de Portugal* (1846–49), on a scale which allowed it to reach only to 1279, and the *Histdria da Inquisição em Portugal* (1854–59) Herculano established himself as the leader of modern Peninsular historians; in 1856 he initiated the important series *Portugaliae Monumenta Historica.* Historiography flourished with names such as the visconde de Santarém, historian of the Cortes, José Simão da Luz Soriano of constitutionalism, L. A. Rebelo da Silva of the period of Spanish rule under the Philips, and José Maria Latino Coelho of the dictatorship of Pombal; if all four have been overtaken by later research, the two latter still rank highly as stylists. Henrique da Gama Barros (1833–1925) and António da Costa Lôbo (1840–1913) followed in the footsteps of Herculano, the first with his erudite *Histdria da administração pública em Portugal nos séculos xii a xv,* the second with the unfinished *História da sociedade em Portugal no século xv,* both monuments of scientific objectivity. The works of J. P. de Oliveira Martins, if not similarly grounded in original research, gave proof of psychological imagination, a notable capacity for general ideas and the gift of picturesque narration; at once the most artistic and most philosophically minded historian of his generation, he left in his numerous writings a vast portrait gallery of the great figures of his country *(Histdria da civilisação ibérica, História de Portugal, Portugal contemporâneo, Os Filhos de D. João I, A Vida de Nun'Álvares).* The 20th century has seen accentuated the trend toward scientific documentation and objectivity. Fortunato de Almeida followed up an *Histdria da igreja em Portugal* with a masterly *História de Portugal* (6 vol., 1922–37). The monumental *História de Portugal* edited by Damião Peres and others (8 vol., 1928–38) provides an exhaustive treatment of the whole field.

The Contemporary Period.—The passage from monarchy to republic in 1910 was accompanied by a revisionary urge in literature associated chiefly with Oporto and self-styled, in token of serious purposes, the *Renascença portuguesa.* Leonardo Coimbra (1883–1936; *O Criacionismo,* 1912) was its philosopher, António Sérgio de Sousa (b. 1883; *Ensaios,* 1920–24) its critic and historian. Its poets—Mário Beirão *(O último Lusíada,* 1913), Augusto Casimiro (A *Vitória do homen,* 1910; A *Evocação* da *vida,* 1912) and João de Barros *(Oração à pátria,* 1917)—adopted the *saudosismo* of Teixeria de Pascoais as key to the nation's soul and so to the recovery of greatness, though the inadequacy as a principle of action of mere nostalgic regret for the past was soon realized. Against this the "Integralist" school reacted from 1913 in favour of Catholic monarchist tradition, under the leadership of the historian and poet António Sardinha (1888–1925; *Tronco reverdecido,* 1910, *A Epopeia da planície,* 1915) ; among his followers were the conde de Monsaraz *(Musa alemtejana,* 1908) and Hipólito Raposo *(Dois Nacionalismos,* 1929). The formula of Afonso Lopes Vieira, another sensitive traditionalist, *reaportuguesar Portugal tornando-o europeu,* synthesized in some degree the objectives of both schools and received a powerful impetus from Portugal's intervention in World War I. Less was heard thereafter of the cult of the past, and poetry, while responsive to developments abroad, grew again personal and introspective in a vein that proclaimed its affinity with Cesário Verde and António Nobre of the preceding century. Fernando Pessoa (1888–1935) published in his lifetime only *Mensagem;* posthumously, in four volumes of which three appeared under pseudonyms *(Poesias de Fernando Pessoa,* 1942, *Poeinas de Álvaro de Campos,* 1944; *Odes de Ricardo Reis,* 1946; *Poemas de Alberto Caeiro,* 1946), he stood revealed as a complex personality responsive to all the winds that blew and gained acceptance as the most inspired poet of his generation. Pessoa's influence was profound and enriched the moods and resources of subsequent poetry without imposing any suggestion of a school. José Régio and Miguel Torga are prominent among more recent names. Régio, poet, novelist and dramatist, has established himself in a dozen volumes from *Poemas de Deus e do diabo* (1925) to *El-Rei Sebastido* (1949) as a religious if sorely perplexed poet of power and the most significant of contemporary dramatists; Torga's works, numbering twice as many from *Ansiedade* (1928) to *Portugal* (1950), reflect in poems, short stories and volumes of autobiography a less introspective mind possessed of a robust faith in the primitive virtues of mankind.

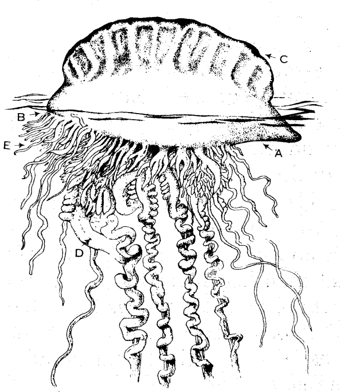
Among novelists may be mentioned Aquilino Ribeiro *(A Via sinuosa,* 1916; *Estrada de S. Tiago,* 1922; *Quando ao Gaviiio cai a pena,* 1935), Mário de Sá Carneiro *(A Confissão de Lúcio,* 1914; *Céu em fogo,* 1915; *Indícios de oiro,* 1938) and J. M. Ferreira de Castro (*Emigrantes,* 1928; *A Selva,* 1930; *Eternidade,* 1935). But the field of contemporary prose achievement is to be found rather in history (Damião Peres, J. M. Queirós Veloso, Luis Gonzaga de Azevedo, David Lopes) and in literary criticism (Fidelino de Figueiredo, Manuel Rodrigues Lapa, Hernâni Cidade) ; thanks to the patient investigations of these and other scholars Portugal's long and distinguished record in the twin spheres of action and letters is at last becoming adequately known.

Bibliography.—Bibliographies: Barbosa Machado, *Biblioteca lusitana,* 4 vol. (Lisbon, 1741–58, 2nd ed., 1930–35) ; Inocêncio da Silva *et al., Dicionario bibliográfico portuguès,* 22 vol. (Lisbon, 1858–1914), supplement by Martinho Fonseca, *Aditamentos* (Coimbra, 1927) ; Pinto de Matos, *Manual bibliográfico* (Oporto, 1878) ; Garcia Peres, *Catalogo razonado de autores portugueses que escribieron en castellano* (Madrid, 1890) ; Fidelino de Figueiredo, *A Crítica literaria como ciência,* 3rd ed. (Lisbon, 1920) ; A. F. Bell, *Portuguese Bibliography* (London, 1922) ; A. J. Anselmo, *Bibliografia das bibliografias portuguesas* (Lisbon, 1923) ; Henry Thomas, "English Translations of Portuguese Books Before 1640," in *The Library* (London, June 1926, continued to 1950 by Carlos Estorninho in *Portugal and Brazil; an Introduction,* ed. H. V. Livermore and W. J. Entmistle, Oxford, 1953). Histories of Literature: C. Michaëlis de Vasconcelos, *Geschichte der Portugiesischen Literatur* in Gröber's *Grundriss* (Strasbourg, 1894) ; T. Braga, *Histdria da literatura portuguesa,* 4 vol. (Oporto, 1909–18) ; Mendes dos Remédios, *Histdvia da literatura portuguesa,* with anthology (Coimbra, 1930) ; A. F. Bell, *Portuguese Literature* (Oxford, 1922) ; F. de Figueiredo, *Histdria da literatura clássica,* 3 vol. (Lisbon, 1917–24), *Histdria de la literatura portuguesa* (Barcelona, 1927), *Histdria literária de Portugal* (Coimbra, 1944) ; A. Forjaz de Sampaio (ed.), *História da literatura portuguesa ilustrada,* 3 vol. (Lisbon, 1929–32) ; G. Le Gentil, *La Littérature portugaise* (Paris, 1935) ; A. J. da Costa Pimpão, *Histdria da literatura portuguesa* (Coimbra, 1947–) ; J. Mouriño, *La Literatura medieval en Galicia* (Madrid, 1929) ; E. Carré Aldao, *Literatura galega,* with anthology (Barcelona, 1911). Anthologies: A. F. Bell (ed.), *Oxford Book of Portuguese Verse,* 2nd ed., rev. by B. Vidigal (Oxford, 1952) ; F. de Figueiredo, *Antologia geral da literatura portuguesa* (Lisbon, 1917) ; J. J. Nunes, *Florilégio da literatura portuguesa arcáica* (Lisbon, 1932), *Crestomatia arcáica,* 3rd ed. (Lisbon, 1943) ; *Corpus illustrium poetarum lusitanorum qui latine scripserunt,* 8 vol. (Lisbon, 1745–48) ; A. de Campos, *Antologia portuguesa,* 28 vol. (Paris, Lisbon, 1919–26) ; G. Young, *Portugal, an Anthology,* with English versions (Oxford, 1916) ; A. de las Casas, *Antología de la lírica gallega* (Madrid, 1928). Texts: *Cancioneiro da Ajuda,* ed. by C. M. de Vasconcelos, 2 vol. (Halle, 1904) ; *Cancioneiro Português da Vaticana,* ed. by *T.* Braga (Lisbon, 1878) ; *Cancioneiro Colocci-Brancuti,* ed. by E. G. Molteni (Halle, 1880) ; Garcia de Resende, *Cancioneiro geral,* ed. by *A.* J. Gonçálves Guimarãis, 5 vol. (Coimbra, 1910–17) ; classical texts in *Coleção Lusitania* (Oporto, undated) ; *Biblioteca de escritores portugueses* (Coimbra, 1923–) ; *Coleção de clássicos Sá da Costa* (Lisbon, 1937–). Literary Criticism: F. de Figueiredo, *Características da literatura portuguesa* (Lisbon, 1915; English translation by Constantino José dos Santos, Coimbra, 1916), *Estudos de literatura,* 4 vol. (Lisbon, 1917–24), *A Épica portuguesa no século xvi* (Madrid, 1931 ; São Paulo, 1950), *Dapois de Eça de Queirds: perspectiva da literatura portuguesa novecentista* (São Paulo, 1943), *Pyrène* (Lisbon, 1935) ; A. F. Bell, *Studies in Portuguese Literature* (Oxford, 1914) ; H. V. Livermore and W. J. Entwistle (eds.), *Portugal and Brazil: an Introduction* (Oxford, 1953) ; Rodrigues Lapa, *Das Origens da poesia lírica em Portugal* *na idade-média* (Lisbon, 1929), *Lições de literatura portuguesa: época medieval* (Lisbon, 1934); P. Le Gentil, *La Poésie lyrique espagnole et portugaise à la fin du moyen âge,* 2 vol. (Rennes, 1949–53); C. Michaëlis de Vasconcelos, *Romances velhos em Portugal* (Coimbra, 1934); J. Ruggieri, *Il Canzoniere di Resende* (Geneva, 1931); studies of Fernam Lopes (Bell), Gil Vicente (Bell), Gaspar Correia (Bell), Camões (Bell), Diogo do Couto (Bell) and Manuel de Melo (Prestage) in *Hispanic Notes and Monographs* (London, 1921–24); M. Bataillon, *Études sur le Portugal au temps de l'humanisme* (Coimbra, 1952); Hernâni Cidade, *Luís de Camões, i, o lírico, ii, o épico,* 2nd ed. (Lisbon, 1952–53), *A Crise mental do século xviii* (Coimbra, 1929), *Tendências do lirismo contemporâneo,* with anthology, 2nd ed. (Lisbon, 1939); T. Braga, *A Arcádia lusitana* (Oporto, 1899). (W. C. An.)

PORTUGUESE MAN-OF-WAR, scientific name Physalia, is a hydrozoan coelenterate belonging to the group Siphonophora (*see* Coelenterata; Hydrozoa). Physalia has a large gas-filled float that may be as long as 10 or 12 in. and is commonly seen in tropical or subtropical waters of all oceans. These animals are sometimes blown ashore in large numbers, and their bright blue, red and sometimes greenish coloured floats can hardly be overlooked. Beneath the float of Physalia there hang numerous polyps of a highly polymorphic nature; they may be described as protective, nutritive and reproductive (*see* Polyp).

The protective polyps (dactylozooids) are of two sorts, large ones with very long tentacles and more numerous small ones with small tentacles. The large dactylozooids possess tentacles specialized as fishing or food-catching tentacles that may be from several feet to several yards long. It is these fishing tentacles, heavily armed with nematocysts, that enable the Portuguese man-of-war to capture animals, including fish, up to as large as itself. The nematocysts of Physalia are larger than most coelenterate nematocysts and contain potent toxins. The sting of Physalia is extremely painful and, in the extreme, can cause death in man.

The feeding or nutritive polyps (gastrozooids) occur in clusters, and the individual zooids do not have tentacles. Once food has been captured by the fishing tentacles, those tentacles contract and carry the food up beneath the float where the gastrozooids can reach it. The gastrozooids apply their mouths to the surface of a food item and will swallow the item if it is small. If it is a large food organism, such as a fish, the mouths of many gastrozooids will spread out over the surface of the captured animal, sometimes completely covering the whole organism. Digestion is believed to be similar to that in other coelenterates.



FROM LIBBIE HYMAN'S "THE INVERTEBRATES," VOL. I (1940); REPRODUCED BY PERMISSION OF MCGRAW-HILL BOOK CO., INC.

FIG. 1.—YOUNG SPECIMEN OF PHYSALIA

(A) Float; (B) growing region of stem; (C) crest of float; (D) large protective polyps (dactylozooids) with fishing tentacles; (E) smaller dactylozooids and nutritive polyps (gastrozooids)

The remaining zooids, the reproductive ones, are more complex than the others. They are complexly branched structures, perhaps representing many individual zooids. These structures, called gonodendra, are made up of clusters of male reproductive units (male gonophores), clusters of female reproductive units (the medusoid female gonophores), long gelatinous processes called gelatinous zooids and short finger-like processes called gonopalpons. Sometimes, but apparently not always, the medusoid female gonophores may be released at sexual maturity. The early stages in the development of Physalia are not known, but once the first polyp appears, part of it becomes the float while an intermediate position, presumably homologous to the stem of most siphonophores, differentiates as a budding region from which the rest of the colony develops.

The zooids of Physalia are set at an angle beneath the float and act like the keel of a ship; thus, instead of simply blowing about the ocean's surface with the wind, these animals tack at an angle to the wind. The relationship of the float to the zooids is different in northern and southern hemisphere representatives of this animal, such that those in the north tack to the left of the wind and those of the south to the right of the wind. The same phenomenon is also known for the colonial hydroid Velella (the by-the-wind sailor), whose sail is differently set in the two hemispheres.

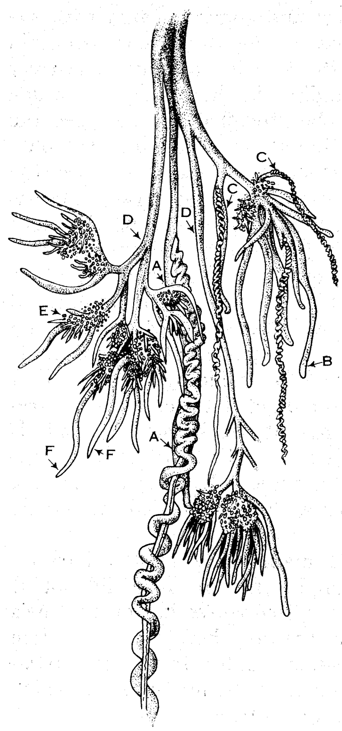


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FIG. 2.—CLUSTER OF POLYPS FROM SEXUALLY MATURE PHYSALIA

(A) Large dactylozooid showing partial length of fishing tentacle; (B) gastrozooid; (C) smaller dactylozooids; (D) reproductive branches (gonodendra); (E) cluster of reproductive units (gonophores) and accessories (gonopalpons); (F) gelatinous processes (zooids)

The float of Physalia has a pore through which the contained gas may escape, allowing the animal to sink. In a short while, the gas-secreting tissues of the float will refill it and the animal will again return to the surface.

The Portuguese man-of-war commonly is accompanied by a fish, Nomeus, which lives among the tentacles of the hydroid and is said to share the food Physalia catches. Nomeus has also been reported to eat the tentacles of Physalia. As long as Nomeus is healthy and has no wounds it is not harmed by Physalia, and the presence of the fish does not cause discharge of the nematocysts. However, once wounded, Nomeus too falls prey to its host just as does any other fish. The nature and origin of the immunity of this fish to the potent nematocysts of Physalia is not understood.

Bibliography.—L. H. Hyman, *The Invertebrates,* vol. i, *Protozoa Through Ctenophora* (1940); C. E. Lane and E. Dodge, "The Toxicity of Physalia Nematocysts," *Biol. Bull.,* 115(2):219–226 (1958); A. K. Totton, "Siphonophora of the Indian Ocean," *Discovery Reports,* 27:1–162 (1954). (C. Ha.)

PORTULACACEAE, the purslane family containing 16 or more genera and more than 500 species of widely distributed rather fleshy annual or perennial herbs or subshrubs with simple entire, often terete leaves and bisexual flowers with usually two green herbaceous sepals and from four to six petals (sometimes fewer).

A few are grown for ornament or as potherbs, among them *Portulaca, Montia, Claytonia* and *Talinum.* A very troublesome weed in many sections of the United States is the garden purslane or pusley (*Portulaca oleracea*). *See* Purslane. (J. M. Bl.)

PORTUNUS (Portumnus), in Roman cult originally a god either of gates and doors (from *porta*) or harbours (from *portus*), eventually associated with both. In the former capacity he was probably connected with Janus (*q.v.*), but the degree of their association is conjectural. At Rome he had his own priest, the *flamen Portunalis,* and a festival, the Portunalia, celebrated on Aug. 17 in his temple near the *pons Aemilius.* He was similarly worshiped at Ostia. The conjecture that he is the god of the gates and keys of granaries may explain the location of his shrine near the storehouses of the Tiber and his festival in the harvest season. He was, however, definitely connected with the guiding of ships to harbour (Virgil, *Aeneid,* v, 241; cf. Cicero, *Nat. deor.,* ii, xxvi) and he came to be associated with the Greek marine deity Palaemon-Melicertes. He is represented as a youth bearing keys.

Bibliography.—W. W. Fowler, *Roman Festivals,* pp. 202–204 (1899); H. Papenhoff in Pauly-Wissowa, *Real-Encyclopädie,* s.v.; Platner-Ashby, *Topographical Dictionary,* s.v. *Portunium.*

(R. B. Ld.)

PORTUS, an ancient harbour of Latium, It., on the right bank of the Tiber, at its mouth. For its origin *see* Ostia.

Claudius constructed the first harbour there, 2½ mi. N. of Ostia, enclosing an area of 170 ac., with two long curving moles projecting into the sea and an artificial island, bearing a lighthouse in the centre of the space between them; the harbour thus opened directly to the sea on the northwest and communicated with the Tiber by a channel on the southeast. The object was to obtain protection from the prevalent southwest wind to which the river mouth was exposed. Though Claudius, in the inscription which he caused to be erected in A.D. 46. boasted that he had freed the city of Rome from the danger of inundation, his work was only partially successful. The Via Portuensis (15 mi.) ran over the hills as far as the modern Ponte Galera, and then straight across the plain. An older road, the Via Campana, ran along the right bank of the Tiber. In A.D. 103 Trajan constructed another harbour, still well preserved in modern times, farther inland—a hexagonal basin enclosing an area of 97 ac. It communicated with the harbour of Claudius and with the canal constructed by him (though it bears the name Fossa Trajana), later forming the navigable arm of the Tiber (reopened for traffic by Gregory XIII and again by Paul V). It mas surrounded by extensive warehouses; the fineness of the brickwork of which they are built is remarkable. The perforated travertine blocks to which the ships were made fast survived in modern times. Farther to the east was built a circular building in brick with niches called the temple of Portumnus.

Portus eventually captured the main share of the harbour traffic of Rome, and though the importance of Ostia did not at once decrease Portus was already an episcopal see in Constantine's time not very long after Ostia, and the only harbour in the time of the Gothic wars. Its abandonment dates from the partial silting up of the right arm of the Tiber in the middle ages, which restored to Ostia what little traffic was left.

To the west of the harbour is the cathedral of S. Rufina (10th century, but modernized except for the campanile) and the episcopal palace, fortified in the middle ages, and containing a number of ancient inscriptions from the site. On the island (Isola Sacra) just opposite is the church of S. Ippolito, built on the site of a Roman building, with a picturesque 13th-century campanile: 2 mi to the west is the modern village of Fiumicino at the mouth of the right arm of the Tiber, 21 mi. W.S.W. by rail from Rome. It is a portion of the commune of Rome. Three miles to the north a pumping station was built to keep the lowland (formerly called Stagno di Maccarese, reclaimed and traversed by many drainage canals) drained.

PORT WINE is a rich, blended and fortified wine which comes from a specific area in the Douro valley in northern Portugal. It is made according to certain principles designed to conserve part of the natural sweetness in the wine; it is thus, generally, a dessert wine.

Port is fortified with grape brandy before the fermentation has finished; it will contain more or less natural sweetness according to the moment when the brandy is added. Although in France a comparatively dry port is popular as an *apéritif*, port is ordinarily sweet and rich.

Wines from the Douro began to be popular in England from 1670 onward; at first they were fortified after their arrival in England. Fortification in Portugal (at the time of the fermentation) was only developed in the 18th century. In England larger quantities of port were drunk than of any other wine from the early 18th century until the end of the 19th. Port trade was exclusively English in origin, and it was not until the 19th century that other countries (such as France and Norway) imported the wine on any scale.

There are two main types of port: vintage port, which is the finest wine from a single very good year, and wood port, which is blended from the wines of different years. With judicious blending (generally of about 12 varieties of grape) not only can any style of wine be produced, but that style can be maintained year in, year out, in spite of the vagaries of climate. Quality apart. the two main types differ in the way they are matured. Wood port is fully matured in wood, for 5 to 15 years; it is bottled only for convenience of sale. Vintage port is bottled after two or three years so that it will complete its maturation in bottle. where it will take longer than in wood, and where it will throw a deposit or crust.

Crusted port or vintage character is neither wood port nor true vintage port, but a blended wine bottled after five or six years to complete its maturation. It resembles vintage port, and like it requires decanting off its crust before it is consumed.

Vintage port is never white, but wood port may be white, ruby or tawny. When port is young, it is generally ruby. but it takes on a tawny hue; for this reason colour should be an indication of its age. Ruby port is not necessarily inferior to tawny because of its youth—a fuller-bodied wine may be preferred to a mellower one—but it is usually cheaper.

In 1916 the United Kingdom agreed by a treaty with Portugal not to permit the sale of any wine as port except that produced in a defined area of about 1,800 sq.mi. in the Douro (actual area under vine cultivation is now about 600 sq.mi.) and shipped from Oporto or its sister port of Vila Nova de Gaia. Other countries produce port-style wines by following methods similar to that used in the Douro, but the results are never like true port. Newfoundland port is true port matured in Newfoundland.

(C. C. H. F.)

PORUS (4th century B.C.), an Indian prince, ruler of the country between the Hydaspes and Acesines rivers at the time of the invasion of Alexander the Great. In the battle on the banks of the Hydaspes he offered a desperate resistance, and Alexander. struck by his independent spirit, allowed him to retain his kingdom, which he increased by the addition of territory. From this time Porus was a loyal supporter of Alexander. He still held the position of a Macedonian satrap when assassinated some time between 321 and 315 B.C.

See Arrian, v, 18, 19; Plutarch, *Alexander*, 60; Quintus Curtius, viii, 14.

PORVOO (Swed. BORGÄ), a seaport in the province of Uundenmaan, republic of Finland, situated at the entrance of the Borga river into the Gulf of Finland, about 33 mi. E.N.E. of Helsinki by rail. Pop. (1950) 8,534.

Once a city of great dignity, it was eclipsed by the rapid growth of Helsinki. In 1809, when the estates of Finland were summoned to a special diet to decide the future of the country, Porvoo was the place of meeting, and it was in the cathedral that the tsar Alexander I pledged himself as grand duke of Finland to maintain the constitution of the grand duchy.

POSADA, JOSÉ GUADALUPE (1852–1913), Mexican print maker. was born on Feb. 2, 1852, in Aguascalientes. As a child he worked as a farm labourer and in a pottery factory. He taught school for a short time and then began to draw, inspired largely by posters for the Rea circus. Gradually he was attracted to print making and became a kind of pictorial journalist with the publication of thousands of broadside illustrations and popular book and song covers. He may be regarded as one of the greatest popular artists of all time. Contrary to belief, most of his works were not executed in woodcut, but engraved or etched in relief on type metal.

Posada died Jan. 20, 1913, in Mexico City.

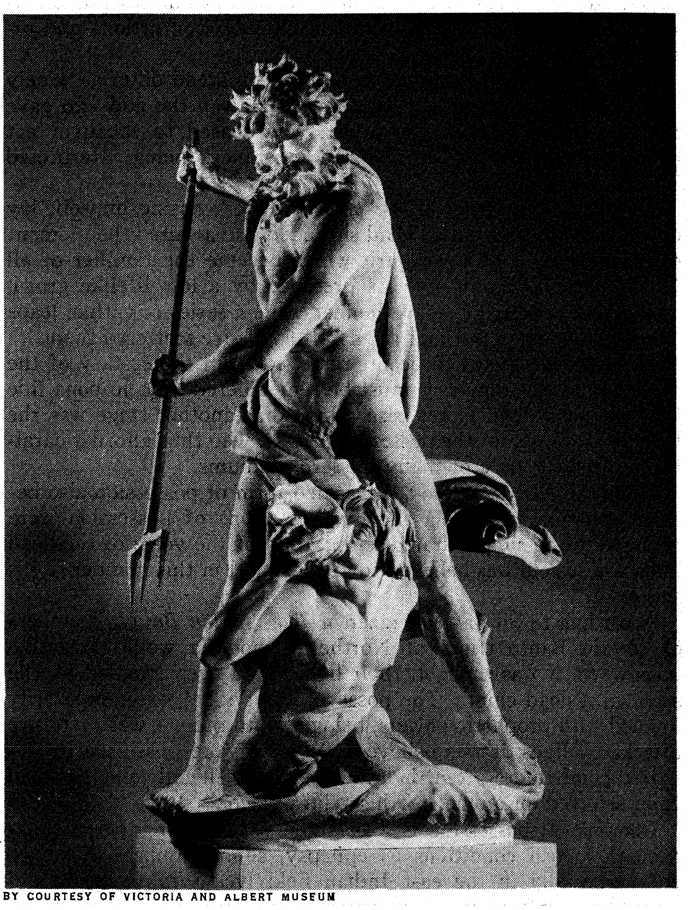
See Carl O. Schniewind and Hugh L. Edwards, *Posada: Printmaker to the Mexican People* (1944). (H. Es.)

POSEIDON, in Greek mythology, god of the sea and of water generally, son of Cronus and Rhea and brother of Zeus and Pluto (perhaps "lord of moisture," or connected with the Greek words for "drink," "a river").

When the three brothers deposed their father Cronus, the kingdom of the sea fell by lot to Poseidon. His home was in a golden palace in the depths of the sea near Aegae in Achaea. In his hand he bore a trident, wherewith he lashed the sea into fury, split the rocks and caused horses and fountains to spring from them. But, while he caused storms and shipwrecks. he could also send favouring winds; hence he was known as *Soter*, "the preserver." Another of his titles was *Gaieochos*, "holder (*i.e.*, encircler?) of earth."

He mas the god of navigation. and his temples stood especially on headlands and isthmuses. Every occupation connected with the sea was under his protection, and seafaring people, especially the Ionians, regarded themselves as his descendants. As god of the sea he disputed with other deities for the possession of the land. Earthquakes were thought to be produced by Poseidon shaking the earth — hence his epithet of *enosichthon,* "earth shaker" — and he was worshipped even in inland places which had suffered from earthquakes. Several striking seismic and other phenomena in historical times were attributed to him. Poseidon was also the god of springs, which he produced by striking the rock with his trident, as he did on the acropolis of Athens when disputing with Athena for the sovereignty of Athens. As such he was called *Nymphagetes,* the leader of the nymphs of springs and fountains, a god of fresh water, probably his original character, and in this connection was a god of vegetation, frequently associated with Demeter.

At Athens he is closely associated with Erechtheus (*q.v.*), with whom many identify him. As he gave, so he could withhold, springs of water; thus the waterless neighbourhood of Argos was supposed to be the result of his anger. Black bulls were sacrificed to him and often thrown alive into rivers; in Ionia and Thessaly bullfights took place in his honour; at a festival at Ephesus cupbearers were called bulls, and he was surnamed "Bull Poseidon."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"NEPTUNE AND TRITON" BY G. L. BERNINI (1598–1680). ITALIAN

Several legends represent him as creating the first horse; horses were occasionally sacrificed to him; and he is called *Hippios* ("lord of steeds"). In the deme of Colonus Poseidon was worshipped with Athena, the reputed inventor of the bridle.

Various explanations of the title *Hippios* have been given: (1) that the horse represented the corn spirit; (2) the resemblance of the crested waves to horses; (3) the impression of horses' hoofs near the god's sacred springs, and the shaking of the earth by them when galloping. In the Trojan War he takes the side of the Greeks, because he had been cheated of his reward by Laomedon, king of Troy, for whom he had built the walls of the city. The blinding of his son Polyphemus by Odysseus brings upon the hero the wrath of Poseidon. He is famous for his numerous amours; his offspring were mostly wild and cruel, like the sea — the Laestrygones, Polyphemus, Antaeus, Procrustes and the like.

He was worshipped as a national god by the Ionians, who took his worship with them from Peloponnesus to Asia Minor. His chief sanctuary was at Mycale, where the Panionia, the national festival of the Ionians, was held. Other seats of his worship were in Thessaly, Boeotia and Peloponnesus. At Taenarum in Laconia he had a famous cavelike temple with an asylum, and on the island of Tenos he was worshipped as the physician, probably in reference to the health-giving properties of the sea air.

By far the most famous of his festivals was that celebrated every alternate year on the Isthmus of Corinth, at which the Isthmian games were held. The horse, the dolphin (the symbol of the calm sea) and the pine tree. with wreaths of which the Isthmian victors were crowned, were sacred to him. His attributes are the trident and dolphin or tunny fish. As represented in art, Poseidon resembles Zeus, but possesses less of his majestic calm. In modern Greece St. Nicholas has taken the place of Poseidon as patron of sailors. But the Zacynthians have a special sea god, half man, half fish, who dwells under the sea, rides on dolphins or in a car drawn by dolphins and wields a trident. By the Romans Poseidon was identified with Neptune (*q.v.*).

POSEIDONIUS (Posidonius) (*c.* 135–*c.* 50 B.C.), nicknamed "the Athlete," Stoic philosopher, the most learned man of his time and perhaps of all the school. A native of Apamea in Syria and a pupil of Panaetius, he spent many years in travel and scientific researches in Spain (particularly at Gades), Africa, Italy, Gaul, Liguria and Sicily and on the eastern shores of the Adriatic. When he settled as a teacher at Rhodes his fame attracted numerous scholars; next to Panaetius he did most, by writings and personal intercourse, to spread Stoicism in the Roman world. and he became well known to many leading men, such as Marius, Rutilius Rufus. Pompey and Cicero. The last-named studied under him (78–77 B.C.) and speaks as his friend.

The titles and subjects of more than 20 of his works, now lost, are known. In common with other Stoics of the middle period. he displayed eclectic tendencies, following the older Stoics, Panaetius, Plato and Aristotle. Unquestionably more of a polymath than a philosopher, he appears uncritical and superficial. His inquiries, however, were criticized by Strabo as alien to the Stoic school. In natural science, geography, natural history, mathematics and astronomy he took a genuine interest. He sought to determine the distance and magnitude of the sun and to calculate the diameter of the earth and the influence of the moon on the tides.

The history by Poseidonius of the period 146–88 B.C., in 52 books, must have been a valuable storehouse. Cicero made much use of his writings.

See also Stoics.

Bibliography.—For the fragments *see* J. Blake (ed.), *Posidonii Rhodii reliquiae* (1810) and C. Muller (ed.), *Fragmenta historicorurn graecorunz,* vol. iii (1849). General works include: E V. Arnold, *Ronzan Stoicism* (1911; new ed. 1958); E. R. Bevan, *Stoics and Sceptics* (1913); E. Zeller, *Philosophie der Griechen,* vol. iii, 5th ed. (1923); M. Pohlenz, *Stoa und Stoiker* (1950). *See* also R. Hirzel, *Untersuchungen zu Ciceros philosophischen Schriften,* 3 vol. (1877–83); C. Thiaucourt, *Essai sur les traités philosophiques de Cicéron et leurs sources grecques* (1885); A. Schmekel *Die Philosophie der mittleren Stoa* (1892); I. Heinemann, *Poseidonios' nzetaphysische Schriften* (1921); K. Reinhardt, *Poseidonios* (1921) and *Kosmos und Syrnpathie: neue Untersuchungen uber Poseidonios* (1926); P. Schubert, *Die Eschatologie des Posidonius* (1927); L. Edelstein, "The Philosophical System of Posidonius," *Amer. J. of Philos.,* vol. lvii (1936).

POSITION ANALYSIS: *see* Topology, Geseral.

POSITIVE (or Portable) **ORGAN,** a medieval chamber organ, known as the *Positivs,* which could be carried from place to place without being taken apart.

When played it was placed on a table or stool and required a blower for the bellows, as well as a performer. It was larger and more cumbersome than the portative organ (*q.v.*), or *Portativs,* with which it has often been confused.

The positive usually had only one kind of pipe, the open diapason of two-foot tone, and in the 16th century the best types had three registers by means of which each note could be sounded with its fifth and octave, or each by itself, or again in combinations of twos.

The positive differed from the regal (*q.v.*) in having flue pipes, whereas the latter had beating reeds in tiny pipes, one or two inches long, concealed behind the keyboard. During the early middle ages most of the pneumatic organs belonged to that type.

A well-known example of an early positive or portable organ of the 4th century is that on the obelisk erected to the memory of Theodosius the Great, on his death in A.D. 395. Among the illuminated miniature manuscripts acquired by the British Museum abound representative, interesting varieties of the portable organ, including examples of the 14th and 15th centuries.

The little organs were found at every kind of civil and religious function; they were used in the dwellings and chapels of the rich; at banquets and court functions; in choirs and music schools; and in the small orchestras of Jacopo Peri and Claudio Monteverdi at the dawn of the musical drama or opera.

(See ORGAN.)

POSITIVE RAYS: see MASS SPECTROSCOPY.

POSITIVISM, a philosophical term used (1) in a broad and (2) in a narrow sense.

1. The term positivism may be applied to any system that confines itself to the data of experience and excludes a priori or metaphysical speculations. In this sense the term is commonly applied to the empirical philosophers, although in fact reservations ought to be made (John Locke and David Hume accept mathematics, Eocke and George Berkeley accept a knowledge of the soul and of God, on nonempirical grounds). John Stuart Mill's "experience philosophy" is positivistic in this sense. Positivists have usually held that theological and metaphysical questions arise but cannot in fact be answered by any method available to men. Others, however, have dismissed such questions as meaningless. This second view connects with pragmatism and with logical positivism (*qq.v.*) and also with the hints to be found in Berkeley and in Hume of an experience test of meaning. Positivism emphasizes the achievements of science; but questions arise even within the sciences which do not seem to be answerable by experimental methods. Ernst Mach attempted to assign an experience meaning to such theoretical questions and to relate theories directly to the evidence for them.

2. More narrowly, the term describes the philosophy of Auguste Comte (*q.v.*), who held that human thought had passed inevitably through a theological stage into a metaphysical stage and was passing into a positive or scientific stage. Comte held that the religious impulse would survive the decay of revealed religion and ought to have an object. He projected a worship of man, with churches, calendar and hierarchy. Disciples (F. Harrison, R. Congreve et *al.*) founded such a church in England, but Mill, who inclined to accept the religion, repudiated Comte's organization.

See Thomas Whittaker, Comte *and* **Mill** (1908). (K. W. B.)

POSSE COMITATUS, an ancient English institution consisting of the shire's force of able-bodied private citizens summoned to assist in maintaining public order. This "power of the county." originally raised and commanded by the sheriff, became a purely civil instrument as the sheriff's office early lost its military functions. From time to time legislation gave authority to other peace officers and magistrates to call upon the poner of the county. While Blackstone stated that liability to serve extended to every person over the age of 15 and under the degree of peer. judicial interpretation (of a riot act of Henry IV) excluded also women, clergymen and the infirm. Failure to respond to the call subjected one to fine and imprisonment. The English sheriff ceased in the 19th century to be a police officer, but an act of 1887 still required every person in the county to be ready and apparelled (*i.e.,* armed) at the sheriff's command to arrest a felon or to assist if there were resistance to the execution of a writ. In the U.S., the posse comitatus was perhaps most important on the frontier. but it has been preserved as an institution in many states through the middle of the 20th century. Statutes confer on sheriffs and other peace officers authority to summon the power of the county. Some have made it a crime to refuse assistance. In general, its members have been privileged to use force if necessary to achieve a posse's legitimate ends, but states' laws differ as to the legal liability of one who in good faith aids an officer himself acting beyond his authority. (V. No.)

POSSESSION, the supposed control of a human body and mind by an alien spirit, human or nonhuman; or the occupation by an alien spirit of some portion of a human body, causing sickness, pain, etc.

The term "obsession" (Lat. for "siege") is sometimes used as equivalent to possession; sometimes it denotes spirit control exercised from without, or it may mean no more than a maniacal monoideism. The spirit is held to have entered the person in order to foretell the future or to proclaim the will of a god; the god himself may be regarded as speaking through the mouth of his devotee. Hence the authority of a prophet. Among peoples in primitive stages of culture, possession by spirits, of the dead is common and is related to ancestor worship. This kind of possession is found in Africa, Polynesia and Asia. Many of the classical oracles were regarded as divinely inspired. The manifestations are often voluntarily induced and are provoked in many different ways; in classical times the eating of laurel leaves, the inhaling of fumes which ascended from a cleft in the rocks of Delphi, the drinking of intoxicating liquors or of a more widely found means of inducing the phenomena—blood—wereall in use. Hypnosis was produced by drugs, drafts of animal blood or, as in Siberia, America and many parts of Africa, by drumming, contortions and orgiastic dancing.

The symptoms of supposed possession by a god differ as widely as do those of the hypnotic trance. In Hawaii the god Oro gave his oracles by inspiring the priest, who ceased to speak or act as a voluntary agent, his frenzied utterances being interpreted by the attendant priests.

In the Malay peninsula the *pawang*, after censing himself, lay down on his back, with his head shrouded and awaited the moment of inspiration. The tiger spirit which became the familiar of all Malay *pawangs* manifested its presence by a low lifelike growl, and the *pawang* scratched at the mat. gave a series of catlike leaps and licked up from the floor the handfuls of rice scattered there.

But his state seems to be far removed from the ecstasy of the Hawaiian priest, though it must be remembered that no bona fide test was possible in either case. In Tahiti another stage was the lofty declamation of the possessed priests, who thus afford a parallel to the utterances of many modern mediums.

Finally in Africa, where the frenzied form of possession also became common, at Sofala the manifestations of possession were confined to the simple dramatic imitation of the voice of the dead king, whose soul was believed to give counsei in this manner to his successor.

According to Sir James Frazer in *The* Golden Bough, members of certain Bantu tribes of Northern Rhodesia would roar like lions when, it was thought. their bodies had been invaded by the spirit of a dead chief. The possessed individual was temporarily imbued with prophetic powers. being able to predict war or future attacks by lions. it was believed. Women were possessed by departed chiefs more often than men, and occasionally the deceased chief selected an animal for his reincarnation.

Demoniacal possession is a common explanation of such psychopathological conditions as epilepsy, somnambulism, hysteria, etc.; especially in the east Indian field lycanthropy (*q.v.*) and magical power (for evil) are commonly attributed to possession. Demoniacal possession is familiar to us from the New Testament narratives, in which those possessed are stated to live among the tombs, to be deaf and dumb or blind, to be possessed by a multitude of evil spirits or to suffer from high fever as a result of possession; the demons are said to pass into the bodies of animals or to reside in uaterless places.

The facts recorded are explicable either as symptoms of mental disease or as results of suggestion.

In the primitive stages of culture diseases are explained as caused by the invasion of the body by spirits (see ANIMISM), but the effects are supposed to be physiological, not psychical. The wrath of an ancestor or other dead person or the malice of a spirit, such as the Malay *hantus*, or of any nonhuman spirit, may set up pathological conditions.

Such cases may be distinguished from the inspirational form by their invariably involuntary character and are dealt with by a variety of means such as spells, purifications, sacrifices to the possessing spirit, etc.

Among the Shilluk of the Anglo-Egyptian Sudan, for example, the possession of a person by the spirit of a dead king was regarded as a common cause of illness. Hence sacrifices were offered to the unwelcome royal spirit to induce it to leave the body of the afflicted person (see NILOTES).

(See also DEMONOLOGY; DEVIL; EXORCISM.)

BIBLIOGRAPHY.—For anthropological data *see* Adolf Bastian, *Der Mensch in der Geschichte* (1860); Naevius, *Demon Possession;* Radloff, *Das Schamanentum;* W. W. Skeat, *Malay Magic* (London, 1900); Otto Stoll, *Suggestion und Hypnotismus*, 2nd ed. (Leipzig, 1904); Sir Edward Tylor, *Primitive Culture*, 7th ed. (1924); Verdun, *Le Diable dans les missions;* Maury, *La Magic*, p. 258 *et seq.;* chamberlain, *Things Japanese*, *s.v.* "Fox." Details of the phenomena are given in all good modern ethnographical works. *See* bibliography to ANTHROPOLOGY. For discussion of New Testament facts *see* W. M. Alexander, *Demoniacal Possession in the New Testament;* Conybeare, in *Jewish Quarterly Review*, vol. viii, 576, vol. ix, 59, 444, 581; Herzog's *Realencyklopädie*, *s.v.* "Dämonische." For patristic literature *see* J. Bingham, *Antiquities of the Christian Church*, vol. iii.

POSSESSION (IN LAW), a term derived from Roman law. It has been said to be either a right or a fact conferring a right, or both together. The latter is the view of Friedrich Karl von Savigny, a leading authority upon the subject (Dm Recht des Besitzes). The definition of W. A. Hunter may be accepted: "Possession is the occupation of anything with the intention of exercising the rights of ownership in respect of it" (Roman Law). Possession is inchoate or incomplete ownership; it is on its way to become ownership.

In both Roman and English law the possessory tended to supersede the proprietary remedies from their greater convenience—that is to say, the plaintiff based his claim or the defendant his right upon possession rather than property. The English possessory action may have been directly suggested by the interdict. Henry de Bracton (103b) identifies the assise of novel disseisin, the most common form of possessory action, with the interdict unde *vi*.

In England ejectment had practically superseded other real actions before the latter were (with the exception of dower, writ of dower and *quare impedit*) expressly abolished by the Real Property Limitation act, 1833, s. 36. The action for the recovery of land, introduced by the Judicature acts, is the modern representative of the action of ejectment.

Possession gives in English law, speaking generally, much the same rights as in Roman law. Thus it serves to found a title (see LIMITATION, STATUTES OF; PRESCRIPTION), and to throw the onus of proof upon the claimant. In an action for the recovery of land the defendant need only allege that he is in possession by himself or by his tenant, and (where such an allegation is necessary) that he had no notice to quit. In English law the doctrine of possession becomes practically important in the following cases:

1. Possession serves as a convenient means of division of estates. (See LAWS OF REAL PROPERTY AND CONVEYANCING.) One of the divisions of estates is into estates in possession and estates in reversion or remainder. It also serves as a division of personal property (*q.v.*). A chose in action is said to be reduced into possession when the right of recovery by legal proceedings has become a right of enjoyment.

2. Possession gives a title against a wrongdoer. In the case of real property it is regarded as prima facie evidence of seisin.[1] In the case of personal property the mere possession of a finder is sufficient to enable him to maintain an action of trover against one who deprives him of the chattel.[2]

3. What is called "unity of possession" is one of the means whereby an easement is extinguished.

4. Possession is very important as an element in determining the title to goods under 13 Eliz. c. 5, the Bills of Sale act, 1878, and the Bankruptcy acts, 1883 to 1890.

5. Possession of goods or documents of title to goods is generally sufficient to enable agents and others to give a good title under the Factors' acts. (See FACTOR.) W

6. In criminal law the question of possession is important in founding the distinction between larceny and embezzlement. (See Sir James Stephen, *Digest* of the *Criminal* Law, note xi.)

7. Actions of possession of ships fall within the jurisdiction of the admiralty division. This jurisdiction in the case of British vessels depends upon the Admiralty Court act, 1861 (24 Vict. c. 10, s. 8), in the case of foreign vessels (in which the jurisdiction is rarely exercised) upon the general po ers of the court as a maritime court. Under the Statutes of Limitation the only question became not whether possession has been adverse or not, but whether 12 years have elapsed since the right accrued.

Scotland.—In Scotland possessory actions still exist eo *nomine*. Actions of molestation, of removing and of maills (payments) and duties are examples. A possessory judgment is one which entitles a person who has been in possession under a written title for seven years to continue his possession (Watson, *Law Dict.*, *s.v.* "Possessory Judgment").

United States.—In U.S. law possession carries much the same important significance that it does in English law. Except in Louisiana, where the civil law prevails, possession is commonly divided into actual and constructive possession. The former concerns actual occupancy or the exercise of dominion over a thing; the latter occurs where there is no actual possession but simply ownership and the possession is either vacant or consistent with the outstanding ownership, such as possession by a servant or bailee.

The doctrine of possession has an outstanding importance in practically every branch of the law, especially in the numerous cases where ownership to realty or personalty is in issue. Especially significant are the doctrines of adverse possession, where long continued and uninterrupted possession of chattels or realty under a claim of right and hostile to the true owner ripens after the statutory period into indefeasible ownership.

In addition to the authorities cited may he mentioned W. A. Hunter, *Exposition of Roman Law*, 4th ed. (1903); O. W Holmes, *The Common Law* (1882); F. Pollock and R. S. Wright, *Possession in the Common Law* (1888); W. Markby, *Elements of Law* (1905); T. H. Holland, *Elements of Jurisprudence*, 13th ed. (1924).

POST, GEORGE BROWNE (1837–1913), U.S. architect of many commercial buildings, was born in New York city on Dec. 15, 1837. He graduated with a degree in civil engineering from New York university in 1858 and was a draftsman under Richard Hunt until 1860, when he and Charles D. Gambrill formed a partnership. His buildings include the Williamsburgh Savings bank, New York city (1874), in Renaissance style; the original New York Times building (1889), Romanesque; the St. Paul building, New York city (1897–99), a 22-story structure using applied classic orders; and the New York Stock exchange (1904). Post died on Nov. 28, 1913, at Bernardsville, N.J.

POST, GEORGE EDWARD (1838–1909), U.S. physician and clergyman, who translated a number of scientific works into Arabic, was born on Dec. 17, 1838, in New York city. Graduated from the New York Free academy (later the College of the City of New York) in 1854, Post studied at the New York university medical school, where he received his medical degree in 1860, and the Union Theological seminary, where he was graduated the following year. During the Civil War Post served as chaplain of a New York regiment and graduated from the Baltimore (Md.) College of Dentistry in 1863.

In the same year he was sent as a missionary for the American Board of Commissioners for Foreign Missions to Tripoli, Syria. Four years later illness forced his return to the United States, but he returned to Syria in 1868. He became professor of surgery and of eye and ear diseases at the Syrian Protestant college (later the American University of Beirut) and later was appointed dean of the medical department.

Post, whose classes were conducted in Arabic, translated a large number of English medical and other scientific textbooks into that

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[1] "Seisin" *and "possession" are used sometimes as synonyms, as generally by* Bracton; *at other times they are distinguished: thus there can he possession of a term of years, but no seisin* (Noy, *Maxims*, p. 2). *It seems doubtful, however, how far* in *English law a* tenant *for years has true* possession, *for he is in law only a bailiff or servant of the landlord. But he certainly has possessory remedies.*

[2] Compare *the* **Code** *Napoleon, art.* 2,279: *"En* fait *de meubles la* **pos***session vaut* titre."

language. He was editor of *Al-Tabib,* an Arabic medical journal, for five years and served as a surgeon at the Johanniter hospital in Beirut.

In addition to his works in Arabic, including a translation of Butler's *Physiology* and, nith C. V. A. Van Dyck and Eli Smith. a biblical concordance. he published *Plantae Postianae* (Lausanne, Geneva, 1890–19001. He also contributed articles on various scientific topics to James Hastings' *Dictionary of the Bible.*

Post died on Sept. 29, 1909.

POST, MELVILLE DAVISSON (1871–1930), **US.** author. best knonn for his mystery stories. was born at Romines Mills. near Clarksburg. W.Va., April 19. 1871. Post practised criminal law and later corporate law in West Virginia. He became active in politics and in 1898 was named chairman of the Democratic congressional committee in West Virginia.

In 1896 he published *Tlze Strange Schemes of Randolph Mason,* a collection of short stories featuring a lanyer who unscrupulously took advantage of loopholes in the law. In the folloning year a sequel. *The Man of Last Resort,* was published. Post's Randolph Mason worked for the ends of justice in *Randolph Mason, Corrector of Destinies* (1909).

Post became best knonn for his series of magazine stories about a rural sleuth in early Virginia. In 1918 a selection of the tales was published as a book entitled *Uncle Abner: Master of Mysteries.* Other mystery stories include *The Sleuth of St. James's Square* (1920); *Monsieur Jonquelle* (1923): *The Bradmoor Murder* (1929); and *The Silent Witness* (1930) He also nrote *Dwellers in the Hills* (1901) a story of West Virginia cattlemen: *Tlze Gilded Chair* (1910) an adventure story; and *The Mountain School-Teacher* (1922) an allegory based on Christ's life

On June 29. 1903. Post was married to Ann Bloomfield Gamble of Roanoke. W Va.. who died in 1919. He died at Clarksburg on June 23. 1930.

POST, PIETER (1608–16691, Dutch architect and painter. one of the principal architects of the Dutch golden age. nas born at Haarlem and died at The Hague. He nas a contemporary of Rembrandt and secretary to Constantijn Huygens Though Post began his career as a painter. he had by 1633 in collaboration nith Jacob van Campen. designed the exquisite Mauritshuis at The Hague. thus shoning his mastery of the typical Dutch baroque style. In 1645 he became architect to the stadholder Frederick Henry. With Campen he designed the House in the Wood (Huis ten Bosch) at The Hague (1645–47) and, independently Snanenburg house (1645), Nieuwkoop almshouses at The Hague (1658) and the weighhouse in Leyden (1658). Post's town hall at Maastricht (1656 ff.) is one of the outstanding buildings of the 17th century in the Netherlands. Post and Campen are notable for anticipating some of the architectural refinements of 18th-century France and for the influence they exerted on English architecture.

BIBLIOGRAPHY.—*Les Ouvrages* de *Pierre* Post, engravings (1715); G A. C Blok, *Pieter* Post (1937); F. A J Vermeulen, Handboek tot de *geschiedenis* der *Nederlandsche bouwkunst,* vol. iii (1941).

(H. MN.)

POST, WILEY (1899–1935), one of the most colourful figures of the early years of U.S. aviation. was born on Nov. 22. 1898. on a farm near Grand Saline, Tex.. and grew up in the oil country of Texas and Oklahoma. Of natural mechanical bent. young Post worked first on well-drilling rigs. then became interested in gasoline-driven engines and in the airplane flights of the barnstormers who performed at county fairs. While working as an oil driller he lost his left eye in an accident, but this did not prevent his learning to fly. Backed by a wealthy Oklahoma oilman. F. C. Hall, for nhom he became personal pilot. Post purchased the Lockheed monoplane "Winnie Mae" and proceeded to set an astonishing series of records, culminating in his solo round-the-world flight July 15–22, 1933. He covered a total of 15.596 mi. in 7 days. 18 hr. and 49 min. On this flight Post proved the value of navigation instruments, including the automatic pilot, that later came into common use in airline service. He had made an earlier round-the-norld trip in the same airplane June 23–July 1, 1931. On that flight he had been accompanied by Harold Gatty as navigator. Post also did pioneering work in high-altitude flying, having designed and tested a prototype of a pressurized suit similar to those later used by military pilots.

In Xug. 1935, while flying in Alaska accompanied by the humorist Will Rogers, Post and his famous passenger were killed in a plane crash near Point Barrow.

See W. Post and H. Gatty, Around the World *in* Eight Days (1931).

(S. P. J.)

POSTAL ORDER: *see* MONEY ORDER.

POSTAL SERVICES. This article is divided into the following main sections:

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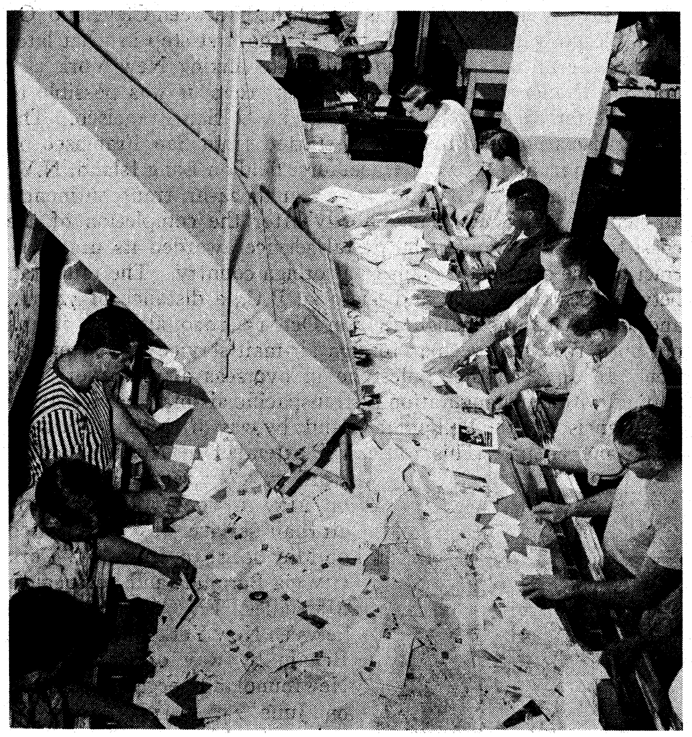
I. UNITED STATES

A. HISTORY

The first postal system in the United States was legalized in 1639 by the general court of Massachusetts. The ordinance directed that all mail brought from overseas was to be left at the home of Richard Fairbanks in Boston, who would have it transmitted onward to destination. Fairbanks was allowed a penny for the transmission of each letter. In 1672 Gov. Francis Lovelace of New York established a monthly post between New York city and Boston over what later became the Boston post road—U.S. highway route no. 1. In 1683 Gov. William Penn of Pennsylvania established a post office in Philadelphia, where Henry Waldy, the first postmaster, was authorized to send mail weekly between Philadelphia and Newcastle, Del., and to supply the riders with horses to serve the routes. A post route extending from Maine to Georgia was established in this same year; these old routes later became the trunk highways serving the eastern U.S. seaboard.

In 1691 Andrew Hamilton of Edinburgh, Scot., was appointed by the British crown as postmaster general for the American Colonies. The first advance toward an organized intercolonial service was made by the granting of a patent to Thomas Neale on Feb. 17, 1692, to establish post offices in North America. An office was established at Philadelphia and rates were fixed to most of the Colonies, but receipts did not cover expenses and in 1707 the government wurchased the rights.



BY COURTESY OF U S POST OFFICE DEPARTMENT

SORTING MAIL AT A METROPOLITAN POST OFFICE

In 1753 Benjamin Franklin became joint postmaster general for the North British Colonies in America and served until 1774, wheh he was dismissed by the crown because of his sympathies with the cause of the American colonists. Many improvements in the colonial postal system were made under his administration. Despite poor roads and great distances between centres of population, Franklin made the postal service an efficient and reliable means of communication.

Service between New York city and Philadelphia was increased from once to three times a week in summer and from twice a month to once a week in winter; post roads were in operation from Maine to Florida and from New York to Canada, and mail between the Colonies and the mother country was operated on a monthly schedule.

Franklin was appointed head of the American postal system by the Continental Congress on July 26, 1775, at a salary of $1,000 a year, and served until Nov. 7, 1776. To Franklin, in great measure, belongs the credit for the establishment of a sound U.S. postal system.

Following ratification of the constitution, George Washington on Sept. 26, 1789, appointed Samuel Osgood of Massachusetts to serve as postmaster general. At that time the postal service was a part of the treasury department and it remained so until 1829, when the postmaster general became a member of the president's cabinet. In 1789 there were only 75 post offices; by mid-20th century there were approximately 40,000 post offices. In 1790 there were only 1,875 mi. of post routes; by the 1950s there were more than 2,100,000 mi. of post routes.

The postal grant under the constitution gave to congress much wider powers, and a vast and important public service was established and developed. Post offices were established as rapidly as possible, speedy transportation of mails was provided and service was extended to distant parts of the country.

In colonial times the policy was to make a profit from the postal service. But after the post office was made a separate department of government this policy was changed; it was felt that the department should render good service to the public consistent with due regard for cost, but it was maintained that such service should not always be self-sustaining. Deficits, therefore, became common in the conduct of the department throughout the years. By mid-20th centurv revenues of the U.S. post-office department began to exceed $1,500,000,000 annually. Expenditures amounted to more than $2,100,000,000, resulting in gross operating deficits of accrual ranging from $500,000,000 to $727,000,000.

Early in 1953, when it had become evident that the annual postal deficit had attained proportions seriously affecting adversely the efforts to balance the federal budget, a program designed to effect rigid economy and increased efficiency was instituted. The gross operating deficit for the government's fiscal year ending June 30, 1955, was $362,673,654, representing a reduction of 47% from the all-time high deficit of approximately $727,000,000 in fiscal year 1952.

Post offices are established in every city, town and village in the United States for the receipt and delivery of mail matter and the performance of such special services appropriate to their size and importance. These offices, each with a postmaster, are of four classes. Postmasters of the first three classes are appointed by the president with the advice and consent of the senate and those of the fourth class by the postmaster general. On Jan. 1, 1956 there were 8,623 first-class, 6,625 second-class, 13,113 third-class and 14,502 fourth-class postmasters.

One of the first major advances in the postal service was the use of adhesive postage stamps for prepayment of postage on mail matter. Legislation was enacted on March 3, 1847, authorizing the postmaster general to issue stamps, and they were first placed on sale in New York city on July 1, 1847. Until that time the rate of postage for a letter weighing less than one ounce and composed of a single sheet of paper for a distance not exceeding 30 mi. was six cents. A maximum rate of 25 cents was charged for more than 400 mi.

B. TRANSPORTATION

The earliest methods of transportation were by horseback riders, stagecoaches and steamboats. The opening of the west and the movement of settlers to new lands broadened the scope of the postal service, and in the following years services were inaugurated which became an integral part of the postal establishment. The advent of railroads in 1834 marked the beginning of a vast change in mail transportation. By the mid-1950s mails were carried over 120,000 mi. of railroads.

With the discovery of gold in California in Jan. 1848 and the rush of thousands westward, the postal service kept pace by sending mail overland to Monterey, Calif., by way of Fort Leavenworth, Kan., and Santa Fe, N.M.; the first overland mail arrived in Los Angeles in May 1848. The pony express, a private enterprise, was inaugurated between St. Joseph, Mo., and Sacramento, Calif., on April 3, 1860, to give faster mail transportation to and from the Pacific coast. The first mail took 10½ days and 75 ponies were used: the fastest time made was 7 days 17 hours to deliver the inaugural address of Pres. Abraham Lincoln in 1861. The company charged $5 for each one-half ounce at the beginning of the pony express, but later reduced the rate to $1. Service was discontinued in Oct. 1861. "Buffalo Bill" Cody was one of the early pony express riders.

C. EXPANSION OF SERVICES

Following adoption of adhesive postage stamps for prepayment of postage on mail matter, the next new service to be adopted by the post office mas the registry system, established in 1855 to afford greater security in sending money and valuables through the mails.

The system was applied to first, second and third classes of mail matter and extended to foreign as well as domestic mails; domestic third- and fourth-class matter could also be insured. This insurance service was established on Jan. 1, 1913. Domestic third- and fourth-class matter and sealed domestic mail matter of any class bearing postage at the first-class rate could be sent collect-on-delivery (service inaugurated on July 1, 1913) on the payment of a special fee.

In 1858 street letter boxes were introduced so that postal patrons would not have to call at post offices to mail their letters. In 1863 free delivery of mail was inaugurated in 49 cities, with 440 carriers so employed the first year. By 1956 there were more than 5,000 communities throughout the country enjoying this service, with 91,427 carriers. Village delivery service was established at certain second- and third-class offices in 1912 and was developed rapidly until most such services were consolidated with city services. Rural free delivery, generally regarded as one of the most far-reaching developments in the mail service, was inaugurated Oct. 1, 1896. when five routes were placed in operation in West Virginia. During the first week patrons on the routes received 214 letters, 290 papers, 33 postal cards and 2 packages. By 1956 there were more than 32.000 routes. 35,282,118 individuals and rural letter carriers were travelling more than 1,540,000 mi. daily.

Until 1862 all mail carried on trains was distributed in post offices; in that year the postmaster of St. Joseph, Mo , tried out a method of sorting and distributing mail on a moving train between Hannibal and St. Joseph, in an attempt to avoid delays in mail departures for the west. The experiment was successful, and on Aug. 28, 1864. the first officially sponsored test of a railway post-office car was made between Chicago, Ill., and Clinton, Ia. On Dec. 22 of that year the post-office department appointed a deputy in charge of railway post offices and railway mails. This marked the beginning of the railway mail service.

There had long been a demand for means of sending funds safely through the mails, and in 1864 the money order system was placed in operation in 139 post offices, mainly to accommodate soldiers who were desirous of sending money to their homes. Money order service was extended to foreign countries in 1867.

Postal notes, which were placed on sale for the first time at post offices throughout the country on Feb. 1, 1945, as an experiment as to whether card money orders would be feasible, were withdrawn from sale on March 31, 1951. It was found that the method of bookkeeping that had been employed to keep track of postal notes received and sold at post offices was too complicated to make their continuance desirable.

Under an order issued by the post-office department money orders could be cashed at any post office throughout the country instead of the initiating office. This resulted in greater convenience to those sending and receiving money orders in the transaction of their business.

Postal cards were first used in 1873. In 1885, to accommodate persons who wanted prompt delivery of mail upon receipt at the post office, the special-delivery service was established. One million of these transactions were handled the first year.

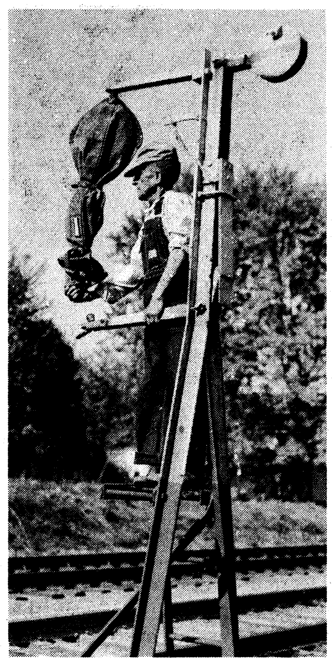
The postal savings system was established in 1911 as a convenient and safe depository for the accumulation of savings and to encourage thrift. Originally the maximum that could be placed in a postal savings account was $500; at mid-20th century the maximum was $2,500. Postal savings depositors in 1955 numbered about 2,700,000, with deposits of more than $2,000,000,000 and accrued interest of more than $95,000,000. Postal savings certificates were on sale at 7,775 depositories, including about 1,000 branches and stations, and savings stamps were on sale at all post offices and practically all branches and stations.

Parcel post, one of the most widely used services of the postal establishment, was inaugurated in 1913 and resulted in a greatly increased exchange of farm products and goods between the rural and urban areas. By 1956 the post-office department was handling approximately 972,928,000 parcels annually. Other categories of fourth-class mail boosted the total for this year to about 1,173,000,000 items.

D. AIR MAIL

The aeroplane, since the days of its humble beginning at Kitty Hawk, N.C., in 1903, when the Wright brothers flew the first heavier-than-air machine, was integrated into the transportation scheme of the United States postal system in ever-increasing measure. Air mail became commonplace—an essential link in communications and a vital part of the economy. Established on May 15, 1918, in co-operation with the war department, which furnished the planes and the pilots, the mails were first flown between Washington, D.C., and New York city, a distance of 216 mi. Great interest was aroused, and Pres. Woodrow Wilson left the White House to witness the departure of the first mail plane from the nation's capital.

On May 15, 1919, service was established between Cleveland, O., and Chicago, with a stop at Bryan, O., the first step in what later became the initial transcontinental route linking New York city and San Francisco, Calif. By May 15, 1920, it was possible to send a letter by air from New York city to San Francisco. The first transcontinental night flight started from San Francisco on Feb. 22, 1921, and ended at Hazelhurst field on Long Island, N.Y., 33 hr. 21 min. later. By July 1924 regular 24-hr. transcontinental air mail was in operation. Shortly after the completion of the coast-to-coast air route, the postal service awarded its first contract for the carriage of mails to a foreign country. The route ran between Seattle, Wash., and Victoria, B.C., a distance of 74 mi., and the service was inaugurated on Oct. 15, 1920, although it was not until 1927 that regular foreign air-mail service was in operation. In 1935 another milestone in overseas air transport was marked with the inauguration of transpacific air-mail service, from San Francisco to the Philippine Islands by way of Hawaii, Midway, Wake and Guam. This route was extended to Hong Kong on April 21, 1937, and to Singapore on May 3, 1941. Transatlantic air-mail service was inaugurated on May 20, 1939, from New York city via Bermuda and Portugal to Marseilles, Fr. Another route between New York city and Great Britain by way of Canada and Newfoundland began operation on June 24, 1941. Direct air service to Africa was made possible by the establishment of a route from Miami, Fla., to the Belgian Congo. After World War II there was a tremendous increase in foreign air transport, and direct air-mail service to every continent was afforded by United States carriers.

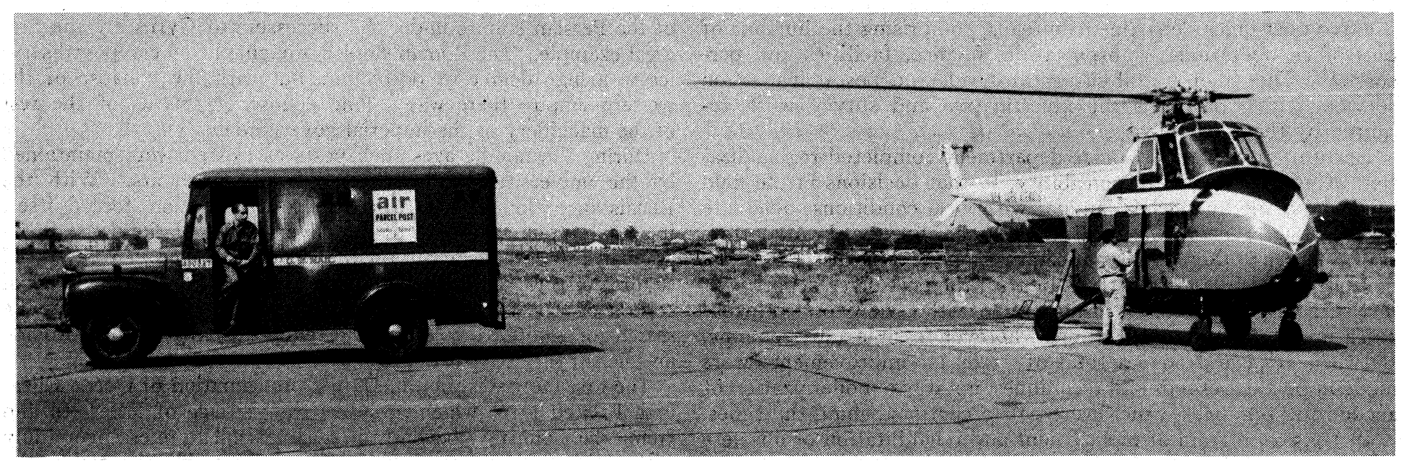


BY COURTESY OF U.S. POST OFFICE DEPARTMENT

MAILBAG FOR RAILWAY PICKUP THE MAIL CAR OF THE TRAIN IS EQUIPPED WITH A CATCHER ARM, A DEVICE THAT PICKS UP THE MAIL POUCH AS THE TRAIN SPEEDS THROUGH SMALL TOWNS

To increase the use of air-mail routes, overseas postage rates to foreign countries were materially reduced. With the exception of Mexico and Canada, where a six-cent-an-ounce rate was in effect, air mail in 1956 could be sent to all countries in the western hemisphere for ten cents a one-half ounce. To Europe and countries surrounding the Mediterranean the rate was 15 cents per one-half ounce, and to all other countries a rate of 25 cents per one-half ounce was in effect. On April 29, 1947, the ten-cent air letter sheet, mailable to any country in the world, was made available to postal patrons by the post-office department as a convenient, economical means of sending communications to foreign lands.

Large metropolitan areas continued to present a problem in dispatching mail to and from the airport. In numerous instances the time saved in sending mail long distances by air was



BY COURTESY OF U.S. POST OFFICE DEPARTMENT

HELICOPTERS PROVIDE FAST SHUTTLE SERVICE OF AIR MAIL FROM AIRPORTS TO METROPOLITAN AND SUBURBAN AREAS

lost by the time consumed in surface transportation. It was thought that the helicopter, because of its ability to land in a small area, on the ground or rooftop, might prove the solution to the problem, and exhaustive tests of the carriage of mail by helicopter were conducted in the Los Angeles area in July 1946. Further tests were made at Chicago in Oct. 1946 and at New York city in Feb. 1947. As a result, the world's first experimental helicopter air-mail service was inaugurated in the Los Angeles, Calif., area on Oct. 1, 1947, over a route linking communities to the north directly with the airport. Shuttle service between the airport and the Los Angeles terminal annex post office was instituted the same day. The route was expanded until by 1956 it served approximately 50 cities and towns in the Los Angeles metropolitan area. Similar service was inaugurated in the Chicago area on Aug. 20, 1949 and in the New York area in Oct. 1952.

International air parcel-post service was inaugurated March 15, 1948. between the United States and 21 countries in Europe and the North Atlantic area. Service to South America was instituted on Sept. 4, 1948, and to the Pacific area on Sept. 11, 1948. Air parcel-post service became available to more than 60 countries throughout the world. Hundreds of planes flown by United States carriers at the end of 1955 were operating over 258,980 mi. of foreign routes, carrying air mail to every corner of the globe and transporting in a matter of hours mail that less than 15 years before took weeks to deliver.

Domestic air parcel-post service to the United States and its territories and possessions was begun Sept. 1, 1948, including all mail carried by air weighing more than 8 oz. and not more than 70 lb. Zone rates varied from 60 cents to 80 cents for the first pound, and from 48 cents to 65 cents for additional pounds, according to the distance flown.

Late in 1953 the post-office department initiated the experimental carrying of regular 3-cents letter mail by air on a space available basis, between New York city and Chicago and Washington. D.C. In Feb. 1954, this experiment was broadened to include Jacksonville, Tampa and Miami, Fla. By 1956 this experimental service had been further expanded to provide such mail transportation between all major cities of the Pacific coast.

E. OTHER DEVELOPMENTS

In 1943 the postal zoning system was placed in operation in many of the larger post offices. At present the zoning system is operative in 106 cities of the U.S. This method of addressing mail had been in use in other countries, and it was found that it permitted faster distribution and sorting of the mail, especially by less experienced personnel, and particularly during the Christmas season when large numbers of temporary clerks were employed at the larger post offices throughout the country.

As early as 1930, officials of the post-office department, anticipating the continuing withdrawal of trains and foreseeing the need of providing an effective substitute for railway post-office service, prevailed upon congress for the necessary legislation to establish highway post offices throughout the country. Operated on the same basis as the railway mail service, the mails on these highway post offices are transported in large bus-type vehicles and equipped with all facilities for sorting, handling and dispatch of mail that are found in railway postal cars. The first route, established Feb. 10, 1941, was between Washington, D.C., and Harrisonburg, Va. By 1956 there were 172 highway post offices. The system proved satisfactory in every respect and justified its continued existence and growth.

F. MAIL MATTER

The act of 1792, first after the adoption of the constitution, recognized letters, packets and newspapers as mail matter. Magazines and pamphlets were recognized in 1799 and unbound journals of the several states in 1825. Lithographed circulars, handbills or advertisements and every other kind or description of printed or other matter were recognized as mailable in 1845. In 1851 bound books were made mailable, with an early weight limit of four pounds. In 1861 maps, engravings, photographic prints, photographic paper, letter envelopes, cards, blanks, seeds and cuttings were made mailable and the weight limit was fixed at four pounds. The act of 1863 excepted books circulated by order of congress from the weight limit.

Mail matter was classified in 1863 and again in 1872 into three classes; in 1879 it was reclassified into four classes as follows: first class, written matter; second class, periodical publications; third class, miscellaneous printed matter; and fourth class, merchandise and matter not included in the other classes and not in form or nature likely to injure the contents of the mailbag or harm those engaged in the postal service, and not exceeding four pounds in weight for each package.

By the Parcel Post act of Aug. 24, 1912, the scope of fourth-class matter was enlarged. On third-class mail matter circulars and other miscellaneous printed matter and merchandise weighing not more than eight ounces were admitted to the mails. On fourth-class mail matter the limit of weight was increased to 70 lb., with the limit of size not more than 100 in. in length and girth combined, except at first-class post offices, where the limitations later were set at 72 in. and from 20 to 40 lbs., the latter depending upon the zone to which the parcel-post matter is shipped.

Congress vested in the post-office department a monopoly in the conveyance of letters, but did not extend this monopoly to any other class of mail matter.

G. ADMINISTRATION AND OPERATIONS

1. Staff.—The post-office department is administered by the postmaster general, who is also a member of the president's cabinet. He is assisted by a deputy postmaster general, five assistant postmasters general and a chief postal inspector.

The deputy postmaster general executes and performs by delegation all powers, functions and duties conferred by law upon the postmaster general. The five assistant postmasters general head the five post-office department bureaus, comprising the bureaus of post-office operations. transportation, finance, facilities and personnel. The chief postal inspector heads the postal inspection service, which performs the investigative and survey work required by the department.

Early in 1956 the post-office department completed regionalization of administrative responsibility, so that decisions in the field might be made by officials familiar with local conditions; adequate over-all supervision was still maintained by the headquarters staff. By 1956 there were 15 postal regions and 91 district offices.

2. Postal Improvements. — In 1953 the post-office department instituted a program of experimentation with a view toward mechanization of post-office operations wherever feasible and economic. Between 1953 and 1956 a total of 73 major improvements were made in postal methods and techniques, notably a modernization of accounting practices, which were half a century behind the times.

In 19j5 a program of replacement and rehabilitation of obsolete and deteriorated post-office buildings throughout the country was proposed by the postal administration. Dependent upon an increase in postal rates from prevailing 1932 levels, it was planned to spend $133,000,000 a year for five years to carry out the program.

It was intended to implement the program largely through the provisions of the Lease-Purchase act of 1954, enacted by the 83rd congress, and through the post-office department's commercial leasing program. The Lease-Purchase act provided for construction of post-office buildings by private enterprise, and the purchase of such buildings by the post-office department on the instalment plan.

3. National Association of Letter Carriers. — The National Association of Letter Carriers was organized at Milwaukee. Wis., in 1889. It affiliated with the American Federation of Labor on Sept. 20, 1917, and with the government employées council of the federation in 1945. In 19jo it affiliated with the postal telegraph and telephone international. Its membership in 1956 was slightly in excess of 100,000, with 4,200 branches in cities throughout the Cnited States. Qualification for membership in the association is that the applicant must be a city, village or rúral letter carrier on a classified civil service register.

The association maintains its own sick and accident insurance and its own life insurance headquarters in Washington, D.C.

4. Dead-Letter **Office.**—Letters or parcels which cannot be delivered because of defect of address or other cause are sent to the 59 offices of dead letters and 15 offices of dead parcel post. They are carefully examined on both front and back for the name and address of the sender; if these are found, they are returned to the sender. If the sender's address. is lacking, they are kept for a period, after which dead letters are destroyed while dead parcels are sold at auction. During 1955, it was impossible to deliver 20,622,644 letters. of ahich 2,293,412 were returned to the senders. Letters containing valuables enclosed numbered 82.165, of which 71,688 contained money amounting to $231,654. There were also 574,510 unclaimed parcels and articles found loose in the mails; 123,093 aere returned to the senders. The remaining 451,417 parcels were sold at public auction and $269,915 was realized.

5. Relationship With International Postal Service. — In 1844 congress enacted legislation authorizing the postmaster general to enter into formal agreements with other countries for the exchange of mails, and the first agreement was concluded in 1847 uith the Hanseatic republic of Bremen. This was followed in 1848 by an agreement with Great Britain. Another postal union known as the Postal Union of the Americas and Spain was formed by the republics of Sorth, Central and South America, Canada and Spain. The Universal Postal union was organized in 1874, with the U.S. as a charter member. (I. GG.; X.)

II. GREAT BRITAIN

A. HISTORY

The history of postal services goes back to the early days of the great empires of the east, when the permanent maintenance of control over a wide area was seen to depend on the organization and maintenance of rapid and frequent communication. The posts of the Persian empire under the successors of Cyrus are the first great example. The Roman empire brought the official postal service to a high degree of perfection, but with the collapse of the western empire there was a long eclipse of this as of the rest of the machinery of the imperial government.

During the middle ages such posts as existed were maintained by the universities or by the guilds of merchants. With the Renaissance the need for private communication forced itself inevitably upon the notice of the governments of the day. In its gradual growth and expansion the policy followed can be traced to three distinct motives. These are the desire to ensure an official control or censorship, mainly of international correspondence; the search for additional sources of revenue; and the wish to provide an efficient service.

The first motive is prominent in a proclamation of Queen Elizabeth I dated 1591, which prohibits the carriage of letters to and from "the Countreys beyond the seas" except by messengers duly authorized by the master of the posts. This was directed at the private posts maintained by the foreign merchants in London and seems to have been effective at the moment in bringing them to an end. In 1609 James I extended the prohibition to the inland as well as the foreign post, but in this case the motive may have been the protection of the postmaster general's revenue. The importance of state control emerged again during the protectorate, and in Oliver Cromwell's Post Office act of 1657 stress is laid on the importance of a centralized post office as a means not only of promoting trade but of discovering and preventing "many dangerous and wicked designs which have been and are daily contrived against the peace and welfare of this Commonwealth, the intelligence whereof cannot well be communicated but by letter of escript." Postal censorship, long discontinued, was revived for both World Wars I and II.

The growth in knowledge and prosperity which marked the 17th century soon led to deep dissatisfaction with the limited and somewhat inefficient services which prevailed under Elizabeth I and James I, and the reign of Charles I saw the first of the great postal reformers in the person of Thomas Witherings. Witherings began his career as "postmaster of England for foreign parts" and carried out sweeping reforms of the foreign post. In 1635 he nas authorized to bring into operation a reorganization of the inland posts. which he proposed to make self-supporting, instead of being a charge to the crown, by the simple method of making them efficient and cheap. Witherings' scheme consisted in the organization of posts travelling night and day on each of the great post roads and covering a minimum distance of 120 mi. a day, with branch posts working to and from the post towns on the way. A letter could thus be sent to Edinburgh and a reply received in six days—an enormous improvement on anything previously attempted. A regular tarifi of rates was established, based on the "single letter"; *i.e.,* one sheet of paper. This method of charging and the zone system of postage rates remained as the underlying principles of the postal service until the reforms of Rowland Hill.

Witherings' rates on the single letter were as follows: less than 80 mi.. *2d.*; 80 to 140 mi. *4d.*; more than 140 mi., *6d.*; on the borders and in Scotland. 8d.; in Ireland, *9d.*

For letters carried on the branch posts an additional *2d.* was charged. In 16j3 the government decided, for revenue purposes, to let the posts out to farm. The successful tenderer paid £10.000 a year, and the system was continued under the Restoration until 1667. The revenue of the post office, however, was not considered simply as a contribution to the general expenses of government. In 1663 it was settled on the duke of Tork and his male heirs, and somewhat later was charged with a number of pensions. which in 1713 amounted to £22,120, or one-third the total net revenue. The last of these pensions, that payable to the duke of Grafton, was continued until 1856, when it was commuted for £91,000.

1. London Penny Post, 1680.—In 1653 Louis XIV had authorized the establishment of a local post in Paris at a charge of one sou. Profiting no doubt by this example, a London merchant, William Dockwra. brought into existence in 1680 the London penny post. **A** rate of *1d.,* to be prepaid, was charged on all packets up to one pound in weight, the packets being insured up to £10. Several hundred receiving offices were opened, from which an hourly collection was made, the letters being brought into six central offices, where they were sorted, date stamped and sent out for delivery. There were 4 to 8 deliveries a day in the greater part of London and 10 or 12 in the business centres. The area covered extended from Hackney to Lambeth and from Blackwall to Westminster, and there was also a daily delivery, for which an additional 1*d.* was charged, to places 10 or 15 mi. from London.

For some time Dockwra struggled with serious financial difficulties, but no sooner had the penny post begun to show a profit than the duke of York, on whom the post-office revenues were settled, asserted his monopoly. Dockwra was condemned to pay damages and his undertaking was incorporated in the general post office.

2. First Postmaster General.—The act of 1657 was the first comprehensive attempt to regulate the postal service by statute. It established a government monopoly, provided for the post of postmaster general, regulated the treatment of letters brought by private ship and prescribed the rates of postage, both inland and foreign. The act was renewed with practically no alteration immediately after the Restoration. The inland rates were somewhat lower than those charged by Witherings, the maximum rate being 6*d.* for a single letter to or from Ireland.

Another Post Office act was passed in 1711, uniting the post offices of England and Scotland, which had been separated in 1695; regulating the postal service in New York, the West Indies and the other American colonies; prohibiting post-office officials from taking part in politics; and increasing substantially the rates of postage in order to provide for the expenses of the war with France.

The development of the posts since the reforms of Witherings had now raised a difficult administrative problem; viz., that of the crossposts, or letters exchanged between one town and another without passing through London. At this juncture another reformer appeared in the person of Ralph Allen, postmaster of Bath. Allen. who had been in the postal service since his boyhood, was convinced that with proper management the crossposts could be turned into a source of revenue. In 1719 he offered to farm them for £6,000 a year, or 50% more than the net receipts at that time, and in 1721 this offer was accepted for a term of seven years. Allen's farm was successful and the contract was renewed, at a constantly increasing rent, until his death in 1769. The net revenue of the post office increased from £96,000 in 1724 to £165,000 in 1769.

The later years of the 18th century were marked by a great development of the main roads and a consequent improvement in speed of communication. Regular stagecoach services began to be established. The establishment of the mail coach service mas the work of John Palmer of Bath. The coaches were all to leave London at the same time—8 P.M.—and to return together as far as possible. The security of the mails was to be provided for by armed guards.

3. First Mail Coach, 1784.—Palmer succeeded in bringing this project under the personal notice of William Pitt, who saw its merits and ordered its adoption. The first mail coach was established between London and Bath in 1784, and within two years coaches were running to Norwich. Nottingham, Liverpool, Manchester. Leeds, Milford Haven, Holyhead, Exeter and other places. By 1797 there were 42 mail coach routes in operation. Examples of times taken are: London to Holyhead 27 hours, to Edinburgh 43 hours, to Falmouth 29 hours. The development of the post was hampered by the necessity of obtaining revenue to finance the war with France, and the rates of postage were periodically increased until in 1812 they attained the highest point they had ever reached, and at which they remained until the reforms of Rowland Hill.

It is surprising that these rates were retained for 25 years after Waterloo, and when Rowland Hill published his pamphlet on postage in 1836 he had behind him a substantial volume of public discontent. Hill argued that the postal administration was conducted on principles which were in effect an obstacle to the development of postal business. The principal features of the scheme put forward were the aboiition of the method of charging postage on the basis of distance and the number of sheets, and substitution of rates based simply on weight; the prepayment of letters by postage stamps; and the adoption of a uniform minimum rate of 1*d.*

4. **Rowland** Hill's Success, 1840.—It was only after four years of agitation and parliamentary inquiry that penny postage was finally established in 1840. This was the most signal service Great Britain rendered to the cause of postal progress, and from the point of view of developing social relations and business communications it was an unqualified success; it established a standard to which it became the ambition of the rest of the world to attain, This success, however, had to be paid for in another direction. Cheap postage rates were not in themselves the gold mine that certain of their enthusiastic supporters imagined. It is significant to note that the post-office revenue, which in 1839 was more than £1,600,000, dropped to £500,000 in the following year. It was not until 35 years after the introduction of Rowland Hill's reform that the revenue was again as much as it had been in 1839.

For several years after the introduction of penny postage the post office abstained from introducing more reforms and devoted itself to developing its existing services. The effect of the new rate on the volume of correspondence was immediate and continuous. In 1840 the number of letters posted was 169,000,000, or more than double that posted in the previous year. In ten years it had almost quadrupled, and by 1870 had reached the total of nearly 880,000,000.

The initial weight of one-half ounce for a letter adopted by Rowland Hill remained unchanged for more than 30 years; it was raised in 1871 to one ounce, at which it remained until the Jubilee reform of 1897, when the weight carried for 1*d.* was raised to four ounces. In 1897 the postage on all weights above the initial 1*d.* was fixed at ½*d.* per two ounces.

World War I, among its other retrogressive results, brought about the abolition of penny postage 78 years after its first establishment. From 1918, when the basic rate was 1½*d.*, there mere various changes up and down, until it was 2½*d.* for the first two ounces and 1½*d.* for each additional two ounces.

Increases in postal (and telecommunication) charges were introduced from Oct. 1957. The letter postage charges were set at 3*d.* for the first ounce, 1½*d.* for the next, and 1½*d.* for each additional two ounces.

5. Newspapers.—The newspaper post had a varied and anomalous history. In 1840 newspapers were by statute carried free of postage. This, however, was not equivalent to the free postage which has been given on a more or less extended scale in other countries, as from the time of Queen Anne all newspapers had contributed to the revenue by the stamp duty which was levied on every copy. This state of things continued until 1855 when the duty was made optional, the privilege of free postage being continued to such newspapers and even to such periodicals as chose to pay it. Unstamped papers were forwarded by book post (see below). In 1870 the position was altered by act of parliament, which established a rate of ½*d.* for each newspaper irrespective of weight, the privilege being confined to papers published at intervals of not more than seven days and complying with certain specified conditions. The principle of a flat rate irrespective of weight was abandoned in 1915, when the rate was increased. Later alterations brought the rate (from Oct. 1957) to 2½*d.* per copy for the first six ounces and 1½*d.* per copy for each additional six ounces, the maximum being two pounds.

6. Book (Now Printed Paper) Post.—The first special rate of postage introduced after 1840 was the book post, instituted in 1848. This was intended to benefit education and literature and was fixed at 6*d.* a pound. Various reductions were made in the scale until in 1870 it was reduced to ½*d.* per two ounces. From 1915 various changes took place; from Oct. 1957 the rate was 2*d.* for the first two ounces, 2*d.* for the next two and 1*d.* for each additional two ounces. the maximum being two pounds. This post comprises practically all kinds of commercial documents wholly or partly printed, as well as books, magazines, etc.

7. Post Cards.—The next reform was not of British growth. The Austrian post office introduced the inland post card in 1869;

it won immediate success, and was adopted in England in 1870, the rate being fixed at $\frac{1}{2}d$. For many years only official post cards were allowed; the admission of private cards paid at the post-card rate, first allowed in 1894, encouraged that notable development, the picture post card. The rate for post cards was increased in 1918 and again later. From Oct. 1957 it was 23d.

8. Sample Post.—This was established in 1863 to allow a special rate to bona fide trade patterns and samples. The rate fixed at that time mas *3d.* for 4 ounces rising to 1s. 6d. per 24 ounces, this being the maximum weight permitted. After various reductions the rate in 1870 was $\frac{1}{2}d.$ per two ounces. Because of the rule that the sample post should be restricted to bona fide samples, it was always found in practice to be extremely difficult to work, and, at various times, it was abolished, only to be reinstituted at a later date. The service is still not very much used. The maximum weight was eight ounces and the charges from Oct. 1957 were *2d.* for the first two ounces, zd. for the next two and *1d.* for each additional two ounces.

9. Registration.—The system of granting compensation for the loss of a packet in the post was a feature of the original London penny post of 1680. A parliamentary commission in 1838 recommended a uniform system of registration at a charge of *2d.*, liability being accepted up to £5. The reform of postage rates, however, caused the postponement of the scheme and it was not until 1841 that a general registration system came into being, and then only in an attenuated form, a fee of 1s. being charged and no responsibility being accepted in the event of loss. The service was not attractive, and little traffic was obtaiped; but though the fee was reduced, it was not until 1878 that the principle of compensation was adopted. The amount was originally fixed at £2, but was gradually increased. In 1906 the present system was introduced. The minimum fee in the mid-1950s, 1s. od., in the inland service now covers compensation up to £10, and the maximum fee £400. The service is extensively used, nearly 130,000,000 registered letters and parcels being sent annually in the mid-1950s.

10. Business.—The growth of postings is of considerable interest as an indication of the expansion of trade, the spread of education and, of course, of the extension of postal facilities. Table I gives for each decade since the establishment of penny postage the total number of packets of all kinds sent by post and the number per head of the population in Great Britain.

TABLE I.—British Postal Statistics

Year	Number of postal packets of all kinds	Percentage of increase or decrease	Number per head of the population
1839 .	82,000,000	—	3.1
1840 .	169,000,000	+106	6.4
1850 .	327,000,000	+ 93.5	13.2
1860 .	646,000,000	+ 97.6	22.2
1870 .	877,000,000	+ 35.7	28.0
1880 .	1,662,000,000	+ 89.5	47.5
1890 .	2,620,000,000	+ 57.6	69.4
1900 .	3,723,000,000	+ 42.1	89.7
1910 .	5,281,000,000	+ 41.8	116.7
1920 .	5,716,000,000	+ 8.2	127.0
1930 .	6,959,000,000	+ 21.7	152.0
1940 .	6,579,000,000	− 5.5	137.0
1950 .	8,732,000,000	+ 32.7	163.7
1954–55 .	9,500,000,000	+ 8.8	186.3
1955–56 .	9,700,000,000	+ 2.1	190.0

B. RAILWAY MAIL SERVICE

1. Letter Mails.—The first regular railway service to be established was that between Manchester and Liverpool in 1830, and the first Conveyance of Mails act was passed in 1838. Under this act, the provisions of 'which still govern in essentials the relations between the post office and the railways, the postmaster general was given powers to call on the railway companies to convey his mails and guards in all trains. ordinary and special, and to provide if required the use of a whole car for the purpose of sorting letters. The only financial provision in the act was that the railway companies should receive "reasonable remuneration" for their services, any negotiations which could not be settled amicably being referred to arbitration.

Even at this early stage it was seen that the value of the railways lay not only in their superior speed but in the facilities they afforded for doing in a swiftly moving railway car the work of sorting letters which would otherwise fall on a stationary office, and so of securing a considerable advantage in time of delivery. The first travelling post office was established between Birmingham and Liverpool in 1838.

Later in the same year another travelling post office was established between London and Preston, leaving Euston station at 8:30 P.M. At mid-20th century it still left Euston at 8:30 P.M. but terminated at Aberdeen. The speeds on the earlier railways were comparatively slow. The journey from London to Birmingham occupied five and one-half hours, and from London to Manchester or Liverpool nine and one-half. These times were. however, less than half those occupied by the stagecoaches. The last coach was not withdrawn until 1847.

In spite of the great improvements which they offered in the mail service, however, the railways entailed a much heavier cost on the post office than their predecessors, and for several years after their establishment there were difficulties between the companies and the post office on the question of payment.

At the outset mails not carried in a travelling post office were dispatched by train in charge of a post-office guard. The system uorked satisfactorily enough for the small mails of the 1830s; but the great growth in the number of letters which followed the introduction of penny postage soon made this method of transmission inconvenient and unnecessarily costly, and in 1848 statutory powers were obtained under which the railway companies were obliged to convey mails by train in charge of their own guards, nhich remained the normal method of transmission for the great bulk of the mails sent by railway.

Far reaching as are the statutory powers of the postmaster general with regard to the railways, in practice they are never invoked, and the details of the postal service are settled by contracts negotiated with the railway authorities. An important requirement of the post office in the contract is the running of trains at times convenient to the mail service, which cannot be altered without the consent of the postmaster general. Great Britain is covered by an intricate network of mail trains providing complete and direct communication between the different divisions and between all parts of the country, the speed of which is equal to or, in some cases, better than that of the best passenger trains. On the west coast route to Scotland there is a special train devoted entirely to the post office, running nightly in each direction between London and Edinburgh, Glasgow and Aberdeen. This is the trunk main-line mail service of Great Britain, and the staff working in the train varies between 50 and 70 at different times on the run. A similar special train runs in each direction between London and Penzance. In all other cases the mail trains convey passengers as well as mails.

A special feature of the English mail-train service is what is known as the mailbag apparatus, a mechanical contrivance by which mailbags can be dispatched from and received in travelling post offices while the train is travelling at full speed.

2. Inland Air Mails.—The internal air services provided for passengers and freight are utilized for the conveyance of letter mails wherever this method of transport enables a worthwhile improvement in service to be made. No additional postage is payable for this air conveyance.

3. The Parcel Post.—An international parcel post was established at the Postal Union conference in Paris in 1880. The Post Office Parcels act of 1882 was passed, establishing an inland parcel service in Great Britain which came into operation in the following year. The maximum weight of parcels was fixed at seven pounds, with a scale of postage varying from 3d. to 1s., according to weight. No individual contracts were made with the separate railway companies, but the post office paid to the railway clearinghouse 55% of the postage received on all parcels conveyed by railway, the distribution of the sums thus received among the railway companies being undertaken by the clearinghouse. This arrangement enabled the post office to maintain the principle of a flat rate of postage for the whole country.

It soon became evident that for short distances it was possible to convey parcels by road at a lower cost than the payment to the railway companies provided under the act, and very shortly after the establishment of the parcel post parcel coaches were established by the post office. These road services took on a new development with the coming of the internal-combustion engine. The higher speed and greater capacity of the motor van made a large extension of the coach system practicable, and by the outbreak of World War I, parcels were being carried by road during the night between large towns up to a distance of 120 mi.

Following fresh negotiations with the railway companies, it was enacted by the Post Office Parcels act of 1922 that the percentage of the postage payable to the railway companies should be reduced from 55% to 40%, the post office for its part agreeing that the railway companies should be entitled to claim a revision of their remuneration if the number of parcels conveyed otherwise than by railway exceeded 10% of the total number transmitted by post. Under these arrangements many of the road services were terminated as being no longer remunerative. From Jan. 1. 1951, the arrangements between the railways and the post office were based on a contract between the parties which superseded the arrangements laid down in the Post Office Parcels acts.

Since the establishment of the service, the maximum weight has been raised from 7 lb. to 15 lb., and the postage rates have been varied from time to time. The rates from Oct. 1957 were 1*s*. 6*d*., 1*s*. 9*d*., 2s. od., 2*s*. 3*d*., 2s. 6*d*., 2*s*. 9*d*., 3s. od.. 3s. 3*d*. and 3*s*. 6*d*. for parcels not over 2 lb., 3 lb., 4 lb., 5 lb., 6 lb., 7 lb., 8 lb., 11 lb. and 15 lb. respectively.

C. MAIL PACKET SERVICE

The first regular government mail packet service was established by Queen Elizabeth I in 1598 between Holyhead and Dublin. At that period, however, foreign communications were of greater postal importance than those with Ireland, and when James I reaffirmed the post-office monopoly in the case of foreign letters and appointed a postmaster for foreign parts. it clearly became incumbent on the post office to provide a regular means of communication with foreign countries. Witherings. who subsequently reformed the inland post, began his career by establishing efficient and regular communication with France by means of hired boatmen engaged to carry the mail between Dover and Calais.

For the next 50 years the service appears to have been somewhat unsatisfactory and development slow; but in 1686 a regular service was established by government packet between Harwich and the Netherlands, which was followed in 1688 by a service from Falmouth to Corunna. Sp., and in 1703 by a weekly service from Falmouth to Lisbon, Port.

The growth of the British oversea possessions in the 18th century led to further developments. After an unsuccessful attempt at the beginning of the century, regular packets were put on from Falmouth to the West Indies in 1745; packets also ran to North America, and by the end of the 18th century they served a great part of the aorld. The packets themselves were small, being only 70 tons on the shorter services and on the ocean routes 150, vessels of the latter tonnage being, according to a report of 1788, considered fit to go to any part of the world.

The next important event in the history of the packets was the introduction of the steamship. Steamship communication with Ireland was established in 1816, and in 1821 a mail packet of 205 tons burden was put on this service, being followed in the next year by a steamship on the Dover–Calais route. It soon became evident, however, that mails could be carried more advantageously by private companies than by the government, and in 1831 the principle of inviting tenders for the mail service from private companies was introduced.

In the earlier part of this period the government definitely adopted the policy of subsidizing steamship companies in order to establish regular communication on routes where ordinary traffic would not have justified the requisite expenditure, and to ensure the provision of a better type of vessel than would otherwise have been forthcoming. The first contract was made uith Samuel Cunard in 1839 for a subsidy of £55,000 a year and was speedily followed by others. The subsidy policy, however, proved in practice costly, the expenditure having by 1853, when it became the subject of a parliamentary inquiry, reached the considerable sum of £853,000. After that time the principle of the subsidy gradually disappeared; its object had been fulfilled by the establishment of such far-reaching mail services as those of the Peninsular and Oriental company, the Royal Mail Steam Packet company and the Cunard White Star line.

The use of noncontract ships for providing the mail service was, in fact, a return to an earlier epoch in the history of the overseas mail service. The government packets in the 17th and 18th centuries were far from covering the whole field; for example, Africa and Asia were never touched by them, and for correspondence to and from a great part of the world the only means of transport was the private ship. The post office for a long period made only a feeble attempt to secure control of this means of communication. The measures taken were not effective, and as late as 1827 certain coffeehouses, which had customarily kept bags for the acceptance of overseas mail, were still collecting letters in defiance of the law. The general improvement in the postal service, and in particular the effective measures taken to establish regular mail services by private ships whenever such a course was advantageous, gradually abolished the incentive to forward letters by other means than by the post office.

D. AIR MAILS

The history of air mails in Great Britain begins in 1911, when to celebrate the coronation of King George V an air-mail service was run between Hendon and Windsor. Twenty-one trips were performed and a considerable number of picture post cards, etc., carried; but the service was irregular and did not hold out much promise of the development which came a few years later, resulting from the great progress made by aviation during World War I. After the Armistice, an experimental service between Folkestone and Cologne, Ger., set up for the benefit of the army of occupation, was followed in Nov. 1919 by a regular service between London and Paris, on uhich the air fee, originally fixed at the high rate of 2s. 6d. an ounce in addition to postage, was soon reduced to zd. an ounce. Other regular services to European countries followed (including an air parcel service between London and Paris in 1921); air-mail services spread further afield, the England-India service begun in March 1929 being the first stage in extending air-mail services from the United Kingdom to the commonwealth.

During the decade preceding 1939 the United Kingdom post office introduced the so-called "all-up" system, whereby first-class mail was sent by air at normal rates of postage whenever it would thereby secure earlier delivery, in the service to many European countries. An all-up system at a postage rate of $1\frac{1}{2}$*d*. per one-half ounce was also introduced, under the Empire Air Mail scheme, on the British Commonwealth air routes to the Union of South Africa and Australia.

The outbreak of World War II led to the suspension of many air-mail services and the reintroduction of surcharge services on other routes. Aircraft capacity mas at a premium and, to meet the urgent needs of forces personnel in particular, an airgraph service, both from and to the United Kingdom. was introduced in 1941. A lightweight air letter service from forces abroad to the United Kingdom was also introduced in 1941, but did not commence in the outward direction until Dec. 1942. In the airgraph service the messages were written on special forms which were handed in at post offices. The form was photographed on a strip of film 100 ft. long by 16 mm. wide. The film strip, containing 1,700 messages, when enclosed in a cardboard container weighed only $5\frac{1}{2}$ oz., whereas a similar number of letters by ordinary post would have weighed about 50 lb. On receipt at their destination by air, prints prepared from the photographed messages were delivered to the addressees in the ordinary way. More than 350,000,000 airgraph messages were conveyed during the four years in which the service operated.

With the termination of the war. steps were taken to reintroduce air-mail services throughout the world, and it was made possible not only for first-class mail but for second-class mail (at a reduced rate of postage) to be sent from the United Kingdom to practically anywhere. The air letter form was retained as a specially cheap form of air-mail service and this type of communication was internationally recognized by the Universal Postal union in 1952 under the name of "Aerogramme." The all-up service to European destinations was reintroduced and extended, but the high cost of air transport in the postwar period precluded its introduction on the intercontinental routes. Air parcel services were introduced to most destinations.

E. MISCELLANEOUS SERVICES

In addition to the general postal service placed at the disposal of the public, a certain number of special facilities may be obtained by those who wish to have a more rapid or convenient method of delivery. The most important is the express delivery, which was established in 1891. There are several varieties of express delivery, the most useful of which perhaps is that by which a letter or packet may. at any time at which messengers are on duty, be dispatched by special messenger to its destination on payment of a small mileage fee. Living animals are accepted for express delivery if a suitable receptacle or lead is supplied and provided the sender takes precautions to safeguard the postal official from injury. A further service provides for the delivery, immediately on arrival, of letters or parcels received by the ordinary mail. at the request of the sender; and the same facility is given at the request of an addressee who is expecting an important letter.

When a quicker transmission is desired than that afforded by ordinary mail, letters can be accepted at many post offices for conveyance by messenger to the railway station for dispatch by the next available train. A messenger mill meet the train and deliver the packet to the addressee. For certain addresses in Great Britain this arrangement applies to inland air services.

When a regular early delivery of correspondence is desired, any firm or person may rent a private box at the post office, from which he or his messenger may obtain his letters and parcels on application. If, again, his postings are on so considerable a scale that the application of postage stamps becomes inconvenient and expensive, he may on certain conditions arrange to pay the postage in cash; large users of the post may have their correspondence or parcels collected from their premises by the post office. Another method of avoiding the use of postage stamps is the employment of postal franking machines, which are licensed by the post office. These machines impress the correspondence with a red franking stamp which is accepted as the equivalent of a postage stamp. Each machine is provided with a meter, which is set from time to time at the post office, postage being prepaid in cash on the number of impressions which the meter is set to register.

F. THE POST OFFICE AS BANKER

1. Savings Bank. — The British Post Office Savings bank was set up in 1861, as a result of legislation introduced by William Ewart Gladstone. The object was to encourage thrift among the lower-income classes, and limits were therefore set to the amount of money which could be deposited. The maximum amount which may be deposited in one year by any individual is £joo and the maximum balance which may be held is £3,000. Interest is allowed on complete pounds at the rate of $2\frac{1}{2}\%$ and is added to the balance at the end of each calendar year. All accounting is centralized, but a depositor may pay in or withdraw money at any post office in the country at which savings bank business is transacted. There were about 20,000 of these offices in the mid-1950s. A withdrawal on demand up to £10 at a time may be made at any savings bank post office, but if more than one withdrawal exceeding £3 is made within a period of seven days the paying officer retains the book for examination at the chief office. To make larger withdrawals a notice has to be sent to headquarters and an authority to pay is issued to the office named by the depositor. Within certain limits withdrawals may be made by telegram. All deposits are handed over to the national debt commissioners. by whom they are invested for the Post Office Savings Bank fund. The post office draws on the fund to cover any excess of withdrawals over deposits, and the interest earned' *, the investments of the fund is set against the interest due to depositors and management expenses. The Post Office Savings bank has enjoyed increasing popularity through the years. The appeal for savings to help finance World War I gave it an additional impetus, but the accretion of business during World War II passed all records. In 1938 the number of active accounts was about 11,000,000 with a total balance of more than £500,000,000. By the end of 1956 the active accounts numbered more than 22,387,000 and the balance due was more than £1,687,000,000. After 1945 more than 6,500,000 accounts had been set up with initial credits of £370,000,000 in respect of war gratuities and postwar credits for personnel of the fighting and civil defense services but many of these accounts were short-lived.

2. Insurance and Annuity Business. — In 1864 the post office was authorized to set up an insurance and annuity business through the savings bank, but this business has never been of more than moderate dimensions. Insurance business was discontinued on Dec. 31, 1928.

3. Post-Office Stock Register. — A much more successful development was instituted in 1880 when facilities were given to depositors in the savings bank to purchase government stock up to a limit of £300. **A** simple method of purchase was devised at a low rate of commission, and dividends were credited to the purchaser's savings bank account. In 191j the link between the savings bank and the post-office stock system was loosened, and it was no longer necessary to be a savings bank depositor in order to hold stock through the post office, nor did dividends need be paid into a savings bank account. During World War I the machinery proved of great value to the government in making it possible for the small investor to purchase or subscribe to government stock. For many kinds of government stock there was a post-office as well as a Bank of England issue, and subscriptions could be made at most post offices. The most outstanding development of the post-office register occurred during World War II, when a special issue of defense bonds, restricted to the post-office register, was made. The bonds made an appeal to all classes; although initially a maximum limit of £1,000 was set to each holding. the peak holdings of the bonds reached a total of more than £1,000,000,000. The issue open to subscription from May 1, 1956, bore interest at $4\frac{1}{2}\%$ per annum and individual holdings were limited to £1,000. Including other stocks the total of investments on the post-office section of the post-office register at the end of 1956 was £798,740,000 and the number of stock- and bondholders was 2,226,000.

4. Savings Certificates. — A further simple and popular method of investment managed by the post office is the national savings certificate. Originally issued in 1916, it proved attractive to all classes during World War I as a means of helping the war finance. and at the end of 1918 the value of the certificates held had reached £207,000,000. During World War II the sale of certificates was phenomenal, and the value of the certificates held increased from £381,000,000 in 1938 to £1,883,000,000 at the end of 1956. These figures are exclusive of accrued interest. The number of holders was about 20,680,000.

The early certificates were based on a unit of £1, which was the value given to the certificate after it had been held for a number of years. The purchase price of the certificate varied from time to time according to the rate of growth and the number of years before the value reached £1. For the first issue of certificates the purchase price was 15*s*. 6d. and the value of £1 was reached in five years. The purchase price of the 10th issue, on sale from Aug. 1, 1956, was 15*s*. with an increase to £1 after seven years. Interest on the certificates is not paid separately but is included in the value when the certificate is repaid. Certificates are repayable at any time after a few days' notice. The accrued interest is free from income tax. Limits are imposed on the number of certificates which may be held by one individual.

5. Premium Savings Bonds. — Premium savings bonds, issued through the post office by the treasury, were put on sale on Nov. 1, 1956. They differ from other securities offered to the small saver in that instead of earning interest they have, after a qualifying period of six months, chances of winning cash prizes free of U.K. tax. Draws for prizes are held monthly and each unit bond gives the holder one chance in every draw for which it qualifies. A novel feature of the scheme was the method of drawing winning bond

numbers. These were generated electronically and entirely at random by E.R.K.1.E.—Electronic Random Number Indicator Equipment—which was built specially by the post office engineering department.

6. Savings Stamps.—Various aids have been introduced from time to time to encourage the saving of quite small sums (*e.g.*, home safes [until 1942] and slips to which postage stamps could be affixed), but the method of national savings stamps became the main as well as the most popular method. The stamps are issued in denominations of 6d. and 2s. 6d. The stamps can be used for the purchase of savings certificates, government stock and premium savings bonds, or for deposit in the savings bank, but they can also be cashed freely at post offices.

7. Savings Department.— The conduct of the savings bank, savings certificate and government stock and premium savings bond business of the post office is concentrated in the post-office savings department, which is thus responsible for accounts containing about £4,866,000,000 of the public's money. There are few, if any, families in the United Kingdom which do not have a share in these savings in some form or other.

8. Money Orders.—The original establishment of the money order service was a result of the desire of the postmasters general toward the end of the 18th century to prevent the theft of money carried in letters in the post. There was some doubt whether such a service could be established by the post office under its existing powers, so by a curious compromise certain officers of the post office were allowed in 1792 to set up a service on their own account, the cost of advertising it being borne by the postmaster general, who also allowed the relative advices to pass free of postage under the post-office frank. The money order service was taken over by the government in 1838. The rates of commission charged to the public have varied from time to time, and the maximum amount for which a single order may be issued increased until by 1950 the maximum for an inland order was £50. Notwithstanding the competition of the cheaper postal order, the money order still appeals because of the security afforded by the special feature of the service—the advice note which is sent to the office of payment and against which the order is checked before payment.

In 1955–56, 30,103,000 ordinary inland money orders were issued representing £255,260,000. The telegraph money order service came into operation in 1889 and is utilized to a considerable extent; in 1955–56, 1,347,000 inland orders were telegraphed to the total value of £13,909,000.

The overseas money order service came into being in 1856, when arrangements were made for an inward service to Britain from army post offices at Constantinople, Scutari and Balaclava, this plan being extended to Gibraltar and Malta the following year. The first two-way service was with Canada in 1859, and services with other colonies soon followed. In 1868 the first foreign money order service was started with Switzerland. The service was extended gradually to cover most parts of the world in which an inland money order service operated.' A telegraph money order service was started with Germany in 1898 and was subsequently extended to many other countries.

World Wars I and II brought considerable difficulty in maintaining a money order service with foreign countries. At the start of war in 1939 the control of foreign exchange was applied to the overseas money order service, and this control is still operated. The number of overseas orders received in the United Kingdom from overseas countries, including the Irish Republic, in 1955–56, in respect of all the overseas money order services was 1,645,000 representing £8,914,000, and the number of orders sent to overseas countries, including the Irish Republic, for all the money order services was 829,000 representing £7,836,000.

9. Postal Orders.—A reduction in 1871 of the commission charged on money orders under £1 was followed by an increased demand for the low-value orders, and by 1875 the service was being run at a loss. The comparatively high charges which would have been necessary to avoid this loss caused the post office to consider the possibility of introducing a new method of remittance for smaller amounts which would dispense with the advice, an expensive feature of the money order service. As a result the postal order (originally styled postal note) was introduced in 1881. These orders were for fixed denominations up to 21*s.* and from 1951 orders for £2, £3, £4 and £5 were added to the range. Odd amounts (excluding halfpence) can be made up by fixing postage stamps to the orders. They must be made payable to a particular person and preferably at a particular office and can be crossed for payment through a bank. The simplicity, cheapness and convenience of the postal order made it an immediate success. In the first two years the number grew from 4,500,000 to 33,000,000 and in 1955–56 the figure was 569,959,000, representing £204,159,000. Considerable use is made of this form of remittance in connection with football pools and newspaper competitions.

The convenience of the postal order soon led to a proposal to extend its use throughout the empire, and in 1903 all dominions, colonies and dependencies were invited to adhere to a scheme for making postal orders available for remittances to and from the United Kingdom, between one part of the empire and another and within the participating country. Most of the commonwealth, with the notable exceptions of Australia and Canada, operates this scheme, and in 1954–55 about 12,332,000 orders were issued overseas.

G. POST OFFICE AND SOCIAL SERVICES

One of the most striking developments of post-office activities in the 20th century was its assumption of functions which had no connection whatever with its primary purpose but which flowed from its possession of a widespread net ork of local offices having day-to-day financial dealings with the public. This development began many years ago in the use of the post office for the collection of local or national revenue by means of licence duties. For example, dog, gun and game licences, excise licences and motor vehicle licences (renewals) are obtainable from the post office, £11,331,000 being collected by this means in 1955–56.

This, however, was a comparatively small item of business and it was far exceeded by business connected with the social services established from time to time. When the Old Age Pension act of 1908 came into operation, the post office became the paying agent. This arrangement was extended to payments under the Widows', Orphans' and Old Age Contributory Pensions act of 1925 and under the National Insurance act which came into operation in 1948. Similarly, war pensions, separation allowances, national assistance allowances and family allowances are paid by the post office. In 1955–56, 633,666,000 orders for all kinds of pensions, allowances, etc. were paid to the total value of £853,159,000.

A considerable number of stamps are sold for other than postal purposes. Certain inland revenue duties may be paid by postage stamps (*e.g.*, receipt duty), but, in addition, the post office has long assisted the inland revenue authorities by selling such inland revenue and fee stamps as are in general use, as well as entertainment duty stamps. There was also a large sale of stamps for the various state insurance schemes culminating in the National Insurance act, 1946. The value of the insurance stamps sold in 1955–56 was £424,548,000.

Revenue is also collected by the sale of broadcast (sound and television) receiving licences. Records are maintained of the persons who hold such licences and steps taken to ensure that the licences are renewed after their validity has expired.

During 1955–56, 14,311,000 broadcast receiving licences (sound and television) were issued to the value of £25,743,000. The post office also issues amateur transmitting licences and other radio licences.

From April 1, 1956, arrangements between the post office and the treasury similar to those existing before World War II were introduced for a trial period of five years. Under these arrangements the post office provides in its commercial accounts for an annual contribution to the exchequer of £5,000,000 which broadly represents what the post office, but for its exemption, would have been paying in recent years by way of taxation. Any surplus then disclosed by the commercial accounts will be available to the post office as a revenue reserve to be used if necessary to offset any deficiency in other years.

H. BRITISH ARMY POSTAL SERVICE

The British army postal service dates back to the Napoleonic Wars. In 1792 a post-office official went to the Netherlands to organize a private communications service for the British troops there. Similar arrangements were made for the Crimea in 1854, but a military postal service as such first operated in the Egyptian campaign of 1882 when a company of the 24th Middlesex volunteer regiment (post-office rifles) undertook postal duties. Since the beginning of the 20th century at least a nucleus army postal service has existed on an army reserve basis. After 1914 it operated abroad continuously in larger or smaller numbers both in peace and war, and ran services for the air force as well as the army.

Modern British army postal technique began to emerge during the South African War, and it was naturally greatly developed during World War I when large-scale army postal services were needed for the first time. In 1918 the personnel both at home and overseas numbered nearly 6,000, of whom about one-third were women, some being sent to base offices in France for sorting work. Excluding peak traffic at Christmas time the maximum dispatches from home were about 12,000,000 letters and 1,000,000 parcels a week.

World War II with its various phases and events, extensive and rapid movements of large armies, the closing of the Mediterranean, the world-wide dispersal of British forces, etc., presented postal problems of an entirely new and complicated character. However, a far greater range of postal facilities was provided, largely of necessity, than in any previous war: surface letters and parcels, ordinary air letters. lightweight post cards, lightweight air letters, airgraphs and various types of telegrams. The service carries the bulk of official mail; it also provides remittance services and savings facilities and distributes newspapers. The overseas destinations where the army postal service distributed mail were more than 25 in number, and the maximum traffic amounted to about 17,000,000 letters, newspapers and parcels a week, although during Christmas pressure periods it was much greater. The staff abroad and in the United Kingdom numbered more than 7,000, of whom about 2,500 were women of the Auxiliary Territorial service who performed most of the sorting work at the home postal depot.

Liaison and co-operation with British Commonwealth and Allied military postal services necessarily grew to great dimensions by 1944. For the first time, army postal facilities were provided for the army and air force at home. This began soon after the evacuation from Dunkirk and later was greatly used for security purposes for troops who were detailed for the Normandy invasion-in 1944.

Toward the end of the war extensive air-mail services were provided. and in difficult areas such as Burma parachute dropping of mails was practised extensively.

The army postal service serves the army and the royal air force wherever they may be serving overseas. Conditions have varied; for example, in Korea wartime arrangements had to be made and in other areas internal security troubles have given rise to the need for exceptional measures.

I. POSTAL STAFF

In April. 1957, the staff of the British post office—postal, clerical, telegraph, telephone and engineering—numbered 347,000 including about 86,000 women, 85,000 industrial staff and 45,000 part-time staff (counted as halves). Between 3,500 and 4,000 of the United Kingdom staff of the nationalized company, Cable and Wireless Ltd.. were added to the staff in April 1950.

The chief administrative questions arising are recruitment. pay, training, welfare and other conditions of the staff. productivity and staff consultation. The bulk of the staff enjoys the usual civil service conditions of permanence of employment and pensionability. Clerical and professional staff generally belong to grades common to the civil service as a whole. Manipulative staff—postmen, telegraphists, telephonists and postal and telegraph officers—are recruited either by interview and selection or by competition; where recruitment is by selection, preference is given to ex-regular servicemen. The manipulative staff have opportunities of advancement both by competition and by promotion to higher rank, including clerical appointments. Pay and major conditions of service are settled generally by negotiations with the staff associations or, failing agreement, by awards of the civil service arbitration tribunal, subject to the overriding authority of parliament.

The day-to-day staff administration is eased as much as possible by the organization of the post office into seven functional headquarter departments, apart from administrative headquarters, and ten territorial regions, subordinate to which are about 466 head and district post offices and 57 telephone managers' areas, and by the utmost possible decentralization of authority to directors, regional directors, head and district postmasters and telephone managers.

British Postal Trade Unions.—The difficulties which trade unionism has met in outside employment were reflected in the history of the postal staff, and it was not until 1899, after two partial strikes, that the duke of Norfolk consented to receive representations from the Postmen's federation. Thereafter many associations were formed in the post office, indicating the variety of work and the consequent multiplicity of grades. In 1955 there were 27 separate associations officially recognized, with an aggregate membership of 306,911. The largest associations and their membership were in 1955 as shown in Table II.

TABLE 11.—Chief British Postal Trade Unions, 1955

Title	Membership
Union of Post Office Workers	161,481
Post Office Engineering union	61,591
Civil Service Clerical association (post-office section)	24,967
National Federation of Sub-Postmasters	18,806
Association of Post Office Controlling Officers	10,833
National Guild of Telephonists	11,292

In 1920 relations between the administration and the staff entered on a new phase with the establishment of Whitley councils. General questions common to the post office and the rest of the civil service are discussed on the national Whitley council, but the post office has its own headquarters departmental councils (working largely through smaller joint committees) to discuss general matters affecting the staff, and local committees in head post offices, etc., to discuss local matters. The Whitley machinery has on the whole worked smoothly and disagreements are comparatively rare. Whitleyism has in no way superseded the separate unions, which continue to act as independent negotiating bodies on matters such as wages.

In 1947 machinery for joint consultation on productivity was set up on the engineering side to discuss measures to increase output, and in 1949 similar but more elaborate machinery mas established for the nonengineering grades. The Trade Unions act of 1927 forced the post-office unions to sever their connection with the Trades Union congress, but, with the passing of the Trade Disputes and Trade Unions act of 1946, five of the unions mentioned above became affiliated with the T.U.C. The Union of Post Office Workers also became affiliated with the Labour party.

III. INTERNATIONAL POSTAL SERVICE

The importance of the international service is evident from the earliest days of post-office history, but the working of the service is somewhat obscure. In the 16th century a regular service seems to have been provided between London and Calais, which was the port on which foreign communications mainly centred. The outward letters seem to have been carried to their destination by English post-office messengers, while inward letters were brought by foreign messengers as far as Calais.

Witherings reorganized the foreign service, and shortly after his time (1670) a regular postal treaty was concluded between England and France. This was renewed in 1698 after the conclusion of the treaty of Ryswick. The treaty provided that the mail from London for Paris and from Paris for London was to leave twice a week. Between Dover and Calais the English post office provided the mail packets in both directions; the service beyond Calais was provided by France. Letters could be prepaid only to a limited number of destinations—Paris, Rouen or Lyons;

any charges for further transmission were collected from the addressee.

This treaty, soon interrupted by further hostilities, was again renewed in 1713. The new version is interesting as containing the germ of the international system of accounting for transit mails which lasted with but slight alteration until the latter part of the 19th century.

On letters for Italy, which could be franked to Turin, France was to be paid at the rate of 21 sols per single letter; on letters for Spain franked to Bayonne the payment was 19 sols; on letters for Turkey franked to Marseilles, 17 sols. Double letters were charged approximately twice, and letters weighing one ounce four times the single rate The accounting between the two offices was based on the sum of the amounts due on the separate letters, mail by mail. The principles adopted in the 17th century show little change in the 18th, and a treaty concluded with France in 1802 shows comparatively little variation from its predecessors of more than a century before.

As time went on the postal treaties required for the establishment of a gradually expanding foreign service became more and more numerous and complicated. The postage depended on the sums payable to the various post offices concerned in the transit of the letters, and these were often based on their own internal rates and units of weight. The result was an extraordinary variety of rates—often differing materially for the same destination according to the route employed—and a considerable variety in the weight covered by the initial postage rate. Moreover, prepayment was in some cases compulsory, in some cases optional; but compulsory prepayment covered conveyance only up to a certain point, all charges beyond that point being collected from the addressee. The unit of weight was in a large number of cases one-fourth ounce, any letter above that weight being charged pro rata. The lowest postage in force was that to France, which mas 4*d.* per one-fourth ounce. A letter from England to Belgrade, Yugos., via France, weighing one ounce. cost 5*s.;* a half-ounce letter to California via Panamá cost 4s. 8*d.*, in addition to a further charge on delivery. Even to Spain the postage was 2s. zd. per one-half ounce, plus a charge on delivery.

From the point of view of post-office management, the complexity of the service was, with the industrial development of the 19th century and the constant growth of correspondence, reaching a point at mhich the rapid and accurate handling of the mails became practically impossible Almost the only advance made over the procedure in force in the 17th century was that letters were weighed in bulk instead of singly. The example of a simple and uniform tariff had been set by the establishment of penny postage, but the principle which underlay Rowland Hill's scheme for obtaining uniformity (viz., that the cost of conveyance of a letter' represented only a small fraction of the total cost of its treatment) was far from being applicable to the conditions of the international post.

1. Formation of the Universal Postal Union.—The first step in the direction of reform was taken by the United States, which in 1862 suggested a conference for the purpose of considering the improvement and simplification of international postal relations. This met in Paris in 1863 and adopted a code of 31 articles, intended to serve as the basis of international conventions. Further progress was delayed first by the American Civil War and then by the Franco-German War.

In the meantime. however, another great postal reformer, Heinrich von Stephan of the North German Postal confederation, had prepared a project for a universal postal union. based in part on the conclusions of the conference and in part on the experience of Germany, which had several years before formed a postal union including Prussia. Austria and all the other German states, nearly 20 in number. The Swiss government. at the instance of Germany, summoned a conference to meet at Berne to consider the proposal to form a general postal union.

The Congress of Berne in Sept. 1874 was attended by the representatives of 22 states, including the whole of Europe, the United States and Egypt. The result of the congress was the signature of the first International Postal convention, which remained from *1875*, with comparatively little modification, the foundation of the international postal service.

The fundamental principle of the union is contained in a striking article which lays down that for the purposes of postal communication all the signatory countries form a single territory. The practical application of this principle lies in the doctrine of liberty of transit; every member of the union binds itself to transmit the mails entrusted to it by every other member by the best means of communication which it employs for its own mail. Thus each country has in effect the full and unrestricted use of the railway and steamship services of the whole world, and any improvement made by any member of the union is placed at the disposal of any other which desires to utilize it.

The membership of the union was at first somewhat limited, and was mainly European, although from the first the United States, Asiatic Russia and Asiatic Turkey were included. Extensions of membership were, however, rapid. Ten years after its foundation the union included *86* postal administrations; by 1900 there were 113 and at mid-century there was hardly any part of the world remaining outside.

2. The Postal Union Organization.—The organization of the union is simple but effective. Most questions are settled directly between the countries immediately concerned. but for matters in which the whole union is concerned an international bureau is maintained at Berne.

The bureau collects and distributes information of common interest, publishes statistical returns, a monthly journal, lists of steamship and air services, etc., and acts if required as a clearing-house for the settlement of accounts. The cost of the bureau is apportioned in a ratio corresponding to their importance between the various members of the union.

The Universal Postal convention and the subordinate agreements are reviewed periodically, usually at intervals of five years, by a congress to which every member is invited to send delegates. In cases of dispute between postal administrations, the union has adopted the principle of compulsory arbitration. Serious disputes are infrequent, but when they occur the arbitration machinery has invariably been effective.

3. Four Chief Principles.—The first principle was the uniformity of postage rates and of units of weight. The Congress of Berne adopted the rate of 25 gold centimes per 15 grams for letters, but permitted a certain variation within a definite maximum and minimum, and the rate of 7 gold centimes, with a similar variation, per *50* grams of printed papers.

In 1878, however, standard uniform rates in gold centimes were adopted for letters, post cards and printed papers and were retained unaltered until 1920. The only variation allowed was the addition of a surtax in cases where heavy costs for sea transport were incurred. The conditions mhich followed World War I swept away the uniformity which had prevailed for 40 years and brought about a reversion to the original principle of a maximum and a minimum rate which has been maintained ever since. The only change in the units of weight has been the raising of the letter unit from 15 g. to 20 g., or to one ounce for English-speaking countries.

The second basic principle is the classification of postal correspondence into three groups—letters, post cards and other matter (including printed papers, commercial papers and samples). Definite conditions of acceptance, as well as separate rates of postage, were adopted; the delicate distinctions between what can be sent at the cheap rate and what must be charged as a letter, which are often puzzling to the public, depend on international decisions which no individual country is in a position to vary.

The third principle was the adoption of definite payments to be made by the country which dispatches mails by the trains or steamships of another country for the use of those services, with the exception that no payment is made to the country of destination, the flow of correspondence in each direction being assumed to be approximately equal. Here there has been no continuity of practice. Rates for sea services in particular were at the outset extremely high. Over the years the rates for sea and land services have been adjusted from time to time to meet changing circumstances.

The fourth principle was the universal adoption of a system of registration and compensation. International registration differs from internal registration in one important particular, which often puzzles and annoys the sender of a letter. The compensation payable is a fixed amount and is allowed only in the event of the entire loss of the registered packet and not for damage or loss of contents. This principle the union has steadily maintained from its inception.

4. Later Changes. — The original convention applied only to letter mails, but from an early date supplementary agreements were adopted at successive congresses for various extensions of the postal service. In 1878 an agreement for an international money order service was signed by a considerable number of countries; at the same time an insurance service, which provided for payment of compensation for loss or damage of letters containing documents of value (paper money, etc.), was established. This was later extended to cover insured boxes containing valuables such as gold or jewelery. The amount insured varies with the fee paid, and the maximum varies in different countries.

A further considerable advance was made in 1880, when 19 countries concluded a parcel-post agreement. The original agreement was limited to parcels not exceeding three kilograms; it prescribed a simple procedure and fixed rates of payment both for terminal and for transit countries. The scope of the service expanded considerably and provides both for an insurance and a cash-on-delivery service. The agreements above mentioned are not adopted universally throughout the union, but where separate agreements have to be concluded, they generally follow with only slight variations the principles sanctioned by the union.

At the Congress of Paris in 1947 the union accepted a relationship agreement with the United xations under which it became a specialized agency.

5. Commonwealth Preferential Postage. — The idea of adopting preferential postage rates on political grounds began to develop in the era following the establishment of the Universal Postal union, and it was decided by the Postal Congress of Washington in 1897 that the postal union convention should permit the establishment, by agreement, of rates below the standard postage. This decision, coinciding with a growth of the feeling of the unity of the British commonwealth, led to the introduction in 1899, following a special conference, of "imperial penny postage" at a rate of 1*d.* per one-half ounce to Canada, India, South Africa and the crown colonies generally; it was extended to New Zealand in 1901 and Australia in 1905. Certain foreign countries, including the U.S., which were closely linked with the U.K. by tradition or trade were subsequently included in the scheme, but the preferential rate to these countries was withdrawn in 1957 for financial reasons. Throughout the various changes in letter postage brought about by World Wars I and II the principle of maintaining the initial commonwealth letter rate at the same point as the initial inland rate has been uniformly observed.

(R. A. Le.; R. H. Le.)

IV. POSTAL SERVICE OF THE COMMONWEALTH OF NATIONS

In the early days of colonial expansion the postal services established overseas were in theory and to a large extent in practice under the direct control of the postmaster general of Great Britain. Reasons of practical convenience and the development of autonomy in the dominions and colonies gradually led to the establishment of independent postal services.

1. Australia. — Australia's largest business undertaking, the department of the postmaster general, had its beginning in the colony of New South Wales with the establishment of the first post office in Sydney in 1809.

The Australian post office serves the public through 10,000 offices and employs more than 80,000 persons. The postal system covers not only the handling of mails and the transmission of money, but extends to the management of telephone and telegraph systems of the country and to the maintenance of the technical side of the national broadcasting service.

An overland mail service between Sydney and Melbourne commenced in 1838. Sydney and Melbourne were further linked by telegraph in 1858. and telegraphic communication between Australia and other countries was established in 1872. The telephone was introduced only two years after its invention in 1876, and the first telephone exchange (in Melbourne) was opened in 1880.

Australia's first official air-mail service was established in 1921 between Geraldton and Derby in Western Australia, and was extended through to Perth two years later. In the mid-1950s more than 50 internal networks linked all states with subsidiary services to many parts of the interior, covering a route distance of about 39,000 mi. In addition, overseas air-mail services operate several times weekly, bringing Europe and America within a few days' distance by correspondence.

Before federation in 1901, each of the six colonies had maintained its own postal, telegraph and telephone services, but with the passing of the Post and Telegraph act, 1901, by the new federal parliament, the six separate postal services were combined into one federal system. In 1901–02, the first full financial year of operation under the control of the commonwealth, the expenditure of the Australian post office was less than £2,500,000. Expenditure had reached £10,000,000 by 1921–22 and £20,000,000 by 1941–42. Six years later, expenditure had again doubled to reach £40,000,000. In 1948–49 it amounted to £53,400,000.

2. Canada. — Postal service dates from the French regime when in 1705 a courier first carried official and private mails between Quebec, Trois Rivières and Montreal. The post office was established under the British crown by Benjamin Franklin in about 1763 and formed part of the North American system until the American Revolution. In 1851 the separate Canadian provinces assumed control of their postal services, which were merged into a centralized Canada post office at the time of confederation. At mid-20th century Canada operated approximately 12,000 post offices, with revenue reported at $95,957,469 for the year 1948–49 —a 300% increase in 15 years. All domestic mail not exceeding eight ounces in weight is carried by available air service provided air transmission will expedite delivery. Canada's air-mail service connects with the United States and world air networks and operates directly to the United Kingdom, the Netherlands, Mexico, Peru, the West Indies, Australasia, Japan and Hong Kong. Its money order service has an annual turnover exceeding $690,824,786, and its Post Office Savings bank does a considerable business.

3. India and Pakistan. — From time immemorial communication between the different parts of India was maintained by means of couriers both on horse and on foot by the rulers, but this was limited to the carriage of the rulers' mail. After the occupation of India by the British, a somewhat similar postal service was established by Robert Clive in 1766; but this was also mainly intended for official correspondence, and the same principle was followed for many years during the gradual extension of British rule in India.

The post was first made available to the public in 1774 when a regular organization was set up. It was not until 1837 that it was considered to be sufficiently developed to warrant the establishment of a monopoly in favour of the official post.

The Indian post office prior to partition in 1947 was governed by legislation called the Indian Post Office act. The area to be served is immense, and the cost of transport relatively heavy; moreover, the policy of uniform rates irrespective of distance, adopted in England in 1840, was accepted in India as early as 1854, and the aim of the government was to fix the rate as low as possible, the post office never having been expected to make any considerable profit. India became a founder member of the Universal Postal union in 1876.

The number of letters delivered annually is about 1,837,000,000, an average of six letters a head each year. Post-office work has shown a steady and considerable increase, the volume having doubled in a period of about 20 years by mid-20th century when the inland letter postage was 2 annas (2*d.*), the post-card rate $\frac{3}{4}$ anna, the newspaper charge for a weight of ten tolas only $\frac{1}{2}$ anna. A considerable parcel-post service was maintained at comparatively low rates, a parcel of 40 tolas (1 lb.) being conveyed for any distance for the low charge of 6 annas (*6d.*).

A money order service with an annual turnover of nearly Rs. 1,180,000,000 is maintained, and the value payable (cash or delivery) post, which by mid-20th century had been established in India for more than 70 years, was also highly developed, the annual value being more than Rs. 340,000,000.

India is one of the few countries where first-class mail is carried by air at night and carried on the all-up basis without any surcharge. India was the first country in the world to use aerial post (in 1911) and also the first country in the commonwealth to issue a special set of air-mail stamps (in 1929).

In Pskistan, air-mail service between the eastern and western parts of the nation was set up soon after the partition of India in 1947. Air-mail links were also established with the United States and practically all other foreign countries. Pakistan also joined the Universal Postal union.

4. New Zealand. — The New Zealand post office, ministerially controlled by a postmaster general with cabinet rank and the permanent head of which is the director general, not only provides all kinds of postal service but also controls the telegraph, telephone and radio services. In addition it acts as agent for many other departments; *e.g.*, the land and income tax department, the social security department, the public trust office, the State Advances corporation and the registrar of births, deaths and marriages.

The first post office was established at Kororareka (Bay of Islands) in 1840, and the first postage stamps were issued in 1855. The postal department and the telegraph department were amalgamated in 1881. In 1901 New Zealand introduced penny postage not only inland but with all countries of the empire and also with every foreign country which would accept it, submitting to the Postal Union congress of Rome in 1906 a proposition, which was not successful, for the introduction of penny postage on a universal basis. The initial letter postage rate was ad. in 1950.

Scattered throughout the country were 1,933 post, telegraph and telephone offices in 1949. In addition, an extensive rural system of mail delivery was operated. Altogether there were 50,000 rural box holders. Postal traffic is heavy in relation to the population. During the year ended March 31, 1949, 319,229,000 articles of all kinds were posted, an average of 180 a head.

5. Union of South Africa. — The first regular postal service was introduced in South Africa in 1803 when communication was established between Cape Town and the important centres by Hottentot postboys. These foot messengers were replaced by horsed post orderlies, and subsequently the development of the railways made rapid communication possible on an extensive scale. Later the internal air service provided a means of transmission for letters.

The four states of South Africa maintained their separate post offices until the formation of the Union in 1910, when a centralized postal administration was formed. By the mid-1950s there were 3,422 post offices in the Union employing a staff of more than 32,000 persons. The total volume of postal traffic for 1955 amounted to 929,740,000 articles of all kinds.

The inland letter rate in the mid-1950s was, by surface mail, zd. for the first ounce and *1d.* for each additional ounce; by air, *3d.* for the first ounce and *2d.* for each additional ounce. The post-card rate was *1½d.* (surface) or 2d. (air). Parcels were charged for at the following rates: up to eight ounces in weight, *6d.;* and thereafter, 8d. a pound. An interesting feature is the agricultural parcel post for the conveyance of primary products of the soil, horticultural and dairy produce and foodstuffs produced within the Union at a rate of 3d. for one pound. Cash on delivery and insured parcel services also operate.

South Africa is the contracting party for the regular sea conveyance of the mails exchanged with the United Kingdom.

V. POSTAL SERVICE IN OTHER COUNTRIES

1. France. — The creation of a state post in France is generally held to go back to the edict of Luxies issued by Louis XI in 1464, the authenticity of which is, however, disputed by certain historians.

In the course of the centuries, modifications in organization were introduced by different sovereigns. They all aimed at reducing the existing privileges enjoyed by private messengers and at increasing the control of the royal power over the postal service. The culmination of this policy is the edict of the consuls of the 27th *Prairial,* year IX (June 16, 1801), the provisions of which, fixing the basis of the postal monopoly, are still in force.

The system of "farming" the posts which was tried in England for a short period during the 17th century was maintained in France up to the time of the Revolution. In 1792 the system was suppressed and the posts raised to the status of a national agency. In year III (1794–95) this was replaced by an administration-general of posts and stagecoaches, which was transformed in 1804 by Napoleon I into a directorate-general placed under the authority of the minister of finance. Later, by reason of the importance which the postal service had come to assume in the general economy of the country, the control of the postal administration was entrusted, sometimes to an undersecretary of state attached to a minister, sometimes to a minister. The postal administration is now generally placed under the authority of a secretary of state or of a minister.

In the course of the 19th century and the first half of the 20th century, various services were attached to the postal administration — money orders (1817), telegraphs (1878), telephones (1889), postal cheques (1918), etc. Moreover, in view of the number of post offices (20,000), which permits contact with the mass of the population, the postal service has been given the task of carrying out various operations on behalf of other organizations or administrations (National Savings bank, National Bank for Old-Age Pensions, payment of civil and military pensions, investment of state loans, payment of dividend warrants, etc.).

The following figures will give an idea of the importance of the postal traffic. In the mid-1950s the French posts transported about 6,200,000,000 items of ordinary correspondence and 155,000,000 registered and insured items annually. Moreover. 246,500,000 money and postal orders were issued representing 8,500,000,000,000 fr.

The economic and financial conditions resulting from World Wars I and II made it difficult to stabilize postal charges. These charges are fixed generally in relation to cost. However, with a view to aiding the development of commerce and of public information, certain charges are fixed below cost — in particular, those for printed matter and newspapers. Similarly, for easily comprehensible reasons. the charges for the internal service are applied as a whole to items for the territories of the French union.

The parcel-post service, as in all countries, is the responsibility of the postal administration. In France, however, the operation of the service is entrusted to the French National railways (S.N.C.F.). The relations between the postal administration and the railways are laid down in various documents, notably in a convention signed in 1945.

The National Savings bank created in 1881 operates under state guarantee; it is placed under the authority of the minister of posts, telegraphs and telephones, and is represented in its relations with depositors by the postal administration. In the mid-1950s there were 12,800,000 National Savings bank accounts in existence and the amount standing to the credit of depositors amounted to 664,500,000,000 fr.

Finally, the postal cheque service created in 1918 enjoys an increasing popularity with the French public. In the mid-1950s there were 4,000,000 current accounts in operation, and the total amount of the transactions, debit and credit, carried out in the course of a year reached 54,255,000,000,000 fr.

2. Germany. — In 1919 postal and telecommunications matters in Germany became the exclusive affair of the German reich—the head of the *Reichspost* being the *Reichspostminister* responsible to the *Reichstag* The *Reichspostfinanzgesetz* (Imperial Post Office Finance act) of 1924 established the post office on an independent financial basis analogous to that of a commercial company, so that apart from a tax on revenue the treasury had no claims on post-office finances and vice versa. The post-office administration fixed the estimates of expenditure, decided on questions of borrowing for post-office purposes. redemption of debt, investment of postal cheque office balances, rates of pay, classes of business and rate of postage and telegraph and telephone charges.

The *Reichspostnzinister* was assisted by an administrative council, and decisions of the council were implemented by ordinances issued by him. In 1934 the council was replaced by an advisory committee, a change intended only to simplify procedures and reduce administrative costs. At the capitulation in May 1945 the *Reichspostministerium* completely disintegrated and only the *Reichspostdirektion* (regional headquarters) and subordinate offices remained in any more or less organized form. By order of the Allied military government all post-office services in Germany were suspended.

At this time 70% of the post-office buildings had been seriously damaged and 17% totally destroyed, and the staff and transport were dispersed and disorganized. During 1945 a zonal administration mas set up in each of the British and U.S. zones oi occupation, but these mere replaced by a bizonal administration early in 1947. With the creation in Sept. 1949 of a federal republic covering the British, French and U.S. zones, the bizonal administration gave way to a iederal ministry for posts and telecommunications. At the end of 1949 the new iederal ministry employed in all services, including postal, telecommunications, savings bank, *Postcheck,* etc., about 272,000 people serving a population of 41,500,000.

Despite the serious setback during and immediately after World War II, the volume of business in 1949 approached the 1938 figures with an annual postal traffic amounting to 3,400,000,000 letters, 99,000,000 parcels and 656,000,000 papers and periodicals The savings bank, which remained in business throughout the whole of the financial chaos following the capitulation, had 37,000,000 transactions (deposits and withdrawal?) in 1949 with a turnover of 220,000,000 DM., while the *Postcheck* service transacted business to the value of 132,700,000,000 DM The number oi telegrams reached a peak of 4,000,000 a month in May 1948 but settled doun to an average of 1,800,000 per month or 21,000,000 a year—a figure 50% greater than 1938

The number of telephone installations totalled 1,750,000 or 5% less than in 1938, but the traffic at 112,000,000 local calls and 21,000,000 long-distance calls per month exceeded the 1938 traffic by about 10%. The revenue from posts and telecommunications operations for 1949 was of the order of 1,700,000,000 DM

Transmitting stations for radio broadcasting were provided and maintained by the *Deutschepost* until 1948, in which year they were transferred to the several broadcasting corporations then in existence. The number of listeners' licences at the end of 1949 totalled 6,250,000—20% more than in 1938

BIBLIOGRAPHY—R Hill, *Post Office Reform, Its Importance and Practicability* (London, 1837); *Report of Secret Committee on the Post Office* (1844); Lewins, *Her Majesty's Mails* (1864); Norway, *History of the Post Office Packet Service* (1895); Joyce, *History of the Post Office* (1893); J. C Hemmeon, *History of the British Post Office* (1912); *Annual Reports* of the postmaster general (1854–1913); Parliamentary *Reports* on the post office, *passim;* Swift, *A History of Postal Agitation* (1900); *The Universal Postal L'nion—Its Foundation and Development* (Berne, 1955); Annual *Rapports de gestion* of International Bureau and *Statistiques générales* of the Postal Union (Berne); Postal Union Convention (Brussels. 1952); Convention of the Pan-American Postal Union (Bogota, 1955); *Handworterbuch des Postwesens* (Berlin, 1927); E Vaille. *Histoire générale des postes françaises* (Paris, 1947); Sir George Murray, *The Post Office* (1927); *The Post Office, an Historical Summary* (London, 1911); Howard Robinson, *The British Post Office, a History* (1948) (R A Le ; X)

POST CARDS. The post card originated in Austria where it was introduced on Oct. 1, 1869. Exactly a year later postal cards, with a halfpenny stamp printed in the corner. were officially issued in Great Britain at 6d. a dozen. One side was for the name and address and the other for correspondence and the cards were court size ($3\frac{1}{2}''\times 44''$). The public demand was so great on the first day of sale that police had to regulate the crowds at the general post office. By 1871 the cards were passing through the mails at the rate of 1,500,000 a week In 1894 a card with an adhesive halfpenny stamp was accepted by the post office and in 1899 the size was increased to $5\frac{1}{2}''$ by $3\frac{1}{2}''$ and half the address side was allowed for correspondence, in addition to the reverse side, which might alternatively be used for an advertisement or a picture.

By this time the picture post card was common in Germany and other European countries. Some cards with small pictures had appeared in Great Britain, but immediately the larger card was alloned, German post-card publishers flooded the English market with chromolithographed cards which sold for 1*d.* or less. English photographers, artists and colour printers soon appreciated the possibilities of this new type of stationery and by the turn of the century the collecting of picture post cards was already becoming a craze. It reached its height around 1904 when an average of 16,000,000 cards was handled by the post office per week. In addition to those which passed through the post, many millions mere collected in a "mint" state, and almost every home had its albums. Most countries had one or more periodicals addressed exclusively to the post-card collector, *The Picture Postcard* (1900–04) being the most popular in England. This was the period when the musical play was popular and portraits of stage favourites were the subjects of an enormous variety of bromide or "real photo" cards, which were a speciality of British and French publishers, although views by the various colour processes formed the largest group in all countries.

In the United States and in the British colonies the craze came a little later. It began to wane everywhere soon after and died out with the advent of World War I. The picture post card, however, still forms an important section of the stationery trade. (W. T. B.)

POSTER. A poster is an announcement publicly exhibited which is designed to be understood at a glance. Advertising an event. product or service, the poster must combine immediate visual effectiveness nith concise communication of a message; it must compete for attention in visually confusing surroundings and yet inform the spectator or communicate the advertiser's message to him. The design of posters is a challenge to the artist. and besides their value as commercial objects many posters are of considerable aesthetic interest. Some of the foremost artists of recent years have devoted themselves to the design of posters, and their work has been studied and collected by students of the arts.

History and Development.— A kind of advertising closely related to the poster is the signboard (*q.v.*) or shop sign, hand painted on a wall or on a piece of wood. Signboards of this kind are still used widely. and they have been present in cities and towns through the ages. In their use of a striking symbol rendered in bold shapes and colours, with wording kept to a minimum, these signs are undoubtedly among the ancestors of the modern poster. But in modern times most posters are printed. and identical copies are posted in many different locations joining familiarity with visual impact in the advertising campaign for which the poster is used.

Printing (*q.v.*), as it now exists, dates from the middle of the 15th century. The first posters which have been preserved date from the early years of printing. Composed almost entirely of text, these posters carried notices of royal proclamations, tax assessments, fairs, markets and newly printed books. From a note on the bottom of one such poster (issued by an English printer and bookseller) it is known that these were meant to be left posted in public places, and hence they were an economical means of carrying a message to great numbers of persons.

Illustrations appear on posters from the early period of printmaking. Handbills often illustrated with crude but spirited woodcuts were used as broadsides which recounted notable happenings; these were essentially newssheets in poster form. The widespread use of posters to advertise products for sale (other than books) does not seem to occur before the early years of the 19th century.

Beginnings of the Modern Poster.— In the 19th century the expansion of industry gave new impetus to poster advertising Now wealthy patronage was available, and also a new method of printing had been devised—a method which allowed brilliantly coloured posters to be produced cheaply and easily.

In 1796 Alois Senefelder devised a method of printing from stone, which he called lithography. (*See* LITHOGRAPH) Since lithography allows the image to be drawn directly onto the printing surface, and does not physically alter the drawing in preparing it for printing, artists soon saw in lithography a medium which allowed them to design posters freely and simply. The firm of Rouchon in Paris was one of the pioneers in poster printing. and boldly coloured lithographic posters issued from it as early as 1845. Among the earliest French artists whose work nas utilized for posters are Paul Baudry and Denis Auguste Raffet.

But it was not until 1867 that the first of the great modern poster artists began his career. Jules Chéret left Paris as a young man, in 1856, to study colour lithography in London. When he returned ten years later, he immediately became interested in the problem of designing theatrical posters. In 1867 ChCret's first poster was published, announcing the appearance of Sarah Bernhardt in the play, La *Biche* au *Bois.* ChCret's style immediately attracted great interest; he used clear, rather pastel colours and shimmering. vignetted backgrounds, against which he placed delicate and elegant figures. His lettering was bold and gaily coloured, and the whole effect of his posters is extremely arresting. The visual impact of ChCret's work, coupled with the fact that he was a prolific worker (he designed about 1,000 posters) make his designs a major influence on later 19th-century posters. But there were other developments as well During the last quarter of the 19th century there was an expansion of the realm of the fine arts. Artists no longer felt constrained to work only in painting or sculpture, but turned as well to designing furnishings, books, textiles and other useful things. Posters were not neglected. Painters such as Edouard Manet, Pierre Bonnard, Edouard Vuillard, and Henri de Toulouse-Lautrec all worked in the field, and the last-named is one of the great masters of the medium.

Toulouse-Lautrec was a master of trenchant characterization. and the means he used in his posters were bold and simple. Inspired by the work of Manet and Edgar Degas, as nell as by Japanese colour woodcuts. Toulouse-Lautrec rendered his designs in large. interestingly shaped areas of bold colour and simple values. He used an exceedingly restricted range of colours and textures. carefully combining his shapes with line for maximum visual effectiveness. His line was bold, but sinuous and sensitive, and his backgrounds were the utmost in simplicity—often consisting of the blank paper itself carefully worked into the design of the whole poster. The lettering of Toulouse-Lautrec's posters was kept to a minimum, and the style of letter he used picked up curving rhythms and colours from the illustrations, welding the entire poster into a unified design. He produced his first poster in 1891, after more than ten years' work at painting and drawing. Between 1891 and 1899 he produced about 30 posters—among them several for clients in England and in the United States.

A contemporary of Toulouse-Lautrec whose work is closely related in style is T. A. Steinlen. The two men worked for some of the same clients, and in fact Steinlen's style seems to have been one of the influences upon Toulouse-Lautrec's early posters. The boldness of their work made Toulouse-Lautrec and Steinlen pioneers of a new movement in poster design. and their influence was felt in every European country and in the United States during the 1890s.

The imprint of these French artists can be found in the work of Edward Penfield and Will Bradley in the U.S. The posters of the "Beggarstaff Brothers" (William Nicholson and James Pryde) in England carry boldness and simplicity even further. Another English artist. Aubrey Beardsley, designed a few posters which had an impact comparable to Toulouse-Lautrec's. Beardsley's elegantly curved thin line, equally elegant solid shapes, and his elaborate linear and dotted textures, created a mood of luxurious and almost mysterious sensuousness. Around 1900 many young artists found this attractive. and Beardsley must join Toulouse-Lautrec as one of the main sources in poster and illustrative art for the so-called *art nouveau* (*q.v.*). England and the U.S. had begun to produce illustrated posters in the 1870s, and with the addition of a style of illustration deriving from the popular painting of the time (*i.e* , the adaptation of Sir John E. Millais' "Bubbles" into a soap poster in England), the posters designed in these countries generally followed French developments. Artists in other European countries produced work along similar lines.

20th-Century Posters.—Around 1900 several new movements in art were forming in the Netherlands, in Germany and in Austria. In the field of poster design. France had previously been a leader, but now for the first time its supremacy as a source for innovation was challenged. Developing further some of the ideas first enunciated by John Ruskin and William Morris, these artists shoaed an interest in crafts, techniques and in machine-made forms; this interest motivated them to make use of simple colour schemes based on primary colours, geometrically derived patterns, etc. Their efforts culminated in the work of the Bauhaus at Weimar and Dessau (1919–28) in Germany. The Bauhaus nas an art school. and the nork of both professors and students gave a new direction to design in posters and in every other field. Although its posters were actually of little significance in themselves, and despite the fact that its more radical innovations were subsequently abandoned, the Bauhaus (*q.v.*) remained the major influence through the mid-20th century.

Artists such as Herbert Bayer, Josef Albers. Gyorgy Kepes and later E. McKnight Kauffer, organized lettering and pictorial matter into clearly-defined rectangular and curved areas. Elaboration of colour and of letter forms was kept to a minimum. and some designers even gave up the use of mixed upper- and lower-case letters to avoid distracting variations in size and shape.

With the growth of the advertising industry in the 20th century, the poster assumed greater importance than ever. Cassandre, Carlu and Savignac were typical of the better French poster designers of the generation following World War I: their work combined simplicity and visual force with genuine wit, and the fame of their posters became world-wide. During World Wars I and II, the major powers involved paid tribute to the effectiveness of the poster in according it many tasks: armed forces were recruited, bond issues advertised. participation in the war effort maintained, all by use of large-scale poster campaigns. James Montgomery Flagg and Ben Shahn were typical of the artists who designed posters for the United States. in World Wars I and II, respectively.

Another aidespread use of posters is to advertise the services of transportation companies. A pioneer in this field was the London Transport company in England. which began in 1908 not only to advertise its services but also to commission prominent and promising artists to design posters describing places which could be reached using the facilities of London Transport. Undoubtedly the entire travel-poster industry owes much to the initiative of the directors of London Transport. By the 1930s virtually every major transportation company was publishing and distributing posters. With the increase in the use of posters in the 20th century, it became necessary to institute measures for the control and limitation of public advertising. Laws to control the dimensions and placement of hanging signs were instituted as early as the 18th century both in England and in France. and similar regulations exist in modern times in many countries the world over. In the 20th century city governmental authority has been exercised to limit the placement of posters on walls, and there exist standardizing and limiting measures to govern the use of free-standing billboards. *See* also ADVERTISING.

BIBLIOGRAPHY —Ernest Maindron, *Les Affiches illustrdes* (1895), *Les Affiches etrangères illustrdes* (1897); E. McKnight Kauffer (ed), *The Art of the Poster, Its Origin, Evolution and Purpose* (1925), *Art for All. London Transport Posters From 1908 to 1949* (1949, 1950); Bernard Champigneulle, "The Earliest Known Colour Posters" in *Graphis # 50* (1953); W. von zur Westen, *Reklamekunst aus zwei jahrtausenden* (1925); *Outdoor Advertising Association News; Graphis; Gebrauchsgraphik; Journal of Advertising Art* (periodicals) *See* also numerous monographs on individual poster designers (A M Fx.)

POSTE RESTANTE, a facility, generally provided at post offices, for the receipt and care of postal packets addressed to be called for. There are usually strict regulations to prevent abuse or fraud. In the United Kingdom it is stipulated that the words "to be called for" or "poste restante" should appear in the address, and it is notified that the facility is intended solely for the accommodation of strangers and travelers, and that even they may not use it for more than three months. Postal packets addressed to initials, or to fictitious names. or to a Christian name without a surname, are not taken in at the poste restante.

Postal packets may not be redirected from one poste restante to another in the same town or from a private address to a poste restante in the same town Redirection from a poste restante is not undertaken for more than 14 days, unless a longer period, not exceeding three months, is specified on the form of application All persons applving at a poste restante are required to furnish sufficient particulars to prevent mistakes and to ensure delivery to the proper person Where a ship is in question the name of the vessel should always be mentioned.

The words "general deliverv" in the US. are synonymous with "poste restante" A general delixerv window is maintained at every post office in the US and is used for handling mail bearing as a part of its address the endorsement "Transient," "To be called toy," "General Delivery" or other words indicating that it is intended for a transient person, such mail to be delivered upon application and identification At those post offices where deliverv carrier service is maintained, residents who use the general delivery window are required to furnish in writing their names and addresses and the reasons for desiring to use the general delivery instead of the carrier service.

POST EXCHANGE: see CANTEEN.

POSTIMPRESSIONISM. The essential difference between Impressionism and Postimpressionism is perhaps best explained by the description of the former as an objective outlook which results in the rendering of the image received on the retina, and of the latter as the mental image expressed in accordance with a subjective outlook. In other words, while Impressionism is based on strict fidelity to natural appearances, the need of Postimpressionism consists, in the main, of absolute attachment to the personal vision, and, in reality, is the expression of the matter received through the glass of Impressionism to be subsequently subjected to an individual thought process.

The statement which emerges from the artist as a result of this process might well be termed Expressionism, mere it not that this name is more exclusively reserved for the excessively brutal German contribution to the movement under consideration. Postimpressionism (a term coined on the occasion of the first exhibition of the work of Cézanne, Van Gogh and Gauguin in London in 1911) provides an alternative which, if less apt, has the merit of being safe.

Postimpressionism was as much a revolt against the naturalism of the Impressionists as Impressionism was a revolt against the tyrannical academic formula. It replaced analysis by synthesis. It despised representation and gave the artist unbridled licence to amplify and distort the forms of nature, acknowledging no law but the artist's sense of fitness in arranging and organizing the contents of his picture so as to express with the greatest possible directness and intensity the material and spiritual significance of his subject — the "treeness" of the tree, as Roger Fry has it, and the "wallness" of the wall.

Delivered from all restraint and rules, the Postimpressionists were able to proceed by leaps and bounds on their excursions into the realms of synthesis and abstraction, to the utter bewilderment of a public which, accustomed to judging art by the degree of its verisimilitude to nature, nas left floundering hopelessly when attempting to fathom the meaning of these startling artistic manifestations.

A quarter of a century was enough to secure for the initiators and leaders of Postimpressionism a position among the beacon lights of European art. Cézanne, Van Gogh and Gauguin are now referred to as the "glorious triumvirate" and the "old masters of Postimpressionism." Their once-despised, numerous and by no means invariably successful paintings are in most of the galleries of modern art, and thousands of pounds are willingly paid for canvases for which the artists during their lifetime would willingly have accepted a few hundred francs.

Cézanne.—Paul Cezanne, who at the beginning of his career threw in his lot with the Impressionists. upon whose technique he formed his own, was among the first to realize the limitations imposed by the Impressionists' scientifically truthful rendering of colour and atmosphere. His dissatisfaction with what he considered the superficiality of Impressionist productions led him to express, more basically and with greater structural firmness, the essential character of the countryside which forever offered him new vistas, new wonders for his interpretation.

His endeavour, in portraiture and still life, as well as in landscape painting, was to accentuate volume and weight — to make the third dimension more clearly and immediately perceptible to the beholder's eye than it is in actual nature, where we are left to guess by experience and by memory of touch. To him is attributable the dictum that all forms in nature can be reduced to the cube, the cylinder and the pyramid.

Van Gogh.—Like Cézanne, Vincent van Gogh derived his technique from the Impressionists; and like Cézanne, he was anything but a facile worker, his heavy hand being but an inadequate instrument for conveying his passionate aesthetic reaction to the thing seen.

Of him it may truly be said that he did not paint, but rather battled with colour and essential line with a frenzy that took no count of finished execution. His pictures are executed in furiously energetic crosshatchings of pure Prussian blue, emerald green, orange and yellow, with a daring justified only by the brilliant harmonies evolved from a palette on which he found no room for neutral tints.

His brushwork can only be likened to vigorous hatchet strokes, corresponding to the elemental force of his emotions. There was something uncanny in his power to perceive and to express the essential nature of any object or scene or person by which his aesthetic impulse was stirred.

Inanimate things became somehow invested with a soul and with a life of their own—a sunflower. a wicker chair, a cypress tree or whatever it happened to be. He was a visionary who found a deep meaning in the humblest objects which his art invested with his own tortured spirit, and which he made eloquent of his own emotions. Van Gogh was the precursor of Expressionism.

Gauguin.—The third member of the great triumvirate, Paul Gauguin. was a close friend of Van Gogh, but of a less impulsive and more reflective turn of mind. Where Van Gogh would shout and even shriek. Gauguin was content to talk, and his words carried more weight, for they were more considered.

If Cézanne devoted his life to the search for volume, and Van Gogh for material and spiritual significance, Gauguin's revolt against Impressionism took the form of a return to decorative pattern, to two-dimensional design as practised by the artists of the far east. He based his effects on abstract form and colour, not on representational truth or on overaccentuation of some particular truth. Ignoring the colour of nature and relying for the expression of his ideas upon his memory more than upon models, Gauguin produced. first in Brittany, then in Tahiti, those splendours of harmonious decoration against which no arguments founded on convention can ever prevail.

It was his belief that, before the spirit of a place could be interpreted, it needed study in all its parts during what he called a "period of incubation." Some proof of the peace Gauguin found can be seen in the restful nature of his paintings.

Matisse.—Of the second generation of Postimpressionists. Henri Matisse went farther even than Gauguin in reconciling western art with the Chinese. He aimed "at convincing us of the reality of his forms by the continuity and flow of his rhythmic line, by the logic of his space relations, and, above all by an entirely new use of colour." His was an art of extreme synthetic simplification, reducing objects almost to symbols, and disdaining any approach to make-believe of reality. It depended entirely on arabesque and was not concerned with the third dimension.

Cubism.—Cézanne had used colour in block form because, by that means. he could best express his feeling for the neight of whatever he depicted, and its relation to other things presented with it, but he kept to the accepted ideas of representation, which were discarded by his Cubist followers, Picasso, Braque, Dérain and Leger, who evolved a new language from Cézanne's suggestion of space. It was a form of art that had nothing whatever to do with realism. and demanded concentration on aesthetic matters to the absolute exclusion of outside practical appearances and accepted canons of judgment. Cubism bears out Ruskin's theory that an artist may deny other truths to the end that one truth may be more apparent.

Like Impressionism, the name "Cubism" was first used in a derogatory sense; it was Matisse who, in 1908, applied it to a painting in which the subject had received treatment of a markedly cubical character. About as far from the Impressionist objective approach as anything could possibly be, Cubism is really a stride — albeit a long stride — beyond the subjective outlook of the Postimpressionists, in that it takes no heed of visual Appearance and renders what are thought to be essential realities in pure abstract form. Pablo Picasso, the most prominent follower of the Cubist gospel. and, indeed. the creator of certain of its elements. was the exponent of scientific Cubism in its purest sense. Another form of Cubism. less pure, is that which is best described as physical, since its fundamentals are culled from visualized realities.

For example, in those of Picasso's works which are based on physical appearances, the objects are presented in a nay at least sufficiently realistic to enable their perception by the ordinary beholder. although he may be at a loss to account for the shapes which they assume. Their recognition, incidentally, at once displaces the work from the category of Cubism in its strict sense. for that entails matters of line and colour wholly unrelated to objects and figures. since the cult does not intend realism to enter into the question. Georges Braque stands, to some extent. as the codifier of Picasso's inventions, acting as an editor of his snipelike movements.

Thus, the products of Picasso are sobered down and reduced to a state of uncompromising logic before being handed on as standardized material. The art of Femand Leger is concentrated upon the mechanical age into which we are advancing. Working in the gay colours of contemporary life, he extracts excellent design from the solid strength of the mechanized world by which he finds himself enveloped.

Albert Gleizes is a devotee of two-dimensional treatment, and his attitude toward a flat surface is that it has no need of the addition of a sculptural third, for the presence of such constitutes a denial of its very nature. This painter, too, does not regard painting as a form of representation, but of presentation of the spirit of the artist. and not of physical matter. Metzinger, Herbin and Lhote are others of the Cubist persuasion, which has demanded. in its time, every conceivable form of liberty. Orphism, Purism, Synchronism. Simultaneism. Integralism, Dadaism and Numeralism all have had their day, and now the parent bids fair to follow them into oblivion. But although Cubism may prove to have been a blind alley, it has been, and still is, an invaluable discipline for artists in general and had its definite use in saving art from the rut of academic pedantry.

Futurism. — Italian Futurism, initiated, heralded and extolled by the eloquent poet Marinetti, and practised by Boccioni, Severini, Carra, Russolo, Balla and other disciples of the founder, was really an offshoot of Cubism, although the connection was not admitted in the Futurist manifestoes. It differs from Cubism insofar as Cubism is concerned with static conditions, while Futurism is essentially dynamic.

This dynamism aims at cinematographic effects, oblivious of the impossibility of creating on a flat surface the illusion of the sequence of movement. Thus, by depicting a horse with 20 legs in various positions to indicate the movement of the gallop, the Futurist endeavours to express the action of the gallop, but does not get beyond the representation of a static horse with 20 legs. Any attempt to change an art of space into an art of time must needs prove abortive.

The dynamic intention of the Futurists also finds expression in "force lines." that is to say in lines, radiating, swirling. wedge-shaped, to indicate either the direction of movement or the manner in which objects would disintegrate in obedience to the force indicated by their form.

Another tenet of Futurism denies the validity of the resemblance of a portrait to the sitter. To the Futurist, a painting of one object covered by another in such a manner that both are visible is a method of indicating his total disbelief in opacity, while a dozen people can be, at the same time and in turn, ten. three, five in number, as well as simultaneously mobile and immobile. Paintings of a box, firmly shut but at the same time disclosing its contents, also are admissible. Pictures must be looked not at but through. and the spectator must feel himself to be in the midst of them. In England, F. T. Marinetti's fiery eloquence enlisted for a time a small following, which included C. R. 1% Nevinson, who adapted with great skill the Futurist formula for a series of remarkable war paintings.

Vorticism.—The chief English contribution to Postimpressionism, however, was the work of the short-lived group of "Vorticists," who, led by Wyndham Lewis, adopted a modified method of Cubism, and included among their number William Roberts, Edward Wadsworth and F. Etchells. In England, as in most countries, these innovators were regarded as incompetent cranks and charlatans, until their employment in connection with the Canadian war memorials and the Imperial War museum brought them official recognition and public fame.

Expressionism. — In Germany the Postimpressionist movement took root and spread with surprising rapidity. Its most abstract form is to be found in the art of the Russian-born W. Kandinsky, who explained his outlook in a book entitled *The Art of Spiritual Harmony*. Max Pechstein, F. Marc, E. Nolde. Oskar Kokoschka and L. Corinth are the most prominent figures among the German Expressionists, among whom must also be counted Marc Chagall, notwithstanding his Russian birth.

Certainly it would seem that the German activities which correspond to those of the Postimpressionist painters in other European countries should be accorded some distinguishing title of their own. The term "Expressionism," therefore, serves the purpose as well as any other, unless one were found which denotes a combination of truth, bestiality, creation and destruction — all expressed in a manner in which a snarling brutality obscures many finer feelings. At the same time it must be admitted that the artist to whom the Expressionists owe so much, the Swiss Ferdinand Hodler, cannot very well be held responsible for the excesses committed by his imitators or contemporaries.

Man and his relation to the world which contains him were subjected by Hodler to every thought process of which his clear brain was capable. and the resulting statements are models of simplicity. precision and originality. Hodler did not attempt to put the unreasoning at ease by being intimate with them, but compelled them, rather, by an almost holy power, to use their own imagination.

Another artist who with Hodler, Cézanne and Van Gogh left his mark upon the evolution of German Expressionism, was the Norwegian Edward Munch, whose achievement in painting leads from the subjective naturalism of the late 19th century to the Postimpressionist tendencies of the present day.

In the United States the new art-gospel of Postimpressionism or Expressionism was popularized mainly by the activity of Jules Pascin (1885–1930), a Bulgarian by birth, who had been working from 1905 onward for *Simplicissimus* and living in France until 1914, when World War I made him seek a new home in the United States.

Pascin was equally distinguished as an illustrator and as a painter, and his work. though always maintaining a very personal note, showed in turn the influence of Daumier, Cézanne, Degas, Renoir and Picasso. He resorted extensively to distortion for the definite purpose of forceful emphasis, and is in this respect related to the German Expressionists.

Effect on **Other** Arts. — Postimpressionism, in its attempts at synthesis, drew on the past to as great an extent as any other movement, but. ignoring the representational tricks discovered by succeeding generations, adopted only the basic, elementary facts of the unsophisticated and consequently more sincere primitive races.

Exploration has brought to light comparatively modern work, in the form of sculpture, pottery and mat designs, by peoples who, throughout the ages, have known no art teaching or influences save those, possibly, of a conquering but equally primitive tribe. From the Congo, Bakota, Benin and other districts of lesser-known Africa, masks and figures have found their way to Europe, there to reveal, to eager searchers for a means of expressing much without complication, wonders of form and rhythm which were bound to receive the investigation of serious artists.

In the same way that Gauguin found stimulation in the vibrant colours of the Polynesian matmakers, so Jacob Epstein and, to a lesser degree, Ossip Tadkine have been helped to fuller expression by deep study of Negro sculpture.

In almost everything — buildings, furniture, dress, design in the home or theatre and especially, perhaps. in that powerful modern factor, advertising — the effect of Postimpressionism and its more successful descendants is very marked, while the benefits accruing to sculpture and the minor arts — woodcuts, engravings, posters, wallpapers and others — have altered the trend of public thought and freed it, to such extent as slow and inartistic officialdom will allow, from the morass of insincerity and vulgarity which had all but swallowed it up.

(*See* IMPRESSIONISM; PAINTING.)

BIBLIOGRAPHY.—J. Meier-Graefe, *Modern Art* (1908); C. J. Holmes, *Notes on the Post-Impressionist Painters* (1910); F. T. Marinetti, *Le Futurisme* (Paris, 1911); Roger Fry, *Form and Design, Prefaces to Catalogues* of *1st and 2nd Post-Impressionist Exhibitions*, Grafton Galleries (1911 and 1912); Boccioni, *Pittura Scultura Futuriste* (Milan, 1914); G Coquiot, *Cubistes, Futuristes, Passeistes* (Paris, 1914); W. Kandinsky, *The Art of Spiritual Harmony* (1914); A. J. Eddy, *Cubists and Post-Impressionism* (1915); W. H Wright, *Modern Painting* (191j); Hermann Bahr, *Expressionismus* (Munich. 1920); F. Lehel, *Notre Art Dement* (Paris, 1926); F. Rutter, *Evolution in Modern Art* (1926); R. H. Wilenski, *The Modern Movement* in *Art* (1927); Jan

Gordon, *Modern French Painters* (1923); A. Gleizes and Jean Metzinger, *Cubism* (P. G. K.)

POSTL, KARL ANTON (1793–1864), Austrian-U.S. novelist whose pseudonym was CHARLES SEALSFIELD. was born in Moravia on March 3, 1793. Ordained a priest, he left his monastic order in Prague and in the 1820s under a pseudonym traveled in the United States. He became a U.S. citizen but settled in Switzerland in 1832, remaining there except for visits to the United States until his death near Solothurn on May 26, 1864.

Postl's books were originally published anonymously and after the publication of his collected works in Stuttgart in 1j volumes (1845–47) under his pseudonym. His identity was not disclosed until after his death. His works were read widely in both English and German editions during the 19th century. Titles in English included The Cabin Book (Eng. trans. 1844) dealing with life in Texas; Frontier Life (1856) and The *United* States as They Are (1828). Postl nas noted for his attempt to characterize broad cultural groups instead of basing his plots on the actions of individual heroes.

POSTLIMINY. Postliminy is a technical term that international lawyers apply to the status of a government in its own territory when this territory has been reacquired from an invading enemy. The territory reacquired may have been the whole territory of the invaded country or merely a part.

Originally the term postliminy was applied to a different situation. A Roman citizen lost all his civil property and matrimonial rights if he became the prisoner of war of an enemy. If he returned he was automatically restored to all his previous rights and obligations and that restoration was called postliminy.

Some few writers still use the term postliminy in the old Roman sense. and a few apply the term to other postwar restoration problems. An example of the latter would be the return of German assets sequestrated in the United States during World War II. (See ALIEN PROPERTY.)

Postliminy in its chief meaning, which applies to returning sovereigns. operates immediately, long before the peace treaty. Normally in the international law of war all final settlements are postponed until peace treaties are made. Under postliminy, however, the returning sovereign may act immediately as if its government had never been absent. Public property seized by the enemy is immediately reacquired. Enemy legislation may be canceled, even with retroactive effect. Property which the enemy has seized and sold may be restored to the owner. Traitors and collaborationists may be punished.

The logical implications of postliminy are so extreme that other rules of international law and morality have to operate against extreme abuses. For instance it would be going too far under postliminy to annul all criminal sentences, to carry actions against collaborationists to the point of imposing standards of martyrdom on the population or to collect debts and taxes already collected by the enemy.

BIBLIOGRAPHY.—Ernst H Feilchenfeld, *The International Economic Law of Belligerent Occupation*, pp 144–151 (1950); Kirchenheim, "Postliminium," in Karl Strupp, *Worterbuch des Volkerrechts und der Diplomatze*, pp 295–299 (1925), J M Spaight, *War Rights on Land*, pp. 366–367 (1911); Luigi Amironte, *Captivitas e postliminium* (1950).
(E H F.)

POST-MORTEM EXAMINATION: see AUTOPSY.

POSTOJNA (It. POSTUMIA, Ger. ADELSBERG), a village of southwestern Slovenia. Yugoslavia, 23 mi. S.S.W. of Lubljana. It was transferred to Yugoslavia from Italy in 1947. Pop. (1953) 4,081.

A mile from the town is the entrance to the stalactite cavern of Postumia, largest in Europe. The cavern is divided into several branches. The Piuca river enters the cavern 60 ft. below its mouth In the sala da ballo (ballroom) grotto a great bail is annually held on Whitmonday, when the chamber is brilliantly illuminated. A mile from the entrance the so-called Elysian fields are reached. from which a view of more than 200 yd. in length can be obtained.

The finest of all, however, is the Grotta del Paradiso. These caves are now joined by a tunnel to the Grotta Vera, and with the abyss of the Piuca, which can be traversed in a boat. The stalactite formations assume fantastic shapes. The length of the passages known is nearly 14 mi. These subterranean wonders were known as far back as 1213 (the earliest names found in it date from 1250) and were probably visited by Dante, who certainly knew the lake of Circonio (Cerkniza) in which the Javornik is reflected. But the cavern remained undiscovered in modern times until 1818.

The Magdalene grotto is celebrated for the extraordinary subterranean amphibian, Proteus anguinus, first discovered there. It is about a foot in length. lives on snails and worms and is provided aith both lungs and gills.

POSTON, CHARLES DEBRILL (1825–1902), U.S. public official, author and explorer, who played an important role in the history of Arizona, was born near Elizabethtown, Ky., on April 20, 1825. Poston worked as a clerk of the state supreme court at Nashville, Tenn., before he moved in 1850 to San Francisco, Calif., where he served as clerk in the United States customhouse.

In search of harbours and mineral deposits, Poston led an expedition along the eastern coast of the Gulf of California and in southern Arizona in 1853. He attempted to begin silver-mining operations in Arizona but abandoned the enterprise in 1861 because of the threat of hostile Apache Indians. He thereafter worked in Washington, D.C., to win territorial government for Arizona. which was granted in 1863.

In that year Pres. Abraham Lincoln appointed Poston superintendent of Indian affairs for Arizona, and he later became the first delegate to congress from the Arizona territory. He was defeated for re-election in 1864.

Poston, who studied irrigation in Asia and Egypt and traveled widely in Europe, was appointed register of the U.S. land office at Florence, Ariz., in 1878. He later served in various official capacities in the southwest and promoted irrigation programs. He also contributed articles to a number of publications and wrote books based on his extensive travels, including Europe in the Summer-Time (1868) and Apache Land (1878), a volume of poems.

Poston died at Phoenix, Ariz., on June 24, 1902. His body was moved in 1925 from Phoenix to the top of Poston's butte, near Florence. Ariz., where a rock monument was erected in his memory. Poston, who became interested in sun worshiping in India, had attempted to establish a temple to the sun on the site.

POSTULATE. Though the propositions of a particular mathematical discipline, or branch of mathematics, are generally established by proof, there must be some unproved first principles, if the process of basing one proposition on others from which it is proved is not to be an infinite regress. Similarly, although the terms used are generally introduced by definition, there must be some undefined terms. These unproved first principles are the postulates, and the terms not defined are the primitive *terms*.

For example, in the case of Peano's postulates for arithmetic (so called after Giuseppe Peano, who proposed them as first principles of arithmetic, though the postulates themselves are due rather to C. S. Peirce and Richard Dedekind), the primitive terms are "0," "number" (in the sense of non-negative whole number) and "successor" (in the sense that $x+1$ is the successor of x). And the postulates themselves are: (1) 0 is a number. (2) Every number has a number as its unique successor. (3) Two numbers having the same successor are identical. (4) 0 is not successor of any number. (5) If 0 belongs to a class F, and if whenever a number x belongs to F the successor of x belongs also to F, then all numbers belong to F.

These may be expressed in logistic notation (see LOGIC) by using an individual constant 0, and two functional constants N and S ("$N(x)$" to mean "x is a number," and "$S(x, y)$" to mean "y is successor of x"). However, the implicit assumption that it is only numbers that have successors is best represented by defining $N(x)$ to stand for $(\exists y)S(x, y)$ (and $N(y)$ to stand for $(\exists x)S(y, x)$, etc.), so that the number of primitive terms is reduced to two. The statement of some of the postulates may then be simplified, and the second postulate is also conveniently divided into two parts: (1) $N(0)$. (2_1) $S(x, y) \supset N(y)$. (2_2) $S(x, y) \supset$.

$S(x, z) \supset y = z$. (3) $S(y, x) \supset . S(z, x) \supset y = z$. (4) $\sim S(x, 0)$. (5) $F(0) \supset . F(x)S(x, y) \supset_{xy} F(y) \supset . N(x) \supset_x F(x)$. The postulates have to be added to an underlying logic, which in this case must be a functional calculus of at least second order (see LOGIC) to make definitions possible of addition and multiplication of numbers.

According to the view now usual, the postulates constitute a definition of the particular mathematical discipline; and a change of one of the postulates to something different or contrary would not be wrong, but would merely lead to the definition of a different discipline. This contrasts with an older view according to which the postulates of arithmetic or of Euclidean geometry are a priori truths. The abandonment of the older view was brought about largely by the discovery of non-Euclidean geometry (see GEOMETRY and MATHEMATICS, FOUNDATIONS OF), since Euclid's parallel postulate and its contradictory lead to two geometries which not only are equally sound logically but, in the absence of experimental evidence against the Euclidean postulate, would be equally applicable to physical space.

A set of postulates is called consistent if, in the mathematical discipline which the postulates determine, not both A and $\sim$A are ever theorems. A particular postulate is independent if it is not a theorem of the discipline determined by the remaining postulates.

In general, a mathematical discipline based on a consistent set of postulates can be strengthened (without adding to the list of primitive terms) by adding new, independent postulates in various alternative ways. But if the set of postulates is categorical, there is a sense in which this is not possible. See CATEGORICAL.

(Ao. C.)

POSTUMIA, VIA, an ancient highroad of northern Italy, constructed in 148 B.C. by the consul Spurius Postumius Albinus. It ran from the coast at Genoa through the mountains to Dertona, Placentia (the termination of the Via Aemilia Lepidi) and Cremona, just east of the point where it crossed the Po. From Cremona the road ran eastward to Bedriacum, where one branch ran left to Verona and thence to the Brenner, the other right to Mantua, Altinum and Aquileia. The military occupation of Liguria depended upon this road. and several of the more important towns owed their origin largely to it. Cremona was its central point, the distances being reckoned from it both eastward and westward.

POSY (a shortened form of poesy, Fr. *poésie,* "poetry") a verse of poetry or a motto, either with a moral or religious sentiment or message of love. often inscribed in a ring or sent with a present, such as a bouquet of flowers. This may be the origin of the common use of the word for a nosegay or bouquet. It has been suggested that this use is due to the custom of the symbolic use of flowers. Walter Skeat quotes the title of a tract (Richard Heber's manuscript, 1442), "A new yeare's guifte, or a posie made upon certen flowers." Posy rings, plain or engraved gold rings with a posy inscribed on the inside of the hoops, were very frequently used as betrothal rings from the 16th to the 18th centuries. Common posies were such lines as "In thee my choice/I do rejoice," "As God decreed/so we agreed," and the like.

POTASH, the crude potassium carbonate obtained by lixiviating wood ashes and evaporating the solution to dryness, an operation at one time carried out in iron pots—hence the name from "pot" and "ash." The term "potash" or "caustic potash" is frequently used for potassium hydroxide. In fertilizer terminology, potassium oxide (K_2O) is called potash. See POTASSIUM.

POTASSIUM, a silvery white metal with a brilliant lustre, is one of the most reactive of the metallic elements. This property is illustrated when it is dropped into water; hydrogen is displaced and both the hydrogen and the potassium take fire burning with a violet flame that usually culminates in a slight explosion.

Potassium is not found in a free state in nature, but in combined form is distributed in nearly all soils and terrestrial waters and many rocks. It is one of the elements important for the nutrition of plants, and its compounds are contained in most plant and animal tissues.

Potassium chloride is an important fertilizer. Other potassium compounds have a wide range of industrial and pharmaceutical applications. Metallic potassium has few uses, the most important being the preparation of potassium superoxide (KO_2) for the manufacture of protective breathing equipment. In the rebreather gas mask, the KO_2 reacts with the exhaled air to liberate oxygen and remove carbon dioxide and water.

The symbol of potassium is K (from kalium, a Latinized form of the Arabic word for alkali). Its atomic number is 19, chemical atomic weight 39.100.

Historical Background.—The history of potassium is closely linked to that of sodium. Materials containing their compounds, particularly carbonates and nitrates, were known and used in some of the earliest civilizations. Native sodium carbonate was used by the Egyptians for making glass as early as the 16th century B.C.; records originating in lower Mesopotamia and dating from the 17th century B.C. mention the use of saltpetre for making glazes. However, the ancient technicians and artisans who used these materials, having no knowledge of the chemical and physical methods of analysis and identification, did not distinguish between similar sodium and potassium compounds. The terms used were often general and implied the source rather than the chemical content of the material. Alkali (*q.v.*) originally referred only to the matenal obtained from the ashes of plants, sodium and potassium carbonates. The term soda (*q.v.*), of unknown etymology, was first applied to any alkali and later to the ash of sea plants, while the term potash (pot-ash) was applied to the ash of land vegetations, both of which generally contained a greater proportion of potassium carbonate. The two alkalies, soda and potash, were successively designated as natural and artificial and as mineral and vegetable. In the first decade of the 15th century, potassium salts were being produced in Scotland from the ashes of seaweed. Finally in the 18th century, after it was shown that the "mineral alkali" occurred in the ashes of sea plants and the "vegetable alkali" in a number of minerals, the terms soda and potash were properly applied to specific substances. Since the chemical nature of these common alkalies had not yet been determined. they were believed by some to be elements. A. Lavoisier did not include them in his list of elements, "because," he stated, "these substances are evidently compounds, although however, the nature of the principles which enter into their composition is still unknown." This problem was finally solved in 1897 by the brilliant young English chemist Sir Humphry Davy, who decomposed both the alkalies, obtaining the metals potassium and sodium. It was he who coined the word "potassium"—a Latinized version of "potash."

Since potassium is one of the strongest reducing agents known, it cannot be isolated by chemical reduction without resorting to unusual conditions which favour the necessary equilibrium shift and permit the removal of the product from the system as it is formed. It is therefore not surprising that potassium and the other alkali metals were prepared only after the discovery of current electricity (1800) and the subsequent development of electrolytic methods. Davy prepared potassium by the electrolysis of molten potassium hydroxide using platinum electrodes. He described the experiment:

> A small piece of pure potash . . . was placed upon an insulated disc of platina, connected with the negative side of the battery . . . ; and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. . . . The potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower or negative surface, there was no liberation of elastic fluid, but small globules having a high metallic lustre . . . appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained, and were merely tarnished, and finally covered with a white film which formed on their surfaces. These globules, numerous experiments soon showed to be the substance I was in search of and a peculiar inflammable principle the basis of potash.

Occurrence and Production.—It is estimated that potassium constitutes about 2.59% of the igneous rocks of the earth's crust, ranking seventh in order of abundance of elements. Its compounds are widely distributed in the primary rocks, the oceans, the soil, plants and animals. Although nearly as abundant as sodium, it is less accessible, and relatively few workable mineral deposits are available; these contain saline residues formed by the evaporation of inland seas which existed in past geological eras. The principal deposit. at Stassfurt, Ger., contains the following minerals: carnallite, $KCl.MgCl_2.6H_2O$; kieserite, $MgSO_4.H_2O$; polyhalite, $K_2SO_4.MgSO_4.2CaSO_4.2H_2O$; as well as kainite, $MgSO_4.KCl.3H_2O$. Important deposits at Wittelsheim in Alsace and in eastern Galicia, Spain, contain sylvinite, KCl.NaCl. One near Kalusz in the Ukrainian S.S.R. contains sylvite, KCl; langbeinite. $K_2SO_4.2MgSO_4$; and kainite. Additional saline deposits are at Carlsbad, N.M., Cardona, Sp., Searles lake in California, the Dead sea in Palestine, Tunis. Lake Elton in the Urals, and Chile. The above minerals are soluble in water and consequently are easily extracted and readily amenable to chemical operations. They represent, however, only a very small fraction of the total quantity of potassium in the earth's crust, the great bulk of which is found in the igneous rocks.

Potassium occurs as an alkali constituent in a number of alumino-silicate minerals, examples of which are: leucite, $KAl(SiO_3)_2$; muscovite mica, $KAl_3Si_3O_{10}(OH)$, ; orthoclase feldspar, $KAlSi_3O_8$; and biotite, $KHMg_2Al_2(SiO_4)_3$. These and other silicate minerals are insoluble in water and, with the exception of leucite. are not processed for their potassium content. In the weathering of igneous rocks, feldspar. for example, is decomposed into clay and soluble potassium salts; it might be expected that the latter would be ultimately carried to the sea by the surface waters. However, the potassium salts are retained by the soil to a large extent, more so than those of sodium, and are utilized by plants. The retention of the potassium ions by the soil may be a result in part of an ion exchange between potassium and the sodium salt of a complex sodium aluminum silicate which belongs to a class of compounds known as zeolites; *e.g.,*

$$2K^+ + Na_2(Al_2H_4Si_3O_{12}) \rightarrow K_2(Al_2H_4Si_3O_{12}) + 2Na^+$$

Soluble potassium salts which are present in all fertile soils are drawn into the roots of plants and accumulate in the plant structure. In the process of plant metabolism part of the inorganic potassium salts are converted into potassium salts of organic acids (*e.g.,* tartrates and oxalates), which, when the plants are burned, are in turn converted to potassium carbonate. All plant structures are therefore potential sources of potassium compounds. The proportion of potassium present in the total plant or animal organism varies widely, but in most vegetation and in higher animals the potassium content is greater than that of sodium. In sea vegetation the balance is more in favour of sodium, but the potassium content is high and in some seaweeds is in excess of that of sodium. Sugar cane and sugar beets contain significant quantities of potassium salts, but the bulk of it (90%) is extracted with the sugar. The residue pulp from the beet or bagasse from the cane therefore contains very little potassium. However, the molasses remaining after the crystallization of the sugar contains 4%–5% of potassium. In some processes the molasses is mixed with the bagasse and burned as a fuel, and the potassium is recovered from the ash. In others the sugar in the molasses is fermented and the potassium salts concentrated in the vinasse which is the residue liquid from the distillation of the alcohol.

The bulk of the potassium salts of industry is obtained from salt deposits and only a very small fraction (approximately 1%) from plant and animal sources. There remains a vast potential source in the silicate minerals such as leucite, wyomingite and glauconite if economic processes of recovery can be' developed.

A number of processes for the preparation of potassium metal by electrolytic reduction and by chemical reduction have been proposed. In 1808 Joseph Gay-Lussac and Louis Thénard obtained the metal by reducing the hydroxide with iron; the materials, including iron wire or turnings. were packed in a gun barrel which was coated with clay and heated to white heat. During the same year F. R. Curaudau prepared potassium by a somewhat similar procedure in which he'reduced potassium carbonate with carbon:

$$K_2CO_3 + 2C \rightarrow 2K + 3CO$$

This reaction was studied by various chemists during the following 50 years, for it was necessary to devise a method for the separation and rapid cooling of the products in order to prevent the formation of the explosive compound $K_6C_6O_6$. These processes were the forerunners of a number of methods in which potassium compounds were reduced by metals such as magnesium and aluminum, or by calcium carbide, hydride or silicide. With the later development of high-vacuum techniques, the use of calcium for reduction of potassium in a vacuum yields the pure metal; the similar use of sodium vapour as the reducing agent has been fairly successful.

Electrolytic methods include the decomposition of the fused hydroxide, the cyanide and a potassium oxysalt dissolved in a fused potassium halide. The Castner cell, developed in 1890 for the manufacture of sodium (*q.v.*), was modified for the more difficult potassium operation, but the results were not entirely satisfactory.

There is very little. if any, industrial demand for potassium metal, and no extensive manufacturing process is known to be in operation. During the first half of the 19th century, metallic potassium was used to produce aluminum by the reduction of the chloride; magnesium, boron and silicon were produced by a similar method. It was shown in 1854 that sodium, which can be produced more cheaply, would serve as well as potassium for the production of magnesium and aluminum, and sodium was subsequently used for these purposes until electrolytic processes were developed. Similarly, sodium replaced potassium in other industrial processes in which the latter was used.

Properties — Naturally occurring potassium consists of three isotopes of mass numbers 39, 40 and 41 with relative abundances 93.1%, 0.0119% and 6.9%, respectively. The least abundant isotope, K^{40}, is radioactive with a half life of 1.2×10^9 years emitting beta particles (electrons):

$$_{19}K^{40} \rightarrow {}_{20}Ca^{40} + e^{--}$$

and, to a lesser extent, gamma radiation by electron capture:

$$_{19}K^{40} + e^{--} \rightarrow {}_{18}Ar^{40} + \gamma$$

Potassium belongs to the group of alkali metals (Group I of the periodic system) and closely resembles the other elements of the group, lithium, sodium, rubidium, cesium and the short-lived radioactive element francium. The atoms of potassium and the other alkali metals each have a single valence electron which is easily removed whereas the remaining electrons are tightly held by the nucleus in completely filled orbitals. Consequently these elements are the most reactive of all the metals and are the strongest reducing agents known. Their valence or oxidation state is uniformly +1 in all their compounds.

When exposed to air, potassium rapidly tarnishes and becomes coated with a film of oxide or hydroxide. At raom temperatures it is soft and pliable and can be cut with a knife, but below 0° C. it is hard and brittle. The vapour of potassium, which is mainly monatomic, contains a small fraction (about 1%) of diatomic molecules which are indicated by a characteristic band spectrum. The solid metal has a body-centred cubic structure with a = 5.25 A. The vapour of potassium is green and it imparts a violet coloration to the flame of a Bunsen burner. The emission spectrum shows a double line (7,699 Å and 7,664 A) near-the infrared and another near the ultraviolet (4,047 Å and 4,044 Å).

Additional physical and atomic properties are listed in Table I.

Many of the physical and chemical properties of potassium may be correlated with its atomic structure. The difference in the atomic radius and the ionic radius is significant; the volume of the atom is nearly four times as great as that of the ion, the valence electron accounting for nearly three-fourths of the total volume. The potassium atom is the largest of the first 36 elements.

TABLE I.--Properties of Potassium

The valence electron is therefore at a relatively great distance from the nucleus and is easily lost to other atoms in chemical reactions. In the solid metal the valence electrons hold the atoms together; but there are not enough of them to form stable electron pairs, so the binding of an atom to its neighbours is relatively weak and the valence electrons can easily pass from one ion to another. Accordingly potassium is soft, has a low melting point and is a good conductor of electricity.

The chemistry of potassium is relatively simple; it has a valence of +1, it does not form complex ions and it is joined to other elements or groups of elements in its compounds by ionic bonds. Potassium is more reactive than sodium and lithium. It inflames spontaneously in moist air, forming a mixture of oxides. Potassium reacts vigorously with water, liberating hydrogen and forming potassium hydroxide. The reaction is:

$$2K + 2H_2O \rightarrow 2KOH + H_2$$

Potassium reacts with nearly all the electronegative elements, including the halogens, sulfur and phosphorus, forming the corresponding halides, the sulfide and phosphide, respectively; with arsenic and antimony forming K_3As and K_3Sb; and with hydrogen to form the hydride. It reacts with organic compounds containing reactive groups (alcohols, halides, etc.); *e.g.*,

$$2K + 2C_2H_5OH \rightarrow 2C_2H_5OK + H_2$$

and vigorously with acids. When heated gently in the presence of dry ammonia gas, potassium reacts to form the amide:

$$2K + 2NH_3 \rightarrow 2KNH_2 + H_2$$

The amide decomposes into the nitride and ammonia when heated strongly:

$$3KNH_2 \rightarrow K3N + 2NH_3$$

Potassium dissolves in liquid ammonia forming a highly conductive blue solution.

The alloying properties of potassium have not been fully investigated. It does not alloy appreciably with lithium nor with gold, iron, zinc or aluminum. but is mutually soluble with sodium. An alloy containing 22.7% of sodium remains liquid at a minimum temperature of −12.5° C. Potassium reacts vigorously with mercury; a number of compounds of the two elements have been identified, among them KHg_2. A compound of cadmium, $Cd_{12}K$, and one with thallium, KTh, have also been reported.

COMPOUNDS

The compounds of potassium are mostly ionic, and their chemical properties in solution are those of the potassium ion and the respective anions. Practically all the potassium compounds are soluble in water, the exceptions being the perchlorate, $KClO_4$ (slightly soluble); the chloroplatinate. K_2PtCl_6; the acid tartrate, $KHC_4H_4O_6$; the fluosilicate, K_2SiF_6; and the cobaltinitrite, $K_3Co(NO_2)_6$. In this and other respects the salts of potassium resemble those of the ammonium ion, NH_4^+.

Oxides.—Potassium forms three oxides and a fourth of less certain existence has been reported. The monoxide. K_2O, may be prepared by heating the metal in a limited supply of air or by heating the nitrate with potassium:

$$2KNO_3 + 10K \rightarrow 6K_2O + N_2$$

It is a white solid, yellow at high temperatures, and combines with water to form potassium hydroxide, KOH. The peroxide. K_2O_2, an orange-coloured solid, is prepared by the reaction of oxygen and the metal, either dry or in liquid ammonia solution. It is not a common substance for it reacts violently with oxygen to form the superoxide. Potassium superoxide. KO,, the commonest of the superoxides, first prepared by Gay-Lussac and Thénard, is made by heating the metal in air at 180°–200° C. or by treating a liquid ammonia solution of the metal with oxygen at −50° C. It is decomposed by water:

$$2KO_2 + 2H_2O \rightarrow 2KOH + H_2O_2 + O_2$$

and oxidizes carbon monoxide to the dioxide below 100° C. At room temperatures it is an orange-yellow solid which turns black when melted. The melting point is 380° C. and the density is 2.15 g. per cubic centimetre. The compound was for many years formulated as K_2O_4, but X-ray studies show the potassium ions and superoxide ions, O_2^-, to be arranged in tetragonal structure. It is paramagnetic with a susceptibility corresponding to one unpaired electron spin; thus the simpler formula, KO,, is indicated. A trioxide. K_2O_3, has been reported, but its behaviour suggests that it may be a mixture of the peroxide and the superoxide, $K_2O_2.2KO_2$.

Potassium hydroxide, or caustic potash, KOH, was formerly prepared by the reaction of an aqueous solution of potassium carbonate with slaked lime (calcium hydroxide):

$$K_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2KOH$$

The insoluble calcium carbonate was removed by filtration or sedimentation and the hydroxide recovered by evaporation. This was the primitive process whereby the alkali was obtained for soap-making, wood ashes being the source of the carbonate. It was also the standard industrial method until the end of the 19th century, when it was superseded by the electrolytic process. Potassium hydroxide is now manufactured by the electrolysis of an aqueous solution of potassium chloride, whereby chlorine and hydrogen are also produced. The cell used for this electrolysis must be constructed so as to prevent the intermingling of the hydroxide and the chlorine, which react to give the hypochlorite at low temperatures and the chlorate at higher temperatures. The Nelson cell has a graphite anode which is immersed in the salt solution contained in a perforated double-walled steel vessel which serves as a cathode. The vessel is lined with an asbestos diaphragm through which the solution seeps at a rate which prevents the hydroxide, formed at the cathode, from migrating to the anode region. The Castner-Kellner process utilizes a mercury cathode at which the potassium ion is discharged to form an amalgam and the amalgam, in turn, reacts with water to form the hydroxide solution. In either process the chloride and other impurities are removed from the solution containing the hydroxide by crystallization and the hydroxide is recovered by complete evaporation.

Potassium hydroxide is a white solid, stonelike in appearance and brittle with a fibrous crystalline fracture. The density is 2.04 g. per cubic centimetre and it melts at 380° C. It is deliquescent and is sometimes used as a drying agent; if exposed to air, it absorbs water and carbon dioxide. It is very soluble in water; a saturated solution, for example, contains 52.8% of KOH at 20° C. and the solubility increases with the temperature. Solutions of potassium hydroxide are never saturated at the boiling point, which rises steadily with increasing concentration.

Potassium hydroxide is a strong base, being almost totally ionized in dilute solutions. It reacts with the various acids and acid oxides forming the corresponding salts. As it is more expensive than sodium hydroxide, its use, other than for the manufacture of liquid soaps, is somewhat limited.

Potassium hydride, KH, is prepared by the reaction of hydrogen on the heated metal. It is a white, saltlike compound with a density of 1.43 g. per cubic centimetre and possessing a cubic structure of the sodium chloride type. In the electrolysis of the molten hydrides of this type the hydrogen migrates to the anode, indicating that it is the negative ion. The compound is a strong reducing agent, acting violently on water liberating hydrogen:

$$KH + H_2O \rightarrow KOH + Hz$$

It inflames in air.

Potassium carbonate, K_2CO_3, was formerly obtained almost exclusively by lixiviating plant ashes. The first method used to manufacture this salt on an industrial scale was an adaptation of the Le Blanc process, previously developed in France for the production of sodium carbonate. The Solvay process, used to manufacture sodium carbonate, is not applicable to potassium carbonate production because of a difference in the solubility of the two bicarbonates. The crucial reaction in this process takes place because sodium bicarbonate precipitates from a concentrated solution whereas potassium bicarbonate, which is about three times as soluble, does not precipitate under similar conditions.

Potassium carbonate is now made either by the reaction of carbon dioxide on potassium hydroxide,

$$2KOH + CO_2 \rightarrow K_2CO_3 + Hz0$$

or by the Engel-Precht process. In the latter process, carbon dioxide is passed into a concentrated solution of potassium chloride containing a suspension of hydrated magnesium carbonate. A double salt of magnesium carbonate and potassium bicarbonate precipitates:

$$3(MgCO_3.3H_2O) + 2KCl + CO_2 \rightarrow 2(MgCO_3.KHCO_3.4H_2O) + MgCl_2$$

The double salt decomposes when heated:

$$2(MgCO_3.KHCO_3.4H_2O) \rightarrow 2(MgCO_3.3H_2O) + K_2CO_3 + CO_2 + 3H_2O$$

The magnesium carbonate is removed by filtration and the potassium carbonate crystallized by evaporation of the solution.

The density of potassium carbonate is 2.29 g. per cubic centimetre; the melting point, 881° C.; the solubility in 100 g. of water at 0° C., 105.5 g.; and at 100°, 156 g. Anhydrous potassium carbonate is a white, somewhat deliquescent salt. The hydrate, $2K_2CO_3.3H_2O$, crystallizes in monoclinic form from a concentrated solution; below −6° C. the hydrate $K_2CO_3.6H_2O$ crystallizes.

Although stable toward heat, potassium carbonate is decomposed by steam at red heat temperatures:

$$K_2CO_3 + H_2O \rightarrow 2KOH + CO_2$$

When a saturated solution of the carbonate is treated with carbon dioxide, crystals of the less soluble bicarbonate are precipitated:

$$K_2CO_3 + H_2O + CO_2 \rightarrow 2KHCO_3$$

The normal carbonate of a high degree of purity may be obtained by decomposition of the recrystallized bicarbonate at 190° C.:

$$2KHCO_3 \rightarrow K_2CO_3 + Hz0 + CO_2$$

Potassium carbonate is used in the manufacture of hard glass, liquid soaps and numerous inorganic chemicals.

Halogen Compounds.—The halides of potassium and of the other alkali metals are typical salts, predominantly ionic and soluble in water.

A number of their properties are given in Table II.

TABLE 11.—Properties of the Potassium Halides

Property	KF	KCl	KBr	KI
Melting points, °C.	846	768	748	693
Boiling points, °C.	1,498	1,411	1,376	1,330
Densities, g. per c.c.	2 48	1 99	2.75	3.13
Heats of formation, kg. cal. per mole	134.5	104 9	94.2	78.9
Interatomic distances in crystals, Å	2 66	3 14	3 29	3.53

Potassium fluoride, KF, may be prepared by neutralizing potassium carbonate or hydroxide with hydrofluoric acid, and upon evaporation cubic crystals of the salt are obtained. It forms the acid fluoride, KHF_2, when dissolved in hydrofluoric acid solution.

Upon heating the acid salt decomposes:

$$KHF_2 \rightarrow KF + HF$$

The more complex salts KH_2F_3 and KH_3F_4 have been reported. Potassium fluoride, unlike the other potassium halides, forms hydrates, $KF.2H_2O$ and $KF.4H_2O$.

Potassium chloride, KCl, the most abundant of the naturally occurring potassium salts, closely resembles sodium chloride. It is a constituent of a number of minerals found in the Stassfurt and other deposits, some of which are hydrated double salts; *e.g.,* kainite, $MgSO_4.KCl.3H_2O$. Potassium chloride is used for the preparation of many other potassium compounds, including the hydroxide and the carbonate. More than 90% of the potassium chloride produced is used as a fertilizer.

Potassium bromide, KBr, is prepared by the reaction of bromine and potassium hydroxide:

$$3Br_2 + 6KOH \rightarrow 5KBr + KBrO_3 + 3H_2O$$

The bromate decomposes upon heating to form more of the bromide:

$$2KBrO_3 \rightarrow 2KBr + 3O_2$$

Another method of preparation utilizes a solution of ferric and ferrous bromides, a by-product from one of the technical processes for the production of bromine. The iron bromides react with potassium carbonate solution,

$$FeBr_2 + 2FeBr_3 + 4K_2CO_3 \rightarrow 8KBr + Fe_3O_4 + 4CO_2$$

and the ferrosoferric oxide is removed by filtration. Potassium bromide is also obtained from natural brines. It is used in the preparation of photographic emulsions, in process engraving and in medicine as a sedative.

Potassium iodide, KI, is prepared by the reaction of iodine and potassium hydroxide solution:

$$3I_2 + 6KOH \rightarrow 5KI + KIO_3 + 3H_2O$$

Upon evaporation and further heating, usually after the addition of some charcoal, the iodate decomposes, yielding more iodide. The iodate may also be reduced to the iodide in solution by bisulfite ion, stannous ion or a suitable metal such as iron. Iodine dissolves in solutions of potassium iodide by forming the complex tri-iodide, KI_3; higher polyiodide ions containing an odd number of atoms, I_5^-, I_7^- and I_9^-, are formed in very concentrated solutions. Upon evaporation of the KI_3 solution, dark-blue or black crystals of the salt are obtained. Potassium iodide is used in the manufacture of photographic emulsions, in organic chemical syntheses, in animal and poultry feed, in table salt and in some drinking waters. In medicine it is used with iodine for the treatment of hyperthyroidism, and the salt containing radioactive iodine is used in the study and treatment of thyroid cancer. For the oxyhalogen salts see BROMINE; CHLORINE; IODINE.

Sulfur Compounds.—Potassium sulfate, K_2SO_4, a constituent of a number of saline minerals, is a colourless or white compound crystallizing in the rhombic form. Its density is 2.66 g. per cubic centimetre, melting point 1,067° C., refractive index 1.4947 and solubility 24.1 g. per 100 g. of water at 100° C. It is used in fertilizers, as an antiflash agent in smokeless powders and in the manufacture of potassium alums, potassium carbonate and glass.

Potassium bisulfate, $KHSO_4$, is a white, deliquescent substance with a density of 2.4 g. per cubic centimetre and melting point of 210° C. At a high temperature it is converted to the pyrosulfate:

$$2KHSO_4 \rightarrow K_2S_2O_7 + Hz0$$

It is soluble in water, the solution being somewhat acidic because of the ionization of the HSO_4^- ion. Electrolysis of the solution yields the sparingly soluble potassium peroxydisulfate, $K_2S_2O_8$. Potassium bisulfate is used as a flux in the analysis of ores and as a chemical intermediate.

Potassium sulfite, K_2SO_3, is prepared by saturating a solution of potassium hydroxide or carbonate with sulfur dioxide. It exists in the anhydrous form, the monohydrate and the dihydrate, $K_2SO_3.2H_2O$, the latter being the commonest. The solubility of the salt is fairly constant over a wide range of temperature.

Potassium sulfide, K_2S, is a yellow or yellowish-red crystalline substance. It may be prepared by the direct combination of potassium and sulfur or by the reduction of potassium sulfate with carbon or hydrogen. In water solution it is strongly alkaline because of the extensive hydrolysis of the sulfide ion. Upon treatment with sulfur, polysulfides, K_2S_x, with as many as six sulfur atoms are formed. The salt has little use except as a laboratory reagent and a depilatory. See SULFUR.

Potassium nitrate, KNO_3, also called nitre or saltpetre, is a white crystalline salt with a density of 2.11 g. per cubic centimetre, a melting point of 333° C. and a refractive index of 1.5038. It decomposes at 400° C. to potassium nitrite, KNO_2, and oxygen. Since the quantity of the salt obtained from natural deposits is limited, it is prepared by the reaction either of synthetic nitric acid and potassium hydroxide or of naturally occurring potassium chloride and sodium nitrate. It is used in the manufacture of fireworks, gunpowder, fluxes and glass and for curing meats, pickling, tempering steel and impregnating candle wicks. *See* NITRIC ACID AND NITRATES; NITROGEN.

Determination.—Potassium may be identified by its emission spectrum or by the violet colour which its compounds impart to the Bunsen flame; if sodium is present the violet flame is masked and can be observed only through a suitable filter such as cobalt glass. Potassium may be identified and gravimetrically determined in the presence of the alkali metals by precipitation as potassium cobaltinitrite, $K_3Co(NO_2)_6$. Ammonium cobaltinitrite is insoluble and similar in appearance to the potassium salt. It is therefore necessary to eliminate ammonium ion from a sample before testing for potassium. Other gravimetric methods involve the precipitation of potassium perchlorate or of potassium chloride. The flame photometer is also used to quantitatively determine potassium. Another procedure involves the elution of the sample with hydrochloric acid in an ion exchange column. The potassium ion moves through the column at a characteristic rate and the solution carrying it is collected, evaporated and weighed as potassium chloride.

PHARMACOLOGY

The principal salts and preparations of potassium used in medicine are the following:

Potassium acetate has been recommended in cardiac arrhythmias, potassium arsenite solution (Fowler's solution contains 1% of arsenic trioxide) for chronic myelogenous leukemia and psoriasis. Potassium bicarbonate is used as antacid and to alkalize urine. Potassium bitartrate (cream of tartar) has been used as a laxative and dusting powder; large doses can cause renal damage. Potassium bromide is used as a sedative and as an antiepileptic. Potassium chlorate has been used as an astringent in conditions such as stomatitis and Vincent's angina. Potassium dichromate has been used externally as an astringent, antiseptic and caustic; industrial contact may result in ulceration of the hands and destruction of mucous membranes; internally it is a corrosive poison Potassium glycerophosphate has been used as a tonic. Potassium guaiacolsulfonate (thiocol; orthocol) has been recommended as an expectorant. Potassium hydroxide occasionally is used as a caustic; it is extremely corrosive. Potassium permanganate is used as an astringent, antiseptic and oxidizing agent in 1:100 to 1:10,000 solutions; toxic symptoms include emesis, profuse salivation, rapid respiration and albuminuria. Potassium phosphate, monobasic, is used to acidify urine; large doses are cathartic. Potassium sodium tartrate (Rochelle or Seignette salt) is used as a diuretic and as a cathartic. Potassium sulfate is used as a cathartic; it is a powerful irritant, excess doses of which may be fatal. Potassium tartrate (soluble tartar) has been used as a cathartic.

Toxicology.—The symptoms of poisoning by potassium hydroxide or other caustic alkalies are violent pain in the throat, vomiting and collapse. If not immediately fatal, stricture of the esophagus may develop. In emergency treatment the patient is given large amounts of dilute acetic acid (1%), vinegar (1:4), citric acid (1%) or lemon juice, followed by milk or whites of eggs beaten with water. Vomiting should not be induced.

See also ALKALI MANUFACTURE.

BIBLIOGRAPHY.—J. W. Mellor, *A Comprehensive Treatise on Inorganic and Theoretical Chenzistry*, vol ii (1922), T. E. Thorpe, *Dictionary of Applied Chemistry*, 4th ed. by J. F. Thorpe and M A Whiteley, vol x (1950); N. V. Sidgwick, *The Chemical Elements and Thezr Compounds*, vol. i (1950); T. Moeller, *Inorganic Chemistry* (1952).

(J. B. Ps.)

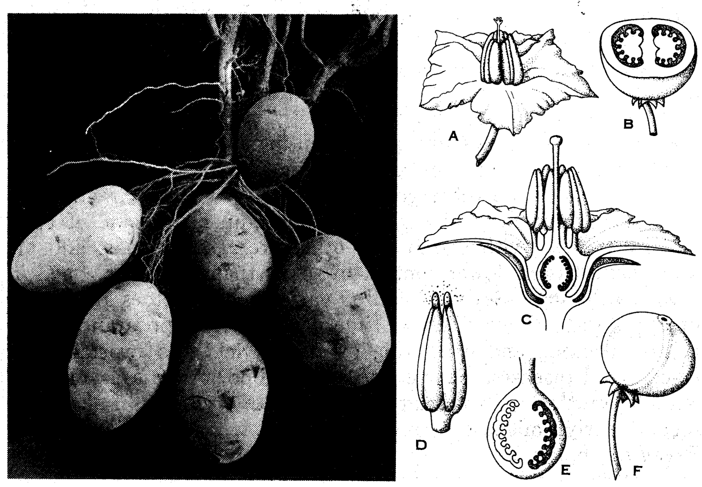
POTATO, white potato or Irish potato, cultivated in North America and Europe for its edible tubers, is *Solanum tuberosum*, one of about 100 tuber-bearing species of the section *Tuberarium* in the genus *Solanum*, one of the largest genera of plants. including also the eggplant and many ornamental and narcotic poisonous plants, of the nightshade family (Solanaceae; *q.v.*). Most of the cultivated potatoes of the Andean region of South America are of the species S. *andigenum*. Other tuber-bearing species resemble wild forms; some are cultivated to a small extent but only in the Andean region.

In this article, unless otherwise specified, "potato" refers to *S. tuberosum*.

This article is divided into the following sections:

I. ORIGIN AND EARLY HISTORY

S. tuberosum apparently originated in the Chilean area of South America. S. *andigenum* and a great many other species originated in the Peru-Ecuador-Bolivia area, where the wild species still abound. All species are native to cool climates, and the cultivated forms require relatively cool and moist climates (a mean annual temperature of 40° to 50° F.). *S. tuberosum*, the cultivated potato of North America and Europe, is best adapted to long summer days, characteristic of the high southern latitude of its region of origin. *S. andigenum* is adapted to short days, characteristic of its equatorial origin. Many species were grown by the Indians of South America before discovery by Europeans.



(LEFT) J HORACE MCFARLAND CO, (RIGHT) FROM BAILLON, "HISTOIRE DES PLANTES" (BONNAIRE)

POTATO (**SOLANUM** TUBEROSUM) SHOWING (LEFT) UNDERGROUND STEMS AND TUBERS. (RIGHT) FLOWER AND FRUIT

(A) Single flower. (B) Fruit cut across to show placenta and developing ovules. (C) Longitudinal section through flower. (D) Ripe anther opening and shedding pollen. (E) Longitudinal section through ovary. (F) Fruit

When potatoes (probably not *S. tuberosum)* were first seen by Europeans in the Andean region in 1537, they were erroneously thought to be truffles. In 1577 Sir Francis Drake found *S. tuberosum* being used by the Indians as a staple food in southern Chile. The species was used as food on Spanish ships soon thereafter. There is, however, no clear record as to when and by whom it was first introduced into Europe. No support is known for the claim that it was introduced into Spain in 1553. Evidence suggests that it was introduced there as early as 1565 to 1570, however, and it was known in Italian gardens in the 1580s. R. N. Salaman cites basis for the belief that Sir Walter Raleigh introduced it into Ireland about 1588. The first description of potato was in John

Gerard's *Herball*, published in 1597. Salaman points out that the illustration Gerard used was a woodcut from Jacob Bergzabern's Neuw Kreuterbuch (1588). Potatoes were introduced into Virginia in 1621 from Bermuda, where they had been taken from England. In 1719 migrants from Ireland took potatoes to Londonderry, N.H., where potato growing in the U.S. got its best start.

II. THE POTATO PLANT

1. Plant Characteristics. — S. tuberosum is a herbaceous annual (two to three feet in height) normally propagated by tubers. Seeds do not produce plants true to variety. Aerial stems are erect or procumbent, with or without axillary branches; stems are round or angular, hairy or smooth, green or tinged with purple. The first leaf is usually simple. other leaves having three or four pairs of large, simple, petioled leaflets and smaller leaflets in between. Leaves are arranged spirally on the stem. Fibrous roots arise in groups of three above the nodes on the stem below ground.

The cymose inflorescences occur at about every sixth axil. Flowers open progressively over several days, are without nectar and are rarely visited by insects. The corolla is wheel-shaped, five-lobed and white, yellow, blue, purple or striped; the five erect stamens borne on-the corolla tube converge around the pistil and discharge pollen by terminal pores. The ovary is two-celled with a single style. The fruit is a globular, brownish-green or purple, inedible berry, usually $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter with many, tiny, smooth, kidney-shaped seeds in the soft flesh.

Lateral stolons extend from axils of the main stem below ground. The ends of the stolons enlarge, forming greatly thickened, succulent, nonwoody, stem structures called tubers. The eyes of the tuber are axils (with the subtended leaf scars of aborted leaves) of this stem, with their terminal and lateral axillary buds. Normally only the terminal bud grows from an eye. but if it is destroyed one or more lateral buds arise. Sprouts normally arise from one or a few eyes at the apical end of the tuber. This apical dominance is destroyed when the tuber is cut into pieces, permitting eyes on each piece to grow. Repeated destruction of sprouts and weakening of the tuber by various means also destroys apical dominance and causes multiple sprouting.

The tuber is covered by a thin, tough, impervious, corky skin. The interior of the tuber contains obscure vascular strands that lie near the surface and lead to the eyes, an outer zone of cells heavily packed with starch and other storage materials and an inner zone having lower content of solids than the outer zone.

2. Varieties. — Several hundred varieties of potatoes are grown in the world. They differ in time of maturity, appearance, skin colour, cooking and marketing qualities, yield and resistance to insects and diseases. A variety that is good in one area may be poor in another. As to maturity, they are classed as first early, second early, midseason and main or late crop. (See Potato Breeding, below.)

III. POTATO CULTURE

1. Seed Potatoes. — For planting purposes potato tubers should be as nearly disease free as feasible because tuber-borne diseases will spread in the field. To minimize disease hazards and ensure varietal purity many countries have established official agencies for inspection of potatoes grown for seed (seed potatoes or seed tubers). The potatoes are certified as being free of certain diseases.

Certified seed is produced in relatively cool districts where diseases are detectable, not being masked by the effects of high temperature. In the U.S. about 25 states produce 45,000,000 to 55,000,000 bu. of certified seed potatoes annually. About half of these are produced in Maine, and Minnesota, North Dakota, Idaho and California produce over 1,000,000 bu. each. In Canada the three maritime provinces produce about 10,000,000 to 11,000,000 bu. annually. Katahdin, Russet Burbank, Red Pontiac, Kennebec, Sebago, Irish Cobbler and White Rose constitute over half the volume of certified seed in the two countries. About 50 other varieties in the U.S. and a dozen others in Canada also are certified.

For planting, tubers must have emerged from dormancy, which in most varieties lasts about two months following harvest. Tubers must have been properly stored and not stored so long as to weaken sprout-producing capacity. Upon harvesting, seed potatoes are stored for two to three weeks at 60° to 70° F. at high humidity to promote development of the corky skin and the healing of wounds, then held at 38" to 40° until three to four weeks before planting time. The temperature is then raised to 50° to stimulate slight sprout development, so that vigorous sprouting can follow promptly after planting.

In some parts of Europe the seed tubers commonly are exposed to light until green sprouts develop before planting, but in the U.S. experimentation showed that there is no advantage to this practice. Cut pieces for planting must contain a bud and should be "blocky" in shape. Tubers or pieces to be planted should weigh at least $1\frac{1}{2}$ oz., preferably 2 oz. Smaller tubers or seed pieces produce less vigorous sprouts and lower yields. Tubers can be cut for seed many weeks before planting if, immediately after cutting, they are held at 60° to 70° F. and high humidity for five or six days to heal the cut surfaces before returning them to cool storage. Such suberization of seed pieces makes them less susceptible to decay than freshly cut seed when planted, and often results in better stands and yields.

2. Soils. — Potatoes are grown profitably on almost all kinds of crop-producing soils except very heavy clays. Deep, friable, rich, moderately acid sandy loams and loams that are high in organic matter are best. Good drainage is essential. Some of the highest yields in the U.S. and some parts of Europe are obtained on loams and mucks, but the highest quality generally is obtained on good mineral soils. The highest yields in England are produced on silt, peat warp and skirty soils. Acid soils of pH 4.8 to 5.3 are desired because scab disease is generally less severe on such soils; yields are low on many alkaline soils.

The soils on which potatoes are grown in different regions are plowed and fitted as they would be for most common farm crops in those regions. They are plowed moderately deeply, eight to ten inches, to cover crop residues and incorporate them into the soil, then disked or harrowed to prepare a medium that is free of clods and trash in which the seed pieces may be planted.

3. Fertilizing. — Fertility of the soil is determined largely by the humus content and by applications of fertilizers. Organic matter or humus is supplied to the soil from crop refuse, rotation with other crops and application of animal manures. In Scotland, England and Ireland, the usual application of animal manure is about 12 tons per acre, supplemented by mineral fertilizers. Seaweed in coastal districts and shoddy or other bulky organic manures in certain other areas in England sometimes replace part of the animal manure. In the United States animal manures are used only on a small portion of the potato acreage, grown by dairy farmers.

Fertilization of the potato crop varies considerably from country to country, state to state and farm to farm with reference to the analysis of the fertilizer and its rate of application. These variations are due to differences in soil type, native fertility of soils, rotations used, soil reaction, rainfall and temperature, varieties used and other factors. Applications of commercial fertilizer in the U.S. and Canada range from none, on some of the rich soils of the west, to a ton or more per acre, depending upon local conditions. The ratios of nitrogen-superphosphate-potash most commonly applied are approximately 1–1–1, 1–2–1, 1–2–2 and 2–3–3. Common analyses of such mixtures in percent are, respectively: 8–8–8, 5–10–5, 5–10–10 and 6–9–9. Fertilizers of higher analyses but similar ratios are used in some districts, especially those requiring large applications. Less fertilizer is used with manure than without manure; often superphosphate only is used with manure. Nitrogen alone may be used on some good mineral soils; superphosphate and potash may be used without nitrogen on some muck soils. Some western soils show no need for added potash.

Responses to Fertilizers. — In western Australia one of the most profitable potato fertilizers proved to be a mixture supplying 200 lb. ammonium sulfate, 800 lb. 22% superphosphate and 100 lb. potassium sulfate per acre. On virgin peat soil 800 lb. superphosphate was found adequate; on old potato soils 400 lb.

gave optimal yields, while on land that had been in pasture 1.600 lb. per acre gave best yields. Potassium is least necessary in that part of Australia.

Nitrogen is of primary importance for high yields of potatoes. Abundant nitrogen produces extensive foliage and prolongs the growing season. With insufficient nitrogen the plants are stunted, leaves are small and light-green colour, the period of growth is reduced and the yields are small. Potato plants producing 400 to 500 bu. per acre contain 120 to 160 lb. of nitrogen per acre. Depending on the native fertility of the soils, soil moisture and other factors, potatoes receive nitrogen applications in commercial fertilizers ranging from none in certain areas in western United States to as much as 160 lb. of nitrogen in some northeastern states.

Response of potatoes to phosphorus applications varies tremendously among potato growing areas. These differences are due largely to the native supply of available phosphorus in some areas in the middle- and far-western United States compared with the eastern and southern areas and also to the large accumulated supplies of phosphorus in some of the eastern soils as a result of annual applications of high quantities of phosphorus. Because of this accumulation from repeated heavy applications more phosphorus is used in some eastern parts of the United States than is necessary for maximum yields.

Potash fertilization for potatoes in the United States varies from none in some of the western areas to as much as 450 lb. K_2O per acre in some portions of the northeast. The chlorine in muriate of potash has a depressing effect on the starch content of tubers and sometimes on the yields when compared with sulfate of potash.

In some of the large potato growing areas of England such as Lincoln and Yorkshire, when the crop follows grain, large quantities of fertilizer are used.. Applications are common of 1,500 lb. per acre of 6–7–10 fertilizer made up of 450 lb. ammonium sulfate, 600 lb. superphosphate and 300 lb. muriate of potash. When potatoes receive applications of animal manures, and in less intensive growing areas where early, second early and main crop potatoes are grown following grain or clover sod, the fertilizer applications are reduced.

Many soils in which potatoes are grown in northeastern United States and along the Atlantic seaboard are deficient in available magnesium for optimum growth of potatoes. These soils are highly acid in reaction. Some of these acid soils, however, do not need magnesium applications, but they respond to additions of calcium in the form of limestone or hydrated lime. Applications of magnesium sulfate are beneficial to the crop in some parts of England. In the United States magnesium in the form of sulfate is sometimes applied as a spray to deficient plants. Soil applications where needed usually are of sulfate of potash-magnesia or of magnesium oxide.

Most soils used in potato production apparently have a sufficient supply of available minor or trace elements and hence do not respond to additions of these elements. On a few soil types, however, and in some limited areas a deficiency occurs and the potato plant responds to applications of one or more minor elements.

Iron deficiency has been experienced in England and has been corrected by spray applications of ferrous sulfate solutions to the foliage.

Manganese deficiency is prevalent in the Fens, Romney Marsh and Yorkshire and occurs occasionally in other parts of Great Britain. Spray applications of 1% manganese sulfate solution at roo gal. per acre supplied the necessary manganese. On neutral sandy swamp soils in western Australia potatoes responded markedly when given five to ten pound-per-acre applications of copper sulfate. The quality of Flava and Ackersegen potatoes was improved by minute applications of boron in Switzerland.

Time and Method of Application.—In most countries of Europe commercial fertilizer is either broadcast after plowing and fitted into the soil before planting or it is distributed in the row just before or after planting. These usually are separate operations as contrasted with the single operation in Canada and the United States of planting and distributing fertilizer in bands on both sides of the seed piece. At the high rates of application used in these countries, this method prevents direct contact of seed piece and fertilizer and therefore avoids burning of the seed or sprout, In some areas of eastern United States, a portion of the fertilizer is applied broadcast before plowing, the remainder being applied in bands through the planter. In some regions of western Europe each of the fertilizers is applied broadcast separately and at different times. The potash is applied in the fall preceding the crop, phosphorus is applied several weeks before planting and nitrogen is broadcast just before or after planting.

4. Rotations and Organic Matter Content of Soils.—It has been shown repeatedly that potatoes grow better in soils relatively high in organic matter. Rotations in which potatoes follow a green-manure crop or one contributing plant residues usually result in increased potato yields. Greatest response to green manures usually is obtained in soils relatively low in organic matter.

Many types of rotations are used in various parts of the world. In some areas in eastern United States potatoes are grown year after year on the same soil. In some parts of Long Island, N.Y., as many as 75 successive crops of potatoes were grown in the same number of years. Rye is usually sown as a cover crop at harvest time and plowed under the following spring. In other eastern areas potatoes are grown in two- or three-year rotations with a small grain, wheat or oats, which has been seeded with one of the clovers, often mammoth red clover. The grain usually is harvested by combine so that nothing but the seed is removed from the field. The clover may be plowed down the following spring as a two-year rotation or allowed to remain the third year and plowed under the next spring. In southern United States soybeans and cowpeas are grown in the potato rotation to supply organic matter to the soil. In western United States potatoes are grown in rotations with alfalfa, sugar beets, sweet clover, small grains or other crops. Many of the rotations containing alfalfa maintain this crop for two to seven years, then potatoes are planted, follo ed by a small grain and then alfalfa again. Dry-land farmers often plant potatoes on summer fallowed land or after some cultivated crop such as beans or corn. Redtop, crimson clover, lespedeza, millet and Sudan grass are often planted in a two-year rotation with potatoes.

As potato growing became more and more a specialized industry, with less being grown by dairymen and general farmers, the rotations became shorter, with potatoes appearing more frequently on the same piece of land.

In England potatoes often follow oats in the rotation. In some areas potatoes follow hay or pasture, especially of wild white clover, and in some sections potatoes follow potatoes. Special crops are also grown for plowing in as green manure, the commonest being rye, Italian ryegrass, rape and vetch.

5. Planting.— In the United States potatoes are planted in nine months of the year. In some of the southern states potatoes are planted in November and December for winter harvest. Later plantings are made in other areas as the season progresses. Most planting is completed by July 1. For the main crop in the northern states, planting should be as early as the soil can be fitted. The critical period in the life of the potato plant occurs when it is developing tubers, and for maximum yields it is necessary that climatic conditions be as favourable as possible during that time. Cool air and soil temperature and ample soil moisture are conducive to maximum growth, setting of tubers and their enlargement.

Virtually all potatoes in the United States are planted with machines. The machine planters are of two general types, the picker and the assisted feed. Two-row planters predominate but there are some one-, three- and four-row planters. The larger planters are adapted only to large, long rowed areas where the land is comparatively level and free of rocks. The rate of planting is determined by the spacing of rows, spacing of seed pieces in the row and size of seed pieces. The rate used is dependent on the natural fertility of the soil, its moisture-holding capacity and the amount of fertilizer that is to be applied. Row spacings in the northern areas of the United States are from 33 to 36 in. In the southern states row spacings often are somewhat greater.

In many parts of Europe planting is done by hand or with machines which require hand labour to place the seed pieces in cups of a chain. The rows are commonly 26 in. apart or less.

As methods of growing improved, space between plants in the row was reduced from about one foot to as close as six to seven inches, especially for producing tubers for seed or to minimize the development of oversize tubers in such varieties as Katahdin and Kennebec which set few tubers per plant. Spacing may be closer where soil and climate favour heavy yields than where medium or light yields generally are obtainable. To plant an acre with two-ounce pieces 8 in. apart in rows 34 in. apart requires 48 bu. of tubers cut into more than 23,000 pieces.

Optimum depth of planting depends on temperature and moisture of the soil, probable weather following planting and mode of conducting field operations later. If planting is shallow, about two inches deep, the soil must be gradually ridged over the row incidental to cultivation. This ensures that the developing tubers are well covered with soil to protect them from light and pests. Early plantings for quick emergence are about two inches deep. Late plantings and plantings for flat culture are about four inches below field level with a two-inch covering of soil. Covering to four inches in depth is completed after the plants have emerged. Shallow planting and quick emergence help avoid losses from rhizoctonia (see Fungus Diseases below). If the soil is hot and dry at shallow depth the pieces should be put deeper, in cooler moist soil.

6. Cultivation. — Potatoes are cultivated mainly to control weeds, but also to break any obstructive crust that may form on the soil surface and to ridge soil over the developing tubers. In some districts the first cultivation consists merely of harrowing the entire soil surface as shallowly as possible just before the plants emerge. In other districts a shallow weeder or cultivator is used. All cultivation must be shallow to avoid injuring the potato roots; working too close to the plants may injure tubers near the surface. Compaction of the soil with heavy machinery and unnecessarily frequent workings are to be avoided. Cultivation should be discontinued at full bloom of the plants or when they nearly meet between the rows. Some cultivation is necessary later to control late-appearing weeds and to move soil over the row to ensure against exposure of shallow-lying tubers.

In some districts weeds are largely controlled by spraying the soil surface with a herbicide before the plants emerge.

7. Effect of Climate on Yield. — The potato tuber is a storage organ, an enlarged stem, and starch is the main material stored. Conditions which favour the formation and storage of starch are necessary for maximum tuber growth. Sugars are formed in the leaves as a product of photosynthesis and starch is synthesized from the simple sugars. The same materials are also used to provide energy for plant growth. Therefore, to have growth and enlargement of the tubers there must be an excess of carbohydrates above that used for vegetative growth.

Rate of photosynthesis is affected by light intensity, temperature, carbon dioxide supply, chlorophyll content of the leaves and stem, and the accumulation of sugars in the tops of the plants. Maximum yield occurs when foliage growth is extensive and rapid early in the season and later declines or ceases; at this time weather conditions should favour photosynthesis, and later the plant should die slowly.

Length of Day. — Long, warm days are most suitable for the growth of tops in the potato. Shorter days are more beneficial for tuber formation. Therefore, conditions most suitable for maximum tuber yields are long days which favour large top growth followed by short days to stimulate tuber formation.

Temperature. — By influencing the rate of photosynthesis and rate of respiration, temperature affects tuber formation and yields of potatoes. Optimum temperatures for tuber formation are from about 59° to 64° F. Usually no tubers are formed above 84° F. In many sections of the U.S. where temperatures during the growing season are above the optimum of 59°–64° there is a negative correlation between temperature and yield. In England and most of Ireland the average growing season temperature is near the optimum. In Scotland it is somewhat lower than the optimum. In some midwestern areas in the United States and in some parts of Australia yields are relatively low, primarily because of the prevailing high temperatures.

There is an interaction between the effect of temperature and day length or photoperiod. By reducing the photoperiod to $10\frac{1}{2}$ hr. tuber formation has occurred at 90° F.

Sunlight. — Little is known regarding the definite effects of sunlight on the growth of potatoes, although it must influence rate of photosynthesis. It is known that shaded plants produce tubers much lower in specific gravity and dry matter than those in normal sunlight.

Rainfall. — In many areas there is a direct correlation between rainfall and yield of potatoes. This is true where rainfall is low and growth of foliage and tubers suffers from lack of moisture. On the other hand, in areas or seasons where rainfall is excessive—interfering with cultivation, waterlogging the soil, etc.—an increase in rainfall may be associated with reduction in yield.

8. Irrigation. — Since rainfall is so important in potato production and since many areas receive insufficient amounts for best growth, irrigation is utilized to supplement this rainfall. In some areas in western United States it is infeasible to try to grow potatoes without irrigation. In these areas furrow irrigation is practised. Furrows are usually made between each row or every other row. On flat areas of heavy soil the furrows should be deep and narrow so that the water will be applied to the soil below the tubers and will not wet the tops of the ridges before it has reached the opposite ends of the rows. Small furrows should be used on steep slopes or in soil that washes badly. Length of the furrows should be determined by the rate at which the soil absorbs water. From three to ten applications are necessary during each growing season. Frequent light applications of water of two to four acre-inches give better results than less frequent heavy applications. All the soil except the tops of the ridges should be kept moist for best growth. In some years it is necessary to irrigate before or immediately after planting to ensure early emergence of the plants. Irrigating in the fall or in early spring before planting is better than irrigating immediately after planting. Some areas in the west also are irrigated by raising and lowering the water table by controlling the water level in ditches spaced 60 to 80 ft. apart. In eastern United States rainfall is often supplemented with irrigation, chiefly the portable pipe sprinkler type. Wells and streams supply the water in these areas.

IV. POTATO DISEASES

Potato diseases are classed according to causal agents into virus, bacterial, fungus, insect, nematode and nonparasitic or physiological diseases.

1. Virus Diseases. — Viruses are often considered to be nonliving chemical entities which are capable of causing disease and capable of reproduction only within the host. They are transmitted from plant to plant by insects and sometimes by other agencies. In almost all cases the disease is perpetuated by tuber propagation. Among the widespread virus diseases of the potato ranking high in importance are mild mosaic or crinkle mosaic, latent mosaic, rugose mosaic, leaf roll, spindle tuber, yellow dwarf and purple top.

Mild Mosaic (Potato Virus A). — This is called crinkle in England. Symptoms are a mottling of leaves with different shades of green, sometimes accompanied by more or less rugosity of the leaf surface. Symptoms are favoured by cool weather and masked at high temperatures. The virus is transmitted by various species of aphids. American varieties which are field resistant are Irish Cobbler, Chippewa, Katahdin and Sebago. These do not become diseased by natural means but can show symptoms if grafted onto diseased plants. Varieties which are very susceptible are Green Mountain, Bliss Triumph and Warba.

Latent *Mosaic* (Potato Virus *X*). — All of the older American varieties and some of those of Europe may be 100% infected but show no visible symptoms. Some of the European varieties, when inoculated, show a severe necrosis of the top with the ultimate death of the plant. These varieties will remain free from the virus except for the individual necrotic plants. Most of the ne er American varieties, free from the virus originally, are infected in varying degrees. If infected with a severe strain of the virus the affected plants show rather severe mottling. The milder strains produce no visible symptoms. The presence of a milder strain usually protects the plant from attack by the severe strains. Spread of the virus is brought about by mechanical means such as the cutting knife or the rubbing together of sprouts or of leaves, etc. Apparently no insect is involved. The severe strains are known to reduce yields and it is possible that the milder ones do also to a lesser extent.

Rugose Mosaic (Potato Virus *Y*).—When this virus is introduced into a healthy plant, the first symptoms are usually necrotic spots on some of the leaves. Later the spotting becomes more extensive, showing as streaks on the back of the veins, on the petioles and on the main stem. The lower leaves become yellow, often with characteristic dark-green circles on them, and drop off completely or remain hanging by a thread. When grown from diseased tubers, the necrotic symptoms are much reduced, the principal symptoms being dwarfing of the plant. rugosity of the leaves, mottling and slight streaking on the veins. Yield is markedly reduced. There are some varieties which carry this virus with little or no symptoms. Spread is by aphids.

Control of Mosaic Viruses.—Certified seed or other seed of low virus content should be planted each year. Plants containing the X virus (latent mosaic virus) but showing no symptoms produce lower yields than virus-free clones of the same variety. In some countries potato stocks free from latent-mosaic and other viruses are selected and maintained.

Leaf Roll.—This is one of the most important and widespread of the potato virus diseases. Current season infection appears first on the upper leaves. The severity of symptoms depends on time of infection; late season infection may result in no symptoms. Secondary symptoms, the result of infection from an infected seed piece, appear first on the lowest leaves when the plants are small. They progress upward on the younger leaves until the entire top is affected. The margins of the leaflets roll or curl upward, the tissues become rigid and leathery and the plant has an abnormally erect habit. Internodes, petioles and stolons are dwarfed, growth is retarded, and the number and size of tubers are reduced. The foliage turns light green and may show a reddish tinge at the margin of the leaf. Tubers of some varieties show net necrosis from current season infection. This shows up as small brown strands at the stem end of the interior of the tuber and extends toward the apical end. Leaf roll is perpetuated by planting tubers from infected plants. It is carried from plant to plant by aphids, the species *Myzus* persicae being most efficient. Use of certified seed, isolation of seed fields, control of aphids and early harvesting of the seed help in control. Development of leaf-roll resistant varieties is in progress in the United States and Europe.

Spindle Tuber.—This disease is widespread in the North American continent but was not reported elsewhere. Tubers from infected plants are often elongated, cylindrical and may be pointed. Plants have an erect habit and the leaves are smaller and more glabrous than normal. Margins of leaflets are fluted. The angle of attachment of the leaves to the stems is more acute than normal. Diameters of stems and petioles are reduced.

Symptoms are more severe in plants grown in wet, hot soil. Infected tubers carry this disease from season to season. It is transmitted by aphids, grasshoppers, flea beetles and tarnished plant bugs, as well as by cutting knives, picker planters and other mechanical means. Use of certified seed is the most practicable method of control.

Yellow Dwarf.—The foliage is yellowish green and the tops are dwarfed or develop into a rosette. Plants may die before or after emergence or may continue a dwarfed growth until normal maturity. Tubers usually are small and misshapen, with small necrotic areas scattered throughout the flesh. Growth cracks often occur. This disease is transmitted by the clover leafhopper. Some varieties such as Warba. Sebago and Russet Burbank appear to have some resistance to this disease. Absence of other host plants such as oxeye daisy in nearby fields helps to control this disease. There appears to be little transmission from diseased potato plants.

Purple Top.—Terminal growth of shoots is retarded and young leaflets roll upward and become rigid in infected plants. These leaflets become pale yellow or purple in colour depending on the variety. Axillary buds start and may become tuberous. Phloem necrosis may occur throughout the tops, roots and tubers. Tubers from affectedplants may be spongy and may produce weak plants or none at all. Few of the tubers produce typically diseased plants. The aster-yellows virus causes this disease and is transmitted by leafhoppers. There is little transmission from potato to potato. Weeds are the source of the virus. No satisfactory control for this disease was developed by the early 1960s.

Other Virus Diseases.—Virus diseases of less importance are calico, witches'-broom, spotted wilt and veinal yellows.

2. Fungus Diseases.—Late blight.—This most serious and widespread of all potato diseases was first recorded in Europe and the United States about 1830. It increased in severity and in 1845–46 almost completely destroyed the crop in Ireland, resulting in the Irish famine. It is most prevalent in the cool, humid regions of the temperate zone. The causal organism is Phytophfhora *infestans,* a parasitic fungus. The first signs of this disease are brownish to black lesions on any portion of the plant tops, principally on the leaves. On the underside of the leaf a white mildew appears on the margin of the lesions. The disease, is favoured by cool, moist conditions and its progress restricted by dry. hot weather.

Tubers may be subjected to infection while in the ground, during harvest and in storage. A brown to purple discoloration of the skin first appears followed by a brownish dry rot which extends under the surface. Infected tubers are the principal source for overwintering of this disease.

Large numbers of microscopic pear-shaped spores are produced on the tiny white threads of this fungus. They are easily detached and carried to other plants by air currents. There, in the presence of water, they germinate by the production of six to ten free-swimming zoospores from each spore. After a few minutes of activity the zoospores come to rest and germinate by the production of a germ tube which enters the leaf. Spores are formed at a relative humidity of 91% to 100% and most abundantly at temperatures of 65° to 70° F. Zoospores form most rapidly at 54° F. and germinate most rapidly at 65° to 70° F. Cool, moist periods thus result in most rapid formation of spores and germination of the zoospores. After infection has occurred, slightly higher temperatures favour rapid growth of the fungus.

Many varieties which are resistant to late blight have been developed by breeding and selection; wild species, such as *Solanum* demissum, have been used for this purpose. The resistant American varieties Placid, Essex, Kennebec and Cherokee are among these. Many physiological races of P. *infestans* have been found. The resistant varieties produced to date are, however, all susceptible to one or more of these races and should be protected with a fungicide when the disease is severe.

Bordeaux mixture has been used for control of late blight in many countries since 1885. This fungicide is effective when the foliage is thoroughly covered by spraying. New growth should be protected by spraying before infection occurs and older growth, from which weathering has removed the fungicide, must receive additional applications. Insoluble copper applications as sprays or dusts also offer adequate protection in many areas. Organic fungicides such as zineb (Dithane Z78 and Parzate) and nabam plus zinc sulfate are also successful in controlling late blight in many areas.

In the Netherlands, England and certain areas in the United States, forecasting late blight epidemics on the basis of current and forecasted weather proved successful in suggesting more timely fungicidal applications. To prevent contamination of tubers during harvest when the disease spores are present, growers often kill the green potato vines before harvest. This is done with sulfuric acid in England and with sodium arsenite, dinitro sprays or with flame throwers and mechanical beaters in the United States.

Tuber refuse, such as culls, from the storehouse should be destroyed by burying, burning or treating with growth inhibitors so that it cannot become a source of infection for the next crop.

Early Blight.—This disease, caused by Alternaria *solani,* appears first as dark-brown to black spots on the leaves. Concentric ridges often form in the dead areas resulting in a characteristic target-board effect. The spots are three or four millimetres in diameter and oval or angular in shape. When the spots are numerous the leaves die. Usually lower leaves are affected first, drying up as the disease progresses toward the top. Slightly sunken, circular or irregular lesions appear on the surface of infected tubers.

Early blight is more difficult to control with Bordeaux mixture than is late blight. Spray applications of the carbamates, nabam plus zinc sulfate and zineb (Dithane Z78 and Parzate) are effective in the control of this disease.

Potato Scab.—Caused by *Streptomyces* scabies, this disease has been known for more than 100 years in Europe and the United States and occurs all over the world. It attacks the surface of tubers and damages their appearance. Sometimes it penetrates two to five millimétres, and is described as pitted scab. It is more prevalent in soils pH 5.2 to 6.5 and relatively scarce in soils below pH 5.0. The organism may live indefinitely in the soil. It is favoured by high temperatures and low moisture in the soil. The young tuber is most susceptible, infection occurring through lenticels, stomata, wounds and through the cuticle.

Varieties differ in their susceptibility to scab. Russet skinned varieties such as Russet Burbank, Russet Rural and Russet Sebago are more resistant than the smooth-skinned Burbank, Rural and Sebago. Other American varieties resistant to scab are Menominee, Ontario, Seneca, Cayuga, Yampa and Cherokee. Resistant European varieties are Jubel, Arnica, Hindenburg and Ostragis.

Seed treatment has been practised for many years to kill the organism on the surface of tubers. Soaks or dips in mercuric chloride, hot or cold formaldehyde and organic mercury dips such as Semesan Bel have been successful. In some soils the presence of mercury increases the severity of the disease. The organism is so widely prevalent in American soils that tuber treatment is of doubtful value. Maintaining soils at about pH 5.0 or lower by avoiding use of lime, adding sulfur or acid-forming fertilizers and the turning under of green-manure crops are useful. Probably the best control is by use of resistant varieties.

Powdery Scab.—This disease, caused by *Spongospora subterranea*, is relatively unimportant in the United States. It is widespread in Europe and parts of Asia, South America, Africa, Australia and New Zealand. It appears as small pustules on the surface of tubers which contain dusty spore masses. These sometimes enlarge to form cankers. In storage, dry rot often follows.

No satisfactory control measures were developed by the early 1960s. Seed treatments used for common scab are sometimes practised. In some countries a search for resistant varieties continues.

Black Wart.—This disease is caused by Synchytrium *endobioticum* and occurs in most countries of western Europe. It occurs in the United States to a slight extent in Pennsylvania, West Virginia and Maryland. It has been restricted to that area in the United States by quarantine measures and planting of immune varieties. This disease may appear as abnormal growth or warts on all underground parts of the plant except the roots. The resting spores may remain viable in soil for many years. Many varieties are immune to this disease. In parts of Europe varieties have been screened for resistance for many years, and only new varieties that are immune may be introduced.

The United States prohibits the entry of potatoes from all countries except Canada and some parts of Mexico, for the purpose of preventing the establishment of black wart and other serious diseases. Those areas in the United States where this disease exists are required to use immune varieties, and export from such areas is not allowed. This disease has been kept under control in Europe by the use of immune varieties.

Verticillium Wilt.—Caused by Verticillium *albo-atrum,* this disease often is confused with other diseases in which wilt occurs. The lower leaves often turn yellow as a first sign. The internodes are short, resulting in a rosette of the top, and upper leaves fold inward toward the midrib. Wilting usually occurs. The vascular system of the lower stem discolours and browning occurs in the stem ends of some of the affected tubers. It results in early dying of tops and reduces yields. This disease is borne in the tuber from one generation and location to another and survives in soil and diseased plants. It may be spread from plant to plant during the growing season by root contact. Disease-free seed is difficult to obtain by roguing.

The disease is rapidly increasing in severity in some parts of the United States and is important in some areas of eastern Canada and eastern and northwestern United States. Rotation and use of resistant varieties are recommended for control.

Fusarium Wilts.—Wilts are caused by Fusarium *oxysporum* and F. solani var. *eumartii*. The disease caused by the first is almost identical as to symptoms with that caused by Verticillium. The wilt caused by F. solani var. eumartii shows also a bronzing and withering of upper leaves, black internal lesions at the nodes of stems and in the interior of tubers and a tuber rot, usually starting at the stem end. Although infection may take place either from the soil or from the seed, soil infection appears generally more important. Discoloration of the vascular tissues in underground stems and in tubers occurs in all the wilt diseases. Rotation and use of certified seed are suggested control measures.

Fusarium Tuber Rots.—Several species of Fusarium cause tuber rots. The rots are soft and wet or dry and powdery, depending more upon the conditions of the environment than the species of fungus. The fungi are soil-inhabiting and the spores are introduced into the storages in the soil adhering to the harvested tubers. The fungi enter the tubers through small wounds made in handling or through cuts made in preparing seed for planting. The best control for these rots is to avoid injuries to the tubers. Healing of wounds may be hastened by maintaining a high humidity and a temperature of 65° to 70° F. for several days after harvest. Treating potatoes with a chemical to destroy the spores before cutting seed is sometimes practised.

Rhizoctonia (Black Scurf).—This disease caused by *Pellicularia filamentosa* (formerly Rhizoctonia solani) is world-wide in distribution and is most conspicuous on the surface of tubers as brown to black spots (sclerotia) resembling areas of dirt. Rarely does this disease penetrate the tuber. The tips of potato sprouts are very susceptible to infection by this organism, and in some instances they are killed before appearance aboveground. Often this results in poor stands in potato fields. Lesions or stem cankers occur on the stems of infected plants. When these are extensive, they interfere with the normal downward flow of carbohydrates to the tubers, there is accumulation in the tops, resulting in stunting, rosetting and formation of aerial tubers in the leaf axils.

This fungus lives in the soil and on the surface of tubers from season to season. Seed treatment with chemicals used for common scab control has been used for control of the disease but is no longer recommended generally. Value of seed treatment is limited because of the disease which remains in the soil. Shallow planting of seed tubers reduces sprout injury and stem cankers, resulting in better stands of plants. The seed pieces gradually are covered deeper by cultivation after the sprouts have emerged.

Other Fungus Diseases.—These include leak, pinkrot, gray mold, skin spot, silver scurf, black dot, Phoma, charcoal rot, powdery mildew, rust, Sclerotinia, southern blight and violet root rot.

3. Bacterial Diseases.—Black Leg.—Caused by *Erwinia* atroseptica, it affects growing plants and tubers in storage, and is called black leg because the base of the stem becomes shriveled and blackened. Plants become rigid and upright and sometimes show a yellowing, particularly of the lower leaves. Growth is retarded. If the young tubers become infected through the stem end, soft rot of the pith occurs. Large plants sometimes show a black soft rot of the aboveground portions of the stem.

The organisms live in the soil, in decaying plants and sometimes in the tubers. Infection usually occurs through wounds in the tuber or through lenticels. The fly and larva of the seed-corn magot, and possibly other flies, are active in spreading this disease. Heat damage, sunscald and freezing injury make the tubers more susceptible to infection. Commercial washing of potatoes often favours soft rot development in subsequent transit.

Preventing bruising of potatoes, protecting tubers from the sun, chlorinating the wash water and drying potatoes after washing help to control storage decay. Healing of wounds by holding potatoes several days at high humidities and 65° to 70° F. also reduces decay loss. Avoiding exposure of cut seed potatoes to light or to insect infestation is recommended. Control of black leg on the plants may be effected by destroying potato refuse piles.

Brown Rot (Southern Bacterial Wilt).—Caused by *Pseudomonas* solanacearum, this is common in tropical countries and in southeastern U.S. Leaves wilt, turn a bronze colour, shrivel and die. Cut stems and tubers exude whitish bacterial masses from the vascular system. Bacterial masses also may exude from the eyes of tubers. Decay of the tuber continues after harvest and the symptoms may simulate those of ring rot. The disease is favoured by high soil moisture and soil temperature.

Since the disease may be spread by infected tubers, seed should not be used from affected areas. Use of certified seed is recommended. In some sandy soils it is possible to control this disease partially by adding sulfur to obtain a pH of 4.0 for several months, followed by lime to attain a pH of 5.0 before planting. Use of partially resistant varieties such as Sebago, Katahdin and Chippewa also is suggested.

Ring Rot.—This rot is a result of infection with *Corynebacterium* sepedonicum. Known in Europe for many years, it was first reported in the U.S. in 1932. The symptoms are similar to those of brown rot. First symptoms are a pale yellow chlorosis between the veins of the leaves. Margins of the leaves die, and the plant is stunted and withers. There is little discoloration of stem tissues. If the underground stem is cut, a milky exudate can be squeezed out. A light yellow vascular discoloration shows up first in the tuber. The affected tissue has a soft cheesy consistency. The tissue of the vascular ring may turn brown and break down, forming cavities which may extend to the pith and cortex and show up as lesions on the surface of the tuber. This disease organism lives primarily in tubers from season to season but also carries over on cutting knives. crates, sacks, storage bins and harvesting and grading machinery. It enters tubers through wounds. It probably is spread in the field by irrigation water and is spread from plant to plant through adjoining root systems. Tubers may carry the organism internally and yet produce infected plants and tubers that show no symptoms if growth has occurred at continuously cool temperatures.

In the United States use of certified seed should help in the control since no visibly infected plants or tubers are permitted in certified seed. Any ring-rot infection should be followed by disinfection of storage house, planters, diggers. cultivation machinery. crates, bags and sorting equipment. Formaldehyde or copper sulfate may be used for disinfection. Disinfection of the cutting knife with boiling water or mercuric chloride also is desirable. Resistant varieties such as Teton may be used.

4. Insect Pests.—The potato is attacked by more than 100 kinds of insects; the following, however, probably cause the most widespread damage: aphids, flea beetles, leafhoppers, wireworms, Colorado potato beetles, potato tuberworms, nematodes and psyllids.

Aphid.—The green peach aphid, Myzus persicae, and potato aphid, Macrosiphum *solanifolii,* are common on potatoes. Both the adults and their young suck the sap from potato foliage, causing the leaves to curl downward. They usually feed on the lower sides of leaves and move very slowly and only short distances unless carried by the wind. They transmit the virus diseases of mild mosaic, rugose mosaic, spindle tuber, leaf roll and unmottled curly dwarf from plant to plant.

The adult potato aphid is about $\frac{1}{8}$ in. long and may be green or pink; the adult green peach aphid is much smaller and is greenish or yellowish green. Most aphids are wingless.

Sprays of wettable powder, or emulsifiable concentrate of parathion or parathion dusts are recommended for control of aphids. They should be applied at a rate of seven ounces of parathion per acre, and the insecticide must reach the undersides of the leaves. It must not be applied within five days of harvest.

Flea Beetle.—The potato flea beetle, *Epitrix cucumeris,* chews small holes in the leaves, giving them a shot-hole appearance. Badly eaten leaves wither and die, thereby resulting in reduced yields of tubers. Flea beetles carry unmottled curly dwarf and spindle tuber diseases from one plant to another. The larvae also scar the surface of potato tubers, sometimes boring into them. Adult flea beetles usually are shiny black and $\frac{1}{16}$ to $\frac{1}{8}$ in. long. They hibernate as adults in soil, grass or weeds. They have from one to four generations a year. Control measures for adult flea beetles are the same as those for Colorado potato beetles (see below). Larvae are controlled by applying two pounds per acre of dieldrin or two to three pounds per acre of aldrin or heptachlor to the soil surface and working it in before planting.

Leafhopper.—This pest, Empoasca fabae, is a pale green, wedge-shaped insect about $\frac{1}{8}$ in. long which feeds mostly on the undersides of leaves. The adults and nymphs suck the sap from leaves and stems, weakening the plants. They also introduce a toxic secretion into the plant which results in hopperburn. The tips and margins of the leaves curl upward. turn yellow and become brown and brittle. Entire fields may be destroyed as if by hot, dry weather. The adults overwinter under leaves, weeds and trash and have two to four generations a year.

Methods of control are applications of DDT, the same as for control of the Colorado potato beetle.

Wireworms.—Two species, wheat wireworm, Agriotes mancus, and eastern field wireworm, *Limonius agonus,* are major pests of potatoes. Larvae of wireworms feed on potato seed pieces and also chew deep holes in the developing tubers, often making them unmarketable. Adults of wireworms are slender, hard-shelled snap or click beetles $\frac{1}{4}$ to $\frac{1}{2}$ in. long. The larvae are yellowish to orange, from $\frac{1}{2}$ to 1 in. long and have jointed bodies. They do most damage on light sandy loam soils and prefer areas where it is cool and moist. They live for several years, feeding in the upper layers in spring and summer and going deeper in the soil during winter.

The wheat wireworm thrives especially in fields planted to sod or hay crops, and clean cultivation gradually reduces its numbers. The eastern field wireworm, on the other hand, thrives in clean cultivated areas. Earlier methods of control were by proper rotations and clean cultivation. Later, however, it proved more efficient to control it with soil applications of insecticides. Four to ten pounds of chlordane or three pounds of dieldrin or of heptachlor per acre sprayed on plowed land and then worked into the top four to six inches of soil just before planting give good control of this pest.

Colorado Potato Beetle.—This insect, Leptinotarsa *decemlineata,* is one of the most widespread pests in the United States and Canada but is becoming of lesser importance as the result of good control measures. It is much feared in western European countries and quarantined areas have been established against it. Adults and larvae, but largely the latter, feed on the leaves and if not controlled may consume all of the leaves, with only the stems remaining. They also are known to spread brown rot, spindle tuber and ring rot.

The adults are hard-shelled beetles about $\frac{3}{8}$ in. long and $\frac{1}{4}$ in. wide with black and yellow stripes extending lengthwise on their wing covers. Orange-yellow eggs are laid on end in masses on the undersides of leaves. The larvae or slugs are dark red with black spots and become orange coloured with age. The adults spend the winter in the ground. There are from one to three generations a year.

Sprays of 50% wettable powder DDT at 2 lb. per acre or 2¼ to 3 pt. of 25% DDT emulsion per acre usually prove effective in control. Five percent DDT dust at 20 to 35 lb. per acre also is recommended. In some areas this pest has developed a resistance to DDT. The recommended control under such conditions is spray applications of $\frac{1}{4}$ to $\frac{1}{2}$ lb. per acre of dieldrin or $\frac{1}{4}$ to $\frac{3}{4}$ lb. per acre of heptachlor.

Potato Tuberworm (Gnorimoschema *operculella).*—This attacks foliage and tubers both before they are dug and in storage. It has been found in more than one-half of the states of the U.S. The adult is a gray moth about $\frac{1}{4}$ in. long with dark-brown wing markings. The larvae tunnel in the midrib of the leaf and in the stem. They also burrow just under the skin or tunnel into the flesh of tubers.

Several control measures are recommended. Spray or dust applications of DDT similar to that for control of colorado potato beetles and leafhoppers will destroy larvae on the foliage. The walls of storage houses also should be sprayed with DDT. Since the moths lay eggs on exposed tubers the rows should be well hilled and tubers should be picked up promptly after digging.

Potato *Psyllid*.—This insect, Paratrioza cockerelli, is destructive in certain areas in western United States. The nymphs suck juices from the leaves and inject a substance into plants that causes a curling and yellowing of the leaves known as psyllid yellows. The first symptoms are curling of the basal portion of terminal leaflets and a change in colour from green to light green or yellow. Curling continues and the leaves become leathery reddish-purple, and the plant is stunted. The set of tubers is increased but growth is retarded and tubers remain small. Sometimes aerial tubers appear in the axils of leaves.

Starting when plants are six inches high, three to four applications of DDT given at 10- to 14-day intervals proves effective as a control. As a spray 2 lb. of 50% wettable powder DDT per acre or 20 to 35 lb. of 5% DDT dust is recommended.

Nematodes.—The nematodes (very small roundworms which live in soil or water) of known importance as pathogens on potato are the root knot nematode, golden nematode, tuber rot nematode and meadow nematode. They may cause serious damage to roots and tubers. Chemical fumigation of the soil seems to be the most feasible control.

5. Nonparasitic Diseases (Physiological Diseases).—Low Temperature Injuries.—Freezing or frost injury may occur by low temperatures just before or during harvest and also later in insufficiently protected storages or during transit. If very low temperatures are prolonged the tubers become soft and watery and subject to bacterial action. At temperatures between 28° and 30° F. injury may appear as ring necrosis, net necrosis or blotch necrosis. Ring necrosis consists of brown or black discoloration in the vascular ring, most often appearing at the stem end of the tuber. Net necrosis consists of darkening of scattered strands of phloem which are toward the interior of the tuber within the vascular ring. Blotch necrosis consists of irregular dark, fairly large areas usually near the exterior of the tuber. Prolonged exposure to temperatures as high as 35° F. may result in injury similar to the above or in mahogany browning.

High Temperature Injuries.—Greening and scalding of tubers may occur when they are exposed to the rays of the sun. Severity of injury depends on light intensity, temperature and exposure time. Chlorophyll accompanied by an alkaloid, solanine, will appear as a green area on the surface of tubers exposed to light. This results in a bitter taste of the tuber. If the temperature and the light intensity are high, scalding of the tuber exterior may occur after several hours exposure. Breakdown on drying out of the affected area may follow and bacterial soft rot often is initiated.

High soil temperatures sometimes result in tubers with internal necrosis, brownish dead areas scattered throughout the interior of the tuber.

Blackheart.—This results when cells in or near the centre of a tuber cannot secure an adequate supply of oxygen. The cells degenerate, stimulating a process which results first in a reddish-brown discoloration which gradually blackens. This condition sometimes develops in overheated cars in transit or overheated storages. Poorly ventilated storage bins also may initiate the occurrence of this defect. At high temperatures, air cannot penetrate the compact tissue of the tuber rapidly enough to supply oxygen at the rate it is needed for the higher rate of respiration which accompanies the high temperature. As a result the tissues break down and turn dark.

Hollow Heart.—This name is given to the defect in which the tissue of the interior of the tuber splits or dies, forming a cavity or space. It occurs most commonly in large tubers; its cause and prevention are not well known.

V. POTATO BREEDING

The potatoes that were brought to Europe from Peru and Chile in the latter half of the 16th century bad very irregularly-shaped tubers, disfigured by outgrowths and extremely deep eyes. These varieties were the rule until the earlier part of the 19th century. In the hands of plant breeders the shape, colour and quality were much improved. Most of the improvements were made after 1845, when potato diseases focused attention on the crop. In that year potato blight reached Europe and became so destructive in Ireland as to cause a famine and much loss of life. This gave an impetus to the search for varieties resistant to disease. Perhaps the first and most important new seedling in Great Britain was the variety Victoria, raised and introduced by William Paterson of Dundee. It was the parent of many other great potatoes later produced, including Champion, Up-to-Date, Great Scot and Ninetyfold. Simultaneously and for the same reasons there was great activity in the production of new varieties in the United States. C. E. Goodrich of Utica, N.Y., conceived the idea that the disastrous epidemics of late blight during the years 1843–47 were the result of a reduction in the vigour of the plants. Though he did not succeed in the control of late blight, he laid the foundation of potato breeding in the United States by furnishing material to be used by other breeders. The ancestry of 170 varieties can be traced back to Goodrich's Garnet Chili, a seedling of the imported Rough Purple Chili. They include several well known varieties of commerce such as Burbank, Early Ohio, Green Mountain and Triumph. The Magnum Bonum, a popular potato of England and north European countries, was bred from Early Rose by J. Clark of Christchurch, Eng. Clark also grew Abundance, Epicure and Ninetyfold, varieties still of some importance.

The second wave of potato blight came in 1870 and caused much destruction in the existing varieties. Breeders concentrated on securing more resistant forms. Nicol of Arbroath then introduced the Champion, a high yielding resistant variety, which soon was largely grown throughout Scotland and Ireland and in time in most potato districts of the world.

Archibald Findlay of Scotland was successful in developing many varieties, including Up-to-Date and British Queen. The Up-to-Date, especially, made both Scotland and Ireland famous for potatoes, and this variety was exported to all parts of the world. From 1907 to 1928 Donald McKelvie was active as a potato breeder; his Arran Chief, Arran Banner, Arran Comrade and Arran Consul became popular in many places. German breeders raised Richter's Imperator, the President and Paulsen's Juli, all of such merit as to justify wide cultivation. The work of C. G. Pringle of Charlotte, Vt., is said to represent the first systematic effort to obtain seed by controlled hybridization. His varietal contributions were the Alpha, Adirondack, Rubicund, Ruby and Snowflake.

Early in the 20th century a number of varieties immune to wart were bred in Europe.

When potato breeding was actively undertaken by the U.S. department of agriculture in 1910 under the direction of William Stuart, the only disease resistance sought was that against the late-blight fungus. It was not until some years later that it became evident that the virus diseases were a greater menace to potato production than late blight. It was soon realized that the widespread occurrence of potato virus diseases such as the various types of mosaic, leaf roll, spindle tuber, curly dwarf, yellow dwarf and streak could be controlled only by the breeding mode of attack. The first step in this direction was toward the development of varieties resistant to one of the commonest of these diseases, mild mosaic. Seedlings that showed some resistance to virus infection were selected by Charles F. Clark, who became associated with Stuart in this work. Clark crossed the resistant seedlings with one another and with other seedlings and varieties. As a result a number of new varieties with a high degree of resistance to mild mosaic, with desirable tuber characters, good habit of vine growth and relatively high yield were distributed to growers. Katahdin, Chippewa and Houma were the first of these.

While this work was being carried on by the department of agriculture a few of the state experiment stations, especially at Minnesota and Cornell universities, had undertaken potato breeding work. It was soon realized that problems and objectives in this field cut across state lines and involved large regions of the entire country. It was therefore decided in 1928 to organize the work as a national project with all interested state experiment stations and the United States department of agriculture co-operating. Material was sent also to any foreign country requesting it. Under the direction of F. J. Stevenson, who took charge of the project in 1930, a number of varieties were developed and introduced. The expansion in the organization greatly increased the number of problems attacked. The so-called economic characters such as yield, time of maturity, depth of eye, shape of tuber and culinary quality were given primary consideration, but intensive work was done also on resistance to various diseases and insect pests. Resistance was obtained to the virus diseases such as mild mosaic, latent mosaic. veinbanding, leaf roll and yellow dwarf. Immunity from late blight was found in many hybrid seedlings of the wild species, *Solanum demissum*, crossed with cultivated varieties of *S. tuberosum*. Resistance to this disease was found also in some of the cultivated varieties themselves and in a number of progenies obtained from Germany. The latter may be related to *S. demissum*. Seedling varieties highly resistant to common scab under a wide range of environmental conditions were produced. Varieties tolerant to Fusarium wilt also were produced. Many of the new productions were resistant, if not immune, to potato wart. Resistance to brown rot and ring rot were found to be inherent in a number of varieties and progenies. Wide differences were found between varieties and seedlings in their reaction to injury by the insect pests, leafhoppers, flea beetles and psyllids.

The principal commercial varieties in the United States were for many years those originated in the middle and late 19th century. These arose as mutations or sports, as chance seedlings, or as a result of crossbreeding. Some of these are still grown in large acreages. Early varieties are Irish Cobbler, Triumph and Early Ohio, and some of the late varieties are Green Mountain, White Rural. Russet Rural, Russet Burbank and White Rose. After 1930 a number of new varieties were originated and distributed to growers under the National Potato Breeding program and independently by some state agricultural experiment stations. Among these are early varieties such as Mesaba, Warba, Red Warba, Chippewa, Pawnee, Kasota, Cherokee, Progress, LaSoda, Early Gem and White Cloud. Late varieties are Katahdin, Sebago, Houma, Mohawk, Pontiac, Red Pontiac, Sequoia, Menominee, Erie, Kennebec, Ontario. Teton and Canoga.

D. Reddick of Cornell university (Ithaca, N.Y.) bred and introduced a number of late-blight resistant varieties, some of which are Empire, Chenango, Essex, Placid, Cortland, Madison, Snowdrift, Virgil and Harford.

In England the leading main crop variety is Majestic, followed by King Edward VII, Arran Peak, Gladstone, Arran Banner and Redskin. Kerr's Pink is by far the most popular variety for table stock in Scotland; others are Redskin and Golden Wonder. In Northern Ireland, Arran Victory is most popular, others being Kerr's Pink, Arran Banner, Arran Peak, Arran Consul and Gladstone. Most popular early varieties in England are Great Scot, Dunbar Rover, Epicure, Arran Pilot, Home Guard, Duke of York, Eclipse and Sharpe's Express. British Queen is most extensively grown in Scotland and Northern Ireland.

VI. COMPOSITION, NUTRITIVE VALUE, COOKERY

1. Chemical Composition of the Potato.—While there are differences in chemical composition among varieties, a much greater variability occurs within any one variety as a result of conditions under which potatoes are grown. Every factor which affects growth of the potato also influences its chemical composition. Therefore, only approximations to average composition of tubers can be given. The following may be taken only as an example: dry matter 18% to 28%; starch 12% to 20%; total carbohydrate 15% to 23%; protein 1 3% to 2.7%; ash 0.64% to 1.3%; fat. trace to 0.5% and crude fibre 0.33% to 1.0%. The following amino acids are found in the potato: lysine, tyrosine, cystine, histidine, arginine, tryptophane, proline, alanine, valine, leucine, phenylalanine and glutamic acid. The following minerals and trace elements are reported in the ash of potatoes: phosphorus, calcium, magnesium, sodium, potassium, iron, sulfur, chlorine, zinc, bromine, copper, boron, silicon, manganese, iodine, lithium, arsenic, cobalt, nickel and aluminum. The total carbohydrates are made up largely of starch, reducing sugars and sucrose. The following organic acids also are found: oxalic, citric, succinic, malic and tartaric. A number of enzymes, several pectins and solanine also are reported. Most of these constituents undoubtedly have an effect on mealiness, colour, flavour and nutritive value of the potato.

2. Nutritive Value of the Potato.—Potatoes are a good source of energy as measured by calories provided and also of vitamin C and several of the necessary minerals. From 100 g. of potatoes with 25% loss in peeling the following food value will be obtained after they are boiled but nothing added to them: 12 g. starch, 0.23 g total nitrogen, 0.04 g. fat, 300 mg. potassium, 35 mg. phosphorus, 9 mg. calcium, 0.65 mg. iron, .0075 mg. vitamin A, .055 mg. vitamin B_1, .008 mg. riboflavin, .3 mg. nicotinic acid and 15 mg. vitamin C or ascorbic acid. Fifty-two calories would be supplied by this portion of boiled potato.

3. Cooking Quality.—Cooking quality is comprised of (1) consistency, texture or degree of mealiness, (2) colour of flesh after cooking and (3) taste or flavour. In the United States and England and several other European countries most consumers desire a mealy potato when it is boiled, steamed or baked. In many other countries a firm or soggy texture is desired. All prefer a white or golden yellow colour of flesh after boiling. A light, golden brown colour of French fries and chips is preferred. A mild flavoured potato probably is preferred by most consumers. High dry matter potatoes are best for baking, French fries, potato chips and dehydrating. Low specific gravity tubers are better for canning since they are not likely to fall apart during processing.

Factors which affect mealiness of potatoes include variety, soil moisture, soil type, amount and analyses of fertilizers applied, date of planting, date of harvest. mulching, temperature during the growing season, especially during the last few weeks, spray program for control of insects and diseases and method of vine killing. In the United States millions of bushels of potatoes are purchased on the basis of specific gravity for potato-chip processing. The potato hydrometer is used for this purpose. Experiments show that it is feasible to separate potatoes by salt solutions into groups that will be mealy when cooked and other groups which will not slough or fall apart when boiled. After-cooking darkening of potatoes is influenced by such factors as variety, growing season temperature, amount of sunshine, fertilizers and maturity of the tubers.

4. Potato Processing.—Millions of bushels of potatoes are processed annually in Europe into starch, alcohol, potato meal, flour, dextrose and other products. Few are processed into potato chips, dehydrated mashed potatoes. French fries and canned potatoes. In the United States. on the other hand, comparatively little potato flour and very little potato starch are made and in normal times practically no alcohol, dextrose, meal, etc. About 40,000,000 bu. are utilized annually for making potato chips, frozen French fries, canned and dehydrated potatoes. For potato chips alone more than 30,000,000 bu. are used annually.

VII. WORLD PRODUCTION AND TRADE

In volume of fresh product, the potato ranks first among the world's most important food crops. It is grown in almost every country in the world. It is of greatest economic importance, however, in countries of the north temperate zone where it is relatively cool during the growing season. It is well adapted to the countries of northern Europe, and production and yields are considerably higher in several of these countries than in the United States and Canada. Over 90% of the potato crop of the world is grown in Europe. Yields in northern European countries are also higher than those of warmer climates in the southern part of the continent.

Potatoes enter extensively into international trade. In the 1950s the Netherlands, Germany, Denmark, Ireland and Italy exported more potatoes than they imported. England and Wales produced large quantities but not sufficient to supply the wants of their population. Much of this demand was supplied by shipments from Scotland and Ireland, where growing conditions are excellent, and an excess is produced. Some countries both export and import, the exports sometimes consisting of seed potatoes and the imports of early crop potatoes grown in an area where they are marketed before the home crop is ready. Such is the usual situation between the United States and Canada, although some main crop table stock also is sent to the United States from Canada.

Large quantities of potatoes in Germany. the Netherlands, Ireland and other northern countries of Europe are grown specifically for manufacture of alcohol, starch, potato meal or flour and for livestock feeding. Only the excess crop and culls are used for such purposes in the United States and Canada. European countries also consume for human food much larger quantities of potatoes than the United States and Canada.

BIBLIOGRAPHY.—United Nations' Food and Agriculture Organization, *Monthly Bulletin of Agricultural Economics and Statistics,* vol. 3 (1954) ; Ora Smith, "Potato Production," *Advances in Agronomy,* vol. 1 (1949) ; G. V. C. Houghland *et al.,* "Potato Production in the Northeastern and North Central States," U.S. Department of Agriculture, *Farmers' Bulletin 1958* (1954) ; W. G. Burton, *The Potato* (1948); Tatham Whitehead, Thomas P. McIntosh and William M. Findlay, *The Potato in Health and Disease* (1953) ; John Charles Walker, *Diseases of Vegetable Crops* (1952) ; J. E. Dudley, Jr.. B. J. Landis and W. A. Shands, "Control of Potato Insects," U.S. Department of Agriculture, *Farmers' Bulletin 2040* (1952).

(H. A. J.; F. J.S.; O. SH.; V.R.B.)

POTATO LIFTER: see HARVESTING MACHINERY.

POTATO RACE, a contest in which the winner is the first who collects in a basket or other receptacle a number of potatoes, usually eight. placed two yards apart along a straight line, and then crosses a line five or ten yards farther on.

POTATO SPIRIT. The replacement of grain by potatoes as the source of supply of alcohol for commercial use has, since the middle of the 19th century, developed into an important industry, particularly in Germany, where it is a prominent feature in the organization of the agriculture of the country. In great measure it is carried on by the mutual co-operation of the farmers who supply the potatoes to joint-owned distilleries for conversion into alcohol, receiving later the spent wash and residues which, containing nitrogen. phosphorus and potash, are of considerable value as a cattle food. Extensive breeding of cattle is thus facilitated, resulting in a heavy production of manure useful in the cultivation of the potatoes. The initial operations in the production of alcohol from potatoes are the mashing and the saccharification of the starch by means of malted barley or acids. The details of the process show considerable variation. In one method extensively adopted, the potatoes, after being cooked by steam heating and reduced to a homogeneous pulp in a mill, are mixed with malt and water. After the mass has been maintained at a temperature of about 60° C. for three to four hours, yeast is added and fermentation takes place. Distillation is accomplished by steam heating with mechanical agitation. In another method the potatoes after being reduced to a pulp in a rasping machine are partially drained of their natural water. Boiling uater and malt are added, the mass being allowed to stand for three to four hours. The clear liquid and subsequent washings are fermented with yeast and the spirit distilled off in the usual manner; this method has considerable advantages over that first described, the distillation from the liquid being cleaner and the residual paste being excellent as a cattle food. The spirit obtained by pot-still distillation is liable to act in a deleterious manner upon the animal economy. It has a strong flavour of fusel oil, since amyl and isobutyl alcohols are present in considerable proportions. These may be almost completely removed by distillation in a patent still. It has been claimed that 28.6 gal. of absolute alcohol can be obtained from a ton of potatoes.

(F. G. H. T.; R. SU.)

POTATO WAR, the name given by the Prussians to the War of the Bavarian Succession in 1778–79 (Kartoffelkrieg). The Prussians and a Saxon contingent, commanded by Frederick the Great and his brother Prince Henry, were opposed to two Austrian armies under Ernst von Loudon and Franz Moritz, Count Lacy. The operations consisted almost entirely of manoeuvres which had for their object the obtaining or the denial to the enemy of food supplies. The war thus acquired the name of *Kartoffelkrieg.* Its duration was from July 3. 1778, to the assembly of the congress of Teschen on March 10, 1779, and its total cost £4,350,000 and 20,000 men to all parties. The war may be studied from a military point as an extreme example of what Karl von Clausewitz calls "war with a restricted aim."

POTAWATOMI, a tribe of North American Indians, Algonkian in language and culture, whose name connotes "firemakers" (with flints or a one-stringed bow). Their traditions unite them to prehistoric Ojibwa and Ottawa of the eastern woodlands, an affiliation which is also affirmed by 17th century Jesuit accounts, and by internal evidence of culture and language. All sources indicate that separation of these tribes occurred in the late 17th century. Like other Algonkins. Potawatomi migrated west from the Atlantic seaboard, in part under Iroquois pressure. Potawatomi were observed in 1670 on islands around Green Bay, Wis., from which they spread south into territories of Michigan, Wisconsin, Illinois and Indiana.

The tribe joined France against the Iroquois and it joined Pontiac in his uprising; it joined England in the American Revolution and opposed England in 1812. Crowded by settlers. the Potawatomi moved west beyond the Mississippi; some in Indiana fled the U.S. military into Canada. In 1846, most Potawatomi were removed by U.S. soldiers to a reservation in Kansas, where they became known as the Prairie Band. Apparently during the westerly trek such new lifeways as communal buffalo hunts (replacing the chase of woodlands big game and fish), associated camp organization and the intertribal Plains sign language were borrowed from alien prairie tribes.

In 1861 most members of the Kansas band decided to take their lands in severalty and sell them for cash, and after disputes with the others, moved in 1868 to Oklahoma's Indian territory. Henceforth they were called Citizen Potawatomi. Despite the parting and the Citizens' assimilation to the dominant white life, the two groups maintained contact with each other, with the small impoverished Forest (or, "Stray") Potawatomi band that had fled to Wisconsin, and with the yet smaller Huron Potawatomi band that fled to Michigan in the 1830s. Separation favoured differences among the bands in social existence and speech.

The Prairie Band cherished its reservation as a home for the dying culture, blending aboriginal crafts and values with others from colonial and contemporary America. During the 1930s there was some cultural resurgence, but in the second half of the 20th century acculturation was proceeding at a rapid pace. (R. LA.)

POTCHEFSTROOM, a town in Transvaal, Union of South Africa, at 26° 30' S., 27° 40' E., altitude 4,436 ft., 88 mi. S.W. of Johannesburg by rail. Pop. (1951) 32,058, of whom 16,708 were white, 13,415 natives (Bantu), 476 Asian and 1,459 coloured. The town is built on the banks of the Mooi river, 15 mi. above its junction with the Vaal. Gold occurs in the neighbourhood.

Potchefstroom was founded in Nov. 1838 by Hendrik Potgieter, and is the oldest town in and first capital of the Transvaal. In 1862 it was the scene of civil war betueen rival Boer factions. In 1880–81 the garrison camped outside the town was besieged by Boers under Commandant P. A. Cronje. The British troops, 250 in number, were confined to a fort 25 yd. square and lost more than one-third of their strength in killed and wounded before they surrendered on March 21, the action having begun on Dec. 18, 1880. Charges of treachery were brought against Cronje for failing to notify the besieged that an armistice had been agreed to by the Boer leaders. Of this armistice Col. R. W. C. Winsloe, who was in command of the British, became aware before the surrender took place. On the suggestion of Commandant Gen. P. J. Joubert the capitulation was considered as cancelled, and a detachment of British troops reoccupied the town until the conclusion of peace. In the Anglo-Boer War of 1899–1902 Potchefstroom was occupied by the British without opposition. Potchefstroom was developed as an educational centre. It has several high schools, a training college, a university college. a constituent of the University of South Africa, and an agricultural school. The latter is situated on the government experimental farm.

POTEEN, called also potheen, potsheen and potyeen, the term usually applied in Ireland to any potable spirit illicitly distilled in a pot still—poit'in, pota or pot. Illicit distillation was extensively practised in the 19th century, particularly in the inaccessible districts of the island, but it has been largely suppressed. The character of the substances used in preparing the wash, which is fermented preparatory to distillation (see RUM; WHISKY; etc.), varies greatly. While malf and barley chiefly are used, the spirit is often obtained by fermentation of molasses or other saccharine matter. Method of fermentation, type of still employed, rate of distillation and proportion of distillate to wash, depending as they do upon the circumstances and wish of the distiller, are also lacking in uniformity. This absence of standardization in materials and methods results in great variation in composition of the spirits. Generally they may be stated to fall into two classes, approximating to whisky when malt and barley are used. and to rum when the wash is of a more saccharine nature. The proportion of secondary ingredients almost invariably is high, however, even when compared with pot-still spirits made by reputable firms. Allen, in a series of analyses presented to the Select Committee on British and Foreign Spirits, recorded 128.8 gr. of amyl alcohol in poteen as compared with an average of 56 gr. in eight samples of Irish whisky. (F. G. H. T.)

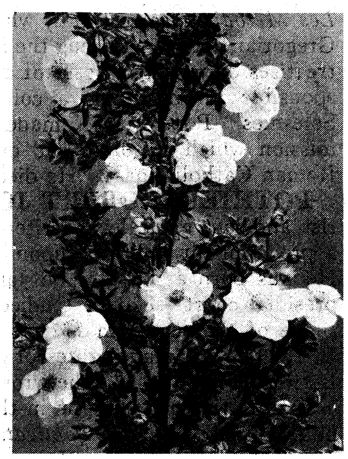
POTEMKIN, GRIGORY ALEKSANDROVICH, PRINCE (1739–1791), Russian statesman, was born at Chizheva near Smolensk. He was educated at the Moscow university and in 1755 entered the "Reiter" of the horse guards. His participation in the coup d'état of July 8, 1762, attracted the attention of the new empress, Catherine II, who made him a Kammerjunker and gave him a small estate. He distinguished himself in the Turkish war of 1769, and in 1771 he became Catherine's prime favourite. Catherine bestowed on him the highest honours, among others the post of commander in chief and governor general of "New Russia" (Ukraine). In 1775 he was superseded in the empress's graces by Zavadovsky; but the relations between Catherine and her former lover continued to be most friendly, and his influence with her was never seriously disturbed by any of her subsequent favourites.

Potemkin's correspondence with the empress was uninterrupted. He was deeply interested in the question of the southern boundaries of Russia and consequently in the fate of the Turkish empire. In 1776 he sketched the plan for the conquest of the Crimea which was subsequently realized; and he was busy with the so-called Greek project, which aimed at restoring the Byzantine empire under one of Catherine's grandsons. In many of the Balkan states he had well-informed agents. After he became field marshal, in 1784, he introduced many reforms into the'army and built a fleet in the Black sea, which, though constructed of very bad materials, did excellent service in Catherine's second Turkish war (1787–92). His colonizing system was exposed to very severe criticism, yet it is impossible not to admire the results of his stupendous activity. The arsenal of Kherson, begun in 1778, the harbour of Sevastopol and the new fleet of 15 liners and 25 smaller vessels, were monuments of his genius. But there was exaggeration in all he attempted. He spared neither men, money nor himself in attempting to carry out his gigantic scheme for the colonization of the south Russian steppes; but he never calculated the cost, and more than three-quarters of the design had to be abandoned when but half finished.

Catherine's famous expedition to the south in 1787 was a triumph for Potemkin, for he concealed all the weak points of his administration. On this occasion he received the title of prince of Tauris. The same year the second Turkish war began, and the founder of New Russia acted as commander in chief. But the army was ill equipped and unprepared. and Potemkin, in a hysterical fit of depression, would have resigned but for the steady encouragement of the empress. Only after Suvarov had valiantly defended Kinburn did he take heart again and besiege and capture Ochakov and Bender. In 1790 he conducted the military operations on the Dniester and held his court at Jassy with more than Asiatic pomp. In 1791 he returned to St. Petersburg, where, along with his friend Bezborodko (*q.v.*), he made vain efforts to overthrow the new favourite, Zubov. The empress grew impatient and compelled him (1791) to return to Jassy to conduct the peace negotiations as chief Russian plenipotentiary. On Oct. 5, while on his way to Nikolayev, he died in the open steppe, 40 mi. from Jassy. Potemkin was indubitably the most extraordinary of all the Catherinian favourites. He was an able administrator, licentious, extravagant, but loyal, generous and magnanimous. Nearly all the anecdotes related of him by Helbig, in the biography contributed by him to the journal *Minerva* (1797–1800) and freely utilized by later biographers, are absolutely worthless.

See V. A. Bilbasov, *Geschichte Katharinas II* (Berlin, 1891–93); C. de Larivière, *Catherine la Grande d'après sa correspondance* (Paris, 1895); anonymous, La *Cour de Catherine II: Ses collaborateurs* (St. Petersburg, 1899); A. V. Lopukhin, *Sketch of the Congress of Jassy, 1791* (Rus; *St.* Petersburg, 1893); *The Papers of Prince Potemkin, 1744–1793* (Rus.; *St.* Petersburg, 1893–95). (R. N. B.)

POTENTILLA, a large genus of plants of the rose family (Rosaceae, *q.v.*), comprising more than 300 species, mostly herbs, widespread in north temperate and arctic regions, many being cultivated as border and rock garden plants. Various species bear brilliantly coloured flowers and graceful foliage. A soil of a good loamy staple, enriched with rotten dung, is most suitable. Potentillas may be increased, though not freely, by parting them into as many pieces as there are crowns, the side growths being those which can usually be thus separated. This may be done in autumn or spring, and the plants will generally bloom the following season. The species and some of the varieties reproduce true from seed, and are readily increased by that means.



J. HORACE MCFARLAND CO

PURDOM BUSH CINQUEFOIL (POTENTILLA PURDOMI)

Nine wild species occur in the British Isles and more than 50 in North America, many being called cinquefoil or five-finger.

POTENTIOMETER: see INSTRUMENTS, ELECTRICAL MEASURING.

POTENZA (anc. POTENTIA), a town and episcopal see of Basilicata, Italy, capital of the province of Potenza, 103 mi. by rail S.E. of Naples. Pop. (1951) 22,371. Situated 2,700 ft. above sea level on an isolated hill above the Basento (anc. Casuentus), it is exposed to winds and has a far more northerly climate than its position (40° 40' N.) implies, and is one of the coldest towns in Italy.

The ancient Potentia lay about 470 ft. lower, by the river, at the intersection of the road leading west to the Via Popillia and northeast to the Via Appia, with the Via Herculia.

Potentia must be distinguished from Potentia in Picenum, on the Adriatic coast. In 1694 there was a severe earthquake; the more terrible earthquake which on Dec. 16 and 17, 1857, passed through southern Italy, and in Basilicata (Lucania) alone killed 32,475 persons, laid the greater part of Potenza in ruins. It was also damaged by the earthquake of 1910. In 1860 it was the first town to rise against the Neapolitan government.

POTGIETER, EVERHARDES JOHANNES (1808–1875), Dutch prose writer and poet, was born at Zwolle, in Overyssel, on June 17, 1808. He started life in a merchant's office at Antwerp. In 1831 he made a journey to Sweden and then settled in Amsterdam. With Heije, the popular poet of Holland in those days. and Bakhuizen van den Brink, the historian, Potgieter founded De *Muzen* ("The Muses," 1834–36), a literary review, which was, however, soon superseded by De *Gids* ("The Guide"), a monthly, which became the leading magazine of Holland. In it he wrote, mostly under the initials of "W D ——g," a great number of articles and poems. The first collected edition of his poems (1832–68) appeared in two volumes (Haarlem, 1868–75), preceded by some of his contributions to De *Gids,* in t o volumes also

(Haarlem, 1864), and followed by three volumes of his *Studien en Schetsen* ("Studies and Sketches," Haarlem, 1879). Potgieter's favourite master among the Dutch classics was Hooft, whose peculiarities in style and language he admired and imitated. In Holland Potgieter's influence has been very marked and beneficial; but his own style, that of ultrapurist, was at times somewhat forced, stilted and not always easily understood.

The best edition of Potgieter's works is that by his friend and executor J. C. Zimmermann, 19 vol. (1885–90).

POTHIER, DOM JOSEPH (1835–1923), French musical scholar, was born at Bouzemont, near St. Dié, Dec. 7, 1835. He became a Benedictine in 1859 and, after holding various positions of authority in two French abbeys, was named abbot of a third, St. Wandrille, in 1898. In 1901, when members of religious orders were compelled by law to leave France, the monastery was temporarily located in Belgium. Shortly after he entered the Benedictine order at Solesmes, Dom Pothier was encouraged by Dom Guéranger, who had started a movement to revive the ancient plain song, to study early church music. In 1880 Dom Pothier published *Les Mélodies grégoriennes,* which became the standard work on Gregorian chants. During the next 25 years he wrote seven other treatises on various phases of ancient religious music and was responsible for beginning a collection of musical manuscripts at Solesmes. Pope Pius X made him chairman (1904) of a commission which re-edited and published the musical parts of the Roman Catholic mass. He died at Conques, Belg., Dec. 8, 1923.

POTHIER, ROBERT JOSEPH (1699–1772), French jurist and last great legal writer before the Revolution, exercised a predominant influence upon the draftsmen of the *Code Civil.* He was born at Orléans on Jan. 9, 1699, son of a judge of the presidial court. Having studied law, he was himself appointed a judge of that court in 1720, a post which he held for 52 years. In 1749 he was made professor of law in the university of Orléans. Between 1748 and 1752 he wrote *Pandectae Justinianae in novum ordinem digestae,* a classic in the study of Roman law. In 1761 he published *Traité des obligations* and followed it with a series of great treatises upon the various categories of contracts and many other branches of civil law. He died in Orlkans on March 2, 1772. His writings rationalized the various *coûtumes* of France into clear and logical legal principles which Napoleon's codifiers often adopted word for word. Even after the code his work was resorted to as authority where the code was silent or ambiguous.

BIBLIOGRAPHY.—Editions of Pothier's collected works by Siffrein (1820–24), by A. M. Dupin (1824–25) and by J. J. Bugnet (1861–62). *See* also A. M. Dupin, *Dissertation sur la vie et les ouvrages de Pothier* (1827); A. F. M. Frémont, *Vie de* R. *J. Pothier* (1859). (L. N. B.)

POTI, a seaport of the U.S.S.R., in the Georgian S.S.R., in 42° 10' N., 40° 38' E., on the Rion river, on the Black sea coast.

There are berths for eight or ten large steamers and an elevator for loading manganese, the chief export from the Kvirili valley. The town is linked by rail with Baku. Pop. (1957 est.) 43,000.

The ancient Phasis, a commercial colony of the Greek city of Miletus, stood on this site. In 1578 Sultan Murad III, of Turkey, built a fortress there, which was destroyed during a war with Persia. In 1640 the Imeretians attacked the town. Poti was a great slave market. It was captured by the Russians in 1812 and in 1829 recaptured and annexed.

POTLATCH, an Indian term, denotes the lavish feasts especially characteristic of the Tlingit, Kwakiutl and other tribes of the northwest coast of America. The potlatch was given by one chief or clan to another on ceremonial occasions and was marked by great profusion of food and gifts, often accompanied by destruction of property by the hosts, as in the breaking of highly prized copper plaques and the burning of blankets and furs. The potlatch reflected a very high value placed on wealth as a status symbol. It was a matter of honour to accept any invitation to a potlatch and to give a grander feast in return. Refusal involved loss of prestige and rank. *See* INDIANS, NORTHWEST COAST.

POTOCRI, IGNACY (1741–1809), Polish statesman and writer, son of Eustachy Potocki, general of artillery of the army of Lithuania, was born at Podhajce. He was educated first at Warsaw beneath the eye of the pedagogic reformer Stanislaw Konarski (1700–73), and subsequently in Italy, where he proposed to take orders. On returning home, however, he abandoned this idea, and as a member of the newly instituted commission of education rendered invaluable services to his country for the next 16 years. He earnestly desired reform of the constitution also and was thus attracted to the party of Czartoryski. Elected deputy to every diet after 1778, he was a conspicuous member of the patriotic opposition. In matters of importance nothing was done without his advice. His influence was at its height during the "four years' " *sejm* (1788–92). He advocated reform of the constitution, defended eloquently the right of the towns to the franchise and urged an alliance with Prussia. Thus he was one of the creators of the constitution of May 3, 1791, although his aristocratic antecedents prevented him from going the lengths of the more radical reformers. On the formation of the confederation of Targowica, Potocki emigrated to Dresden, but on the outbreak of the revolution of 1794 he returned to Poland, was appointed a member of the national government and entrusted with the conduct of foreign affairs. At the fall of Warsaw he surrendered to Suvorov and was sent to Russia, where he remained until 1796. When he returned to Poland he retired to the village of Klimuntowo, where for the next 13 years he devoted himself to literature. At the end of the war of 1809 he was commissioned to go to Vienna to present to Napoleon the petitions of the Galicians for the incorporation of their province with the grand duchy of Warsaw. He died at Vienna the same year.

POTOCKI, STANISLAW FELIX (1752–1805), Polish politician, son of Franciszek Salezy Potocki, palatine of Kiev, was born in 1752. Through family influence, he became grand standard bearer of the crown at the age of 22. In 1782 he was made palatine of Russia, in 1784 a lieutenant general and in 1789 purchased the rank of a general of artillery, Liberal, enlightened, a generous master and a professed patriot, he had awakened great hopes; but he identified the public welfare with the welfare of the individual magnates, and, when elected to the four-years' diet, schemed to divide Poland into an oligarchy of autonomous grandees exercising the supreme po er in rotation (in fact, a perpetual interregnum). The election of Stanislaw Malachowski (*q.v.*) and Kazimierz Sapieha as marshals of the diet still further alienated him from the Liberals, and he retired to Vienna where he continued to carry on an active propaganda against the new ideas. He protested against the constitution of May 3, 1791, and, after attempting fruitlessly to induce the emperor Leopold to intervene, proceeded with his friends in March 1792 to St. Petersburg, and subsequently with the connivance of the empress Catherine formed the confederation of Targowica (May 14, 1792), of which he was the marshal, or rather the dictator, directing its operations from his castle at Tulczyn. When the May constitution was overthrown, Potocki (March 1793) went on a diplomatic mission to St. Petersburg; but, finding himself duped, he settled down at Tulczyn.

POTOMAC, a river in the east central United States, rises in the Appalachian mountains of West Virginia and flows southeastward into Chesapeake bay, draining an area of approximately 14,500 sq.mi. Its two headwaters; the north and the south branch, join about 15 mi. below Cumberland, Md. From there to the bay it is 287 mi. long, 117 of which are tidal. At Harpers Ferry it receives the Shenandoah river from the Appalachian valley to the south and after traversing the easternmost mountain chains through a series of spectacular watergaps it is joined by the Monocacy river in the Piedmont region and by the Anacostia or east branch at Washington, D.C. Together with its north branch, it forms the boundary between Maryland and West Virginia from its source to Harpers Ferry, and from there to its mouth it is the boundary between Maryland and Virginia. The District of Columbia lies on its left bank at the head of tidewater. Navigability of the tidal portion is assured by channels dredged to a depth of 18 and 21 ft, at Washington and of 24 ft. through all the shoals. Washington and Alexandria (Va.) possess minor port facilities; the lower Anacostia is navigable to Bladensburg, Md., for small craft. For a stretch of about 12 mi. upstream from Washington the Potomac descends from the Piedmont to the coastal plain in a series of rapids and falls, of which Great Falls contains a cataract about 35 ft. high. The Chesapeake and Ohio canal. paralleling the Potomac, was completed in 1850 from Georgetown to Cumberland; traffic ceased at the beginning of the 20th century but the canal remains a scenic and recreational asset.

(F. O. A.)

POTOROO: *see* RAT KANGAROO.

POTOSÍ, a department of Bolivia, bounded north by Oruro and Cochabamba, east by Chuquisaca and Tarija, west by Chile and south by Argentina. Pop. (1950) 534,399. Area 45,644 sq.mi. Situated in the southwest of the country, it ranks second in population and fourth in territorial area among Bolivia's departments. Potosi (*q.v.*) is capital of the department and of the province of Cercado. Indians, mestizos and people of European descent make up the population.

The department is noted for its great mineral wealth and its high physical altitude. The surface is extremely rugged, being traversed by the eastern branch of the Andes, and the climate is rigorous. Elevations range from about 6,000 ft. to more than 20,000 ft. above sea level. The capital city stands at an altitude of over 13,700 ft., and the temperature there seldom exceeds 59" F. Livestock grazing and agriculture are carried on, chiefly at lower elevations owing to the harsh natural environment of the Altiplano. Vegetation is scarce and there is little water for irrigation. The region is drained mainly by the affluents of the Pilcomayo. The department is also deficient in fuels, a significant obstacle to industrial development.

The Spanish mining industry in Bolivia began in 1540 with the operation of the silver mines of Porco (now the province of Quijarro) by Gonzalo Pizarro and Diego Centeno. The discovery in 1545 of Cerro Potosi, a conical mountain rising 15,680 ft. above sea level, establishzd Potosi as the foremost silver producing region in the world. It is estimated that the region subsequently produced $1,000,000,000 worth of silver. The Cerro is composed of one of the richest ore bodies yet discovered, an ore containing tin, bismuth and tungsten in addition to silver.

Potosi declined in importance as a mining area as a result of the diminution of the more readily available ores and to progress in technology which made feasible the use of lower quality ores in more accessible locations. The exploitation of Bolivia's tin ores which began shortly before the turn of the 20th century, restored mining activity in the department. The construction of a railway from Antofagasta to the centre of the plateau in 1892 made it possible to ship out ores of lesser value than those of silver; newly discovered uses for tin created an expanding market for that metal. Lead, zinc, antimony, copper, bismuth, sulfur. gold, silver and wolfram, are also worked in the region. Among the 13 provinces of the department, those notable for minerals comprise Sud Chichas (regarded as the richest), Cercado, Chayanta, Bustillo, Charcas, Linares, Alonso de Ibañez. Nor and Sud Lipez and Nor Chicas. Extensive deposits of solid salt, the Salar de Uyuni (3,500 sq.mi.) and Copaisa, Chiguana and Empexa, south of Lake Poopó, are also exploited.

Air, railroad and highway facilities are available within the department. A branch line of the Antofagasta-La Paz railway extends to the city of Potosi from the junction at Rio Mulato. This line (15,705 ft. above sea level at Condor) is one of the highest railways in the world. (J. L. TR.)

POTOSÍ, a city in Bolivia, capital of the department of Potosi, is located on a cold and barren plateau 275 mi. S. of La Paz. Pop. (1950) 45,758. One of the highest cities of the world (altitude over 13.700 ft.), it stands in the shadow of the fabulous Cerro Potosi and its 5.000 mines. The temperature seldom exceeds 59° F. Legend attributes the name to "potojchi," Quechua word meaning "thunder," on account of rumblings inside the mountain. The city came into existence after the discovery of silver in the *cerro* by the Indian Gualpa, whose master Juan de Villaroel registered the first claim April 21, 1545. Charles V conferred upon it the title Villa Imperial (1547). Philip II chartered the university (1571) and the mint (1572). So great was the wealth of the mines that "as rich as Potosi" became a current expression. About 200 merchants supplied the city with luxuries from all parts of the world. It was a turbulent city full of factions, such as the Vicunas and Vascongados, who waged full-fledged civil war, 1623–26. Population fluctuated with the mineral production. Of the estimated 160.000 residents in 1650 only 8,000 remained when Simón Bolivar liberated the area in the final battle of the Wars for Independence, Oct. 5, 1825. Rich tin deposits replaced the diminishing silver lode and 20th century Potosi became the leading industrial city of Bolivia. Iron, steel, shoes, soft drinks, beer, furniture, electric products and mosaics supplemented mining (tin, lead, copper, silver) and refining industries.

Although flood and earthquake have taken their toll, Potosi retains its colonial charm. The city is laid out in squares with narrow, sometimes winding streets originating in the central plaza, around which are grouped the government house, city hall, national college, mint. treasury and cathedral, dating back to colonial times. It is on a highway* and the Sucre-Potosi railway connects with the Antofagasta-Bolivia line.

See Lewis Hanke, *The Imperial City of Potosi* (1956). (G. B. Co)

POTOTAN, a municipality (with administrative centre and 64 *barrios* or districts) of the province of Iloilo, island of Panay, Philippines, on the Jaluar river, and located along the railway, about 17 mi. N.E. of Iloilo, the provincial capital. Pop. (1959 est.) 42,530. The chief agricultural products are sugar, maize (corn), palay (rice), tobacco and abacá (Manila hemp). Cattle, carabao and horses are bred for local use and for export. Panay-Bisayan is the vernacular. Of the inhabitants aged 6 to 19 inclusive, 41.7% in 1939 attended school, while 51.8% 10 years old and over was literate.

POTSDAM, a town in Germany in the district of the same name and formerly one of the residences of the German emperor, on the Havel river, 16 mi. S.W. of Berlin, on the main line of railway to Magdeburg. Pop. (1950) 118,180. It is connected with the capital by two local lines and by a steamboat service through the chain of lakes formed by the river. Potsdam, originally Poztupimi, a Slavonic fishing village, is first mentioned in 993. A town in the 14th century, it was unimportant until the great elector built a palace there between 1660 and 1682, and even at the close of his reign it contained only 3,000 inhabitants. The elector Frederick William I greatly enlarged Potsdam, and his stiff military tastes are reflected in the monotonous uniformity of the streets. Frederick the Great continued his father's work. and was the real creator of the splendour of the town.

The palace, a large quadrangular building of the 17th century, is chiefly interesting for the numerous relics it contains of Frederick the Great. It also contains reminiscences of Voltaire, who resided there for several years. The principal churches are the Nikolaikirche; the Church of the Holy Ghost, built in 1728; and the Friedenskirche, or Church of Peace, erected in 1845–50, to which is attached a mausoleum. Among other conspicuous buildings are the military establishments, the town hall and the Brandenburg gate. Potsdam has manufactures of chemicals, furniture, chocolate. soap, tobacco and surgical and musical instruments. Market gardening affords occupation to many of the inhabitants, and the cultivation of winter violets is a specialty. The Havel is well stocked with fish. To the south of the town lies the observatory.

POTT, PERCIVALL (1714–1788), English surgeon, the first surgeon of his day in England, excelling even his pupil John Hunter, was born in London on Jan. 6, 1714. He became assistant surgeon at St. Bartholomew's in 1744 and was full surgeon, 1749–87. Pott introduced various important innovations in procedure, doing much to abolish the extensive use of excharotics (corrosive agents) and the actual cautery that was prevalent when he began his career. A particular form of fracture of the ankle which he sustained through a fall from his horse in 1756 is still described as Pott's fracture. His book *Some Few Remarks Upon Fractures and Dislocations* had a far-reaching influence in Great Britain and France. Pott's disease is an osteitis of the vertebrae of which he gave an excellent clinical description in his *Remarks on That kind of Palsy of the Lower Limbs Which Is frequently*

Found to Accompany a *Curvature* of the Spine (1779). Pott died in London on Dec. 22, 1788.

See Fielding Hudson Garrison, *Introduction to the History,* of *Medicine,* p *344* (1929).

POTTER, ALONZO (1800–1865), U.S. Protestant Episcopal bishop and educator, was born at Beekman (now La Grange). N.Y.. July 6, 1800. He graduated in 1818 at Union college. where he became tutor and then professor of mathematics after a brief period spent in studying theology at Philadelphia. He was a rector of St. Paul's. Boston. from 1826 to 1831, when he returned to Union as professor of philosophy and political economy, becoming vice-president of the college in 1838. He was consecrated bishop of Pennsylvania on Sept. 23. 1845.

Potter died on board ship in San Francisco harbour on July 4, 1865.

By his publication with G. B Emerson of The School and the *Schoolmaster* (1842) and by his lectures Potter did much to extend and better public school education. He was particularly interested in work for young men and in temperance reform, As a legislator in the church he was wise and progressive. He established the Philadelphia Divinity school (1863) and laboured for the hospital of the Protestant Episcopal Church in Philadelphia

See M. A De Wolfe Howe, *Memoirs of the Life and Services of the Rt. Rev. Alonzo Potter, D D. (1870).*

POTTER, HENRY CODMAN (1834–1908), U.S. Protestant Episcopal bishop, the son of Bishop Alonzo Patter, was born in Schenectady, N Y., on May 25, 1834. In Oct. 1883 he was consecrated assistant to his uncle Horatio Potter, bishop of New Tork, whom he succeeded in 1887. He died in Cooperstown, S.Y.. July 21, 1908. During his administration the cornerstone of the cathedral of St. John the Divine was laid (Dec. 27, 1892). As rector of Grace church he worked to make it an "institutional church" with clubs for working men and girls, day nurseries and kindergartens.

Potter won fame on the centennial of Washington's inauguration by his address on the dangers and corruptions of the spoils system

See Harriette *A* Keyser, *Bishop Potter, the People's Friend* (1910), and the official biography by George Hodges (1915).

POTTER, PAUL (PAULUS) (1625–1654), Dutch painter and etcher. celebrated chiefly as an animal painter. son of the painter Pieter Potter, was born at Enkhuizen in 1625. He entered the Guild of St. Luke at Delft in 1646. In 1649 he moved to The Hague, where in the following year he married Adriana, daughter of the architect Claes van Balkeneynde. In 1652 he settled in Amsterdam, where he died on Jan. 15, 1654. Potter probably received his early training from his father, but his style shows little dependence upon that of earlier masters. Animals appear prominently in all of Potter's characteristic works, sometimes singly (the "Grey Horse," dated 1653, Hamburg), more usually in small groups silhouetted against the sky. or in greater numbers with peasant figures and rustic buildings in an extensive landscape. So lifelike is his portrayal of cows, horses and other domestic animals that many critics tend to regard this as his only talent, and to treat him as one of the minor Dutch masters—charming, but limited in range. This is an undervaluation of Potter's genius. His range of subject matter is limited by his own choice, but within that range he displays powers far above many contemporaries who are usually judged to be more eminent. No Dutch painter of his time was more sensitive to the passing moods of nature, or to the countryside's timeless harmony of beast, landscape and weather, and none gives the impression of having observed the landscape of his country with deeper love or understanding. In addition, Potter possessed a remarkably developed feeling for design, expressed in the grouping of his forms and in his use of eloquent silhouette, dark on light or light on dark. All of these qualities can be admired in the superb "Early Morning" (1647. Salzburg museum). which is possibly his most perfect masterpiece. This is a fine, open composition, painted with a small, but firm and lively touch; the light of early morning—and of early spring—is deliciously rendered. and there is a keen understanding of both animal and human behaviour. Like most of his really successful pictures it is on a small scale, and painted on panel.

In so tragically short a career there was naturally little development in style between the earlier and the later works, but 1647 seems to mark a peak in his achievement, for many of the finest paintings bear this date. Characteristic works are: "Cattle in a Stormy Landscape" (1647; National gallery, London) ; "Horses Tethered at a Cottage Door" (1647 or 1649; Louvre. Paris); "Peasant With Cattle" (1648; Cassel) and "Cattle Reflected in Rater" (1648; Mauritshuis. The Hague). Among works which depart from his normal scale or style, the huge "Young Bull" (1647; The Hague), which is on the scale of life, is his most celebrated though surely not his finest work, while "Orpheus Charming the Beasts" (1650; Rijksmuseum. Amsterdam). is an untypical excursion into a poetic world reminiscent of Roland Savery. Potter's etchings of animals show all the skill and sympathy of his paintings.

See T van Westrheene, *Paulus Potter, Sa vie et ses oeuvres* (1867); *C.* H. de Groot, *Catalogue* of . . . Dutch *Painfers,* etc, vol. iv (1912).

(R. E. W. J)

POTTERIES, THE, a name applied to a district of north Staffordshire. the principal seat of the china and earthen are industry in England. It lies in the upper part of the Trent basin. For a distance of 9 mi. from southeast to northwest and about 3 mi. from northeast to southwest, the district resembles one great town, but the chief centres are Burslem. Hanley. Longton, Stoke-on-Trent. Fenton and Tunstall (except Fenton, the "Five Towns" of Arnold Bennett's novels). These towns were amalgamated in 1910 as one municipal borough under the name of Stoke-on-Trent (*q v.*), which was made a city in 1925. Newcastle-under-Lyme, though not sharing in the staple industry, may also be reckoned in the district. In 1769 Josiah Wedgwood founded potteries at Etruria, by the Trent and Mersey canal; they are now at Barlaston. Wedgwood and Minton are the two most famous family names connected with the china industry of the district. Coal, from the north Staffordshire coal field, and coarse clay are the only local natural products used in the industry, the finer clay and other ingredients being brought from elsewhere.

POTTER'S CLAY: see KAOLIN.

POTTERY AND PORCELAIN. The word "pottery" (Fr. *poterie*) in its widest sense includes all objects fashioned from clay and then hardened by fire: the word "porcelain" should only be applied to certain well marked varieties of pottery. Pottery is dependent on two important natural properties of that great and wide-spread group of rocky or earthy substances known as clays viz., the property of plasticity and the property of being converted when fired into one of the most indestructible of ordinary things "Ceramics" or "keramics" (Gr. *keramos,* earthenware) is a general term for the study of the art of pottery. It is adopted for this purpose both in French (*ceramique*) and in German (*Keramik*).

INTRODUCTION

The primitive races took such clay as they found on the surface of the ground, or by some river-bed, and, spreading it out on a stone slab, picking out the rocky fragments, then beating it with the hands, with stones or boards, or even treading it with their feet, proceeded to fashion it into such shapes as need or fancy dictated. Fired in an open fire, such pottery may be buff, drab, brown or red—and those from imperfect firing become smoked, gray or black. For ages tools and methods remained of the simplest—the fingers for shaping or building up vessels, a piece of mat or basket-work for giving initial support to a larger vase—until some original genius of the tribe found that by starting to build up his pot on the flattened side of a boulder he could turn his support so as to bring every part in succession under his hand, and thus the potter's wheel was invented.

At first this simple hand-made pottery was hardened by drying in the sun, but the increasing use of fire soon brought out the fact that a baked clay vessel became as hard as stone. Different districts produced different colours of clay, and thus colour decoration arose. On this substructure all the pottery of the last 4,000 years has been built, for behind all Egyptian, Greek or

Chinese pottery we find the same primitive foundations.

In subsequent articles on this subject we find that the Egyptians evolved schemes of glowing colour—brilliant glazes fired on objects, shaped in sand held together with a little clay, or actually carved from rocks or stone; the Greeks produced their marvels of plastic form, and then turned the plastic clay into imitations of metal forms; the Romans spread some knowledge of the craft over all the empire, but with its fall pottery was forgotten along with its greater achievement. Egypt and the Near East continued the splendours of their glorious past, and glazed and painted pottery was still made by traditional methods. Many interesting kinds of decorated pottery were made at Old Cairo, Alexandria, Damascus, in Syria, Anatolia and elsewhere (on which the later Moslem potters founded their glorious works).

Meantime, in the farther East, the Chinese—the greatest race of potters the world has ever seen—were quietly gathering strength, until from their glazed, hard-fired pottery there emerged the marvellous, white translucent porcelain, one of the wonders of the mediaeval world.

With the dawn of the 15th century, the state of affairs was practically this: In European countries proper, we find rudely fashioned and decorated wares in which we can trace the slow development of a native craft from the superposition of Roman methods on the primitive work of the peoples. The vessels were mostly intended for use and not for show; were clumsily fashioned of any local clay, and if glazed at all then only with coarse lead-glazes, coloured yellow or green; in no case above the level of workmanship of the travelling brick- or tile-maker. The finest expression of this native style is to be found in the Gothic tile pavements of France, Germany and England.

As early as the 12th century the superior artistic pottery of the Moslem nations had already attracted the notice of Europeans as an article of luxury for the weaithy; and we may well believe the traditional accounts that Saracen potters were brought into Italy, France and Burgundy to introduce the practice of their art, while Italian potters certainly penetrated into the workshops of eastern Spain and elsewhere and gathered new ideas.

During the 15th and 16th centuries, Chinese porcelain also began to find its way into Europe, and by the whiteness of its substance and its marvellous translucence excited the attention of the Italian majolists and alchemists. The first European imitation of this famous oriental porcelain of which we have indubitable record was made at Florence (1575–85) by alchemists or potters working under the patronage, and, it is said, with the active collaboration of Francesco de' Medici. This Florentine porcelain was the first of those distinctively European wares, made in avowed imitation of the Chinese, which form a connecting link between pottery and glass, for they may be considered either as pottery rendered translucent or as glass rendered opaque by shaping and firing a mixture containing a large percentage of glass with a very little clay.

During the 18th century not only was there a very large trade in imported Chinese and Japanese porcelain, but there was a great development cf porcelain manufacture in Europe,

The 19th century witnessed a great and steady growth in the output of porcelain and pottery of all kinds in Europe and the United States. Mechanical methods were largely called in to supplement or replace what had hitherto remained almost pure handicraft. The English methods of preparing and mixing the materials of the body and glaze, and the English device of replacing painted decoration by machine printing, to a large extent carried the day, with a great gain to the mechanical aspects of the work and in many cases with an entire extinction of its artistic spirit.

The 20th century opened with a wider outlook among the potters of Europe and America. In every country men were striving once again to bring back to their world-old craft something of artistic taste and skill.

TECHNIQUE

All pottery, whether of ancient or modern times, is made by the simplest method. The clay, dug from the earth's surface. is prepared by beating and kneading with the hands, feet or simple mallets of stone or wood. Care is taken that all stones and hard particles are picked out. In ancient pottery, the clay, well tempered with water, was almost invariably used without any additional material. From this pure clay, vessels were shaped by scooping out or cutting a solid lump or ball, by building up piece by piece or by squeezing cakes of clay on to some natural object or prepared mould or form. The potter's wheel, though very ancient, was a comparatively late invention, arrived at independently by many races of men. In its simplest form it was a heavy disk pivoted in a central point to be set going by the hand, as the workman squatted on the ground. About the Christian era, and in Egypt apparently, a much larger disk, which the potter could rotate with his foot, was introduced; this gave the potter an opportunity to use both hands in the manipulation of the clay. In the 17th century the wheel was spun by means of a cord working over a pulley, and in the 19th century the steam driven wheel was introduced.

The rotating process completed, the piece is removed from the wheel and set, aside to dry. When it is about leather-hard, it may be recentred carefully on the wheel (the old practice), or placed in a horizontal lathe (16th century) and turned down to the exact shape and polished to an even, smooth surface. Many Greek vases have obviously been "thrown" in separate sections. So too with the Chinese; many of their forms have been made in two or three portions, subsequently joined together and finished on the outside as one piece. *(See* TERRA-COTTA.)

Firing.—The type of kiln used by the potters of ancient Egypt or Greece have not entirely vanished from present day use; it is only in the civilized countries of the modern world that they have been replaced by improved and perfected devices. The potters of certain sections of the Near East and of Japan remain content with the crudest and most primitive types of kilns. With the organization of the pottery as a factory industry in the 18th century, improved kilns were introduced, and the type of kiln now used in civilized countries is a verticle furnace from 10 to 22 ft. in diameter and of similar height, capable, therefore, of cantaining at one firing a quantity of pottery that would have formed the output of a mediaeval potter for a year. Gas-fired kilns and ovens are now being used or experimented with in every country, and their perfection, which cannot be far distant, will improve the most vital of the potters' processes both in certainty and economy.

Glazes.—We can only consider as glazes those definite superficial layers of molten material which have been fired on the clay substance. Glazes are as varied as the various kinds of pottery, and it must never be forgotten that each kind of pottery is at its best with its appropriate glaze. The most important types of glaze are (1) alkaline glazes, *e.g.,* Egyptian, Syrian, Persian, etc., the oldest and most uncertain; (2) lead glazes, the most widespread in its use and the best for all ordinary purposes; (3) felspathic glazes, the glazes of hard-fired porcelains, generally unsuited to any other material; (4) salt-glaze, produced by vapours of common salt, the special glaze of sione-wares.

Colours.—The primitive potters of ancient and modern times have all striven to decorate their wares with colour. The simplest, and therefore the earliest, colour decoration was carried out in natural earths and clays. The clays are so varied in composition that they fire to every shade of colour from white to grey, cream, buff, red, brown or even to a bronze which is almost black. One clay daubed or painted upon another formed the primitive palette of the potter, especially before the invention of glaze. When glaze was used these natural clays were changed in tint, and native earths, other than clays, containing iron, manganese and cobalt, were gradually discovered and used. It is also surprising to note that some of the very earliest glazes were coloured glasses containing copper or iron (the green, turquoise and yellow glazes of the ancient Egyptians and Assyrians). Marvellous work was wrought in these few materials, but the era of the finest pottery-colour dawns with the Persian, Syrian and Egyptian work that preceded the Crusades. By this time the art of glazing pottery with a clear soda-lime glaze had been thoroughly learnt. Vases, tiles, etc., shaped in good plastic clay, were covered with a white, highly siliceous coating fit to receive glazes of this type, and giving the best possible ground for the painted colours then known. The colours already spoken of were either clay colours or what are known as "under glaze" colours, because they were painted on the pottery before the glaze was fired.

The earliest glazes of the Egyptians appear not to have been white, but were coloured throughout their substance, and this use of coloured glazes as apart from painted colour was developed along with the painted decoration by the later Egyptian, Syrian and Persian potters. Green, yellow and brown glazes were almost the only artistic productions of the mediaeval European potters' kilns, and their use everywhere preceded the introduction of painted pottery.

With the exceedingly refractory felspathic glazes of Chinese porcelain very few underglaze colours could be used; and the prevalence of blue and white among the early specimens of Chinese porcelains is due to the fact that cobalt was almost the only substance known to the potters of the Ming dynasty which would endure the high temperature needed to melt their glazes. Consequently the Chinese were driven to invent the method of painting in coloured fusible glasses on the already fired glaze. They adopted for this purpose the coloured enamels used on metal; hence the common term "enamel decoration," which is so generally applied to painting in those colours which are attached to the already fired glaze by refiring at a lower temperature. With the introduction of this many-coloured Chinese porcelain into Europe the same practice was eagerly followed by our European potters, and a new palette of colours and fresh styles of decoration soon arose amongst us.

It must be pointed out that the colour possibilities in any method of pottery decoration are largely dependent on the temperature at which the colour needs to be fired. The clay colours are naturally more limited in range than the under-glaze colours, and these in their turn than the on-glaze colours.

Metals. — The noble metals, such as gold, platinum and silver, have been largely used since the early years of the 18th century as adjuncts to pottery decoration, especially on the fine white earthenwares and porcelains of the last two centuries. At first the gold was applied with a kind of japanner's size and was not fired to the glaze, but for the last 150 years or so the metals have generally been fired to the surface of the glaze like enamel colours, by mixing the metal with a small proportion of flux or fusible ground glass. There can scarcely be a doubt that the ancient lustres of Persia, Syria and Spain were believed to be a form of gilding, though their decorative effect was much more beautiful than gilding has ever been. The early Chinese and Japanese gilding appears, like the European, to have been "sized" or water-gilt, not fired; and it seems probable that the use of "fired" gold was taught to the Oriental by the European in the 18th century. To-day "liquid" gold is exported to China and Japan from Europe for the use of the potter. (For Egyptian pottery, *see* EGYPT: *History: Ancient Civilization and Culture;* for primitive far eastern and near eastern pottery, *see* section *Near and Far East* of this article. *See* also BABYLONIA AND ASSYRIA. and POTTERY, PRIMITIVE.) (X.)

GREEK POTTERY

The pottery of ancient Greece, prehistoric and historical, is distinguished from all other fictile wares of the same ages by its free development of naturalistic painted decoration. The ceramic painter's art was so far separated from the potter's in the classical period, that each could put his signature to his own portion of the work, and there can be little doubt that the best Minoan pottery was equally the joint product of the two craftsmen. This uniformity in Prehellenic and Hellenic ceramics can hardly be fortuitous. Though Late Minoan (Mycenaean) vase-painting contains no visible element of design that was adopted by the Geometric artists, the technique of potter and painter passed intact across the apparent gap in culture that separates the Aegean ages of Bronze and Iron, and the subsequent revival of naturalistic ornament in the Archaic Greek period shows that something more than mere mechanical skill had been inherited.

Prehistoric Origins. — The technique in which the masterpieces of classical vase-painting were executed was first perfected in Minoan Crete, but its invention was not Cretan. Painted pottery was made in prehistoric Mesopotamia and Egypt long before its appearance in Aegean lands. Pre-Sumerian ware bears decoration fired on pale clay in a dark medium of ferruginous earth fused with an alkaline flux, and one variety of Egyptian predynastic pottery has dull white pigment similarly fired on a dark ferruginous wash. Both processes were applied in Early Minoan pottery; the latter was brilliantly exploited in the polychrome Middle Minoan style (Kamares ware), but the former finally prevailed, because of its greater freedom, in the Late Minoan age. *(See* CRETE: *Archaeology.)* At the close of the M.M. period, when Cretan arts were transplanted to the Greek mainland, the colonial (Mycenaean) fabric of Minoan pottery displaced the inferior and largely handmade native wares, Helladic, Cycladic and Thessalian, which formerly marked the various cultural regions. *(See* GREEK ARCHAEOLOGY.) By the end of the Mycenaean age the pottery of the whole Aegean area was uniform, except on its northern and eastern borders, where Danubian and Anatolian influences were preponderant. This latest Mycenaean ware preserves the forms and fabric of the best Minoan models, but its ornament is atrophied. Shells, octopods and seaweed have degenerated into rows of wavy lines, lily and papyrus flowers appear as groups of parallel curves or chevrons, and the rich designs of linked and running spirals give way to bands of single coils. But the clay is finely worked, the pots accurately turned, the firing hard and even, the glaze dense and lustrous. Two Mycenaean fabrics can certainly be distinguished. The more numerous class has a warm yellow clay surface and its black glaze fires red. The smaller group is made of exceedingly smooth pale greenish clay, and painted with brown-fired glaze, which tends, to flake away from the close texture of the surface. The latter belongs to the Argolid, and was made from the same white clay that produced the later Protocorinthian and Corinthian wares.

The Geometric Style. — The next historical phase in Greece was the transition from bronze to iron, about 1000 B.C., a cultural change that involved the violent downfall of the Mycenaean polity. Arts were generally submerged, but the pottery can be identified. It is called Submycenaean or Protogeometric, as its elements appear to attach themselves to the old Minoan or the new Hellenic system. The technique is still Minoan and is often brilliant, but many of the pot-shapes are modified and the decorative patterns assume a new character. The surviving Mycenaean motives are resolved into their simplest linear elements, and these tend to combine again in rigid geometric schemes. Another tendency was to abandon painted patterns and cover the whole pot with black glaze. In this potent fallow the new principles of Hellenic art were laid, and the so-called Geometric style sprang rapid and luxuriant. In its mature phase a Geometric vase is covered with narrow horizontal bands of minute and crowded ornament, rows of repeated figures, triangles, lozenges, circles, continuous or panelled bands of zig-zags, chequers and, chiefly characteristic, the maeander. This last motive, always drawn in double outline filled with hatching, is probably the key to the origin of the style. It appears at the same period in Italy, in the pottery and bronze work of the Villanova culture, and since there is no evidence of intercourse between the two countries at this date, must have been introduced into both from a common northern source. Its first occurrence in Greece is in isolated bands or panels reserved on necks or bodies of black-glazed pots, a rudimentary form of decoration which was as universal as the former Mycenaean style. Subsequent developments were local, and many styles have been identified in mainland Greece, the Aegean islands and the coast of Asia Minor. The most elaborate is that of Athens, called Dipylon ware after the cemetery at the city-gate, where the largest vases have been found. These are huge sepulchral jars which sometimes bear among the geometric patterns broader bands or longer panels filled with pictures of funerals, a corpse surrounded by mourners, and processions of chariots, human and animal figures being drawn schematically in black silhouette. These subjects are the first expression of Hellenic delight in representation, which quickly dominated decorative art and ultimately destroyed it. The live subject, human and animal, was also utilized in the Geometric style as a decorative unit, in bands of soldiers carrying shields and spears, of grazing horses, deer and goats, running dogs and birds. The birds belong, like the maeander, to primary sources of the style, but the grazing and running quadrupeds are a later feature, and are probably the first signs of oriental influence.

Oriental Influences.—The political changes that destroyed the Mycenaean power had also interrupted Aegean relations with Asia and Egypt, but when contact was restored, about the 10th century, the new Greek world became doubly linked with the ancient foreign civilizations, by its colonies on the coast of Asia Minor as well as by its own and Phoenician commerce. The effects of oriental contact are visible in all Greek arts after the 9th century. The actual commodities that served Greek vase-painters for models have not been identified, and if, as is possible, they were textiles, cannot have survived. They seem to have been brightly coloured, for touches of red and white paint enliven the black figures in all the orientalizing styles. But accurate drawing and incised contours suggest metal prototypes, and some bronze and silver bowls and cups engraved in the same manner have been found in Greece and Italy. (See BRONZE.) Oriental motives in the late Geometric style, besides the bands of animals, are cable-pattern (guilloche), palmettes in bands or panels, and base-rays. The latter are derived from the petals of a flower-calix; originally Egyptian, they are a common feature of Asiatic pottery, and particularly of late Hittite vases. These novelties broke up the conventional Geometric art, and the succeeding local wares bear very little resemblance to one another.

Protocorinthian, etc.—The principal early orientalizing styles are Protocorinthian, Protoattic, Island (Melian), and Ionian (Rhodian). They belong broadly to the 7th century. The true Protocorinthian fabric was located in the Argolid, where a very precise and simple geometric style had been established. Precision is the distinguishing feature of Protocorinthian ware, and is accentuated by the miniature forms of nearly all existing vases. They are made of the smooth pale yellow clay which distinguishes the local Mycenaean fabric, and which invites fine craftsmanship by its plasticity. Conical cups (skyphoi) and pointed oval scent-bottles (lekythoi) are typical forms. Their earliest subgeometric ornament of simple linear patterns was soon displaced by bands of animals, particularly running dogs, palmettes and lotus, cables and rays, all of which were in turn subordinated to a main frieze containing human or monstrous figures, sphinxes, chimaeras, centaurs and the like. The background in the figure-friezes is filled with detached ornaments, in this style typically the dot-rosette, a device which belongs properly to metal reliefs, where it is simply executed with a round-nosed punch. The influence of metal-work is also visible in the sharpness of this style and in its use of engraving to define outlines and inner markings of the silhouettes. The colour is enriched with patches of dull red and white. as if inlaid on the black-glaze figures, for details such as manes, throats and bellies of animals, armour, clothes and hair of men. Masterpieces of the Protocorinthian style are the Chigi vase in the Villa Gierlia at Rome, a large jug with an amazingly elaborate battle-piece and hunting-scenes in three friezes, and two small scent-bottles, with fancifully modelled tops and hardly less elaborate hunts and battles on their bodies, in Berlin and London (the Macmillan lekythos). A purely decorative Protocorinthian scheme consists of scales or tongues closely incised on a black-glazed surface and painted alternately white and red, together with thin bands and dot-rosettes in the same bright colours. Large and small vases are entirely or partially covered with these ornaments. This fabric was largely exported, particularly to Italy, where it was more or less successfully imitated by Greek and Etruscan potters. Another Protocorinthian group consists of little vases moulded in natural forms, squatting men, busts and heads, animals, birds and shells. They were largely copied from Egyptian faience figures. and in their turn influenced the Egyptian vase-shapes. Large quantities of these Egyptian blue-glazed wares were exported from the Greek settlement of Naucratis, and some were evidently made there, or in some Greek colony in Asia, for the style of many pieces is more Greek than Egyptian, and one found in Rhodes bears a Greek inscription. The same shapes, particularly heads in helmets, were made in ordinary Greek pottery in Rhodes, and other plastically decorated fabrics from the same island are made of black ware like the Etruscan bucchero nero. Large storage-jars, with plastic patterns worked in relief or impressed in friezes with engraved cylinders, are also represented on Ionian sites. Protoattic pottery exhibits the same developments as Protocorinthian, but in a very different style. Vases and their painted decoration are large and vigorous, their fabric rather coarse, in red clay. Various stages of development are called by names of places where typical examples have been found, Phaleron and Vourva. They illustrate the intrusion and refinement of the Oriental repertory, from the animal-frieze with its close array of filling-ornaments to the isolation of human subjects in a clear field. The Island style is as bold as the Attic; it affects heavy spiral ornaments, gay colours, and ambitious narrative-subjects. Crete was a main channel of the new influence, but its pottery is not yet adequately represented. A typical Island form is a large high-necked bowl with a tall conical foot. Some examples, usually attributed to Melos, are painted over a white slip.

Ionian.—In this technical peculiarity they resemble the fabrics of Ionia, where the white slip was universal. This is a pipe-clay wash laid on the rough body of the vase to make a ground for painting. It is rare in Geometric fabrics, and seems to have come in with Oriental decoration; it was probably an anciept Anatolian invention, for it occurs in Hittite, Syrian, and Cypriote wares, and its immediate source may have been Lydia. The many fabrics of early Ionian style are generally represented by Rhodian vases. These are mostly jugs with rays or lotus-wreaths on foot and shoulder, and animal-friezes on the body, done on the white ground in large black-glaze figures with dull red patches. Among the filling-ornaments are looped semicircles (roundels) attached to the borders of the frieze. Human subjects are rare, the most prominent animal-figures are sphinxes, and the characteristic motive is a band of grazing goats. Large plates are a frequent shape, painted with lotus designs, or with concentric panel-friezes containing heads of goats and birds. A very similar fabric, mostly found in the Ionian city of Naucratis in Egypt, has been called Milesian, but may have been made locally. Clazomenae is chiefly represented by large painted sarcophagi. The red and white ornament on black, which was used in Protocorinthian ware, appears also on Rhodian vases, though not quite in the same forms. Red and white bands stand alone, or separate the floral and animal friezes, and the same colours are used for drawing lotus wreaths, or for filling tongues or lotus and palmette-petals, or even animals outlined by incision on the black ground. A fabric resembling the Ionian, but apparently belonging to mainland Greece, is the so-called Cyrenaic, which, since the discovery of a complete stylistic series in Spartan temple-deposits, has been known rather as Laconian. The excavation of Cyrene should decide the question of its origin. It is a white-slipped ware with bold decorative painting, large black and white chequers and step-patterns and solid rays in its subgeometric form, pomegranates and lotus-buds formally disposed between animal-friezes in its orientalizing phase. Its early shapes are somewhat fantastic; a typical drinking-cup (*lakaina*) has a low convex body, from which two long loop-handles spring, and a tall concave lip or neck. A mature work is the famous *kylix* in the Bibliothèque Nationale of Paris, with a picture of King Arcesilas of Cyrene supervising in oriental state the lading of a ship. It is this scene that caused the fabric first to be attributed to Cyrene.

The Black-figure Style.—Towards the end of the 7th century the local fabrics, which had diverged so widely in their orientalizing phases, tended to come together again, perhaps under Athenian influence, in the Black-figure style. The expansive interest in human form and human life enlarged the fields in which these subjects were accommodated; animal and floral friezes were reduced in width and relegated to the less conspicuous positions on the pots. In the mature style of the 6th century ornamental animals hardly occur at all, and floral patterns are only used for borders or bands and panels in which narrative-pictures are displayed. But the new pictorial style retained the technique of the old ornament. The figures are drawn in black silhouette on the clay ground, and inner details are indicated by incision and by colour. The same dull red and white pigments were laid on the black glaze or on the clay in place of it. Both were decoratively applied without consideration of reality to produce a colour-pattern, but white was specially used for faces and limbs of women. White slip disappears as a mark of locality, but occurs on special occasions in several fabrics. The normal surface has the same colour as the body of .the clay, light yellow in Corinthian, light red in Attic and most other wares. The natural colour of Attic clay was enriched with red ochre (*miltos*) and this substance had shch industrial importance that its supply was strictly controlled by the Athenian Government. Corinthian ware in its latest development tried to imitate the Attic colour with a red wash. The history of Greek pottery in the 6th century is the continuous progress of the Athenian fabric towards its ultimate monopoly. At the beginning of the century there were numerous other black-figure wares, Protocorinthian and Corinthian, Laconian (or Cyrenaic), Boeotian, Chalcidian, and Ionian, but hardly any of these survived beyond its elementary stages. The passing of Protocorinthian into Corinthian was accompanied by such a fundamental change of content that the process is obscured, and it is sometimes supposed that the Corinthian potteries displaced those of some neighbouring city, perhaps Sicyon, which had produced the Protocorinthian ware. But though the output was increased and the style changed, the fabric remained constant, and most of the old forms continue to appear with the new decoration. The change took place at the end of the 7th century, and was evidently due to new Oriental models, perhaps textiles instead of metal work. Globular and baggy oval bottles (*aryballoi* and *alabastra*) came into fashion, with large figures, often monstrous or grotesque, painted in a loose style which is the antithesis of Protocorinthian precision. Backgrounds that had been sparsely studded with neat dot-rosettes are now filled up with irregular patches. This is the common ware that was distributed east and west by Corinthian trade. Besides it is a pictorial style which omits the filling-ornament. There is a splendid series of large Corinthian bowls (krateres) bearing scenes from life and legend, with single subsidiary bands of animals or horsemen. In their free use of colour, their technique of outline-drawing, and their deep designs of overlapping figures, these vase-pictures probably give a better idea of monumental painting than any other surviving documents. Chalcidian pottery stands very close to metal work in its angular vase-shapes and sharp figures. The evidence by which the various fabrics are assigned to their localities lies in the forms of the letters in which the names of gods and heroes are inscribed beside their figures. Ionian black-figure designs are lively in colour and in action; the Clazomenian fabric, like the Laconian, retains its subgeometric subsidiary bands. Ionian wares were largely imitated in Etruria, and some of them may have been made there by immigrant craftsmen. Such are the Caeretan *Hydriai,* a brilliantly decorated series of water-jars found at Cervetri (Caere). Their free floral patterns connect them with the Fikellura vases (so-called after a Rhodian site), an odd old-fashioned group that keeps the white slip technique and is shy of narrative-pictures. One of the last Ionian inventions, the *eye-kylix* (a cup mainly decorated with two large pairs of eyes), was adopted by Attic potters. A related Attic series (*Kleinmeister* kylikes) has miniature figures, often single, in an upper band, and below these, or sometimes alone, a line of minute writing, a drinking posy, a love-name or an artist's signature.

Signatures. — The practice of signing vases began in the 7th century; a Protocorinthian lekythos and a (perhaps Argive) krater with the names of their potters, Pyrrhos and Aristonothos, are the earliest examples. Timonidas, Chares and Milonidas are the only known Corinthian painters; there are four or five Boeotians, and the rest are Attic. Names are always accompanied by the words made (ἐποίησε) or painted (ἔγραψε), sometimes by both. The former is taken to be the potter's signature, but the term is not explicit, and may apply to the owner of the factory, to the manipulator of the clay, or to the maker and decorator. But double signatures indicate that the functions of potter and painter were generally separate: "Ergotimos made me, Klitias painted me" on the François vase; and one man occasionally claims both honours: "Exekias painted and made me." More than roo Attic masters are known by name. Many were manifestly foreign, and some were slaves from the unpromising regions of Thrace and Scythia. One of the great black-figure potters bears an Egyptian name, Amasis; his work reveals Ionian affinities and shows that the Athenian monopoly was partly achieved by attracting foreign craftsmen to the city. Mature Attic pottery incorporates the best qualities of the fabrics which it superseded, technical excellence accomplished draughtsmanship and a large repertory of pot-shapes and decorative schemes.

Vase Shapes. — In archaeological usage the numerous shapes are denoted by 'ancient names which do not always rest on ancient authority, but they are accepted as a convenient means of classification. Important forms are two-handled storage-jars (amphora, *pelike*, stamnos), mixing-bowls (krater, in variety), water-pots (*hydria, kalpis*), jugs (*oinochoe,* olpe, *prochoos*), drinking-cups (*kylix,* kantharos, kotyle, *phiale,* skyphos), and oil-bottles (alabastron, *aryballos,* askos, lekythos). All were, copied from metal models. Greek pottery was never a free art; its forms and decoration were inspired, controlled, and finally destroyed by progress in the arts of painting and metallurgy. After the middle of the 6th century, when technical perfection had been achieved, Attic decorators set themselves to perfect their draughtsmanship and power of expression, and the interest of painted pottery after that time is largely as a document in the history of drawing. The finest early black-figure work is the François vase in Florence, a monumental krater signed by Klitias and Ergotimos. It is covered with bands of lively narrative, the Calydonian boar-hunt, the funeral games of Patroclos, the marriage of Peleus and Thetis, the death of Troilos, and the battle of Pygmies and cranes. Among many later masterpieces is an *amphora* in the Vatican made and painted by Exekias, with a single panel-picture on each side. One picture shows Achilles and Aias playing draughts. The group is a stock subject reproduced by several painters, an excerpt, doubtless, from a monumental picture of the siege of Troy. The intentness of the poses and the elaboration of incised detail represent the last possible achievement of this style.

The Red-figure Style. — The innovation was made before the end of the 6th century, about 520 B.C. Some masters, notably Andocides and Pamphaios, produced vases in both styles, and even combined the two on one vase. In the new process the background was blacked and the figures reserved on the red clay; inner markings, details of limbs and features were drawn in thin lines of black glaze, hair and clothing were occasionally done with a diluted brown or yellow wash of the same medium. The glaze has not been successfully reproduced by modern experiment, but analysis shows that it was composed of ferruginous earth with an alkaline flux. It was applied to the pot after the clay was dried, and before firing. The design was lightly sketched with a point, then drawn in outline and detail, apparently with a pen. The background was blacked in, and certain contours of the figures accentuated with relief lines of thick glaze. Touches of colour, red and gold, were very rarely added, and pot and glaze were fired together in a single operation. The new drawing had unlimited freedom and made rapid progress in truth and expression, but its decorative qualities were slight. The formality of archaic art and the restraint of early classical drawing preserved the decorative value of the figures to some extent, but after the middle of the 5th century, when the problems of representation had been solved, this character was lost, and facile drawing admitted weak design.

Attic Masters; Love-names. — Epiktetos, Euphronios, Euthymides, Brygos, Hieron, Douris, are a few names of the great archaic-masters; Sotades, Polygnotos, Meidias, of the free style. Some of these signed as potters, some as painters, and there are anonymous painters, no less capable and far more numerous, whose style can be recognized in their work. Recent research has gone far towards identifying all the hands in Attic red-figure drawing. Where the artist is not known by name, he is called after the potter for whom he worked (the Brygos painter, Meidias painter), after one of his vases or the collection in which it is preserved (the Villa Giulia painter, the painter of the Bowdoin Box) or a notable subject (the Pan painter), or after other persons named on his vases (the Panaitios painter). These, the so-called love-names, refer to popular idols of their day. When known to history they are youths of noble family, and the form of inscription *Panaitios* is handsome (Παναίτιος καλός) indicates that their fame rested on their good looks. The duration of this popularity was therefore not very long, and the use of historical names, Glaukon, Leagros, Miltiades, is valuable evidence for the dates of the vases. The character of red-figure subjects changes with the style. Archaic artists favoured heroic deeds and genial life, exploits of Herakles and Theseus, battles with Amazons and Centaurs, athletic contests and drinking-bouts. The early free style suited contemplative subjects, boys leaving home for the wars, religious and musical ceremonies. In the late free or florid style the scene is largely filled with idle women clad in voluptuous robes and trifling with winged love-gods.

Late Attic and Italian Fabrics.—In the early 4th century an attempt was made to revive this dull field again with colours, white generally for flesh of one or two figures in a group, blue, green, red and gold for drapery and jewels. Gold was often laid on details modelled in relief. These vases have been largely found in North Africa and South Russia, and take their name from the Crimean town of Kertch. They represent the last phase of pictorial painted pottery in Greece. The art survived, however, and even flourished for at least another hundred years in South Italy, where it was first established at the end of the 5th century. Another Attic fabric, the white-slipped ware which was regularly used for funeral lekythoi and occasionally for kylikes and other shapes in black-figure and outline-drawing, also came to a natural end in the 4th century, but was not involved in the same artistic decadence, since its decoration had proceeded on the broader lines of painting. These little vases, oil-bottles made for offerings to the dead, generally bear pictures of the tomb with boys and maidens bringing gifts. Clothes and mourning-sashes are painted in bright colours, and free brush-work dominates the designs. But painted patterns did not entirely disappear with pictorial subjects.

Hellenistic Relief-wares.—There was always a large class of black-glazed vases which had no other painting, but were sometimes fluted or impressed with slight ornaments in close imitation of metal. These were further adorned in the 4th and 3rd centuries with wreaths and necklaces drawn or engraved, or modelled and painted white or gilt, and occasionally with moulded figures like bronze plaques in relief. This style seems to have been universal in Hellenistic Greece, and was also produced extensively in Apulia and Campania (Gnathia and Capua wares). Another Hellenistic fabric, usually black-glazed, has purely plastic decoration, being exactly copied or even cast from contemporary bronze and silver vessels ornamented with reliefs. One group of bowls is called, for no good reason, Megarian or Homeric; it may be the Samian ware mentioned by Pliny, and is certainly the prototype of the Roman pottery wrongly called by that name. Bowls have decorative foliate patterns, or bear mythological and heroic scenes, often accompanied by written descriptions or verses quoted from the plays or poems which they illustrate. Another type, called Calene *phiale,* and mostly made in Italy, is a shallow bowl with a central medallion or interior border-frieze in relief. Two examples in the British Museum, with a frieze of chariots, are replicas of a silver bowl in the same collection. (See SILVERSMITHS' AND GOLDSMITHS' WORK.) Some Hellenistic wares preserved the old tradition of black painted ornament on a light clay ground or slip. Their designs are mostly wreaths and garlands, and their fabrics seem to be located in the East, particularly at Alexandria in Egypt (Hadra vases). Alexandria and Tarsus were the first centre5 of manufacture of Greek pottery glazed in modern fashion. Blue and green faience mas the speciality of Egyptian potteries. It had been imitated by the archaic Greeks and appears with Greek designs again in the Hellenistic age. But the new glaze is quite different, and was probably an Asiatic invention. It is a thick vitreous substance made with a metallic flux, in colours ranging from brown through yellow and green to blue, and was usually laid over lamps and similar small vessels moulded in relief or entirely modelled in natural forms. But at this point Greek plastic pottery finally merges with Italian. The art of the Mediterranean world in the 2nd century B.C. was Hellenistic, industry was cosmopolitan, and it is not always possible to know in which country the fabrics were located.

ANCIENT ITALIAN POTTERY

North and south Italy were separate cultural provinces in prehistoric times. The south, with Sicily, produced some elaborately painted pottery, which may be related to the Neolithic wares of mainland Greece, and some incised with rectilinear patterns like those on the earliest fabrics of Troy and Crete. But there is no evidence of contact between the Aegean and Italian areas before the Late Mycenaean age (c. 1300 B.C.), and the mutual resemblances in the pottery are equally referable to the universal similarity of primitive abstract decoration. In any case this south Italian art lived and died in isolation. Contemporary pottery of the north and central regions was of much coarser type, seldom decorated at all and never painted. But the Bronze age (Terremare) fabrics, though inferior in quality, had a plastic character that influenced the southern shapes and developed through the Villanova style into classical Etruscan ware. It was probably not fortuitous that the Hellenistic relief styles were largely established in Italy, and that the pottery of the Roman empire bore plastic decoration.

Prehistoric Origins.—The decorative elements in Terremare pottery are knobs and ribs on the bodies and fantastic modelling of handles, which often end in horns and crescents. The same elements, which had Danubian affinities, persisted in early Iron age (Villamova) fabrics, and the Geometric style in which the other Villanova ornament was designed also reflects the influence of central European art. The similarity of this Villanova Geometric to the contemporary Dipylon Geometric style of Greece has sometimes been referred to Greek influence in Italy, but there is no other trace of contact at this time (c. goo B.C.), and it is probable that the same style penetrated both peninsulas from the north. In each case the new designs found an effective medium ready for their expression. Greek Geometric pottery was painted in the old Minoan technique, the Italian patterns were engraved or stamped or modelled in soft clay. The characteristic maeander, which the Greeks painted in a hatched band, appears in Italy in a band of parallel incisions. The Italian style, like the technique, is far more primitive than the Hellenic. Villanova pottery is not wheel-made; its clay is coarse, red or brown in body with a darker surface which at its best is polished black. This type of pottery is known in Italian archaeology as impasto. The surface colouring was probably done by fumigation. The fabric is thick and clumsy and the shapes are composed of the simple globular and conical forms that belong to elementary metalwork. A typical cinerary urn has a tall biconical body with a single horizontal handle on its wide middle. Its mouth is often covered with a shallow one-handled bowl. The natural development of such pottery was towards closer imitation of metal in refinement of fabric and accuracy of form, but the process was disturbed by the intrusion of foreign influences from Greece and Asia. This contact, which began in the 8th century, coincided with the first settlements of Greeks in Italy and with the rise of Etruscan civilization.

Etruscan **Bucchero.**—The native Etruscan pottery is called in Italian bucchero nero, or simply bucchero. The clay is fine and coloured black throughout its substance, probably by chemical reduction in the kiln or by previous staining. The fabric is generally heavy, since most of the vases were made in moulds and the wheel was rarely used. There are, however, some very fine, thin pieces. Besides the simple developments from Villanova forms, among which the arched band-handle is conspicuous, are copies of Greek and oriental models, *oinochoai, kantharoi, kylikes,* enriched with various kinds of moulded ornament, engraved, impressed or modelled. The three processes were often applied to one pot. Linear designs were drawn freehand with a graver or a wheel; they consist of animal and human subjects, floral ornaments, palmette and lotus and simple geometric figures, zig-zags, hatched triangles, linked arcs and spiral coils. Common patterns are fan-shaped groups of dots or dashes impressed with toothed wheels. Small decorative units like rosettes and stars were applied with separate stamps, and continuous patterns such as cables *(guilloche)* were done with engraved wheels. Elaborate friezes in relief were similarly executed with cylinders like Babylonian seal-stones engraved with real and monstrous animals and scenes of hunts, races, banquets and funerals. They were applied to all kinds of vases, but are particularly common on the body of the characteristic Etruscan *kylix* or *calix,* a cylindrical cup on a heavy stem which was a Phoenician form, and perhaps originally Hittite. Some ivory examples carved with similar reliefs were among the foreign articles in the Barberini tomb at Praeneste. Many of these cups are supported by three or four modelled struts, in addition to or instead of the central stem, set between the edges of base and body. They are in the form of human figures or flat strips decorated in relief or openwork. Plastic ornament was also applied to these and other vessels in large reliefs, usually of single animal figures on the bodies, rows of masks on rims, and heads standing free on handles. Bodies were also ribbed and fluted and moulded with gadroons, tongues and petals.

Greek Influences. — Though the foreign influence in this modification of Etruscan pottery may have been Asiatic and derived through Phoenician channels, Greek models introduced the innovation of painted patterns in ferruginous glaze. Greek artistic influence was doubly strong in Italy because the workmen were imported together with their works, 'either as colonists in the Greek settlements of the south or as adventurers in Etruscan cities. There was, for instance, a considerable manufacture of Protocorinthian ware at Cumae (Naples), founded from Chalcis about 750 B.C., and the local Greek fabric can only be distinguished from imported originals by a slight difference in the clay. But some other pieces found at Cumae reveal their provincial origin in coarser forms and decoration, and still more debased versions found on Etruscan sites are evidently the work of Italian potters. The Greeks rediscovered Italy at the end of their Geometric period and the first Etruscan ware painted in the Greek method bears simple rectilinear patterns, not often closely copied from Greek designs, in dull black glaze on light clay. At the same time, and perhaps earlier, there was painted decoration in Etruscan and Latin pottery done in dull white on the dark *impasto* and *bucchero* surfaces. A fabric of red *bucchero* connected with Falerii frequently bears white linear patterns. Greek and oriental subjects, bands of animals and lotus, were also painted in the same medium, and black *bucchero* was perhaps more often finished with polychrome ornament than the present condition of the vases indicates, for these colours were badly fixed and are very fugitive. Protocorinthian and Corinthian pottery were more skilfully copied and to such an extent that the Italian versions of these styles are now as plentiful as Greek originals, particularly jugs with subgeometric patterns, *lekythoi* and *alabastra* with polychrome imbricated decoration and those with bands of running dogs. In the black-figure period (6th century) Greek influence was so intense that it is not possible to decide whether some groups, Caeretan *hydriai* and Pontic *amphorae* were made in Italy, Ionia or Greece. But ordinary Italian products are easily detected by their inferior style and fabric. As Greek art progressed, Etruscan fell behind, and there can be no confusion between the two fabrics in the red-figure style, though most of the existing Attic vases have been found in Etruria. For this reason they were thought on first discovery to be Etruscan, and the false name still lingers in popular usage. It has also been supposed that Attic vases were made chiefly for the Etruscan market, but the fact is that their better preservation in Italy is due to the Etruscan practice of burying them as funeral furniture in chamber tombs.

South Italian Red-figure. — Between the later Attic originals and their Etruscan imitations stand the great series of red-figure vases made in the Greek cities of south Italy, which are derivative rather than imitative, and contain many Italian elements. They had a vigorous life for a hundred years after the disappearance of the true Greek industry. Painted pottery had been made by the natives of south Italy since the 8th or 7th century, at first without any traces of Hellenic influence, in fantastic shapes, large *askoi* and strongly curved and carinated cups with horned handles, elaborately ornamented with geometric patterns (Peucetian ware), and in the 5th century with Greek floral motives in place of the rectilinear designs (Messapian). Some of their peculiar shapes were ultimately incorporated in the red-figure fabrics, but the new style at first was wholly Greek, and its earliest examples are not easily distinguished from Attic vases; they may, indeed, be the work of Athenian artists living in Italy. But in the 4th century definite local styles were formed, differing from Attic in certain vase-shapes, colours of clay and paint, types of subjects and styles of drawing. The recognized south Italian fabrics are Lucanian, Campanian and Apulian, with a special group attributed to Paestum. They differ from one another in some technical and stylistic details, but all are marked by dull brownish clays, extravagant shapes and florid ornament. The simplest style is Lucanian, which probably represents an early phase of the industry. Mature Campanian and Apulian are gaily and profusely ornamented, but the effort is generally limited to one face of the pot, the reverse side being filled with dull conventional figures. Some large vases bear mythological scenes, but ordinary pieces have commonplace subjects of youths and maidens lounging in exaggerated elegance and a close atmosphere of ribbons, flowers, pet animals and domestic furniture. The filling of the backgrounds approaches that of the Greek orientalizing styles. Border patterns, palmettes, waves and foliate wreaths are bold and large. Subsidiary colours, white, yellow, red, were freely applied in dots, lines and washes. Men's costume often reflects Italian fashions, particularly on Campanian vases, a very short tunic with broad belt, and feathered helmets and triangular breastplates for soldiers, presumably the Samnite armour. Dress, pose and gesture of the figures have a histrionic extravagance which seems actually to have been taken from the stage. An important class of subjects consists of theatrical scenes, particularly from the tragedies of Euripides. Burlesques of tragic and heroic legends are also depicted. These were the local *phlyakes,* the kind of farce that the Tarentines were attending in the theatre when they saw the Roman fleet entering their harbour, in 302 B.C. The stage and scenery are often illustrated in these pictures. Only three artists are known in the Italian schools, and two of them, Assteas and Python, belong to the Paestum group. Both painted theatrical scenes. A *krater* by Python shows Alcmena on the funeral pyre, Antenor and Amphitryon setting light to it, and in the upper background, by a characteristic and perhaps theatrical convention of perspective, half-figures of rain-nymphs pouring water out of pitchers on the fire at the behest of Zeus. The most imposing Apulian vases are great sepulchral *amphorae, hydriai* and *krateres.* They bear pictures of elaborate funeral monuments, done in white paint, gabled tombstones or shrines with reliefs or statues of the dead, to whom mourners (in red-figure) bring gifts. Another florid south Italian class of pottery has free plastic ornament; large globular *askoi,* a native shape, have gorgon-masks and fronts of harses on their bodies, large statuettes of women, cupids and winged goddesses standing on rims and handles, all brightly painted in blue and red.

Hellenistic Relief-wares. — These Graeco-Italian fabrics were succeeded, in the 3rd century, by Hellenistic pottery imitating metal, black glazed ware painted with white, yellow and red necklaces and garlands or moulded in relief, The first class takes the name from Gnathia (Egnazia) in Apulia, where much of it has been found. There was certainly an Italian fabric in this style, for several pieces bear Latin legends, mostly dedications to deities such as *Aecetiai pocolom (Aequitiae poculum,* the cup of Justice) painted with the foliate decoration. Some of the contemporary relief wares were also made in Italy. Moulded signatures on several bowls fix their place of origin at Cales in Campania and their maker's nationality as Roman: L. *Canoleios* L. *F. fecit Calenos.* A similar fabric assigned to Bolsena in Etruria is unglazed, and may have been gilt or silvered.

Roman Pottery. — It was also in Etruria, at Arezzo (Arretium), that the first Italian fabric was established of the fine red pottery, variously called Arretine or Samian or *terra sigillata,* which became the standard ware throughout the Roman world for several centuries. *Terra sigillata* is the modern archaeological name for the whole class. Samian is a misnomer; it may perhaps be applied to some Greek fabrics, but means nothing definite. Pliny says that the reputation formerly held by Samian table pottery had passed in his day to Arretium and other places in Italy, Spain and Asia Minor. There is no trace of a Spanish fabric in the existing material, but examples of Asiatic origin have been found at Laodicea, Pergamon, Myrina and elsewhere. It is a purely Hellenistic type of pottery, whether made in Italy or Greece.

Arretine.—Arretine is the name of the Italian fabric, which was not made solely at Arezzo. Provincial Roman varieties, mostly Gaulish, are named from their places of manufacture, La Graufesenque, Lezoux, etc. All this pottery is made of bright red clay and, when ornamented, moulded with reliefs (*sigilla*). Some early (2nd century B.C.) products of Arezzo are black glazed, but they hardly enter into the series. The vases are generally small, for table use, and very rarely have handles; they are mostly bowls, cups and saucers of shallow cylindrical and globular forms. Their lustre was produced with a thin alkaline glaze, which gives an extraordinary depth and richness to the colour of the clay. The earliest decoration was copied from the embossed silverware which was originally a speciality of Alexandria and Antioch. (*See* SILVERSMITHS' AND GOLDSMITHS' WORK.) The bodies are completely covered with floral and foliate designs, masks and decorative furniture, human and animal figures, allegorical and mythological scenes, processions, sacrifices, battles, hunts, dances, feasts and similar episodes of social life The vases, or their decorated bodies, were cast complete in clay moulds, which were prepared mechanically by means of separate stamps, for the component elements of the design. The final artistic effect was therefore dependent on the potters' manipulative skill. The potters' signatures were stamped into the moulds, sometimes appearing in relief on small tablets among the ornamental figures, sometimes in sunk spaces, rectangular, round or fancifully shaped as footprints, wreaths or stars on rims or bases, inside or outside the vessels. Plain wares are ordinarily stamped inside the base. The names of Arretine potters begin about 100 B.C. They represent owners of factories, whose names are sometimes given in the formal Roman manner, sometimes greatly abbreviated and in monogram, and the actual potters, slaves, who often have foreign names. The master potter Marcus Perennius signed M. *Perenni,* M. *Peren, M. Pere, M. Per,* and *M. Pe.* Seventeen slave names occur on his vases, sometimes in conjunction with the master's, sometimes alone. Bargates and Tigranes are the best known; the latter signed *Tigran, Tigra and Tigr.* Aulus Titius signed *A. Titi. Figvl(ina) Arret(ina).* The factory of Rasinius was directed by Lucius of that family in the Augustan period and by Gaius Rasinius Pisanus in the Flavian, by which time the Arretine potteries were turning out replicas of Gaulish work. The large numbers of names and the many varieties of vase shapes and types of ornament that were produced during the long life of this pottery, have been very accurately recorded, and the pottery has become a valuable archaeological index for determining the dates of other Roman objects, buildings and sites, with which it is found in excavation.

Gaulish Terra **Sigillata.**—The Italian fabric came to an end about A.D. 100, being displaced in Italy and the provinces by *terra sigillata* made in France Italy still produced its own coarse pottery for ordinary domestic use, unglazed and undecorated vessels, which formed the bulk of ancient pottery at all periods. The new Gaulish ware was precisely the same as Arretine in fabric, and at least as good in technical quality; its colour is even superior, a darker and brighter red, and its paste is usually harder than the Arretine. But the decoration is inferior, the ornament is in very low relief, and designs and figures are generally small and mean. It is found all over the Roman world, but most abundantly in central France. Finds of moulds and kilns have fixed the localities of the two principal fabrics at La Graufesenque (Aveyron) and Lezoux (Puy-de-Dame), in the ancient Rutenian and Arvernian territories. The Gaulish fabrics began before the middle of the 1st century A.D. and ended about the middle of the 3rd, but ornamented vases were probably not cast from moulds after the middle of the 2nd century. The names are often Gaulish, and even Roman names are spelt in Gaulish fashion, *Tornos* for *Turnus.* It is a strange fact that native elements do not appear in the designs. The forms were at first identical with Arretine or derivative, and there was the same distinction of shapes for ornamented and plain wares. The commonest type of ornamented vase was a carinated bowl with a band of design on each plane *(Form* 29). It was succeeded in popularity about A.D. 150 by a bowl cylindrical in form, which in its turn gave place to a type of hemispherical shape *(Form* 37). The commonest plain red vessels are very wide and shallow cylindrical and conical bowls or flat saucers. The earliest ornament consists of purely decorative motives, wreaths and scrolls, with a few animals incorporated in the foliate designs. These bands are continuous, but the figure-subjects, which began about A.D. 75, are broken up in panels, medallions and arcades, and a free style of figure composition was not reached until the 2nd century. It is characteristic of Lezoux bowls. The figures are minute and were generally taken from well-known Hellenistic sculptural types. There are a few mythological groups. A purely Roman subject, the gladiatorial duel, is very frequent. In the free style hunters chasing animals are popular subjects.

Barbotine **and** Lead-glaze. — A technical innovation of the and century was relief applied in *barbotine,* slip clay laid on by piping. It seems to have been a German invention, since it appears first on native Rhenish pottery of the 1st century. Its early use in *terra sigillata* was for small foliate patterns on the rims of flat bowls and dishes, but in the 3rd century it began to replace moulded work on bowls of the standard Roman shape. Another Teutonic element in the Roman fabrics of this date is a globular jar with narrow neck (*olla*), which could not be cast entire. Its ornament was therefore made in separate plaques or medallions and affixed to the pot; scrolls in *barbotine* form a setting for these reliefs, which are largely topical in subject, portraits of emperors, gladiatorial contests and theatrical scenes, often accompanied by explanatory inscriptions. These were made in Provence and also at Lezoux, where they were the last products of the Roman industry. The Gaulish output was not large in Roman times and its forms were trifling, small vases and lamps and toys ornamented with reliefs or modelled in the shapes of animals and common objects. But in the Eastern empire the process was generally used for Byzantine pottery. It was adopted by the conquering nations after the fall of Rome, and became the medium of ceramic decoration in mediaeval Europe. (E. J. F.)

BIBLIOGRAPHY.—H. B. Walters, *History of Ancient Pottery* (1905, bibl.); E. Pfuhl, *Malerei und Zeichnung der Griechen* (1923, bibl.), and an abridged version translated by J. D. Beazley (1926); A. Furtwangler and K. Reichhold, *Griechische Vasenmalerei* (1904), accurate large scale drawings; W. Riezler, *Weissgrundige Attische Lekythen* (1914), photographic reproductions; G. M. A. Richter, *The Craft of Athenian Pottery* (1923); F. Courby, *Les Vases Grecs à Reliefs* (1922); F. Oswald and T. D. Pryce, *Terra Sigillata* (1920, bibl.)

EUROPEAN POTTERY

TO END OF 18TH CENTURY

Byzantine. — The Eastern Empire with its capital at Constantinople was the channel through which, after the downfall of Roman civilisation in the West, the art and culture of the East was communicated to Europe, and the artistic ancestry of later European pottery is to be sought, in part, in this quarter. Evidence is scanty, however, as to the nature of Byzantine pottery, owing to the cessation of the pre-Christian custom of burying earthenware and other vessels in the tombs of the dead. What little we know is derived from finds of potsherds in excavations at Constantinople and a few sites in Greece, Cyprus, the Crimea and elsewhere. These are of two main types, both of red-bodied earthenware with a surface coating of transparent lead glaze. The decoration in one type is in relief, produced with impressions of a wooden stamp; in the other it is of the kind known as *sgraffito,* engraved with a pointed tool through a coating of white slip. The fragments are mostly those of bowls and deep dishes; the ornamental motives include human figures, animals and birds of symbolic import, simple leaf designs, interlacements, monograms and the Greek cross. The glaze is generally yellow; a bright copper-green is also found.

Hispano-Moresque Ware.—The chronology of the Byzantine wares discussed above is difficult to establish, but it is probable that they date from the two or three centuries immediately preceding the Turkish conquest of Constantinople in 1456. Pottery of artistic quality was known long before this date in Spain, fragments with painted decoration akin to that of the contemporary wares of Mesopotamia and Egypt having been found on the site of Medina az-Zahra, the palace of the Caliphs near Cordova, destroyed in the 11th century. References are found in writers of the 12th century and later to the "golden pottery" of Calatayud (in Aragon) and of the Kingdom of Granada; this phrase undoubtedly means the tin-enamelled earthenwares painted in metallic lustre colours, derived from silver and copper, which are the most famous of the Hispano-Moresque wares, although no surviving specimens are known which can be referred to a date earlier than the 14th century. To this period belong the celebrated vase in the Alhambra, with its decoration of confronted gazelles, arabesques and inscriptions, in golden lustre with touches of blue, and the similar vases scattered in various museums. A bowl of similar style, at Berlin, which is marked with the name of Malaga, suggests that that city rather than Granada was the place of origin of this Andalusian class of lustred pottery. In later times the manufacture passed to the kingdom of VALENCIA, whence in the 15th century such wares were shipped to places so far distant as Leeuwarden, London, the Crimea and Cairo. The chief Valencian pottery centre in the 14th century was Paterna, where quantities of enamelled ware have been found with human figures, animals and foliage designs of pronouncedly Gothic character painted in manganese-purple and green. In the neighbouring town of Manises, on the domain of the Buyl family, lustred pottery was made which the writings of Eximenes show to have been already famous for its beauty in 1383. In the earlier Manises wares we find designs of strongly Oriental character, comprising the Islamic "tree of life," palm-motives and Arabic inscriptions (generally the word *alafia,* "blessing," repeated in formalized characters). Early in the 15th century we find bold heraldic animals in blue against lustred spirals, and from about 1450, especially in wares made with heraldic designs for export to Italy, beautiful diapers of vine-leaves and small flowers. In the 16th century renaissance foliage makes its appearance, and in the decadent 17th century wares a crowded ornament of birds and leaves in a fiery copper lustre. Fine blue-and-white wares were made at Teruel (Aragon). At Seville and Toledo especially were produced polychrome-enamelled tiles, at first cut so as to form geometrical and other designs in enamel pigments, which are kept within the outlines, first by painting these in manganese mixed with a greasy medium (de cuerda seca), and afterwards (from about 1510) by moulding the outlines in slight relief (de cuenca). Earthenware dishes with bold animal designs executed by the cuerda seca technique were made at Toledo. Mention must be made also of the great amphora-shaped wine-jars, well-heads and fonts with stamped or incised ornament, sometimes covered with a green enamel, which were made at Triana (Seville) and elsewhere in southern Spain in the 14th and 15th centuries.

Italian **Maiolica.**—The Italian wares of the early Renaissance period represent the highest achievement of the potter's art in Europe. They are mostly of the type known as maiolica, that is, earthenware coated with an opaque tin glaze or enamel as a recipient for painted decoration. The name was first used in Italy in the 15th century of the lustred Valencian wares imported in Majorcan trading ships and mistakenly supposed to have been made in Majorca; it was afterwards extended to Italian limitations of them and finally to unlustred earthenware with a tin enamel. Such wares have been found at Orvieto, Faenza, Siena and elsewhere, dating from the 14th and 15th centuries, with designs of animals, birds, foliage and heraldry of Gothic style in manganese-purple and green, recalling those of the Spanish wares of Paterna.

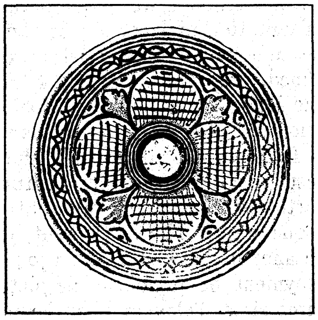

BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM
DERUTA MAIOLICA DISH

By the end of the 15th century the palette was extended to five principal colours or more, but the designs retained their purely decorative character. After 1500 a change to pictorialism came about, with a further range of colouring, dishes and vases being at last treated merely as recipients for subject-paintings (*istoriati*); later in the century the arabesques of Raphael and his school based on ancient Roman wall-paintings began to influence maiolica design, and in the 17th century decoration of this type found a rival in monochrome blue painting in emulation of Chinese porcelain and the Dutch wares of the time, heralding the downfall of the art of maiolica in competition with English earthenware in the 18th century. A great part of the output of the maiolica-potters, in the form of large dishes, wall-panels and vases, was intended from the outset for decoration only; dishes with appropriate designs were a favourite form of gift as love-tokens or to celebrate betrothals and weddings. The "useful" wares include plates, jugs and large pitchers, and expecially drug-pots for the equipment of feudal or monastic pharmacies, either with a handle and short spout or of the waisted cylindrical shape known as albarello. Pavement-tiles were also an important part of the output of certain workshops. From about 1500 onwards the influence of contemporary graphic art becomes increasingly apparent in the decoration of maiolica. Woodcuts in devotional and other books and the engravings on copper of German as well as Italian masters provided the painters with motifs.

Early in the 15th century, under the lordship of the Manfredi, Faenza became an important centre of the craft; the city soon rose to such predominance that its name was adopted in French and other languages for enamelled earthenware in general. Floor-tiles, dated 1487, of great beauty, powerful design and colouring in the church of San Petronio, Bologna, are shown by inscriptions on them to have been made at Faenza in the workshop of the Betini family. The leading Faventine workshop from about 1500 was the Casa Pirota; the dishes and drug-vases there made display a great wealth and variety of ornament based on early Renaissance motives — cupids, masks, dolphins, cornucopias and the like, generally in reserve on a blue ground. One class of wares is painted in dark blue and white on an enamel stained lavender-blue. A great master of the craft, identified by the signature on the back of a dish painted with Christ amongst the Doctors as Ieronimo da Forli, is believed to have lived at Faenza; he adapted compositions of Diirer and others in paintings displaying all the resources of the art in unexcelled beauty of harmonious colour ("The Resurrection," Victoria and Albert Museum, London; "Martyrdom of St. Sebastian," Florence; "Death of the Virgin," British Museum).


BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM
CAFFAGGIOLO MAIOLICA JUG

It seems that maiolica was not made at Florence, but potteries existed in its neighbourhood at Montelupo and Caffaggiolo. To the former perhaps belong the noble 15th century wares, especially two-handled nearly globular drug-pots, painted in a thick blackish blue and purple with animals, birds and human figures amongst foliage which from its type has won for these wares the appellation "oak-leaf jars"; in the 17th century this place produced dishes with crude figures of musketeers. A pottery attached to a castle of the Medici, Caffaggiolo, was the source of some of the most sumptuous maiolica ever made, great dishes, bowls and pitchers with the arms of the Medici and of the two popes of that family, triumphs in the manner of Mantegna, and subjects after Florentine artists. Hardly less splendid are the wares of Siena, particularly of one Maestro Benedetto; they excel in vigorous ornamental designs of early Renaissance character, in a palette dominated by a rich orange-yellow. Conspicuous among them are the drug-vases with an oval panel on one side formed by a ribboned wreath of fruit and foliage and traversed by a wide band bearing the name of the intended contents. The typical Sienese painting is seen also in the heraldic and grotesque designs of the pavement-tiles of the Petrucci Palace, Siena, now scattered in various museums. The Sienese wares were imitated at Deruta, near Perugia, which was, however, better known for its lustred wares (the earliest with a date, a relief of St. Sebastian in the Victoria and Albert Museum, is of 1501); these are painted in blue outline and shading, filled in with a pale lemon- or straw-yellow lustre. They take the form especially of two-handled vases and goblets and heavy wide-rimmed dishes, often painted with a lady's bust accompanied by a moralising adage or with figures influenced by Perugino.



BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM

ANTWERP MAIOLICA DISH

A large share of the production of maiolica in the 16th century belongs to the duchy of Urbino. Castel Durante (now called Urbania) made wares predominantly decorated with fancifully-conceived arrangements of weapons, musical instruments and the like combined in trophies with grotesque masks, dolphins and cornucopias. One Zoua (*i.e.,* Giovanni) Maria employed such themes as borders to enclose figure-subjects of exquisite delicacy. Castel Durante was also the birth-place of Nicola Pelliparío, the greatest of maiolica-painters, who migrated to Urbino and there adopted the name Fontana; he brought narrative (istoriato) painting to an unsurpassed pitch of perfection in several services of plates with. mythological and other subjects, particularly one with the arms and devices of Isabella d'Este and another now in the Museo Civico, Venice. He freely adapted motives from engravings, including the woodcuts of an edition of Ovid's Metamorphoses published at Venice in 1497. Nicola's style was followed, in progressive deterioration, by his grandson, Orazio Fontana, and others of his family, and by Francesco Xanto and Alfonso Patanazzi, all of whom owned or painted at potteries at Urbino itself. In these, about 1550, a new and pleasing style of ornament was adopted, of airy and fanciful arabesques in the manner of Raphael scattered over a creamy white ground; about the same time also Urbino began to produce imposing snake-handled urns, fountains, wine-cisterns, salt-cellars and inkstands (the latter often in the form of a group of figures) in shapes largely borrowed from bronze or silver. Pictorial wares similar to those of Urbino were made about 1560 in the workshop of the Lanfranchi family at Pesaro. The maiolica of Gubbio, made by Maestro Giorgio Andreoli and his successors, is famous for its lustre painting, in golden yellow and especially in a rich ruby colour; at first this artist followed the style of the Deruta lustred wares, but about 1518 he began to produce designs of his own, including grotesques and trophies like those of Castel Durante, figures of *putti* within symmetrical border-ornament, and pictorial subjects based on engravings, chiefly after Raphael. Besides making pottery for his own decoration, he added lustre enrichments to already-painted wares sent from Urbino, Castel Durante and Faenza for the purpose.

There were several maiolica factories at Venice. In some of these pictorial wares were made like those of Urbino, but generally of indifferent quality. One Maestro Lodovico produced about 1530–50 a distinctive class of wares strongly influenced by the Near Eastern pottery and Chinese porcelain then beginning to be imported by Venetian traders; they are painted solely or chiefly in blue on an enamel stained to a pale greyish-blue. The 17th century Venetian maiolica displays a fondness for architectural subjects and occasionally ornament in high relief imitating contemporary *repoussé* silver.

The potteries of the Ligurian coast between Genoa and Savona came into prominence in the 17th century with their blue-and-white maiolica sometimes directly copied from Chinese porcelain; at the same time close imitations of Turkish earthenware were being made at Candiana near Padua. From about 1670 onwards the potteries of Castelli, in the Abruzzi, and its neighbourhood produced wares with polychrome painting in subdued colouring of figure-subjects and landscapes.

Italy is remarkable not only for its maiolica but also for a distinctive kind of lead-glazed earthenware with decoration incised through a coating of white slip (*sgraffito*). The glaze is generally of a deep buff tone, giving a dark brown colour to the red body where revealed by the engraving of the decoration, which is often heightened by touches of green and purple laid on with a brush before the application of the glaze. The technique, derived through the Byzantine dominions from the Islamic East, attained artistic importance in Italy towards the end of the 15th century. Recent investigations have shown that although it was practised at several other places north of the Apennines, the wares in which it is displayed at its best were made under the patronage of the Bentivoglio family at Bologna. Sgraffito ware was made at Bologna until the 17th century.

French Faience. — pottery found in excavations at various places in Provence, and at Agen, and tiles from the church of Brioude, prove that tin-enamelled earthenware, with painting in manganese-purple and green, was made in Southern France as early as the late 14th century. Maiolica of a more developed type was made in the 16th century at Lyons by Italian potters from Florence and Faenza; to them are attributed certain wares with pictorial subjects in the Urbino style and French inscriptions, and tiles from the church of Brou. About 1540–60 Masseot Abaquesne was making maiolica and tiles painted with purely French renaissance designs at Rouen. Some rare examples with heraldic decoration are believed to be the work of Antoine Sigalon of Nimes.

In 1578 a pottery for this kind of earthenware (called in French faience) was set up at Nevers by three brothers named Conrade, from Albissola near Genoa, and continued in the hands of their descendants. In the 17th century, under Chinese influences, polychrome gave way to blue-and-white painting, with manganese for the outlines, though classical themes continued for a time in favour. Soon after, subjects adapted from late Ming Chinese porcelain became the fashion.

A privilege for making faience at Rouen was accorded in 1644 to Nicolas Poirel, who was succeeded by Edme Poterat and his son, and in the reign of Louis XIV. the city became a thriving centre of the faience industry, noteworthy for the large dimensions of many of its wares — dishes, wall-cisterns, and life-size busts on pedestals. A distinctive style of decoration was introduced characterised by wide borders and radial arrangements of palmettes, scrolls and festoons somewhat resembling lace; in the motives of this graceful lambrequin decoration Chinese elements are blended with those of the classical baroque. The painting is carried out in blue, either alone or combined with red or ochre-yellow. About 1730, in the pottery of Guillibaud and others, a change came about in favour of a more varied polychrome palette; motives borrowed from the Far East assert themselves, together with the asymmetrical scrollwork, shells and cornucopias of the rococo, and towards the end of the century the enamel-painted flowers of contemporary porcelain were imitated. The faience industry at Rouen as elsewhere was killed by competition with imported English wares.

At Moustiers in Provence faience began to be made shortly before 1700 by members of the Clérissy family. Among their early productions are dishes of exceptionally large diameter with hunting-subjects after engravings by Tempesta and wares, especially oblong trays, with airy baroque designs in the manner of Bérain; these were at first in blue, afterwards polychrome. In 1738 Joseph Olerys, a Moustiers potter who had spent some years at Alcora in Spain, introduced a new floral style in colours with sprays resembling potato-blossoms, and grotesque figures borrowed from the engravings of Callot. About 1677 one of the Clérissys of Moustiers moved to Marseilles and there made faience, similar to that of his native town, in the suburb of St. Jean-du-Désert. Several factories were at work at Marseilles during the 18th century; chief among them were those of Veuve Perrin, Joseph Robert and Honré Savy.

In Lorraine flourishing faience-factories were carried on at Strasbourg and Niderviller, both conspicuous for the fine quality of their overglaze enamel painting. The Strasbourg pottery, in the hands of the Hannong family, came to an end in 1774 after some half century of existence. Its earliest wares were blue-and-white in the manner of Rouen. Its later table wares in good rococo shapes based on silversmith's work show quasi-naturalistic flower-painting skilfully rendered in fresh colours dominated by a strong crimson, which exercised a great influence on the work of other French faience factories. That founded by Baron Beyerlé in 1754 at Niderviller and transferred in 1774 to the Comte de Custine made similar enamel-painted faience, including admirable figures, mostly of children or peasants, from models by the sculptors Cyfflé and Lemire.

Faience of artistic quality was made at many other French towns in the 18th century. Sceaux near Paris produced both porcelain and enamel-painted faience hardly inferior to porcelain. Aprey is known for gaily-coloured wares of a more homely kind. In Paris, at Lille and Rennes the formal style of Rouen was followed. St. Omer and St. Amand-les-Eaux in French Flanders, and Montpellier in Languedoc also had faience-factories.

Faience of Northern Europe, Spain and Portugal. — Early in the 16th century an Italian potter from Castel Durante, Guido di Savino, was settled at Antwerp, and from this time may be dated the beginning of maiolica-production in the Netherlands. The Antwerp wares, which included pavement-tiles, show the influence of the Faenza potteries in simple floral and linear motives, but soon took on the distinctive characteristics of Netherlandish renaissance design. About 1560–70 maiolica-potters from Antwerp carried their arl as Protestant refugees to Holland and England. Rotterdam and Haarlem became centres of production of earthenware and wall-tiles with animal, flower and fruit motives in strong colouring, and large tilework pictures with figure-subjects. Towards 1650 Delft came to the fore and for more than a century continued with its numerous potteries, known by their signs (the Peacock, the Star, etc.), as a thriving centre of industry exporting its wares all over the civilized world. Aelbrecht de Keizer is the earliest Delft potter whose productions are known, if the initials AK on certain blue-and-white pieces are rightly identified as his; the designs on these are borrowed from the contemporary Chinese porcelain then being imported in quantities by the Dutch East India Company. About 1600 we find plates and panels charmingly painted in blue with Dutch or Italian landscapes, by Frederick van Fritjtom. Samuel van Eenhoorn developed the Chinese fashion in a broad highly decorative manner of his own. To Adrianus Koek are owing the imposing blue-and-white hyacinth-vases made to the order of Queen Mary for the adornment of Hampton Court Palace; their ornament is borrowed from the French baroque designer, Daniel Marot. Other potters adopted Biblical subjects or scenes from Dutch life of the time (often in series continued through a set of plates or dishes) for the decoration of their wares. About 1700 close imitations of Chinese porcelain of the reign of K'ang Hsi, both blue-and-white and five-colour, were made, especially by Lambertus van Eenhoorn and Louwijs Fictoor, whose monograms are indistinguishable; notable amongst them are chimney-piece sets of large covered jars and vases, often reeded (so-called cachemire ornament). The wares produced became ever more varied, including statuettes and even model violins. Before 1700 muffle pigments and gilding were introduced by Rochus Hoppesteyn, in vases with classical figure-subjects, and by Adriaen Pijnacker, in imitations of Japanese polychrome porcelain dominated by a vivid red. Coloured enamel grounds were also occasionally used, notably a fine black in imitation of lacquer. As the 18th century advanced the wares became more commercial in character; the Delft potteries declined, only ten surviving till 1794. Somewhat rustic wares in the Delft style continued to be made till recent times at Makkum and elsewhere in Friesland.

BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM

BRISTOL DELFT DISH, TULIP DESIGN

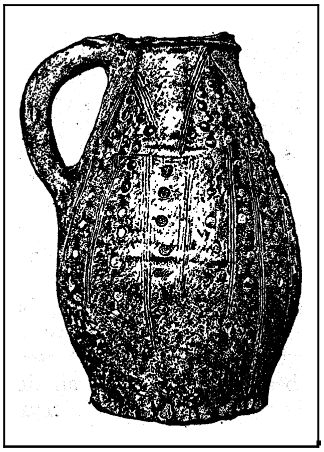
In Spain the adoption of the renaissance and Italian influences resulted during the 16th century in the production of enamelled earthenware entirely different in character from Hispano-Moresque ware. The settlement of an Italian tile-painter, Nicoloso Pisano, in Seville about 1503 brought about a widespread employment of maiolica tile-pictures for wall-decoration. At the same time Talavera and the neighbouring Puente del Arzobispo became the leading centre of pottery production. They produced, alongside wares in which Netherlandish renaissance ornament can be recognised, others of a strongly native character painted with animated hunting and battle scenes or with large busts or animals amongst loose foliated scrolls, in blue alone or in a limited range of colours dominated by a strong copper-green. From Talavera, potters went out to Mexico and there founded a vigorous industry. The foundation of a faience factory by the Count of Aranda in 1727 at Alcora led to the decline of Talavera. The faience mostly painted in blue and purple made in the 17th century at Lisbon, in which freely-handled Chinese themes are blended with renaissance motives has decorative value.

It is recorded that about 1567 Jasper Andries and Jacob Sanson fled from Antwerp to England to escape religious persecution and set up potteries at Norwich, whence in 1570 they moved to London. Their productions have not been identified, but it is likely that they resembled the maiolica at that time made in the Netherlands, and it is possible that certain jugs with mottled blue, purple and orange colouring over a tin enamel, generally found with silver mounts, were made by them. The earliest piece of maiolica of certain English origin is dated 1601; we may note here that at a later stage such wares were known as "delft," after the chief Dutch centre of production from about 1650 onwards. After 1625 dated pieces made at Lambeth and elsewhere near London become plentiful, chiefly dishes and small mugs with decoration painted either in blue in crude imitation of contemporary Chinese porcelain or with coloured designs of fruit and flowers or arabesques in imitation of Dutch and Italian wares. Wine-bottles painted with the name of the intended contents were also made in quantity. Towards 16jo figure-subjects, mostly scriptural (especially the Fall) become plentiful. Imitations of the "Persian" blue ware of Nevers were also made. From London the maiolica industry was carried to Brislington, near Bristol, where in 1682 we find working one Edward Ward, who in 1683 established a pottery at Temple Back, Bristol. He was succeeded at Brislington in 1697 by Thomas Frank. Other leading Bristol potters of the 18th century were Richard Frank, and Joseph Flower. John Bowen and Michael Edkins were painters employed by several of the potters. The earliest recorded date on Brislington-Bristol ware is 1652. The early designs include tulip and other flower designs in the Dutch manner, Chinese subjects and portraits of sovereigns or celebrities of the day. After 1700 Chinese motives take the lead, but adapted in a free and original manner. Landscapes of a lccal character with figures, in blue, were also in favour. The third great centre of delft production in England was Liverpool, which in the 18th century exported such wares in quantity to America. Shaw, Pennington and Barnes were the leading potters. Their wares show less individuality than those of Bristol. Notable among them are the punch-bowls made for skippers with polychrome paintings of their vessels; a speciality of Liverpool were the delft tiles with transfer prints in black or red executed by Sadler and Green. Delft was also made at Wincanton, Dublin and Glasgow.

Tin-enamelled earthenware was made by German potters from 1620 onwards. They learnt the art of maiolica in Venice, amongst them Augustin Hirsvogel of Nuremberg; he is believed to have been the maker of the owl shaped jugs made apparently for presentation purposes. The earliest known date on German maiolica is 1526. These early wares were painted in blue, with imitations of Venetian designs, or with figure-subjects derived from contemporary German engravings. Maiolica-painting was applied to the decoration of tilework stoves in the Tyrol, in Austria and especially at Winterthur in Switzerland, where from 1590 to 1740, approximately, a flourishing maiolica industry was carried on by the Pfau family and others. About 1618 the majolica technique was introduced by Lorenz Speckner in the potteries of Kreussen, in Bavaria (of special note are his drug-pots boldly painted with spirals in blue), and about the same time blue-and-white wares, especially narrow-necked pear-shaped jugs, showing Chinese influences, were made at Hamburg. The settlement of two Dutch potters at Hanau in 1661, and the establishment of a factory at Frankfort-on-the-Main in 1666 mark the beginning of a second phase, under Dutch influences, in which the Chinese fashions of the day determined the styles of decoration. Frankfort is notable for large dishes and jars with bold adaptations of late Ming motives in a remarkably clean vivid blue. Faience-factories at Nuremberg, Bayreuth, Ansbach, Dresden, Berlin, Potsdam and elsewhere are witnesses to the spread of these wares in cheap imitation of blue-and-white and five-colour porcelain. Potsdam was the first place to attempt to simulate Chinese "powdered blue" on faience. Tankards with baroque panelled designs or somewhat crude polychrome renderings of Chinese landscapes were made extensively at Erfurt and minor factories in Thuringia. In the 17th century glass-enamellers such as Johann Schaper and Abraham Helmhack of Nuremberg took to decorating in their own homes (as *"Hausmaler"*) faience obtained "in the white" from the factories. Their paintings of landscape or scriptural and other figure-subjects in black monochrome (*schwarzlot*) or bright polychrome are often of extraordinary fineness of execution. From their work arose the adoption of overglaze enamel-painting in the potteries themselves. This prepared the way for the third phase, the spread of French influences from Strasbourg and Marseilles, seen in coloured naturalistic floral decoration and French rococo forms for the wares. Disseminators of this technique were Johann Eberhardt, Ludwig Ehrenreich and Johann Tannich; the latter, trained under Hannong at Strasbourg, worked afterwards in several factories, notably at Kiel and Mosbach. From Germany the manufacture of faience spread to Scandinavia; flourishing factories at Copenhagen, Sleswick, Rorstrand near Stockholm and Herreboe in Norway produced chiefly blue-and-white wares showing Dutch and Chinese influences; large tea-trays, sometimes used as table-tops, and punch-bowls in the form of a bishop's mitre are conspicuous amongst their output. At the Marieberg factory, Stockholm, founded in 1758, the enamel-painted faience of Strasbourg was successfully imitated. Hollitsch in Hungary also produced enamel-painted faience of good quality closely resembling that of Strasbourg.

Mediaeval Pottery of North-west Europe.—The mediaeval pottery of western Europe is unpretentious and often crude in technique, but shows at the same time great virility and dignity of form. Glaze had passed entirely out of use in the Dark Ages. On later wares, when present, it is a soft galena glaze, sometimes stained brown with iron or green with copper. Decoration is effected by scratching with a point, or by impression with cut stamps or the application of reliefs such as overlapping scales or strips of clay pressed on with the potter's thumb, or rough floral and heraldic ornaments shaped in moulds; painting with red, brown and white clay pigments is the exception, but clays of various colour are often combined in relief decorations. Vessels such as aquamaniles, in rude human or animal form, and jugs modelled into human features, are not unusual. These characteristics are common to France, Germany and England.

In France the revival of glaze began in the 13th century, when Savignies, in the neighbourhood of Beauvais, began to become an important centre of production, of which in the 15th and 16th centuries the bluish-glazed wares with applied heraldic and floral ornament enjoyed some esteem; from the 14th century La-Chapelle-des-Pots near Saintes, was another important centre. Fine earthenware with inscriptions in Gothic characters and floral designs, made after the Italian manner by the *sgraffito* technique and including Italian shapes such as the *albarello* jar, appear towards 1500, and shortly after polychrome lead-glazed wares began to be made. Ornamental earthenware finials for gables were produced, especially in Normandy, from late mediaeval times onward.


BY COURTESY OF THE YORKSHIRE MUSEUM
MEDIAEVAL ENGLISH JUG

Remains of mediaeval potter's kilns have been found in England at Nottinghani, Lincoln and Cheam, and community of characteristics amongst vessels dug up at Oxford indicate local production; the same is true of York, and simple pottery must have been made at many other places. The earliest remaining wares, certain tall slender jugs of light buff earthenware, with a double swell in their profile, are attributed to the 13th century. In the 14th century forms tend to become more squat, glaze and applied or incised decorations appear. Greater refinement of shape is seen in green-glazed jugs of the 15th century, and under the Tudors elaborate moulded heraldic reliefs are found. In Germany the hard-fired semi-vitrified ware known as stoneware was first made, from the 14th century onwards. The earliest specimens are slender jugs, strongly wheel-marked, in a creamy-white body, made at Siegburg near Bonn. Drinking-vessels of great elaboration, often double-walled, the outer wall being pierced with Gothic tracery, were made of a hard brown ware in the 15th century at Dreihausen, Hesse. Floor-tiles form a great part of the output of mediaeval kilns, and were made wherever great churches were being built. Those of France and England have glazed bichromatic inlaid decoration, the German tiles, mostly unglazed, showing stamped or moulded designs. Tilework was used in Germany for architectural details also, and especially for stoves.

French and German Lead-glazed **Earthenware.**—With the arrival of the renaissance in France pottery rose in that country to a higher level of general esteem, and two highly specialized experimental developments took place. One of these passed without lasting influence on ceramic history, that of the famous so-called Henri II. ware; the place of its production was for long a mystery but it is now known to have been made at St. Porchaire in Poitou, approximately from 1525 to 1560. It is of a fine whitish clay, with a cream-coloured glaze, and decorated with designs built up from impressions of metal stamps like those of a bookbinder and inlaid in the manner of *niello* with darker clays; in the later examples touches of blue, green and purple pigment are added. The early forms are imitations of metalwork; later, salt-cellars, standing cups and ewers were built up like architecture in miniature with applied reliefs and statuettes and inlays imitating tile pavements. Devices of François I. and Henri II. and the crescents of Diane de Poitiers appear on many of the pieces.

Of greater significance was the work of Bernard Palissy (*q.v.*). After years of experiment he made coloured lead glazes, blue, green, purple and brown, of an excellence never attained before. His earlier wares were decorated with casts from the smaller fauna and flora of the district of Saintes. Later he adopted reliefs of figure subjects or formal designs. He was succeeded by two sons and by several potters who early in the 17th century made wares in his manner, including statuettes after bronze originals, at Avon and Fontainebleau, and at Manerbe (Calvados). Earthenware with a rich dark brown lead glaze. in forms copied from metalwork, was made towards 1600 at Avignon.

Contemporaneously with Palissy various potters in south Germany were making polychrome earthenware of a similar type, but combining a white tin enamel with coloured lead glazes. This technique was employed specially in the production of stove-tiles, which from about 1550 onwards were commonly decorated with figure-subjects of biblical or allegorical reference, reflecting the all-pervading religious pre-occupations of the time, rendered in relief under a renaissance arched recess. Potters known as Hafner, who worked in this manner, were settled at Nuremberg (Paul Preuning and others) and also at Salzburg and elsewhere in Austria. Besides stoves they made jugs with applied reliefs (sometimes including figures in the round in a recessed niche) and bright-coloured glazes. An analogous ware, made from about 1550 at Neisse in Silesia, is characterised by designs rendered by means of deeply-incised outlines separating the coloured glazes and enamels. In the 17th century the wares of the Hafner in Central Europe fell to the level of peasant pottery, which, however. has often great aesthetic value.

German and Flemish Stoneware — Artistic stoneware began to be made at Cologne about 1540. It is characterised by the ferruginous brown stain of its salt glaze. Its commonest form is that of a round-bellied jug with a bearded man's mask applied on the front of the narrow neck, a form which under the name *Bartmann* or "greybeard" became common in most stoneware potteries. Small applied medallions resembling the Roman coins frequently dug up in the city and its neighbourhood, and coiled branches with small oak leaves and acorns, are also frequent motives of decoration. About 1 j66 one of the Cologne workshops was removed to Frecher, where the manufacture especially of greybeards for Rhenish wine, exported in quantity to England and elsewhere, lasted into the 18th century. At Siegburg the mediaeval white stoneware took on a renaissance dress about 1550; the place was famous for its tall slightly-tapering tankards (*Schnellen*) with heraldic and figure reliefs in three adjacent vertical panels, the finest being the work of the Kniitgen family. Raeren, near Aix-la-Chapelle, was also a centre of the industry; its wares are deep brown-glazed, and (at a later stage) grey ware with cobalt-blue colouring in places. The characteristic productions are jugs, often of large dimensions, with elaborate mouldings and reliefs which generally take the form of a frieze, either continuous or broken into arcading, round the belly and sometimes also the neck. Jan Emens and Baldem Mennicken were the most gifted of the Raereṇ potters. Soon after 1600 the potteries of Siegburg (sacked by the Swedes in 1632) and Raeren declined, and many of the potters migrated .to the Westerwald district near Coblentz, where at Grenzhausen and Höhr the industry lasted till it was superseded by earthenware of the English type late in the 18th century. The Westerwald stoneware is grey in body, and its relief decorations, in which figure subjects tended to give place to formal floral motives, are picked out with colouring in cobalt blue and occasionally also in manganese purple. Stoneware, mostly inferior imitations of the Rhenish, was made in the 17th and 18th centuries at Bouffoualx and elsewhere in the south Netherlands. Kreussen in Bavaria produced in the 17th century a chocolate-brown stoneware with reliefs (of the Apostles, Electors of the Empire, etc.) painted in the vivid colours of the contemporary enamelled glass. Altenburg in Saxony and Bunzlau in Silesia also made relief-decorated stoneware.

BY COURTESY OF THE DIRECTOR OF THE VICTORIA AND ALBERT MUSEUM
JUG, OF COLOGNE STONEWARE

English Stoneware and Lead-glazed Earthenware. — The importation of German stoneware in the 17th century led to various attempts to imitate it in England. The most conspicuous was that of John Dwight, an Oxford scientist, who set up a pottery at Fulham about 1670 in which he made not only bottles and mugs in stoneware of various colours but also statuettes, modelled by an unknown artist (perhaps the sculptor, Grinling Gibbons), in white or dark brown clay with a thin coating of salt-glaze; these famous works, including busts of Prince Rupert and others and figures of classical deities, are amongst the most remarkable achievements in the history of plastic art. Stoneware of good quality, with a lustrous brown glaze, decorated with stamped, incised and moulded designs, often dated, was made at Nottingham from about 1695 onwards by John Morley and others of that family. Similar ware was made later at Chesterfield and Swinton. Another experimenter in stoneware was Francis Place, who worked about 1685 at York. Dwight had competitors also in the brothers Elers, two Dutch silversmiths who made teapots in a fine red-bodied ware, imitating Chinese boccaro ware, at Bradwell Wood near Newcastle-under-Lyme; their work was of great importance in its revolutionary effect on the output of the North Staffordshire potteries.

Mediaeval traditions in the production of coarse red earthenware with decoration in white "slip" (that is, clay diluted to a creamy consistency) were followed throughout the 17th and 18th centuries in many small potteries throughout England. Wrotham in Kent produced "tygs" (drinking-vessels with several handles) and posset-pots with neatly applied pads of clay stamped with initials or floral devices, animals and birds. At Bethersden near Ashford the inlay technique of the mediaeval tiles was adopted for pottery. By working with a comb the different coloured clays in a semi-liquid state on the surface of the wares, marbled and feather patterns of real distinction were often produced. No attempt at lightness and refinement of shape was made in the district until the advent of the brothers Elers, which stimulated the local potters to improve their technique. Soon after 1700, in response to the demand newly created by the introduction of tea-drinking, John Astbury was making tea-services, with small stamped reliefs in white on a red ground, and similar wares in a harder fired drab stoneware, from which about 1720, by the introduction of ground flints into the body, the Staffordshire white salt-glaze ware was evolved. A further advance came with the introduction of the process of casting the wares in plaster moulds with relief designs. About 1750 "marbled" wares were made by mixing clays of different colours, also "tortoiseshell" ware with mottled glazes, and tea-services in the form of cauliflowers and pineapples coloured after nature; such wares were produced especially by Thomas Whieldon, who in 1753 took into partnership a young potter destined later to revolutionise the industry. This was Josiah Wedgwood (*q.v.*). His new productions were "black basaltes" ware, an improvement on the black unglazed stoneware of the district, and jasper ware, a fine stoneware stained with blue, green, lilac and other colours and generally decorated with applied cameo reliefs in white. For shapes and decoration he drew upon the recently-published repertories of Greek vases, conforming entirely to the neo-classical taste of the period. He engaged John Flaxman and other sculptors to provide him with designs. An important part of his output were small medallions with portraits or other reliefs, made for mounting in furniture or as jewellery. For decorating his Queen's ware he introduced transfer printing, sending it at first to Liverpool to be printed by Sadler and Green. Wedgwood had many competitors who produced imitations of most of his wares; in Staffordshire, Adams, Neale, Turner and Palmer were the most important. Cream-coloured ware of good quality was made from about 1770 onwards at Leeds and elsewhere in Yorkshire; pierced decoration is its most characteristic feature. Earthenware figures emulating those of the porcelain factories were made at Burslem from about 1765 onwards by Ralph Wood, his son Ralph, and his grandson Enoch, and by many other Staffordshire potters. The earliest, painted in coloured glazes in the manner of Palissy ware, are mostly from models by a French artist, John Voyez, who generally copied the figures of Cyfflé of Niderviller; they have considerable artistic merit Lead-glazed earthenware of good quality was also made in the late 18th century at Liverpool, Bristol, Swansea, Newcastle-on-Tyne and Sunderland. A variety made in many places is the so-called silver lustre ware, coated with platinum, in imitation of silver plate. After 1800 the English earthenwares were rapidly degraded. (B. RA.)

EUROPEAN PORCELAIN TO END OF 18TH CENTURY

From the time of its first appearance in Europe, at the latest in the 15th century, Chinese porcelain was regarded by potters as in the highest degree worthy of imitation. Admiration for its whiteness led to the use of a white enamel or slip-covering on the earthenwares of Italy and other countries, whilst its translucency and vitrified texture misled the potters into supposing that a substance of the nature of common glass entered into its composition. Attempts to imitate it in this way were made in small manufactories at several places—as at the glass-making centre of Venice and elsewhere in Italy, more particularly at Florence, where a factory was started under the patronage of Francesco de' Medici, not later than 1581. Medici porcelain was decorated, as a rule in a soft blue only, with motives drawn from Italian maiolica in combination with Chinese elements imitated from wares of the type made for export to Persia. The manufacture is supposed to have been continued at Pisa; later and not dissimilar porcelain is to be attributed to Candiana near Padua. No settled manufacture was, however, in existence before the latter part of the 17th century. Edme Poterat of Rouen and his son Louis were granted a privilege in 1673, whilst another factory founded in 1677 at St. Cloud near Paris had by the end of the century grown to considerable size. These artificial porcelains, fired at a low temperature and made translucent with the aid of a previously fired glassy mixture or frit, were of the type now known as soft-paste (*pâte tendre*). They remained the characteristic porcelains of France for nearly a hundred years, and somewhat similar compositions were widely used in England, Italy and Spain during the 18th century.

Meanwhile in Germany the insight of Tschirnhausen and Bottger (see below) had perceived that porcelain of Chinese type could be made only with potters' materials, and by experiments with the fusing of clays were discovered, first, a hard red stoneware. and in 1709 true, that is. hard-paste, porcelain, which is essentially a high-fired mixture of the fusible and non-fusible silicates of alumina, called by the Chinese *petuntse* and *kaolin*, and in English china-stone and china-clay. From the manufacture founded at Meissen upon Böttger's discovery sprang others making hard-paste at Vienna and other places in Germany, at Venice, St. Petersburg and elsewhere Hard-paste began to be made at Sèvres in 1769 but did not entirely displace the *pâte tendre* until the beginning of the 19th century. In England hard-paste was independently rediscovered before 1768, but it was used in a single manufacture only and was superseded towards the end of the 18th century by a universally-adopied hybrid composition in which china-clay was partially replaced by the ashes of calcined bones, an ingredient which had for some time previously been used in a characteristic type of English soft-paste.

STAFFORDSHIRE SLIP WARE: DECORATION MADE WITH WHITE CLAY DILUTED TO CREAMY CONSISTENCY

France.—The rare porcelain attributed to the Poterats of Rouen resembles in decoration the blue-painted faience of the same city, and similar painting in Louis *Quatorze* style is characteristic also of much of the St. Cloud porcelain. Jugs, cups and saucers, pomade-pots and other small objects, as well as flower-pots of considerable size, were the chief productions of St. Cloud: they were as a rule tastefully and substantially potted with a fine feeling for the qualities of a rather yellowish but pleasant-toned material. Plum-sprays amongst other motives in relief were sometimes copied from *blanc* de *Chine*, for which this French porcelain has often been mistaken. Fluting and scale-pattern were also favourite decorations Painting in turquoise-blue, red yellow and green was inspired by Japanese Kakiemon porcelain. Boldly modelled figures inclining to the grotesque were done. St. Cloud (which was founded by Pierre Chicaneau in 1677) came to an end in 1768. Very similar porcelain, as a rule indistinguishable from the St Cloud, was made in Paris at a factory in the Rue de la Ville-l'Evêque and at Lille.

Porcelain of distinctive character was made at Chantilly, where a factory was founded in 1725 by Louis-Henri of Bourbon, duc de Condé Here for the first twenty years or so the material was singular in being covered with a glaze made opaque with oxide of tin At its best Chantilly is of a beautiful creamy white colour. "Kakiemon" patterns were freely copied in designs of great charm. The Meissen styles of flower painting (*q.v.*) and the formal "Indian" and naturalistic "German" flowers were adapted in the French taste, as were some of the figure-models of the same factory. In the later Chantilly, coloured grounds were imitated from Skvres and the tin-glaze was given up; slight decoration in underglaze blue was favoured for cheaper wares. The factory ceased to make soft-paste about the end of the century.

The factory at Mennecy-Villeroy, near Paris, was a continuation of one in the Rue de Charonne in Paris, founded in 1735 by François Barbin, who removed his establishment to Mennecy in 1748 to place it under the patronage of Louis François de Neufville, duc de Villeroy. The earliest of Barbin's productions were in Rouen-St. Cloud style, but later a great variety of small objects was made and enamelled in colours of a singular freshness, amongst which a purplish rose-pink is prominent. At its best, Mennecy porcelain is of unsurpassed quality, mellow in tone and texture and of a warm white colour. Some charming figures were'made. The factory was removed in 1773 to Bourg-la-Reine and ceased to make porcelain about 1790.

The beauty of material characteristic of the French soft-pastes was achieved in the highest degree in the productions of the royal factory at Vincennes, which was removed to Sèvres, between Paris and Versailles, in 1756. This factory was established in 1738, under the patronage of Orry de Fulvy, by two workmen named Dubois, who, however, failed to produce porcelain. A workman named Gravant eventually succeeded, in 1745, and a company was formed with a subvention from Louis XV., who finally in 1759 took over the factory, which enjoyed certain exclusive privileges (such as the use of gilding) amounting to a monopoly. The Royal proprietorship ended, with the Revolution, in 1793, but the establishment has continued under State control to the present day. The Vincennes productions at first consisted chiefly of porcelain flowers in imitation of those of Meissen, intended for mounting in ormolu. Meissen styles of painting were copied in this early period, though the forms, largely in rococo style, were designed by the court-goldsmith Duplessis. Jean-Jacques Bachelier supervised the painting and gilding, whilst the chemist Hellot was in charge of the technical side. Painting in panels reserved on a coloured or diapered ground enriched with gilding, soon became the characteristic Sèvres decoration, and the succession of the ground colours is the chief feature in the chronology of the great period of 40 years from 1749 onwards. The dark gros *bleu*, probably 'imitating Chinese powdered-blue, was introduced in 1749 and abandoned in favour of the brighter bleu de roi about 1756. Turquoise-blue (bleu *céleste*), yellow (jaune jonquille) and green grounds made their appearance in 1752, 1753 and 1756 The rose Pompadour (miscalled in England rose du Barry), invented by Chrouet, appeared in 1757 and went out of fashion in seven years. The favourite painting in monochrome (*en*-camaieu) was at first generally in crimson, later in blue. Particulars of many of the painters and the marks used by them may be found in several books of reference. Late in the period, about 1780, an enameller named Cotteau invented the so-called jewelled decoration in which drops of coloured enamel were fused over gilding. Glazed and coloured figures were made in the early years of the factory in rivalry with Meissen, but about 1751 Bachelier introduced biscuit or unglazed porcelain as a medium for novel work for which the painter Boucher made designs to be executed by Blondeau and others. The sculptors Falconet and la Rue in the earlier period, and Pajou and Boizot in the later, created many models for execution in Skvres biscuit. The influence of Boucher is apparent throughout in the painting and modelling, whilst the so-called *Louis* Seize neo-classical style began to replace the rococo soon after the transfer to Sèvres in 1756. For technical skill and perfection, and for delicacy and taste (if not for more vital qualities) Skvres porcelain is unsurpassed. Soft-paste at all times has the merit of absorbing enamel-colours into its easily-fusible glaze, and this is nowhere more evident than on Sèvres china.

Though soft-paste was the medium of the finest Skvres productions, hard-paste was made occasionally (from kaolin found after long search at St. Yrieix near Limoges) as early as 1769 and finally superseded the other altogether in 1804, when the newly appointed director Brongniart gave up the manufacture of the more costly material with a view to repairing the financial distress of the factory, caused by the Revolution. Hard-paste became the medium of a style marked by a severe and even pompous classicism, shared also by a number of other factories which had sprung up in the latter part of the 18th century in Paris and the neighbourhood, largely under the patronage of members of the Royal family. Rue Thiroux, La Courtille, Rue de Bondy ("Manufacture d'Angoulême") and Rue Popincourt (Nast's factory) were the chief. Other French factories making hard-paste and equally concerned to imitate Skvres, were at Lille, Étiolles, La Seynie, Boissette, Limoges and Valenciennes.

Hard-paste of distinctive character was made at the faience factories of Strasbourg and Niderviller and of Joseph Robert at Marseilles. The first-named was closed at the instance of Vincennes in 1753 and Paul Hannong, its proprietor, crossed the frontier to found the Frankenthal factory.

Some soft-paste of fine quality was made also at Sceaux, Orleans, Arras and St. Amand-les-Eaux, whilst at Tournai (which was part of France in the 18th century) soft-paste was used for wares inspired as much by Meissen as by Skvres.

Germany. — The discovery of hard-paste by Johann Friedrich Bottger was the result of experiments into the vitrification by heat of clays and rocks, conducted by him in association with Ehrenfried Walther Tschirnhausen, with whom he had been concerned in the establishment of a faience factory at Dresden. Like almost all scientists of the time, Bottger believed in the possibility of transmuting base metals into gold, and he was kept, virtually a prisoner, in the service of Augustus the Strong, King of Saxony, who hoped to benefit by the exclusive property of his alchemist's secrets. The first important product of Bottger's labours was a hard red stoneware, comparable with the so-called buccaro of Yi-hsing in China. First produced in 1708, it was quickly developed into a medium capable, by cutting and polishing, of expressing much of the baroque taste of the time. Silvering and gilding and a black glaze, invented by Bottger, were sometimes added to it. Imitations were made at Plaue-an-der-Havel, and at Bayreuth. The first glazed white porcelain was produced by Bottger alone in 1709; its regular manufacture did not begin until four years later. The earliest specimens inclined to a smoky tone, and the decoration (for which Irminger, a goldsmith, was responsible) of applied acanthus leaves, masks and rich mouldings, was similar to that of the red ware.

In 1710 the manufacture was removed to the Albrechtsberg at Meissen, but the making of the white porcelain was not fully mastered until 171j. Though without adequate financial support, Bottger succeeded in the four years before his death in 1719 in perfecting his material and in inventing a wide range of enamel colours, including a rare pale-violet lustre-colour almost peculiar to the factory and much used in the subsequent period.

In 1720 the painter Johann Gregor Heroldt was appointed director, and in the next 20 years introduced many new decorations—*chinoiseries* in gold and colours, landscape- and figure-subjects, as well as adaptations of Japanese and Chinese flowers (*indianische* Blumen) and other designs. Purple and red monochromes were used in a novel style. About 1740 Heroldt introduced the naturalistic deutsche *Blumen.* Though underglaze blue was never thoroughly mastered, many new colours were compounded for use as grounds, often richly gilt in baroque style, with panelled decoration. Almost every ground colour used elsewhere later on was employed at Meissen under Heroldt.

The appointment as modeller of Johann Joachim Kaendler in 1731 marked the beginning of a period of great development in the plastic decoration. The king had constantly pressed for colossal figures in porcelain which Kaendler's predecessor, Gottlob Kirchner, had failed to produce to his satisfaction. Kaendler succeeded with these so far as the natural unfitness of the medium would allow; and then proceeded to create a succession of new forms for table-ware — plates, tureens, sweetmeat-stands, candelabra, etc.—with modelled ornament, as well as a range of highly individual small figures. It was the court custom to group wax or sugar models on the dinner-tables, and Kaendler, helped by Friedrich Elias Meyer, Johann Friedrich Eberlein and Peter Reinicke, created many porcelain figures for use in the same way. Some subjects were novel in being drawn from contemporary life, embodying a satirical or witty commentary. Kaendler was the first to understand the potentialities of glaze and colour in the make-up of the porcelain figure, which in his hands was never merely monumental sculpture reduced in scale. French rococo was not without influence on Kaendler's style after about 1740, but he remained essentially a baroque sculptor, and continued to work for the factory until his death in 1775.

Meissen remained the premier porcelain factory in **Europe** until the Seven Years' War, which broke out in 1756, when Frederick the Great virtually sacked the place. Technically excellent work was done under the direction of Count Marcolini (1774–1813), but the former position was never regained. Skvres fashions were copied, and an artist actually from Skvres, Michel-Victor Acier, made many characteristic models in the sentimental style, whilst an academic sculptor, Christoph Jiichtzer, made biscuit figures in the classical manner.

Following the fashion set in Saxony, many other German princes sought to establish or patronise china-factories, and by 1760 no fewer than eight had come into existence in this way. Broadly, Meissen styles prevailed until about 1760, when Skvres fashions and the neo-classical began to predominate. The dependence upon Meissen and Skvres, however, was very much less than a superficial view would indicate.

In 1718 a runaway Meissen workman, Christoph Konrad Hunger, enabled Claude du Paquier to start a factory at Vienna, which was in 1744 sold to the state. Much of du Paquier's china was decorated by independent enamellers (*Hausmaler*); the factory's own styles were remarkable for the frequent use of a black (Schwarzlot) and other monochromes in rich baroque designs. Mayerhofer became director in 1751. Vienna figures of the period about 1760 have a very distinct and airy charm. In 1784 a prosperous period began under the directorship of Konrad von Sorgenthal. A modeller Anton Grassi (who had previously made some lively enamelled figures) began to use biscuit with success, whilst in the last decade of the century was made the porcelain with elaborate miniature pictures in the style of oil paintings, with rich gilding and coloured grounds which was formerly considered the best, and still is the most famous, Vienna work.

At Berlin, a wool manufacturer Wilhelm Kaspar Wegely made porcelain of fine quality, including figures, from 1752 to 1757. A few years later, a financier named Gotzkowsky started a factory which in 1763 was taken over by Frederick the Great. Berlin table-wares tend to favour simple colouring with a special fondness for pink diaper (Mosaik) borders. Some good figures were made by Friedrich Elias Meyer (brought from Meissen in the Seven Years' War), his brother, Christoph, and others.

With the help of one Löwenfinck from Meissen, porcelain was made at a faience-factory at Höchst as early as 1746, under the patronage of the Elector of Mainz, but not in any quantity until 1760. Very lively figures in Meissen rococo styles preceded those made by Johann Peter Melchior (appointed 1767), upon which the factory's fame chiefly rests. Melchior's very personal style shares the same inspiration as the contemporary Sèvres models: he showed an equal mastery in the treatment of the nude, in figures of children, and in portrait busts and plaques. All have the smooth, not glossy surface and soft colouring that are characteristic of Hochst.

The factory at Fiirstenberg in Brunswick was established in 1753 by Duke Charles I, with the help of Johann Benckgraff of Hochst. A feature of the early porcelain was the use of elaborate moulded patterns designed to disguise the imperfections of the material. In the last twenty years of the 18th century biscuit was used for a series of portrait medallions in white on blue.

The Bavarian state factory, founded in 1747 at Neudeck, and transferred in 1761 to Nymphenburg, is chiefly famous for its figures, for which Franz Anton Bustelli (*fl.* 1754–63) made models which are perhaps the finest plastic expression of rococo. The same qualities, however, distinguish the delicately painted table-wares and vases of the factory. Bustelli was followed by Aulicztk, who in turn gave place in 1797 to the Höchst and Frankenthal modeller J. P. Melchior.

The Frankenthal factory was founded by Paul Hannong of Strasbourg in 1755 under the patronage of the Elector Palatine. The early figures modelled by J. W. Lanz, their subjects chiefly drawn from contemporary life, are amongst the best produced in Germany, whilst the classical models of Konrad Link (made 1762–66) share the largeness of style of the best later work of Kaendler. Other able modellers were J. G. Luck, and Karl Gottlieb Luck, and in 1779 J. P. Melchior came to Frankenthal from Hochst.

Though the porcelain of Ludwigsburg is seldom free from imperfections and generally grey in tone, it was the medium of some excellent figures, for which amongst others the sculptor J. C. W. Beyer (1764–67) made some models combining rococo character with the classical style. The factory was founded in 1756 and taken over in 1758 by Charles Eugene, Duke of Württemberg.

Amongst the minor German factories founded in 1756 by the Prince-Bishop of Fulda has a deserved reputation for high quality both in the modelling of figures and the painting of table-wares. Another factory, started in 1758 at Ansbach and transferred four years later to Bruckberg, closely followed Meissen models. Others of some importance were at Ottwtiler in Nassau-Saarbrucken (founded 1763), Cassel in Hesse (founded 1766), Pfalz-Zweibrucken (founded 1767), Baden-Baden and Kelsterbach. In the forest region of Thuringia, many private factories sprang up soon after 1760 making cheap useful wares, as well as imitations (often definitely fraudulent) of the better Meissen china. Very good porcelain, however, was made at Kloster-Veilsdorf, Gotha, Ilmenau and Volkstedt. The rather crude figures of Limbach sometimes have an attractive simplicity. Porcelain was also made at Gera, Gross-Breitenbach and Rauenstein.

In the earlier days of Meissen and Vienna no serious attempt was made to prevent undecorated porcelain from reaching the hands of independent enamellers, though eventually the Meissen factory adopted the plan of cancelling its mark (by a cut in the paste) on all defective pieces sold in the white. Amongst many excellent *Hausmaler* may be mentioned J. Aufenwerth of Augsburg and J. F. Metsch of Bayreuth; Preussler, Ignaz Bottengruber and his pupils H. G. von Bressler and C. F. von Wolfsburg, all of Breslau, who specialized in monochrome painting, chiefly in red and in black, in which last also Jacob Helchis decorated Vienna porcelain in a distinctive manner. The wandering arcanist C. K. Hunger of Meissen, Vienna and Venice, practised a style of painting in thick gold, and about the middle of the century, F. Mayer of Pressnitz worked in several styles, and Canon Busch of Hildesheim made original engravings on porcelain with a diamond-point and coloured them with black.

Switzerland. — In Switzerland, porcelain was made at a factory at Schoren near Zurich, founded in 1763. Though smoky in tone and painted in subdued colours, Zürich china has a very distinct charm and delicacy. Another Swiss factory at Nyon made hard porcelain in French style in the late 18th century.

Belgium and Holland. — Hard-paste factories of no great importance were in existence in the 18th century at Weesp (afterwards transferred to Oude Loosdrecht and Oude Amstel) and The Hague, where, however, Tournai and other porcelain was sometimes decorated and marked. Paris styles were followed at Etterbeek near Brussels.

Denmark and Sweden — At Copenhagen as at Marieberg (Stockholm) soft-paste was made at first. At the former from about 1760 Louis Fournier from Vincennes made wares in French style until hard-paste began to be made about 1772: in this last a series of Norwegian peasant-figures is noteworthy. At Marieberg, Pierre Berthevin from Mennecy made soft-paste from 1766 to 1769, and a hybrid porcelain was used for the next twenty years.

Russia. — Hard porcelain in German style was made in Russia as early as 1745, but was scarcely an established manufacture until the time of Catherine II. (1762–96). Amongst the little that is distinctive in the Imperial porcelain from the St. Petersburg factory a series of figures of Russian folk-types may be mentioned. Other factories included one conducted by an Englishman, Gardner, at Verbilki and Tver near Moscow.

Italy. — Venice shares with Meissen and Vienna the distinction of a porcelain factory established in the first quarter of the 18th century,' in the period of the baroque style. Two brothers, Francesco and Giuseppe Vezzi, founded their factory in 1720 with the aid of the Meissen and Vienna workman Hunger. It ceased to exist soon after the death of the first-named in 1740. The Vezzi porcelain resembles Meissen in its technique of painting, in which iron-red plays a prominent part, but a certain Italian fantasy and irresponsibility distinguishes it. Another Venetian factory seems to have been in operation from 1758 to 1763 under one Hewilcke of Dresden, but little is known of it, and that founded by Geminiano Cozzi in 1765 made most of the porcelain for which Venice is celebrated. Meissen was again much imitated, but the fantastic Italian rococo and a freshness of colour mark much of the Cozzi china, which was a kind of soft-paste. The existing Doccia factory was founded about 1735 by the Marchese Carlo Ginori, with the help of a chemist from Vienna, Karl Wendelin Anreiter. Its earliest work included some distinctive baroque decoration, and later on in the 18th century some highly dramatic groups were made. Factories at Nove, Vinovo near Turin, and Treviso produced more or less original work, whilst at Capo-di-Monte near Naples, a celebrated factory was in operation from 1743 until 1759, when its patron Charles, king of Naples, succeeded to the Spanish throne and the establishment was transferred to Buen Retiro. Typical Capo-di-Monte china is a glassy soft-paste, extravagantly decorated with reliefs, often of figure-subjects; it was much imitated at the Naples factory which was in a sense its successor (1771–1821), and at Doccia and elsewhere in the 19th century.

Spain and Portugal. — The Madrid or Buen Retiro porcelain (1759–1808) was of various quality but included some of the most beautifully modelled and coloured figures ever made in Europe. For these the modeller Giuseppe Gricci was probably responsible. Amongst many styles of painting on vases and table-wares there is much that is of a minute but significant delicacy. The manufacture was revived at La Moncloa from 1817 to 1849. Porcelain was also made at the count of Aranda's faience-factory at Alcora from 1774, and at Vista Alegre in Portugal from 1790.

England. — No certain English porcelain is known of earlier date than the so-called "goat and bee" jugs, made of a soft paste resembling milk-white glass and incised with the name of the Chelsea factory, the date 1745 and a triangle. This "triangle-period" of the Chelsea factory is believed to have ended about 1750, when Nicholas Sprimont apparently displaced Charles Gouyn as manager. Chelsea china of the next eight years is the finest ever made in England. Of a smooth soft-paste capable of giving the most delicate quality to enamel-painting, Chelsea is more often original than any other English porcelain, though its styles were largely inspired by Meissen. The figures in particular are unsurpassed for beauty of modelling. The mark of an anchor, at first in relief, later painted in red, belongs to this period, 1750–58, which ended with the death of the proprietor, Sir Everard Fawkener. In the subsequent period, when Sprimont was proprietor as well as manager, the rococo style (at the time outmoded at Sèvres) survived for ten years in extravagant forms of great interest. Coloured grounds, including a dark "mazarine" blue and a rich broken crimson were inspired by Sèvres, as were figure-subjects, *chinoiseries,* and other styles of painting. Profuse gilding of fine quality, richly brocaded costumes and *bocages* or backgrounds of flowers and foliage were characteristic of the boldly modelled figures, some of which were at one time erroneously attributed to the sculptor Roubiliac. The beautiful Chelsea toys—scent-bottles, seals, bonbonnières and the like—were made from about 1750 onwards and even continued to be done at the factory after its sale in 1770 to William Duesbury, the proprietor of the Derby factory. This had been in existence since 1750 and had made figures and other porcelain in Chelsea styles, but of comparatively little merit. The productions of the period 1770–1784 (when the Chelsea works were closed) are often known as Chelsea-Derby china. The pseudo-classical vases and the figures (including some in biscuit) in the fashionable sentimental Sèvres styles are of less importance than the table-wares which are the chief title to fame of the Derby factory. Later porcelain in the same excellent tradition was painted by artists whose names are known, such as Zachariah Boreman and William Billingsley. Derby declined after the succession to the management of Robert Bloor in 1811, and came to an end in 1848.

The Bow factory was perhaps in existence in 1744, but its productions before 1750 have not been certainly identified. From 1749 (when a distinctive bone-ash paste was adopted) to about 1760 its productions were largely inspired by, and often close copies of Meissen, but rank next to Chelsea for delicacy of modelling, and have the attraction of a beautiful ivory-toned material and clean strong colouring. Later Bow, which was marked with an anchor and a dagger, shows a distinct falling off in these respects. Lowestoft was an offshoot of Bow and largely imitated the productions of other factories, as well as Chinese models, in soft-paste. At Longton Hall in Staffordshire from about 1750 to 1760 William Littler made excellent figures and other wares of a soft porcelain in which are apparent some of the attractive qualities of the more rustic Staffordshire earthenware. A rich blue enamel used as a ground, and a fondness for dishes and vessels in the form of folded leaves were characteristic of Longton Hall. At Lowdin's factory at Bristol, transferred to Worcester in 1752, soapstone (steatite) was used in the paste, and Chinese, Japanese and Meissen motives were employed with an attractive simplicity. Amongst the best Worcester china, made between 1755 and 1765, may be singled out the beautiful armorial mugs. Transfer-printing was adopted very largely as a mode of decoration at Worcester. About 1768, painters from Chelsea were engaged, and a showy style with rich gilding and coloured grounds, including a distinctive "scale-blue," became the fashion of the day. The painting of highly-coloured "exotic birds" was inspired by Chelsea. The later "Flight" and "Flight and Barr" periods of Worcester (which succeeded the so-called Dr. Wall period, 1751–83) show a marked decline in taste. Some Liverpool factories and that at Caughley (the "Salopian" factory), making porcelain from about 1760 to 1772 respectively, may be regarded as offshoots of Worcester. At Plymouth, William Cookworthy had discovered the secret of hard-paste before 1768 (when he took out a patent), and made figures and useful ware employing Chinese, rococo and classical motives. His factory was transferred to Bristol in 1770, and sold in 1773 to Richard Champion, who made much handsome table-ware as well as figures in the classical style. The Plymouth and Bristol china often fails in effect on account of its comparatively hard glaze, into which the colours have not fused. Champion sold his patent in 1782 to a Staffordshire syndicate who continued to make hard-paste in "cottage style" at the New Hall factory until about 1810. Meanwhile a hybrid porcelain made of hard-paste materials in combination with bone-ash had been introduced before the end of the century by Spode and others. The history of this china, like that of a beautiful but unpractical soft-paste made by William Billingsley, at first at Pinxton (1796) and afterwards at Nantgarw and Swansea (1814–17), belongs to the 19th century.

Bibliography.—*General.* E. Hannover (ed. B. Rackham), *Pottery and Porcelain, A Handbook for Collectors.* Volume III. (European Porcelain) (London, 1924) (Comprehensive and up-to-date, and includes a very full bibliography: the following list includes some standard books together with some published since the date of the bibliography in Hannover).

France. X. de Chavagnac and E. Grollier, *Histoire des Manufactures françaises de porcelaines* (Paris, 1906).

Germany. Max Sauerlandt, *Deutsche Porzellan-Figuren des 18 Jahrhunderts* (Cologne, 1923). *Meissen:* E. Zimmermann *Meissner Porzellan* (Leipzig, 1926). *Hausmalerei:* G. E. Pazaurek, *Deutsche Fayence- und Porzellan-Hausmalerei* (Leipzig, 1925).

England and Wales. W. B. Honey, *Old English Porcelain, A Handbook for Collectors* (London, 1928). *Chelsea:* W. King, *Chelsea Porcelain* (London, 1922). *Worcester:* R. L. Hobson, *Worcester Porcelain* (London, 1910).

NINETEENTH CENTURY EUROPEAN POTTERY AND PORCELAIN

The period of the Napoleonic Wars marks a definite break with the older traditions of craftsmanship: European civilization emerged impoverished and found the Industrial Revolution complete. In the more pretentious wares, the Empire style was a pompous and frigid continuation of the neo-classical, and the "revived rococo" of 1820–50 was one of the first of the series of revivals that make up the greater part of the "styles" of the century. Some of the older factories, such as Meissen and Vienna, were even content to reproduce their former inventions, whilst the Great Exhibition of 1851 saw a general attempt to outdo in "exquisiteness" the most costly Sèvres productions of the 18th century. At Sèvres itself work of a high order of technical accomplishment was done under the management of Brongniart, who remained director until his death in 1847. In England the porcelain made by the Spodes and their successors Copeland's, of Stoke-on-Trent, by Minton's of the same place, and at Coalport and Swinton (Rockingham factory) was often very creditable technically but artistically of little account.

Amongst the cheaper types of pottery, the cream-coloured earthenware of Staffordshire commanded at the beginning of the century a world-market which it retained for a long time despite Continental rivals perforce driven to make the so-called *faience anglaise.* In France the English method of transfer-printed decoration was also adopted, notably at Creil and Montereau, and the development of the deposits of kaolin in the neighbourhood of Limoges led to a rapid growth of the pottery industry in that part of the country. In Italy, some distinguished and fanciful painting was done on cream-ware by the firm of Giustiniani of Naples.

After the Great Exhibition, manufacturers began to be aware of "Art," and pottery inspired by Renaissance models—by maiolica, "Palissy ware" and Limoges enamels—made its appearance. The Paris Exhibition of 1867 introduced a fashion for Japanese naturalism and asymmetry, and some European porcelain was even made (as at Worcester) in imitation of the degraded "export Satsuma" of the period. The collecting of Turkish and Syrian pottery (called at the time "Rhodian" and "Persian") brought a vogue for designs in the same style, from which issued the work of William de Morgan who at a later stage began to make ruby-lustred wares inspired by Italian maiolica; he was also in a sense the representative in pottery of the Morris movement towards handicraft as against industrial machine-work. In France Théodore Deck made similar essays towards the rich colour of the "Damascus" wares; and indeed the most noteworthy pottery of the last forty years of the century was the work of individual artists striving to emulate the great achievements of past times. In particular, Chinese single-coloured and *flambé* glazes inspired the high-fired stonewares and porcelain of Chaplet, Lachenal, Delaherche and Dalpayrat in France, and of Mr. Bernard Moore in England. Mr. William Burton developed some distinctive single-coloured glazes and lustre-pigments for Pilkingtons of Manchester, and similar lustred effects were also obtained by Zéolnay of Pecs (Fiinfkirchen) in Hungary, and by the Massiers of Golfe Juan in France. The so-called Arts and Crafts movement in England, by drawing attention to the virtues of peasant art, brought a sentimental fashion for simpler lead-glazed decorative wares; at Florence the Montelupo style was revived, whilst more or less exact copies of Hispano-Moresque and later Italian maiolica were made by Cantagalli and also by various other potters.

At the older porcelain factories in the latter part of the century some innovations of importance included the crystalline glazes and subdued green, grey, mauve and blue underglaze colours introduced at the Royal Copenhagen factory, and used for delicately painted vases and figures of Danish peasants and animals, modelled by some able sculptors. Similar work was and is being done by Bing and Grondahl of the same city, by Heubach of Lichte in Thuringia, and by the Meissen and Rorstrand (Stockholm) factories. A mode of impasto decoration, known as *pâte sur pâte,* in which successive layers of white or coloured slip were applied to a dark ground, was skilfully practised at Skvres by several artists, notably by Taxile Doat, and was brought to England by M. L. Solon, who worked for Minton's of Stoke-on-Trent. This was perhaps the foremost English factory, where Léon Arnoux was director, and the well-known sculptor, A. Carrier-Belleuse (afterwards at Sèvres) a principal modeller. At Wedgwood's another French artist, Emile Lessore (who had also been at Minton's), developed a delicate and individual manner of painting on cream-coloured earthenware.

Salt-glazed stoneware was revived in national styles by Villeroy and Boch of Mettlach, and by Doulton's of Lambeth, one of whose modellers, R. W. Martin, with his brothers Edwin and Walter, employed the material for grotesque figures and vases which have the merit of attractive colour in their sombre browns and greens, and show, moreover, a true feeling for pottery technique. Equally attractive work in stoneware was done by the French sculptor, Jean Carriks, and by E. Bigot of Paris. In Germany, Max Lauger of Karlsruhe developed an interesting style of decoration modelled in slip under coloured glazes. At the national factories of Berlin and Sèvres, highly accomplished work was done in many styles, with the support of up-to-date scientific knowledge, and the Paris Exhibition of 1900 marked the culmination of what may be called the eclectic period of European ceramic art. (W. B. Ho.)

BIBLIOGRAPHY.—General: E. Hannover, *Pottery and Porcelain,* I. "Europe and the Near East" (London, 1925), a thorough illustrated survey, with full classified bibliography. Italy: O von Falke, *Majolika* (2nd ed., Berlin, 1907), the most authoritative monograph. Netherlands: B. Rackham, *Early Netherlands Maiolica* (London, 1927). Germany: A. Stoehr, *Deutsche Fayencen und deutsches Steingut* (Berlin, 1920); O. Riesebieter, *Die deutsche Fayencen des 17 und 18 Jahrhunderts* (Leipzig, 1922). France: M. J. Ballot, "La Céramique française," *Documents d'art, Musée du Louvre* (Paris, 1924). Spain: P. Paramó, *La cerámica antigua de Talavera* (Madrid, 1919); M. Escrivá de Romani, conde de Casal, *Hiatoria de la cerámica de Alcora* (Madrid, 1919). England: B. Rackham and H. Read, *English Pottery* (London, 1924).

MODERN CONTINENTAL

At the end of the 19th century the movement in the domain of the applied arts, with which the names of Ruskin, William Morris, Walter Crane and their fellow-artists are connected, wrought a great change. At first this tendency scrupulously supported the preservation of the methods of handicraft, and strongly opposed manufactured articles. But the same principles with which it originated, and which were indeed identical with those out of which the applied arts had developed in all previous periods, gained ground in the meantime, and the possibility of having artistic articles for practical use came once more within the purview of increasingly larger groups. Gradually also there came into being a desire to bring them within the reach of the many by changing the expensive handmade articles for manufactured goods, but such production was to be led by artists. But in proportion as these ideas became more general, a reaction set in against their excessive rationalistic elements. Consequently, after the beginning of the 20th century taste inclined towards the ornamental, the lively, the richly coloured, though the basic principle that the shape and appearance of the object should be determined by the requirements of material, technique and purpose was not neglected.

Artists, sensitive to shape and colour, could be satisfied with the ceramic production, for working the soft clay on a potter's wheel allows scope for the most individual expression. So far as the continent of Europe was concerned, there were two centres whence the above described development sprang: France and Denmark, or, more strictly speaking Copenhagen. An important development in Holland has exerted little influence outside its own boundaries, and similarly in Germany, while both have undoubtedly profited from French and Danish artists.

MODERN CERAMIC TECHNIQUES

By ceramics is meant all production of which the final result is baked clay in different grades of hardness and purity.

Porcelain.—The composition of European hard porcelain has remained about the same since the 18th century. The ingredients consist of the plastic material, kaolin. and the non-plastic quartz and felspar, which, in the process of working, is used as a diluting element, and in firing, as a cement. The kaolin is principally found in Germany, but always mixed with another soil. It has to be purified by washing. The quartz and felspar must be cleaned. The fragments of iron, in particular, have to be removed, as they are dangerous to the product. By mixing these ingredients the plastic material is obtained. This is made homogeneous by a mechanical method, and it frequently lies unmoved for some months in a special cellar in order to be moulded once again. Then the shaping can begin. It is not usual to shape this fine material by hand, but moulds are used which have been made of plaster after the models fashioned out by artists. The plastic material is pressed into these moulds or poured out in them as a pulp. In the latter case the plaster absorbs so much liquid that a sheath is formed alongside the inside of the mould, out of which the superfluous pulp can be poured. Shaping is followed by drying. After that there is the controlling and the removing of the casting seam and other unevenness. If the object consists of more than one part these are joined together. They are then put in the kiln in sagars or clay boxes so that the heat is more evenly distributed over the piece, and heated to about 950 degrees. The porcelain has then become hard and water-tight but dull. This is therefore followed by glazing. The objects are dipped into a liquid consisting of the same ingredients as the material, but in which felspar and quartz predominate. The objects which have been glazed in this way must then be fired in a heat of 1,370°–1,458°, again in sagars. This heating lasts from 20 to 30 hours, and is followed by a gradual cooling which takes three days. A full kiln never produces everything perfect, the many dangers in the firing—for example all objects shrink about one-sixth of their volume—result in articles being spoiled by exploding, warping, etc.

The porcelain is then ready to be painted with dyes, with which a very lightly fusible glass-powder has been mixed. In order to make these melt together with the glazing and become durable the painted objects are heated in an enamelling-furnace to a heat of 700°–800°. This heat must be reached quickly and the cooling takes place equally rapidly in order to keep the colours bright. The old porcelain bakers painted on the so-called biscuit-ware, *i.e.,* after the first baking and before the glazing, but they could only make use of very few colours at this stage—really only cobalt blue, as most other colours could not endure the heat of the second firing. Modem ceramic technique, however, has considerably extended this process of painting before the glazing. Since Copenhagen's success with it, it has been more generally used and imitated. In these cases the paint is put on the material in a different way, viz., as a liquid with a brush or squirt and then engraved in order to increase the plastic impression of depths. After that the objects are glazed. In a high temperature the colours under the glazing mix with the material, except in the case of cobalt blue, which mixes with the glaze. This process has the technical advantage of making the colours durable, but on the other hand it has a disadvantage in the artistic sense, in that the covering colour reduces the lustre of the porcelain itself by breaking the rays of light which cause the minute crystals in the porcelain to glitter. This is not the case with painting after glazing. Another way of ornamenting, which, however, has the same artistic disadvantage, is to coat with coloured glaze, which is applied in one colour. By adding metals the glazing can be made what is known as "streaming"; or, by choosing a glazing compound, the coefficient of expansion of which is smaller than that of the material, irregular fissures or artificial crackles can be obtained with the cooling.

Grès.—Grès has many qualities in common with porcelain, but it is grey or ash-coloured and not translucent. The material needs less working in order to purify it. As this clay is already fairly hard after being dried in the open air the first firing can be omitted and the ornamenting begun at once. After being painted the objects can be put in the furnace without sagars and may be baked at a temperature of 1,190°. Throwing salt in the furnace causes an evaporation which brings a glaze on the objects. The colour is then ash-like, or, with a higher temperature, red-brown. The modem ceramist, however, prefers a superior kind of grks, which is more carefully washrd, has the colour of ivory, and to which kaolin can be added (French grks kaoliné). The painting takes place as with the ordinary grès before the glazing, after which it is baked and is coated with lead glazing. The grks can also be coated with an engobe-like pulp glaze.

Earthenware. — In England, at the end of the 18th century, this imitation and rival of porcelain was invented. In the course of the 19th century it obtained a prominent place in ceramic production, especially for domestic use. It consists of a plastic clay, freed as much as possible from iron and white-burning, but with which some quartz and felspar are mixed. Sometimes some kaolin also is added. The washing must be done very carefully. The exact shape is obtained by the moulding of the liquefied clay. Both during the first and second firing the objects are placed in sagars. Between the two firings the painting and the glazing take place. The ornamenting can also be done by coating the whole object with a pulp glaze.

Maiolica.—This is the name of a kind of porous pottery which after the drying and firing is coated with a tin glazing, either by immersion or squirting. On this non-transparent coating decoration is painted with dyes consisting of metallic oxides—a work that requires great skill, as retouching is impossible. During the process of baking the colours mix with the glaze. The effect is sometimes improved by coating the colours with a second glaze, this time a transparent lead glaze. So-called lustres can also be obtained by means of metallic reductions.

Pottery. — Pottery is the earliest ceramic production of mankind. For this a slightly calcareous potter's clay is used, which when baked becomes a red or yellow shard that still has to be glazed to render it water-tight. Decoration can be done in different ways—for instance by putting on ornaments of clay in a different colour (barbotine *décor*), or by painting them. The whole object can also be coated with another kind of clay and the décor in the original reproduced by scratching away the outer coating. It can also be engraved (*graffite décor*). In all these cases a transparent lead glaze is applied. By a combination of the different techniques all kinds of variety are possible and usual.

Historical Survey. — Interest in this fine old handicraft was revived in the period beginning with the Great Exhibition in London in 1851. Museums of industrial art were opened, and applied-art schools followed the lead, by the imitation of old models. Imitation led to a revival and improvement of old techniques and this was fostered by chemical science which in these years grew more and more important. People grew tired of imitation, however, and inspiration was sought elsewhere. It was found in the closer acquaintance with Japanese ceramic art at the Paris exhibition in 1867 and more especially in that of 1878. This inspiration took effect in two directions. First, it showed the possibility of another attitude towards nature and the reproduction of nature, and so pointed out a new way to porcelain; a new way to which Denmark was to lead a few years later. Secondly, it demonstrated the splendid ceramic qualities of the old Japanese grès. From this originated the new ceramic art of the French. This is the starting point of the history of modem ceramics.

FRANCE

The revival of French ceramic art was initiated by Ernest Chaplet, who was born at Skvres in 1835 and whose work became world famous 20 years before Jean Carriks, the sculptor, became a ceramist, under the influence of the exhibition of 1878. Chaplet entered the Skvres factory in 1848, and at the exhibition of 1855 he produced work of his own. Afterwards he worked at Laurin's at Bourg la Reine, where he reapplied the old barbotine technique. For it he used very white earth mixed with colour-oxides, which he painted on ordinary potter's earth. The success he had with this at the exhibition of 1878 did not last. In 1875 he became manager of the ceramic factory of Haviland in Paris, which factory he took over in 1885, and in 1887 he went to Choisy-le-Roi, where he lived and worked until his death in 1909. His great merit is the application of "flammés"—colour glazes without real figure ornamentation that cover his grks and sometimes his porcelain, copper-red, white, violet and blue in all varieties and combinations. First Japanese grks, and later the monochromatic Chinese porcelains inspired him, but his own work retains an independent quality. His trade mark is the rosary (*chapelet*). By the time that Chaplet reached the high-water mark of his fame Carriks had already achieved success. Jean Carriks was born in 1855. As a sculptor, with strong leanings to the decorative, he sought for picturesque effects. Deeply influenced by the charm of the Japanese work exhibited in 1878, he decided to devote himself to ceramic art, and to use grks as his material. Far from Paris, in St. Amand-en-Puisaye and Montriveau, in the neighbourhood of Nevers, where he found his material, he began to experiment in a furnace of his own, and in the exhibition of 1889 he showed the results which won universal admiration. The Japanese influence is strong, especially in his vases and bowls that are ornamented with streaming glazes. But his work has a character of its own, and he avoids what he considers the too great brightness of the Japanese glazes, and so obtains a better harmony between the colours of the glazes and the clay.

Besides numerous vases and bowls, simple and with no ornamentation other than the glaze, Carriks created a great number of plastic works such as masks, heads, figures of animals, etc., which please not only by their construction, their exquisite colour and beautiful surface, but also by their subtle characterization. His last work was a monumental hall which the Princess de Scey-Montbeliard had made in her hotel in the Avenue St. Martin. But he did not live to see it completed. He was ill when the work began, and on July 1, 1894, he died. His friend, the architect G. Hoentschel, who made china after the same method as Carriès, gave a large collection of the latter's work to Paris (Musée du Petit Palais). Another disciple was Paul Jeanneny (1861–1920), who took over Carriks' atelier in St. Amand. Neither he nor Hoentschel has done any plastic work. Jeanneny's work is even more closely connected with Japanese ceramics than is the work of the others.

In the meantime Chaplet had started a school, and the most prominent of the artists, who with their master formed the group of "L'Art du Feu," was Auguste Delaherche, who, when Chaplet went to live at Choisy-le-Roi, took over his furnace at Vaugirard in 1887. At first he worked with streaming glazes, and sometimes combined these with designs in relief. But gradually he simplified his methods. In the museum at Skvres there is an early dish of his with a motif of oak leaves; but his later work is remarkable only for the dull glow of his warm-coloured émails, strong and deep, dark and velvety. Other disciples of Chaplet are: Adrien Dalpayrat, born at Limoges, who collaborated first with Voisin-Delacroix and later with Mlle. Lesbros. His work can be recognized by the deeply coloured blue, blood-red or yellow opaque glazing, reminiscent of oil painting. Technically his workshop was very highly developed; sometimes he made vases several yards high in blue and red spotted grks.

Edmond Lachenal was much more under Japanese influence. For ornamentation, especially in his dull green glazed pots, he used naturalistic branches and flowers or blossoms, brought out in relief, and tinged with white or rose red. By giving his works an acid bath he succeeded in making the surface peculiarly velvety

—*émail velouté*. Albert Dammouse considered the material more, and his work at the Sbvres factory has a character entirely its own. For the decorating of his rather simple forms he used plant motifs, and often those of mosses and seaweeds. In so-called *pâte-décor,* the glaze and the pâte material are applied side by side or one over the other, as in enamel painting. Dammouse avoided bright colours and tried to get dark, deep harmonic tinges. In connection with this the Englishman Taxile Doat might also be mentioned. He worked at the Sèvres factory and produced *pâte-décor* Especially remarkable are his grbs articles on the surface of which have been affixed small porcelain insets with heads of animals. Alexandre Bigot, who has carried out designs for Henri van der Velden, and J. C. and M. Cazin (father and son), attained fame with their richly coloured running-glazes. They are inferior, however, to some of the younger artists, who in closer association with Chaplet and Delaherche, raised, with the help of the latter, French grbs to a height not reached by the older artists. First among these are Emile Lenoble and Emile Decoeur. Lenoble, Chaplet's son-in-law, not only took over Chaplet's furnaces, but also inherited his preference for grbs. But his work is quite different. Except in some of his Japanese-like products with a half coating of brown-black glaze, he specialized in engobes, in which he knew how to produce simple but very strong straight-lined ornaments by erasing. The colours of his engobes are of a blackish brown, grey, deep blue, green, orange-red, and white, and always of a quiet tone that harmonizes with the simplicity of the grey clay material. Decoeur is finer and more complicated with his dim, delicate glazes, occasionally bright, but generally dull, in which colour is more important than with Lenoble. Other ornament is lacking in his work or is reduced to a minimum, such as a few simple lines, a small cufic motif in relief, or a margin of leaves reminiscent of Chinese celadons. His bowls and pots are covered with a soft brown-yellow, a delicate green or blue glaze, usually rather thick and applied in a somewhat streaming manner. For softness of surface, his work equals the very best old Chinese and Japanese wares. Raoul Lachenal, the son of Edmond Lachenal, follows after Decoeur, and sometimes his work is equally good. Henri Simmen does the same, but he often imitates Japanese examples too servilely. Jean Mayodon decorates his work with figures like those on antique and Persian examples; *e.g.,* slender, leaping deer. René Buthaud has another technique—his decoration is of large flat human figures and a strong relief produced by deep incisions.

Of the artists who work in earthenware André Methey must be particularly mentioned. He is the greatest lover of colour and the greatest decorator, an artist who seeks inspiration not in Chinese or Japanese work, but in the rich ceramic production of ancient Persia whose metallic lustres he tries to equal. He is at his best when he builds up his décors from rhythmical repetition of very simple motifs taken from nature. Etienne Avenard follows his example. Félix Massoul uses in his work much heavier colours, his décor is more geometric and not so delicate as Methey's. Finally, the very simple but always fine forms and décors of Jean Besnard are not without merit.

While French ceramic artists were following new paths and bringing French work into world-wide prominence the development of the porcelain factory at Shes — the former glory of France—was negligible save in one respect, that of technique. At the Great Exhibition of 1851, Sbvres created a very bad impression. In 1852 Regnault was made director. An improvement resulted, but only in so far as the art director Dieterlé (till 1856) and after him Nicolle tried to make very clever imitations of the 18th century examples, instead of the dull repetition of the old traditions. Under L. Robert who was in charge from 1872 the old post of "directeur des travaux d'art" was reinstituted, and Carrier-Belleuse was appointed to it; new men were engaged, amongst others the young Rodin from 1880–82. But, in spite of these efforts and the experiments of the able and resourceful T. Deck a new ceramic art was not born. After Deck's death in 1891 the factory was reorganized, and in 1896, in anticipation of the Paris Exhibition of 1900, an extensive working scheme was drawn up as the basis for more modern and artistic development.

By a decree of Oct. 1, 1926, greater independence was granted to this factory.

Outside the Sèvres factory the only names worthy of note are those of Taxile Doat who has already been mentioned, and Camille Naudot, who about 1900 did some fine work in porcelain tendre. Haviland, in Limoges, worked at painting-before-glazing and also tried to produce artistic earthenware, but without producing anything special. A group of artists in Glatigny, near Versailles, who called themselves after this place, produced porcelains with streaming glazes reminiscent of grbs. Their example was followed by Pillivuyt in Paris. The first to attempt to make artistic stoneware of this kind in France was G. de Feure. In general, however, few good things have been produced. There were several tea and dinner sets at the exhibition of 1925, designed by decorative artists, but they seldom had a cachet of their own. Good work was done by Robert Bonfils, Maurice Dufresne, Suzanne Lalique and, probably the best of all, Marcel Goupy.

GERMANY

In connection with the revival of the German ceramic industry in the 20th century two names may be mentioned here, Th. Schmuz-Baudisz and Max Lauger. Both were attracted to the ceramic industry by knowledge of the so-called peasant pottery. and both learned the industry in its simplest forms from potters in Bavaria or the Black Forest. In this way it was impressed on them that the first thing a ceramist should know is that the shape and decoration of any object must depend very largely on the nature and composition of the material and on the technique of firing.

Max Lauger, who worked at Karlsruhe, decorated his vases and jugs, which were simple in shape and of a deep and even colour, with motifs from nature applied in clay of a different colour. His work resembles the *barbotine décor.* Working for a factory in Kandern he also designed, with the technical expert C. Mayer, architectonically applied earthenware, a great number of tiles, tile-tableaux, and mural coverings. Later, he worked in maiolica for the Majolica Manufaktur at Karlsruhe, and produced articles decorated in strong colours. These have greatly influenced younger artists, such as Ludwig Koenig and Georg Schrimpf, who, however, are inclined to an affected naïveté. Th. Schmuz-Baudisz was a painter at Munich, who after 1896 devoted himself to ceramics. He began to shape his objects himself and decorated them with motifs of flora and fauna which he cut out in the engobes that covered his pots. His decorations are much more strongly stylized than those of Lauger. In 1902 he became director of the Staatliche Porzellan Manufaktur at Berlin. The work of Elisabeth Schmidt-Pecht must also be mentioned; it is simple in decoration and form. In the meantime the porcelain factories took some interest in modern work. The Berlin factory, although strongly dependent on the taste of the court, had already, under Dr. Seger, about 1884, made experiments with copper-oxide glazes, and had even obtained good results in red and blue on the so-called flammés and running-glazes. The plastic articles, however, remained of little importance in spite of some successful products by Franz Metzner. But when Schmuz-Baudisz, who had started making domestic porcelain with simple decorations at the factory of Swaine and Company in Huttensteinach, moved to the factory at Berlin, the example of Copenhagen was soon followed and painting-before-glazing was applied. Of the artists, Adolf Flad and Max Durschke must be mentioned. Schmuz-Baudisz, who set himself the task of designing landscapes in coiour on large porcelain tiles, attempted a difficult technique which was not always justifiable from an artistic point of view. For many years the plastic work at Berlin could not free itself from the influence of the court. Since that time, however. Hermann Hubatsch has made clever statuettes, and in animal pieces Anton Pachegger (1917) and Edmund Otto have done sensitive work But a great deal has not been accomplished, and in this respect Berlin is just as unimportant as Meissen for the same period. in that, although technically very clever, it produced nothing really important until 1918.

In 1918 Max Adolf Pfeiffer was made director; he brought new life into the factory and made a great improvement especially in plastic work, to which some of the younger artists, for instance E. P. Borner, Max Esser and Paul Scheurich have contributed. More important than Meissen and Berlin in modern ceramics has been Nymphenburg in Bavaria. In 1888 Albert Bauml became director, and he soon attached some young artists to his establishment who, so far as plastic work is concerned, have obtained astonishing results. Jozef \F'ackerle was especially prominent here. He made beautiful types of peasant pottery, and also humorous groups from 18th century life. He fully mastered the possibilities of porcelain, and made some clever models in maiolica. For some years Wackerle worked at Berlin. Theodor Karner has done animal pieces which are in the first rank; of his disciples W. Neuhäuser must be mentioned.

Among other important factories may be mentioned the Schwarzburger Werkstätten für Porzellankunst at Unterweissbach, later combined with those at Volkstedt, of which M. A. Pfeiffer was director. He knew how to escape the influence of Copenhagen and sought to produce original work. Jozef Wackerle first worked here and also Ernst Barlach, who with his figures of Russian peasants introduced an entirely new style. Moritz Pfeiffer's table decoration "Hunting scene" also deserves mention. Besides these, good plastic models have been made by Hugo Meisch and by Arthur Storch, while Hans Poelzig has succeeded in making porcelain subservient to modern interior decoration.

Andreas at Leipzig has attempted to make expressionist porcelain pieces, but so far the fine qualities of porcelain have not been adapted to this method of expression. Maiolica offers a better field, and is better adapted to painting. The somewhat affectedly naïve products of L. Koenig and G. Schrimpf have already been mentioned. They work at the Majolica Manufaktur at Rarlsruhe, where other younger artists are also engaged. Another and smaller workshop is that of the women ceramists J. Biehler and M Goossen at Nymphenburg. They have made good reliefs and also free pieces. Two other Munich workers deserve mention, Georg Kemper, who produces miniature pieces, sensitive in form and colour, of *putti* and such like; while Konigsbauer attempts a close resemblance to mediaeval forms with his double-surfaced sided jugs of which the outer one is open-worked. Something like this is also found in the maiolica work of Otto Müller who was inspired by Chinese examples, and in the pottery of Kurt Feuerriegel who is more inspired by 16th century models, though both of them, especially the former, produce work with a character of their own. The same can be said of Auguste Papendieck who works independently in the neighbourhood of Bremen, and who, in her monochrome, slightly glazed vases, aims at great simpiicity and pure technique.

Finally some important progressive features can be seen in the development of stoneware. The domestic pottery of the firm of Villeroy and Boch, who have factories in various places, is frequently meritorious work. In particular their Dresden factory has obtained good results. J. Kühne and Jean Beck design forms and décors The Wachtersbacher Steingutfabrik at Schlierbach has had as art directors Chr. Neureuthet and, after his death, Ed. Schweitzer. Good plastics have been made by Ernst Riegel.

AUSTRIA

During the 19th century there was no artistic ceramic work to speak of in Austria. The revival dates from the first years of the 20th century. Following an exhibition of simple and brightly coloured ceramics at the Viennese Secession in 1902, Bertold Loffler began his attempts to create something new with ordinary red clay, and was joined soon after by Michael Powolny, the most important person in Austrian ceramics. They established a workshop, the Wiener Keramik, where Powolny's pieces of ordinary clay, fired and brightly glazed, were produced. In 1907 there followed the collaboration with the Wiener Werkstatte, where Josef Hoffmann sought and found new possibilities for the entire industrial art. On the ceramic side he was helped by Kolo Moser (d. 1918). The Werkbund exhibition of 1912 showed not only the *putti* and other figures wreathed and surrounded by flowers, but also the ceramics in black and white under-glaze which has become a special Viennese type and has been imitated endlessly. In the same year the Wiener Keramik collaborated with the Gmundener Keramische Werkstatte, where, under the directorship of Franz and Emile Schleisz, peasant pottery developed into an artistic product. An important side of this industry was practised by Powolny, who made work for interior decoration and tiles for stoves at Gmunden. One of the most prolific designers is Otto Prutscher. Meanwhile, Powolny has a number of disciples at the Wiener Kunstgewerbeschule, who work at the Wiener Werkstatte or in small studios of their own. The Wiener Porzellan Manufaktur has come under the influence of the revival in earthenware. Multi-coloured décors by Franz Zulow cover its products. In general, however, lively and dainty as the whole of Austrian ceramic production may be, it is always in danger of becoming affected.

HOLLAND

In the 19th century the famous ceramic traditions of the early maiolica and Delft ware, with its cream pâte, had completely disappeared. That which had taste imported from elsewhere flourished. In the last quarter of the century there was a revival. J. Thooft in 1876 bought the last remaining Delft factory, De Porceleyne Fles, and. together with Ad. Lecomte, he applied himself to the revival of Dutch artistic pottery. Unfortunately at first this usually consisted of an imitation of old Delft ware,—blue and, later on, coloured; but shortly after, in 1884 at The Hague, the German ceramist W. Von Gudenberg together with the decorative artist Th. Colenbrander, began to make more original work in the Rozenburg factory. Colenbrander's designs were novel and distinguished, his décors sometimes under Japanese influence, but usually completely his own, were in rich colours and usually had phantasies of plant motifs. There are amongst these bright and slightly too brilliantly glazed pieces of faience hints of futuristic compositions, but they are purer from a decorative point of view. Production of this kind at the Rozenburg factory lasted only until 1889 when Colenbrander left it. It was not revived until 1916, when the vogue was for rather heavy, darkly painted faience. A peculiar product was a kind of very thin pseudo-porcelain, in pale colours, shaped and painted in Jugend style. Japanese influence can be recognized in the ornament. The material, as thin as paper, has not been generally used. Meanwhile the De Porceleyne Fles found two clever artists in L. Senf and E. L. F. Bodart who made various experiments, including dark brown earthenware with running glazes and graffite ornaments, and glass-covered faience with painting inspired by Persian colour and décor. Gold and silver lustre ware has also been successful.

A third tendency became apparent, the influence of the English movement in industrial art inspired by Morris and Crane. On the one hand this was seen in the workshops when first at Amstelhoek and later at Distel an attempt was made to produce beautiful domestic ware with simple materials and old ceramic techniques. On the other hand an independent potter, W. C. Brouwer, turned original shapes on a potter's wheel, which, coated with self-made glazes, were simple but elegant objects. Very little plastic work was done, but the sculptor J. Mendes Da Costa made very delicate and typical small groups of Jewish women and animals in lead-glazed grès.

An important figure in the 20th century was C. J. Lanooy, who, as an independent ceramist, imitated the grès flambés of the French, and produced very original and most beautifully coloured pieces. His glazes in which metallic oxides play an important part, are frequently very fortunate discoveries. B. Kienhuys, for a long time a teacher at Hagen, Westphalia, and later at the industrial school at Amsterdam, has a fine feeling for harmonious colouring, and his pots and vases certainly have good and original shapes. Th. Nieuwenhuys and C. Lion Cachet, who as decorative artists occupied themselves with many forms of art, designed faience for the Distel which is deserving of attention. About 1912 Colenbrander, for a short time, made faience covered with dull glazes on which his peculiar décors, principally in blue and brown, were painted. Again, about 1925, in his old age, he designed underglaze décors on the faience of the Arnhem factory Ram. At the same time the factory of Eskaf produced beautiful domestic ware with white streaming glazes, sometimes decorated in black in a plastic manner, and also miniature plastics, both by H. Krop. At the factory of Z. Holland at Gouda, domestic ware of good shape ana colour was made by C. De Lorm. Brouwer still continues his work and also frequently designs ware for interior decoration. Besides those of Senf and Bodart and their disciples the De Porceleyne Fles produces very good tiles, usually in monochrome, but also in fine colours. Generally speaking, Dutch faience—no porcelain or grès is produced—has a distinct character of its own.

(H. E. VAN GE.)

SCANDINAVIA

Interest in ceramics in Scandinavia was renewed with unusual vigour about the end of the 19th century. This movement, particularly in Denmark, may be attributed to Philip Schou, for some time the manager of the Royal Porcelain works. The white underglaze porcelain, introduced at the end of the 19th century by Arnold Krog, by virtue of its plastic qualities and the depth and perspective it can give to a picture, demands decorations taken from nature and everyday life. The decorations and the more severe ornamental lines which in other ceramic art attain such beauty of perfection, are out of place here; but a sentiment from the air, from the water, from bird, animal or plant life, is reproduced by this underglaze porcelain as by nothing else. This school, which is thus of a national character, is bound up with a great development in sculpture, especially of animals portrayed as they are in life, and of figures, which also reproduce Danish atmospheres, whether taken from life or literature, as for example, Hans Andersen's fairy tales. Another type, the fluted porcelain, which in English-speaking countries is called "the blue Danish pattern," is akin to the underglaze porcelain. The pattern originally came from China, but in course of time has become entirely Danish and has undergone an interesting development. All the models, even the plainest, are the work of the best and most artistic designers and thus the whole set is stamped with a refinement which makes it probably the most popular dinner-service in the world at the present moment.

It is interesting to note that the first great novelty which appeared after underglaze porcelain had made its mark was its direct antithesis—the overglaze. It is interesting also to see how three different artists solved the problem of creating modern overglaze porcelain and its sculpture. Henning, imaginative, artistically great, with a cosmopolitan stimulus, conjures up romance by blending the cultures of East and West in beautiful, rather voluptuous figures; whereas Carl Martin Hansen takes his themes from the almost forgotten national dresses of men, women and children in the various parts of his native country; and A. Malinowski seeks the ideal of his art in white porcelain, only very discreetly and very slightly decorated with a little sepia and gold.

Biscuit, a peculiar material, was at one time, particularly towards the close of the 18th century, admired over the whole world. And then the taste for it died away, probably because the ceramic importance of the material was not sufficiently appreciated. Compare old Sèvres with modern Sèvres, old Wedgwood with modern Wedgwood, and the difference will be seen—and this difference is not due solely to age, for all porcelain changes slightly with age; it is presumably due to the failure to recognize the importance of the question of material. Even when biscuit was introduced in the reproduction of the works of Thorvaldsen, this recognition was lacking, and it was only after more than zo years of research and experiment that the Royal Porcelain works in Denmark discovered a faintly cream-coloured biscuit—amber against the light—which artists, particularly Malinowski, have endeavoured to mould to their work.

Only three principal colours can be used on underglaze porcelain, blue, green and a reddish tone, and painters have therefore had recourse to overglaze technique where every colour is available, especially gold. However, after numerous experiments with white and grey porcelain, and with stoneware, etc., our artists have found in greyish crackled porcelain a background for painting that inspires them to break new ground. In this porcelain the artist works with vigour, and his decorations possess at the same time a sweetness, a charm, a freshness and a freedom made possible by the employment of this new material, and it is an interesting fact that to attain their effects the artists are not content with crackled porcelain; they want the crackled large or small, square or round, according to the motifs they have created; and the potter knows how to satisfy these demands. A closer collaboration between technique and art scarcely exists.

Of late years unusual interest has been taken in celadon, that remarkable old Chinese porcelain which was discovered through iron having become mixed in the glaze, the effect being that the glaze became green when the porcelain was baked in a certain way. The material is not easy to work with; it requires its own artistic treatment, its own particular shapes, a very special glazing and a special glaze. The material gives opportunity for line effects, architectural effects and reliefs. Often it assumes a jade-like character and is in the closest harmony with the old Chinese culture.

Almost simultaneously with the renaissance of overglaze technique, work was started upon stoneware, a ceramic material that is between porcelain and faience. Porcelain is a siliceous, translucent material; stoneware is a siliceous, opaque material; faience is a porous material. It is interesting to see the strange and unexpected effects which appear gradually as one studies the material more and more. There are the coloured glazes, the fine surface aptly termed *peau de vierge* in France; Jais Nielsen's strong, turquoise-blue glazes, which make one think of the ceramic wonders of Persia and Samarcand, and Kyhn's splendid animals.

From the beginning of the 20th century the Copenhagen Faience works has endeavoured to create a modern style of faience of high artistic merit. It must be remembered that present-day faience is generally different from faiences which delighted the world in mediaeval times. The fine collections of Italian and French and Moorish faience all have tin glazes. These tin glazes are less used in modem faience; for technical reasons potters have turned to a lead glaze or a hydric borate glaze, and attention has principally been devoted to finding an artistic expression for a product of this kind. Here, too, the work is under the glaze where, in contrast to porcelain, one can employ the whole of the colour scale. The designs produced under the leadership of Joachim are gay and lively, rich and glowing, and characteristically Danish. The ground colour resembles that of English faience; but it will not be denied that the artistic treatment of faience in this modem material is much more difficult than tin faience and porcelain, because the glaze is a clearer and lighter glass than the glaze upon porcelain and tin faience, and it has required great trouble to obtain the proper harmony between body, colour and glaze. Joachim has attained great heights with this remarkable faience. The simplicity of decoration and colour, and the definite glaze shades are a constant source of pleasure.

There is in Denmark another very important pottery, Bing and Gröndahl's Porcelain works, which were established in 1853. The same desire which seized Philip Schou to ennoble the material on the basis of Danish artistic culture also animated Harald Bing, who was manager at that time. He engaged the artist, Peitro Krohn, whose finest work is, perhaps, the beautiful heron set, in which he has created something extremely decorative by means of a combination of underglaze and gold. In 1900, at the exhibition in Paris, it entered upon entirely new paths. Later on Bing and Grondahl attached such artists to their establishment as Kai Nielsen, whose Venus seems to be a symbol of complete harmony between art and material. In 1925, at the exhibition at Paris, Jean Gauguin exhibited a number of works in stoneware with chamotte, in which he proved himself a very gifted artist. By various chemical means, he created peculiar and beautiful works which, in stoneware, may to some extent correspond to biscuit in porcelain. Jean Gauguin's latest works, in faience with tin glaze, demonstrate the fresh and bold imagination of the artist in a sculptural sense.

A beautiful and peculiar art which has arisen in Denmark is the manufacture of earthenware, particularly at Kähler's works at Nastved, where two generations have succeeded in showing novel and interesting results in refined glazed earthenware. The material itself is ordinary clay from the fields near the factory. The work lies in the baking, the painting and the glaze, in which much is done with lustres—the red copper lustres ranking higher, in some ways, than both Clément Massier's from Golfe de Juan and the Hungarian lustres from Fiinfkirchen. The factory has extended the colour range of these lustre glazes and has some grey lustres which, in the hands of the painter Tirslund, have attained the finest effects.

On the island of Bornholm there is a small factory, Hjort's pottery. It is, perhaps, not very well known outside of Denmark, but Hjort's stoneware is of excellent quality, even though the output is limited. He turns out small vases and figures with coloured glazes, 6th a charm characteristic of his own touch. His glazes excel by their great thickness. And finally, we must not neglect to name the artist, Hansen-Jacobsen, who has dreamed of creating ceramic wonders and so often realized his dreams.

Sweden has worked on different lines. Whereas Denmark has, perhaps, devoted herself principally to the free ceramic art, Sweden has had a background for her ceramic development that might well be envied by other countries. Sweden has always possessed a great folk-art which has produced distinguished work, especially in her textile wares, her wood-carving and her iron, and this art has influenced the great factories, such as Gustafsberg, Rorstrand and Gafle, in their production of characteristic dinner-sets which are in the closest possible harmony with Swedish home-life. There is no doubt that this art is very desirable and peculiar to Sweden, and that the highest ceramic ideal lies in raising the artistic level of such dinner-sets, where the scope of the artist is so much more limited than in free art.

Norway, in the two factories, Porsgrund and Egernsund, the one porcelain and the other faience, has repeatedly been on the verge of creating something national and unique, but has unfortunately abandoned it uncompleted.

The factory, "Arabia," in Finland, has attempted to achieve the same end, but stern necessity has doubtless confined its production within the boundaries set by the economic life of the country. (F. DA.)

ENGLAND

English cream-coloured earthenware still retains much of the market it gained by its excellent quality in the latter part of the 18th century, and modern taste has reverted to slight graceful patterns not at all unlike those on Wedgwood's early "Queen's ware." Some noteworthy private decorators have contributed to this. Alfred and Louise Powell have painted some interesting designs on Wedgwood pottery, and latterly on wares of their own making. Dora Billington's fancifully decorated table-wares should also be mentioned here, amongst the work of a small group of people whose efforts, though slight in themselves, are significant as determining the styles eventually adopted by the manufacturers. Standing apart from all other "useful wares" are the charming and original things designed by John and Truda Adams and made by Carter, Stabler and Adams of Poole: a novel and pleasant half-glossy surface and distinctive clean colour are amongst their good qualities.

The decorative styles first inspired, late in the 19th century, by the Chinese *flambé* and other glazes have been continued by (amongst others) W. Moorcroft of Stoke-on-Trent, Doulton's of Burslem, W. Howson Taylor (Ruskin Pottery, Smethwick), Bernard Moore and Pilkington's of Manchester. The last-named have continued their work in lustre-painting, and in 1928 introduced some very pleasant grey glazes, with effective slight designs in black by Gwladys Rodgers. The later work of the Martin brothers in salt-glazed stoneware showed a praiseworthy advance in simplicity. Doulton's Lambeth stoneware with coloured glazes has been used for statuary by Gilbert Bayes in a manner practised also with success by Mr. and Mrs. Harold Stabler. Perhaps the best and certainly the most promising work in glazed pottery-sculpture has been done by John Skeaping. Interesting figures on a smaller scale, inspired by 18th century china, have been made by Charles Vyse and Gwendolen Parnell.

Amongst the studio-potters, W. Staite Murray's genius has produced much work superficially resembling the early Chinese but highly personal in its low-toned glazes and austerely beautiful forms and decorations. Of equal importance is the fine work in stoneware of Bernard Leach, also inspired by Far Eastern models. The art of Reginald Wells is less simple and direct, stressing colour rather than form, but capable of charming effects. Amongst the other artist-potters, Frances Richards has produced some interesting glazes on stoneware and three other women, Nora Braden, K. Pleydell-Bouverie and Sylvia Fox-Strangways, deserve mention for original work. Mr. Leach and his pupil, Michael Cardew, have revived with success the interesting English slip-ware technique, but high-fired stoneware is likely to be the most fruitful medium in this branch of the potter's art. (W. B. Ho.)

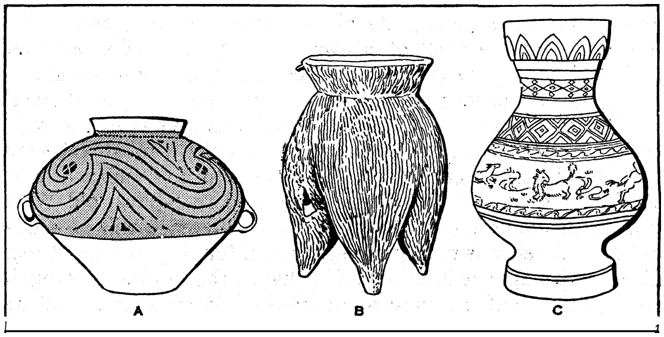
Other Countries. — There has been no important development in ceramics in countries other than those dealt with above. Neither Spain nor Italy has produced more than imitations of the old Spanish-Mauresque and Italian styles; Czechoslovakia and Switzerland are endeavouring to produce a distinctive native pottery, but with no very remarkable results.

BIBLIOGRAPHY.—R. Borrmann, *Moderne Keramik*, 1902; O. Pelka, *Keramik der Neuzeit*, 1924; René Jean, *Les Arts de la Terre*, 1911; Lucien Magne, *Décor de la Terre*, 1913; *L'Exposition Internet. des Arts Décoratifs*, 1925, ed. "Beaux Arts"; *L'Art Décoratif Français 1918–1925*, ed. A. Lévy; Arsène Alexandre, *Jean Carriès imagier et potier*, 1898; G. Migeon, *Prkface à l'Exposition de l'oeuvre céramique du potier E. Chaplet*, 1910; A. Hayden, *Chats on Royal Copenhagen Porcelain*, 1918; J. F. Blacker, *XIX. Century English Ceramic Art;* L. W. Rochowansky, *Wiener Keramik*, 1923; H. E. Van Gelder, *Ned. Pottenbakkerskunst*, 1927; Arthur Hayden, *Royal Copenhagen Porcelain*, 1911; Emil Hannover, *Pottery and Porcelain*, vols. ii. and iii., 1925 (ed. by Bernard Rackham); Gustaf Munthe, *Udstillingen i Goteborg, Svenska Slojsforeningens Tidsskrift*, 1927 (French translation in *La Renaissance*, Feb. 1, 1927); Gabriel Mourey, Art. in *Art et Décoration*, June 1, 1925; Victor P. Christensen, Arts. in *Connoisseur*, Nov. 1922, August 1923; Erik Wettergren, *The Modern Decorative Arts of Sweden* (1928).

NEAR AND FAR EAST

CHINA

The supreme excellence of Chinese pottery in mediaeval and later times gives an unusual zest to the enquiry into the first phases of Chinese ceramic history; and we welcome the new light recently shed on them by Prof. J. G. Andersson's discoveries in Honan and Kansu which reveal the existence of two distinct kinds of pottery in pre-dynastic times. The Andersson finds have been provisionally divided into six periods; and the earliest and, oddly enough, the most artistic of his pottery can hardly be later in time than 3000 B.C. It consists both of funerary wares and pottery for general use, made by hand (helped perhaps by a slow wheel) of

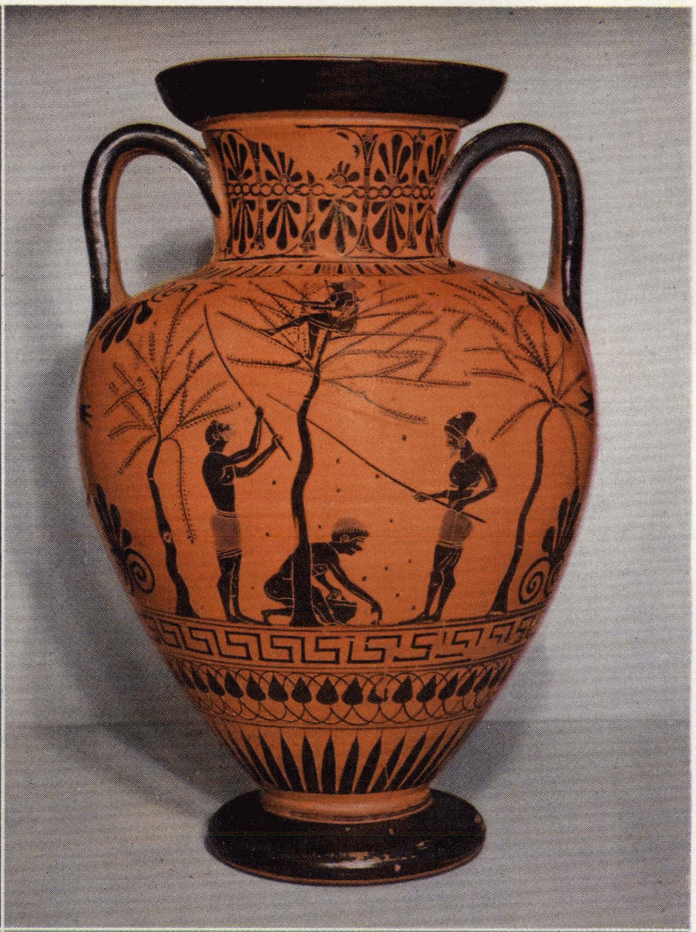


(A AND B) FROM ANDREWS, "MEMOIRS OF THE GEOLOGICAL SURVEY OF CHINA" (C) BY COURTESY OF THE BRITISH MUSEUM

EARLY CHINESE POTTERY; (A) NEOLITHIC POTTERY FROM KANSU. (B) NEOLITHIC MAT-MARKED POTTERY FROM HONAN, (C) PAINTED POTTERY OF THE 4TH CENTURY B.C.

finely levigated, thin and strongly baked buff and red clays, shaped in pleasing, and often quite imposing, forms and decorated with elegant painted designs in red, black, purple and white clays which have been submitted to the fire of the kiln. This painted ware, which is superior in technique to any of the pre-Han pottery of dynastic times so far known, has interesting, if superficial, resemblances to the painted pottery found at Anau, Susa and other western Asiatic sites of late neolithic date.

Alongside this painted ware Andersson found another type of pottery, a coarser, grey earthenware made without the wheel and often impressed on the exterior with markings which suggest that



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GREEK, ROMAN AND ETRUSCAN POTTERY

Top left: Terra-cotta antefix in the form of a woman's head. Etruscan. 6th century B.C.

Top right: Amphora (two-handled jar) by the Antimenes painter. "The Olive Harvest." Athenian. 6th century B.C.

Bottom left: Athenian psykter (jar for cooling wine) signed by Douris. "Revels of the Seileni." About 510 B.C.

Bottom right: Footed bowl of Arretine ware with a design of the seasons in relief. Made about 10 B.C. in the factory of Cn. Ateius

NOTE: THE PHOTOGRAPHS ON THIS AND THE FOLLOWING PAGES WERE SELECTED AND ASSEMBLED BY GEORGE SAVAGE, PLATES XXXI AND XXXV WITH THE ASSISTANCE OF HUGH WAKEFIELD OF THE VICTORIA AND ALBERT MUSEUM

BY COURTESY OF THE TRUSTEES OF THE BRITISH MUSEUM

EARLY GREEK AND RELATED POTTERY

1. Mycenaean krater or mixing bowl. 1400–1000 B.C.
2. Kyathos, a single-handled cup, depicting the story of Herakles and the Erymanthean boar. Attic Black-figure style, about 540 B.C.
3. *Amphora,* a two-handled storage jar, showing Achilles slaying Penthesileia. Attic, 540 B.C.
4. Krater from Cyprus. 1375–1200 B.C.
5. *Alabastron* (oil bottle) showing a maenad at a Bacchic ceremony. Signed by Pasiades. Attic, about 500 B.C.
6. Skyphos (drinking cup). Attic, about 550 B.C.
7. Hydria (water jar). Laconia, about 550 B.C.
8. Hydria showing horses being harnessed to a quadriga (four-horse chariot). Attic, about 540 B.C.
9. Oinochoe (jug with a trefoil lip) in the style of Andokides. About 525 B.C.


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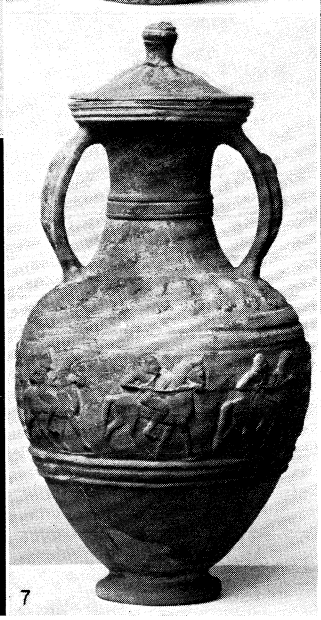
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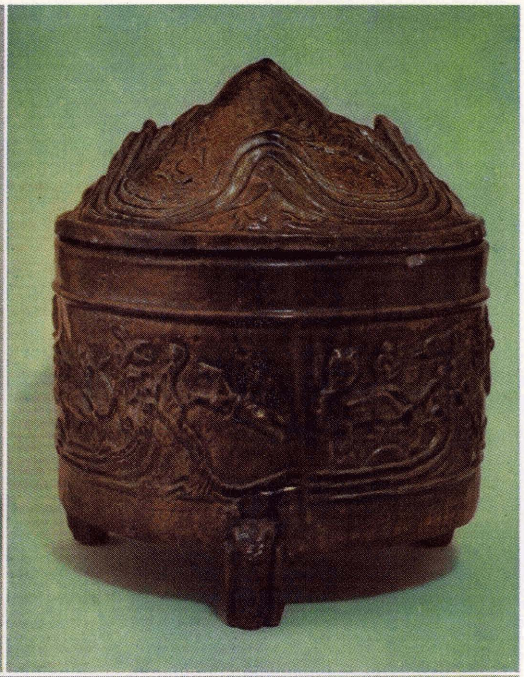
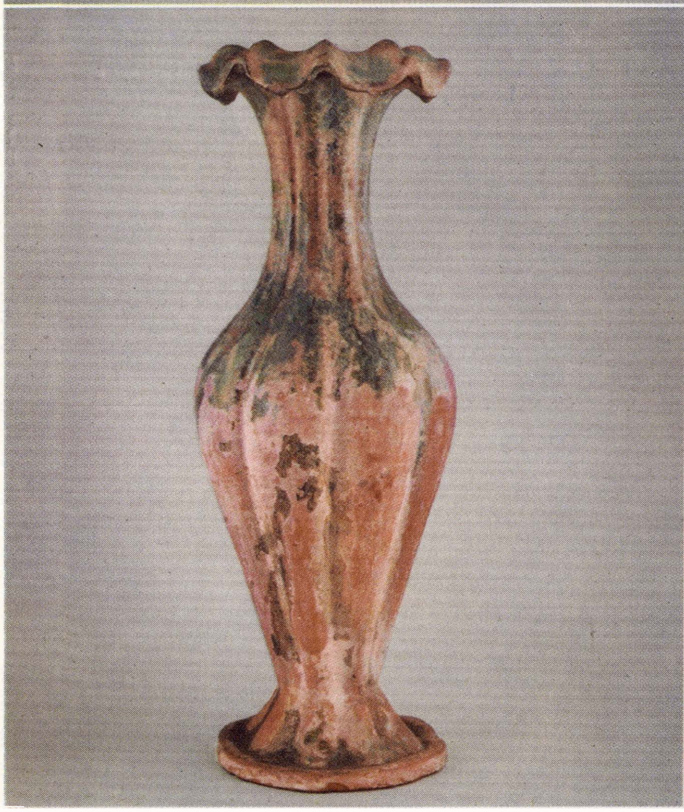
8

EARLY GREEK AND EUROPEAN POTTERY

1. Bowl of Samian ware with moulded decoration. Probably Gauiish, about 1st century B.C.
2. Bell krater. Paestum, southern Italy, 4th century B.C.
3. Kantharos (drinking cup) in the form of a female head. Attic, about 480 B.C.
4. Etruscan canopic jar of bucchero (moulded) ware. 6th century B.C.
5. Krater with medallion handles showing Boreas and Oreithyia. Apulia, southern Italy, second half of the 4th century B.C.
6. Detail of the interior of the kylix shown in Fig. 8
7. Amphora decorated in relief. Etruscan bucchero ware, 6th century B.C.
8. *Kylix* (drinking cup) in red-figure style and painted by Eplktetos. A scene showing Herakles slaying Busiris. Attic, about 480 B.C.





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CHINESE POTTERY AND STONEWARE

Top left: Funerary urn from the Pan-shan cemetery. Lanchow, Kansu province. About 3000 B.C.

Top right: "Hill" jar, or censer, with the cover made to represent the Taoist "Isles of the Blest." Han dynasty. 206 B.C.–A.D. 220

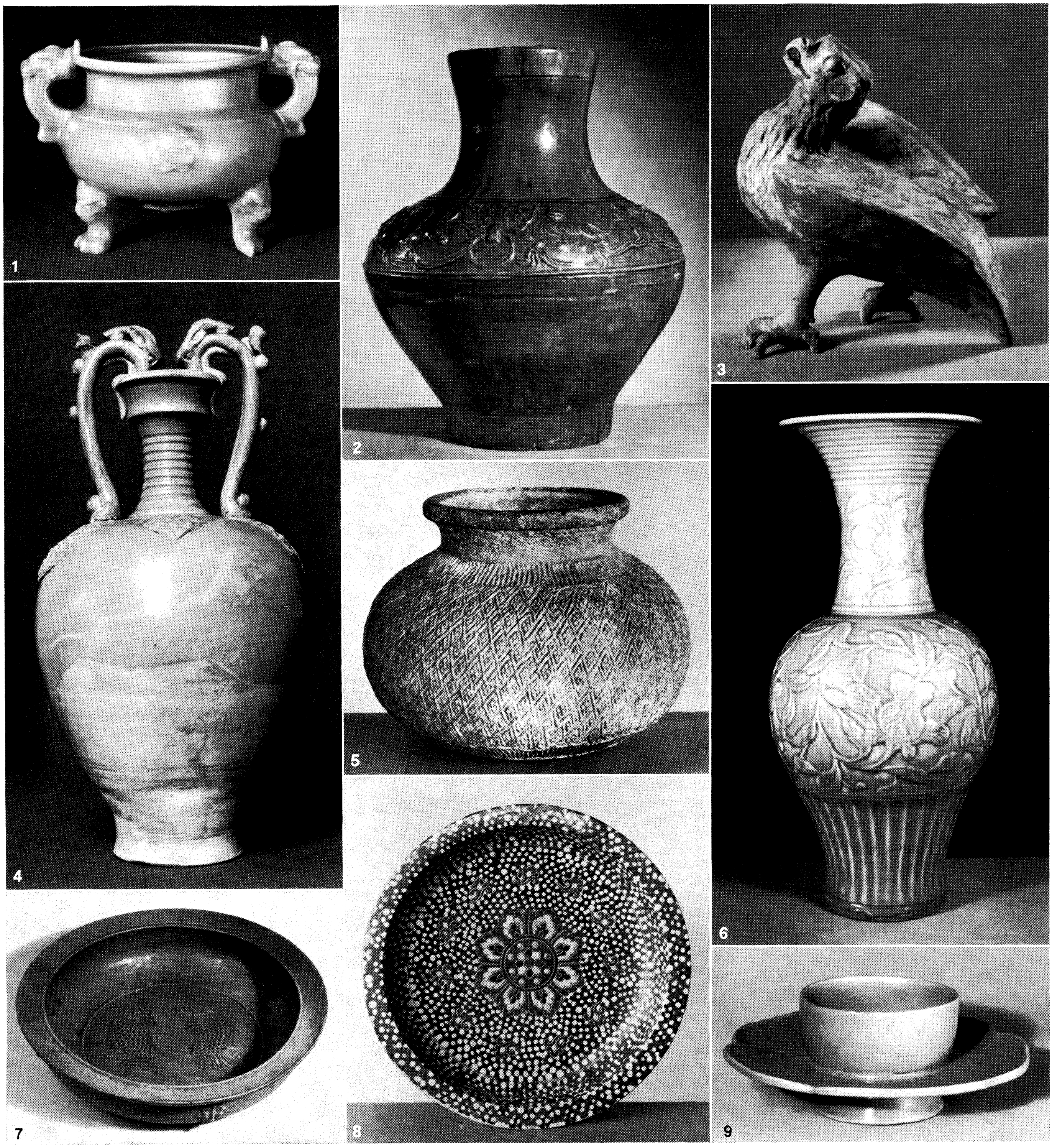
Bottom left: Pigmented pottery vase. Period of the Six dynasties. A.D. 220–589

Bottom right: Lion decorated with coioured glazer. T'ang dynasty. A.D. 618–907

BY COURTESY OF MISS JOSEPHINE MORRISON

CHINESE POTTERY

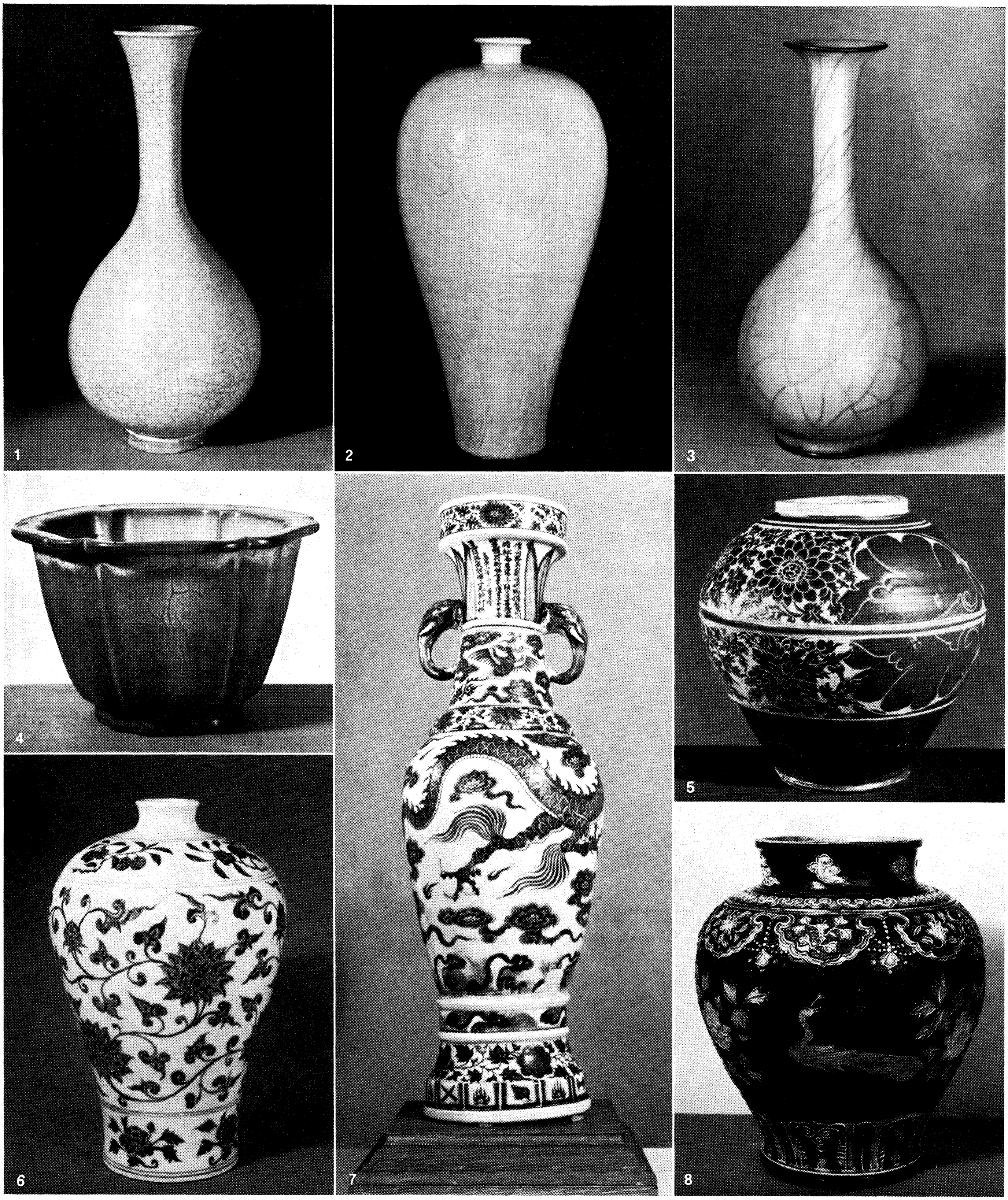
Bactrian camel in glazed pottery. Reaovered from T'ang dynasty tomb. A.D. 618-906



BY COURTESY OF (1, 6, 7, 9) PERCIVAL DAVID FOUNDATION OF CHINESE ART, (2–5, 8) VICTORIA AND ALBERT MUSEUM

CHINESE POTTERY AND PORCELAIN

1. Grayish-white porcellanous incense vase covered with a jade-green celadon glaze, the ornament in applied relief. Lung-ch'uan ware. Sung dynasty (960–1279)
2. Wine jar (*hu*) in red earthenware with a moulded frieze of decoration probably taken directly from a bronze original. Dark green glaze. Han dynasty (206 B.C.–A.D. 220)
3. Bird in green glazed earthenware. Han dynasty
4. Vase with dragon handles showing traces of Greek influence. Straw-coloured glaze. T'ang dynasty (618–907)
5. Food vessel in unglazed earthenware with impressed pattern. Late Chou dynasty, perhaps 500 B.C.
6. Grayish white porcellanous vase with sea-green celadon glaze. Decoration both carved and applied. Inscribed with the name of Lung-ch'uan and the date. 1327. Yuan dynasty (1279–1368)
7. Bowl of Yüeh ware, gray stoneware with a thin olive-green glaze. Probably from Chiu-yen. Period of the Six dynasties, 3rd century A.D.
8. Dish of white earthenware decorated with impressed designs and coloured glazes. T'ang dynasty
9. Buff-white porcellanous ware with lavender-gray glaze netted with a fine crackle. Ju ware. Sung dynasty



BY COURTESY OF (1–4, 6–8) PERCIVAL DAVID FOUNDATION OF CHINESE ART, (5) VICTORIA AND ALBERT MUSEUM

CHINESE POTTERY AND PORCELAIN

1. Grayish-white ware with a faint greenish-gray glaze and a golden brown stained crackle. An early variety of Tung ware, 10th century. 2. Grayish-white porcelain with a warm ivory-white glaze covering carved design of lotus flowers and foliage. Ting ware. Sung dynasty (960–1279). 3. Dark black-brown stoneware with lustrous pale blue-gray glaze and golden brown stained crackle. Kuan ware. Sung dynasty. 4. Grayish-white porcellanous stoneware with a thick opalescent purple glaze frosted with gray. On the base is the number five (*wu*) under the glaze and 18th-century Palace marks incised through the glaze. Chun ware. Sung dynasty. 5. Jar of buff stoneware with design cut through a brown and black glaze. Tz'ŭ Chou type. Yuan dynasty (1279–1368). 6. Vase of *mei ping* form decorated in underglaze blue. Early 15th century. 7. White porcelain temple vase decorated in underglaze blue. Dedicatory inscription on the neck dated 1351. Yuan dynasty. 8. Porcelain vase with design outlined in threads of clay and decorated in turquoise, yellow and white on a ground of intense violet-blue. Ming dynasty, about 1500

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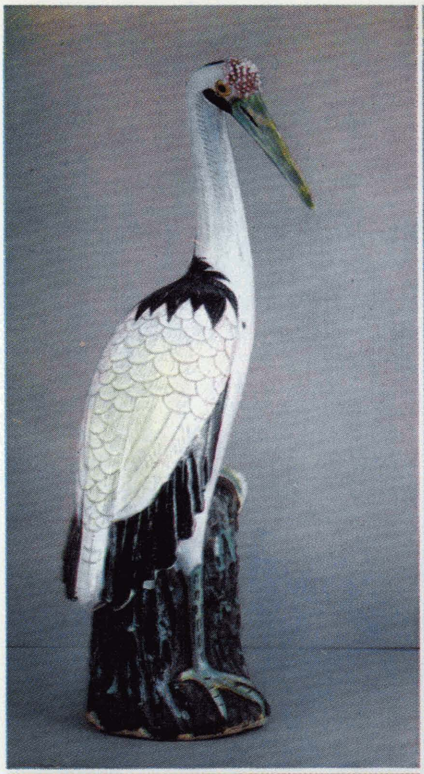
CHINESE PORCELAIN

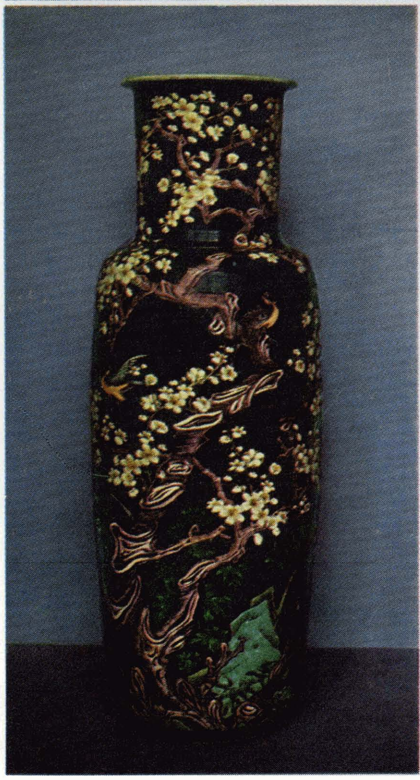
Top left: Flask painted in underglaze blue showing a dragon over waves, and an aquatic bird and floral sprays above. Ming dynasty. 14th century

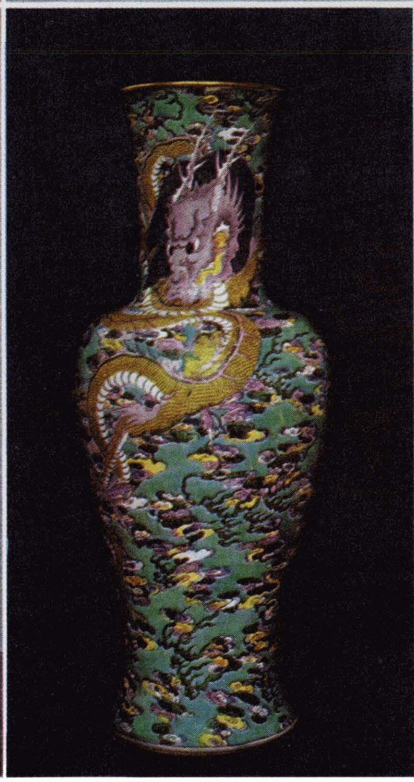
Top right: Pear-shaped bottle with "garlic" mouth, painted in underglaze blue and overglaze enamels. Ming dynasty. Signed on the lip with the six-character mark of Wan Li (1573-1619)

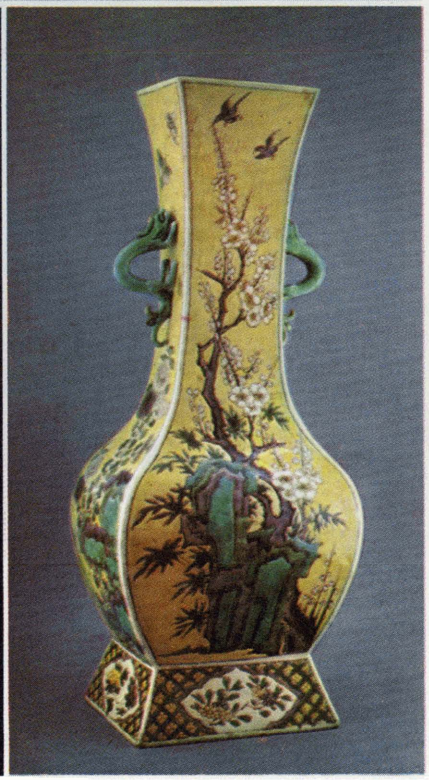
Bottom left: Vase of *mei ping* form with carved floral decoration beneath a green glaze. Tz'ŭ Chou ware, Sung dynasty. 960-1279

Bottom right: Another vase of *mei ping* form decorated in the cloisonné style with coloured glazes separated by clay threads. Ming dynasty. About 1525









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LATER CHINESE PORCELAIN

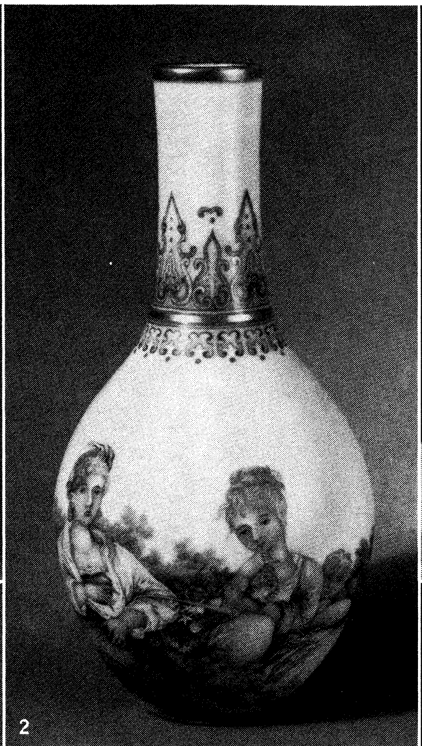
Top left: Stork figurine. Reign of the emperor Ch'ien Lung (1736–95). The stork was a symbol of longevity
Top right: Kuan Yin, Buddhist deity. Reign of the emperor K'ang Hsi (1662–1722)
Bottom left: Vase of the ***famille noire*** (black family; enamelled over green-black ground) painted with ***famille verte*** (green family) enamels. K'ang Hsi
Bottom centre: Vase decorated with enamels of the *famille verte*. K'ang Hsi
Bottom right: Vase painted with enamels of the ***famille verte*** on a yellow ground. ***Email sur bisque.*** K'ang Hsi

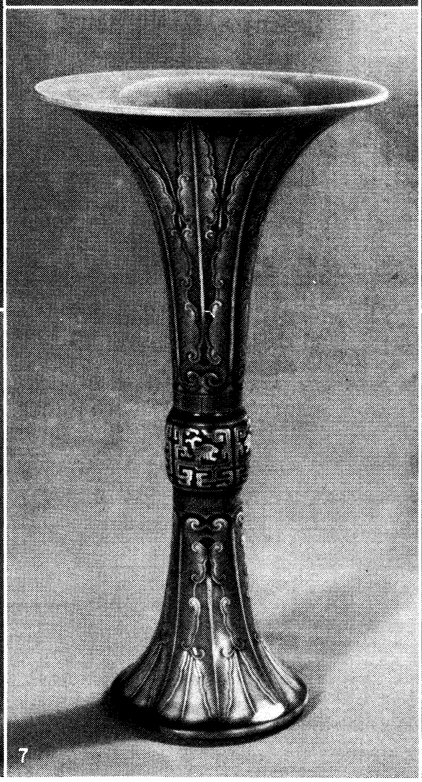
POTTERY AND PORCELAIN

BY COURTESY OF (1–7) PERCIVAL DAVID FOUNDATION OF CHINESE ART, (8) VICTORIA AND ALBERT MUSEUM

CHINESE POTTERY AND PORCELAIN

1. White porcelain stem cup decorated with five-clawed dragons incised into the paste and covered with underglaze red in a ground of blue waves. Ming dynasty, 15th century. 2. Figure of Buddha seated in a meditation pose. Tê-hua (Fukien province), 17th century. 3. Porcelain cup decorated with two five-clawed dragons disputing a pearl. Unglazed biscuit on a dark blue ground. All biscuit parts were gilt. Ming dynasty. Six-character mark of the emperor Chia Ching (1522–66). 4. White porcelain decorated in famille rose enamels, the design winding over the rim to ornament the underside of the dish. Ch'ing dynasty. Six-character mark of the emperor Yung Chêng (1723–35) in underglaze blue. 5. Eggshell porcelain dish decorated in *famille* rose enamels, the back covered with a ruby-pink glaze. 18th century. 6. Pilgrim flask decorated in enamels of the *famille* rose. Ch'ing dynasty. Six-character mark of the emperor Yung Chêng. 7. Ewer in the form of a girl performing a sleeve dance, decorated with enamels of the green and red family with details in dark underglaze blue and with traces of gilt design over the enamels. 16th century. 8. Ridge tile in the form of a dernon decorated with coloured glazes. Ming dynasty (1368–1644)

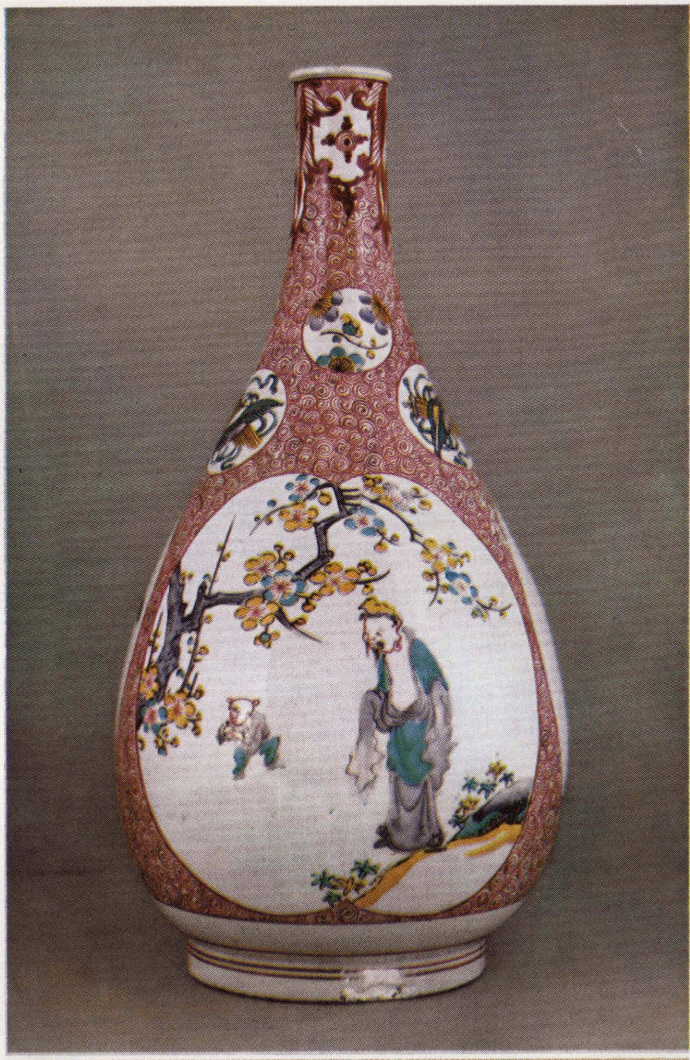


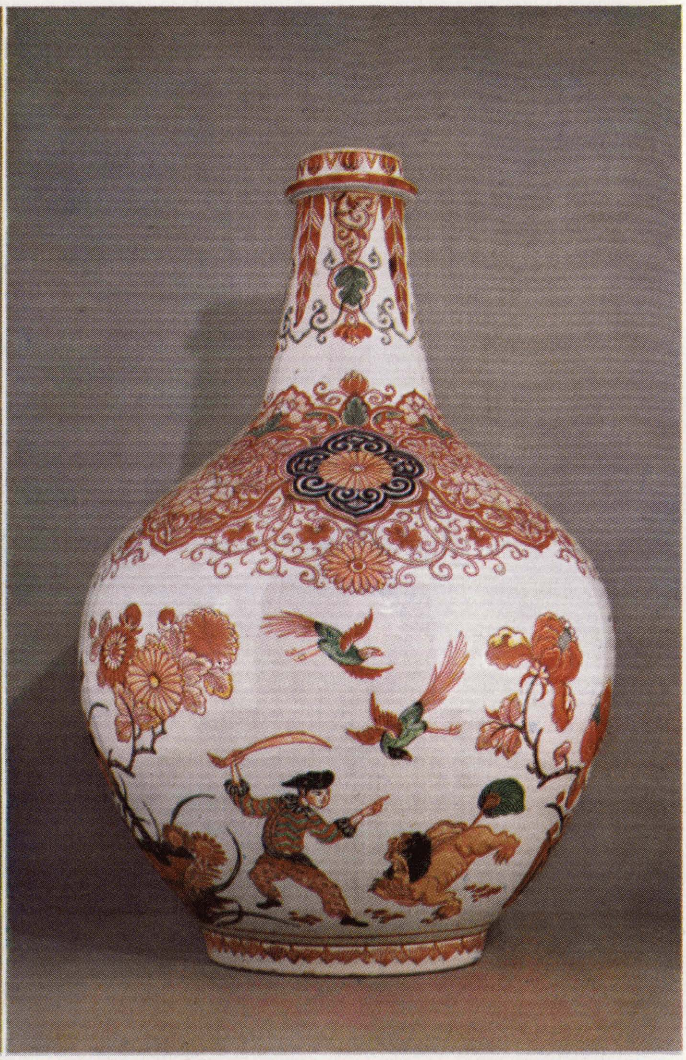


BY COURTESY OF (1, 3–6, 8) THE VICTORIA AND ALBERT MUSEUM, (2, 7) PERCIVAL DAVID FOUNDATION OF CHINESE ART

CHINESE AND JAPANESE PORCELAIN

1. Satirical group showing a European merchant and his family. Chinese. Tê-hua (Fukien province), late 18th century
2. *Famille* rose enamelled porcelain decorated with a European subject. Chinese Ku Yüeh ware. Reign of the emperor Ch'ien Lung (1736–95)
3. Tyrolese dancers, copied from a Meissen model (about 1745) by Johann Friedrich Eberlein. Chinese, about 1765
4. Plate painted with a scene from *Don* Quixote. So-called oriental "Lowestoft" ware, probably painted in Canton. Chinese, about 1750
5. Plate depicting the baptism of Christ by St. John. "Jesuit porcelain" painted in black monochrome. Chinese, about 1750
6. Dish painted in underglaze blue and enamel coiours. Japanese Nabeshima ware. Okawachi (Hizen province), about 1725
7. White porcelain of bronze form (*ku*) covered with a slightly crackled turquoise glaze. Chinese, early 18th century
8. Plate decorated in underglaze blue and enamel colours. Japanese. Arita (Hizen province), early 18th century





BY COURTESY OF GERALD REITLINGER

JAPANESE PORCELAIN

Top left: Pear-shaped bottle with **Chinese philosophers,** painted in three peach-shaped panels against a scroll ground. Kutanl. Second half of the **17th century**

Top right: Apothecary's jar (one of a **pair).** Porcelain made at **Arita,** Hizen province, and enamelled in **Hol-**land at Delft. About 1730

Left: Lobed dish with a bouauet of chrysanthemums **in** a paper holder. Kaklemon ware, Hizen province. About 1700

BY COURTESY OF (TOP) GERALD REITLINGER, (BOTTOM) VICTORIA AND ALBERT MUSEUM

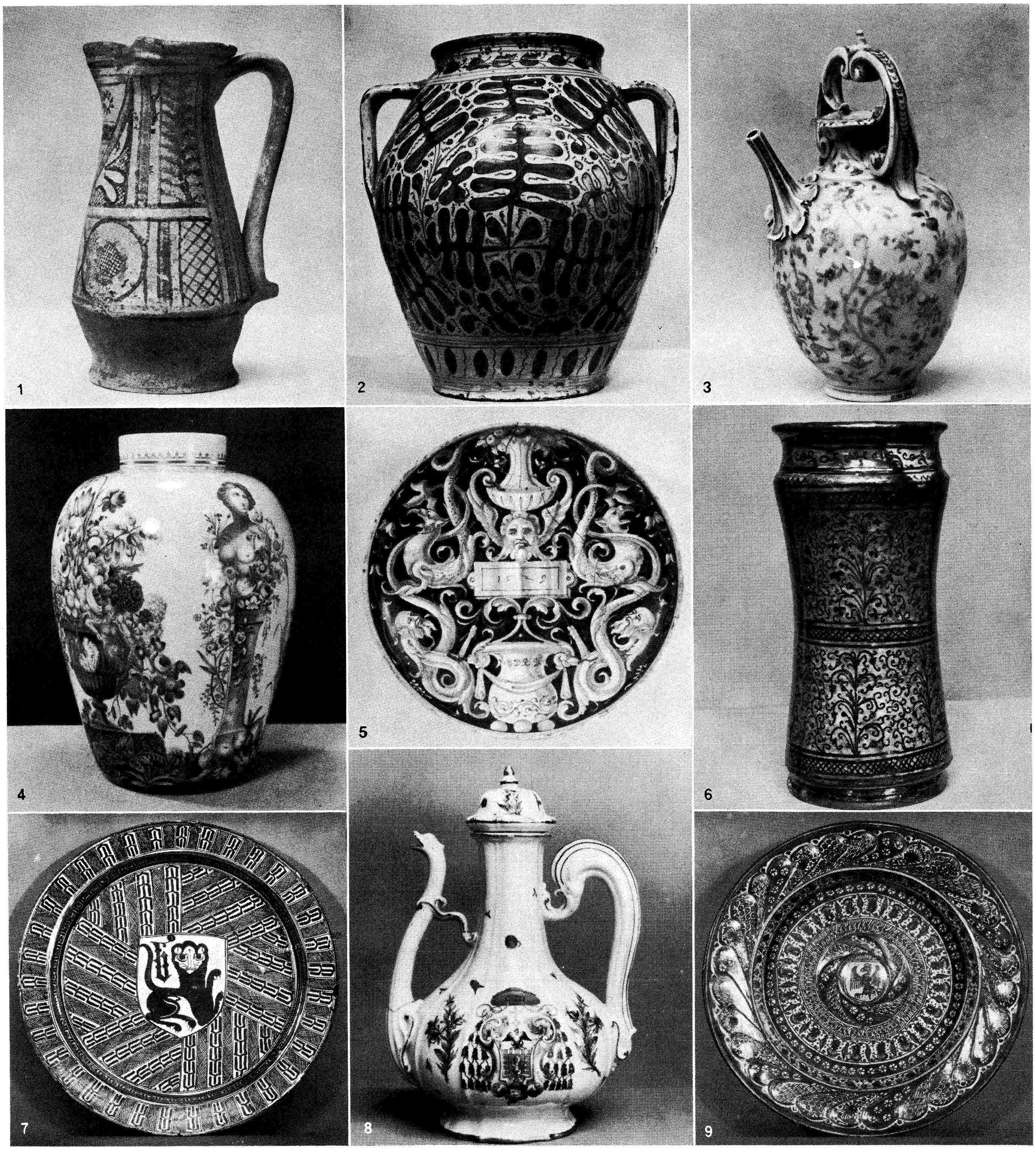
PERSIAN POTTERY

Top: Bowl painted in black and cobalt on a white slip (liquid clay). Kashan. About A.D. 1200
Bottom: Blue-glazed Saljuq bowl with carved floral decoration. About A.D. 1150

BY COURTESY OF THE VICTORIA AND ALBERT MUSEUM

NEAR EASTERN POTTERY

1. White earthenware bowl painted in gold lustre showing a Coptic priest; signed by the potter Sa'd. Egyptian.. Fatimid period, first half of the 12th century
2. Bowl in white earthenware painted in lustre with an animal figure. Mesopotamian, 10th century
3. Tankard with decoration cut through a black slip (liquid potter's clay) and covered with a turquoise glaze. Found at Sultanabad. Persian, 12th century
4. Jar of white earthenware painted in underglaze blue and black. Syrian, 14th century
5. Tankard in white earthenware painted with underglaze colours. Turkish (Anatolia). Isnik (Nicaea), second half of the 16th century
6. Jug of white earthenware painted with underglaze colours. Turkish (Anatolia). Isnik, second half of the 16th century
7. Dish of white earthenware painted in underglaze blue in imitation of Chinese porcelain of the Ming dynasty, the original belonging to the middle of the 15th century. Pseudo-Chinese mark. Persian, 17th century
8. Dish showing St. Michael saving a man's soul, inscribed in Armenian. Turkish (Anatolia). Kutahia, dated in 1719
9. Dish of white earthenware painted in blue and turquoise in imitation of Chinese porcelain of the Ming dynasty. The border is a debased version of a Ming "rock and wave" pattern. Turkish (Anatolia). Isnik, first half of the 16th century



BY COURTESY OF (1, 2, 5–7, 9) THE TRUSTEES OF THE BRITISH MUSEUM, (3) METROPOLITAN MUSEUM OF ART N.Y., (4, 8) VICTORIA AND ALBERT MUSEUM

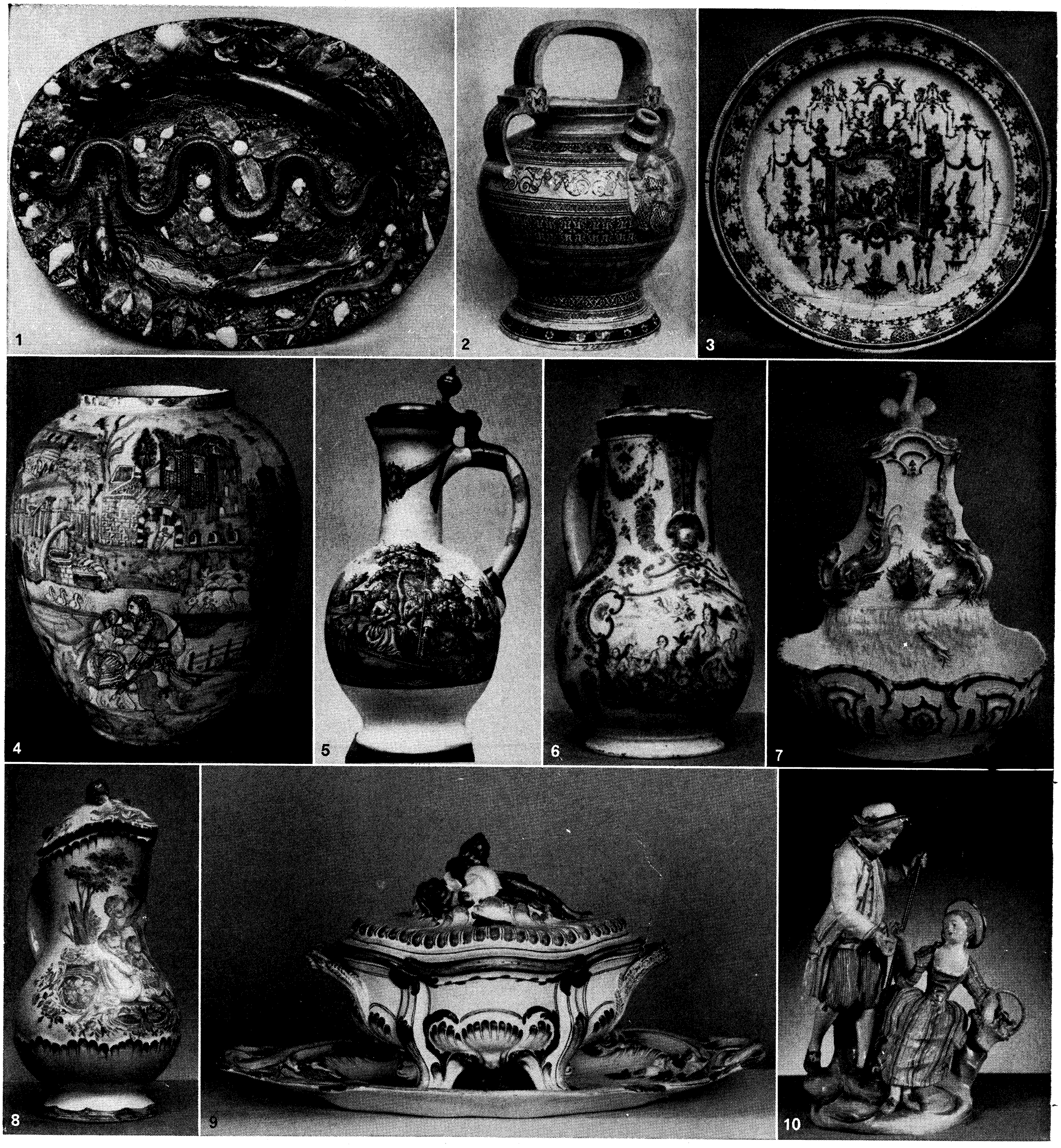
ITALIAN AND SPANISH POTTERY AND PORCELAIN

1. Jug painted in purple and green. Italian. Florence, 14th century
2. Oviform jar with oak-leaf decoration. Italian maioiica. Florence, about 1450
3. Ovoid porcelain ewer painted with vines and flower sprays and the figure of a man in classic dress (under the spout). Marked with the dome of the cathedral at Florence and the letter F. Italian, Medici porcelain. Florence, about 1580
4. Oviform porcelain vase painted in enamel colours. Italian. Capo-di-Monte (near Naples), about 1750
5. Maioiica dish decorated with groteschi. Italian. Castel Durante (Urbania), dated 1529
6. Drug jar (*albarello*) painted with lustre on a blue ground. Spanish, Hispano-Moresque ware. Valencia, about 1450
7. Earthenware dish painted with lustre pigment. Spanish, Hispano-Moresaue ware. Valencia, about 1460
8. Porcelain coffeepot with the arms of Cardinal Francesco Stopponi. Italian. The factory of the Marchese Carlo Ginori, Doccia (near Florence), about 1755
9. Dish painted with lustre pigment. Spanish, Hispano-Moresque ware. Valencia, about 1450

Left: Dish decorated with floral sprays on a coloured ground. Isnik (Nicaea), Anatolia. About A.D. 1580. Wares of this kind were formerly attributed erroneously to the island of Rhodes and called "Rhodian ware" because fragments were excavated at Lindos

TURKISH POTTERY

Right: Ewer mounted in silver gilt. Isnik. 1597–98



BY COURTESY OF (1–3, 5, 6, 8) THE TRUSTEES OF THE BRITISH MUSEUM. (4, 7, 9, 10) VICTORIA AND ALBERT MUSEUM

FRENCH AND GERMAN FAIENCE

1. Dish by Bernard Palissy decorated with reptiles, shells and insects in relief. French, about 1570
2. Ewer of the so-called Henri II ware with decoration impressed with bookbinders' stamps and filled with clay of a contrasting colour. French. St. Porchaire, about 1560
3. Plate painted with a scene showing the rape of Helen. French. Clérissy factory, Moustiers, about 1710
4. Vase painted with Old Testament scenes, probably by Jacques Conrade. French. Nevers, second half of the 17th century
5. Jug painted by F. L. Faber. German. Nurernberg, about 1683
6. Jug painted in colours. French. Moustiers, about 1750
7. Table fountain. French. Factory of Paul Hannong, Strasbourg, about 1760
8. Jug painted in crimson. French. Sceaux, about 1760
9. Tureen, cover and stand. French. Perhaps Lunéville, about 1755
10. Youth and girl. French. Niderviller, about 1775

POTTERY AND PORCELAIN

BY COURTESY OF (1, 6) MUSEUM OF FINE ARTS, BOSTON, (2) THE TRUSTEES OF THE CECIL HIGGINS MUSEUM, BEDFORD, (3) FORSYTH WICKES, (4, 7) VICTORIA AND ALBERT MUSEUM, (5, 8–10) THE TRUSTEES OF THE BRITISH MUSEUM

FRENCH PORCELAIN

1. Teapot with decoration in underglaze blue. St. Cloud, about 1720
2. Covered jug decorated with Japanese patterns in the Kakiemon style. Cnantilly, about 1725
3. Tureen, cover and stand. Green ground with gilding, the reserved panels painted with cupids, birds, trophies and flowers. Model by Duplessis. Originally from the Hermitage, St. Petersburg. Vincennes, about 1753
4. Tureen, cover, stand and ladle, painted in the Kakiemon style. Chantilly, about 1725
5. Group, "Les Trois Contents." Modeiied by E. M. Falconet. Sevres, about 1765
6. One of a pair of vases in the Louis Seize style. Sèvres, 1776
7. Group in biscuit porcelain allegorical of the birth of the dauphin. La Ccurtille factory. Paris, about 1780
8. Jardiniere painted by Dodin showing the children of the duc de Praslin. After a painting by J. G. Drouais. Sèvres, 1763
9. Bust of Louis XV after a portrait by J. B. Lemoyne. Pedestal painted in blue and green by Dodin. Sèvres, 1761
10. Tray with apple-green ground depicting Mercury, Venus and Cupid, painted by Dodin after "L'Education de l'amour" by Carl van Loo. Gilding by Noel. Sèvres, 1761

BY COURTESY OF (1) MR. AND MRS. JACK LINSKY, (2, 7, 9) CECIL HIGGINS MUSEUM, BEDFORD, (3, 4, 6, 8) MR. AND MRS. SIGMUND J. KATZ, (5) MUSEUM OF FINE ARTS, BOSTON

CHINESE INFLUENCES IN 18TH-CENTURY PORCELAIN FIGURES

1. Old man holding a nectarine. French. Mennecy, about **1750**
2. Vase with Chinese figures. English. Chelsea, about **1755**
3. Lu Tung-pin, one of a group of eight Taoist immortals. copied from the white porcelain of Tê-hua. English. Lund's factory, Bristol, **1750**
4. and 6. Busts of a Chinese man and woman. English. Bow, about 1750
5. Les Delices de *l'Enfance* from an engraving by J. J. Baléchou after Franpois Boucher. English. Chelsea, about **1752**
7. Two Chinese figures. English. Derby, **1750-55**
8. Group of a woman. boy and cat. English. Chelsea, about **1750**
9. Pair of flower holders. French. Chantilly, about **1750**

BY COURTESY OF (1, 3) IRWIN UNTERMEYER, (2) VICTORIA AND ALBERT MUSEUM, (4, 6, 8, 10) THE TRUSTEES OF THE CECIL HIGGINS MUSEUM, BEDFORD, (5, 7) STAATLICHE PORZELLANMANUFAKTUR NYMPHENBURG, (9) GEORGE SAVAGE

GERMAN AND RELATED PORCELAIN FIGURES

1. Harlequin in a Tyrolese hat dancing with Columbine, from the ***commedia dell' arte.*** Model by Johann Joachim Kaendler. Meissen, about 1745
2. Columbine, from the Italian comedy. Model by F. A. Bustelli. Nymphenburg, about 1760
3. Lady in a crinoline. Model by J. J. Kaendler. Meissen, about 1744
4. The elector Augustus as a Freemason. Model by J. J. Kaendler. Meissen, about 1740
5. Graf Sigismund von Haimhausen by F. A. Bustelli, one of the most distinguished portrait busts ever to be made in porcelain. Nymphenburg, about 1760
6. Diana and nymphs. Perhaps modelled by J. C. W. Beyer. Ludwigsburg, about 1770
7. Diana with a hunting dog. Model by Dominikus Auliczek. Nymphenburg, about 1770
8. One of a pair of groups showing children playing. French. Factory of Hannong, Strasbourg, about 1770
9. Figure of a lion from a model by Johann Gottlob Kirchner. Meissen, about 1735
10. "The Angry Shoemaker." Modeller unknown. Höchst, about 1765

ITALIAN MAIOLICA

Large dish decorated with hunting scenes, signed by the potter and the winter on the reverse, and dated 1594. Diameter 30 in. Attributed to Modena workshop

POTTERY AND PORCELAIN

BY COURTESY OF (1–3, 6) THE TRUSTEES OF THE CECIL HIGGINS MUSEUM. BEDFORD (4) THE METROPOLITAN MUSEUM OF PRT, N.Y., (5, 7, 8) VICTORIA AND ALBERT MUSEUM (9) THE TRUSTEES OF THE BRITISH MUSEUM

GERMAN AND OTHER CONTINENTAL PORCELAIN

1. Teapot of baroaue form with decoration enamelled in black (*Schwarzlot*). German. Meissen, about ***1725***

2. Teapot decorated with a Teniers subject, probably by Osterspei. German. Frankenthal. about ***1760***

3. Coffeepot painted in *Schwarzlot* and iron red by Bartholomaus Seuter at Augsburg, Ger. Meissen porcelain, about ***1735***

4. Tureen and stand with the knop in the form of an oriental figure. Austrian. Hausmalerei, Vienna, Du Paauier's factory, about ***1725***

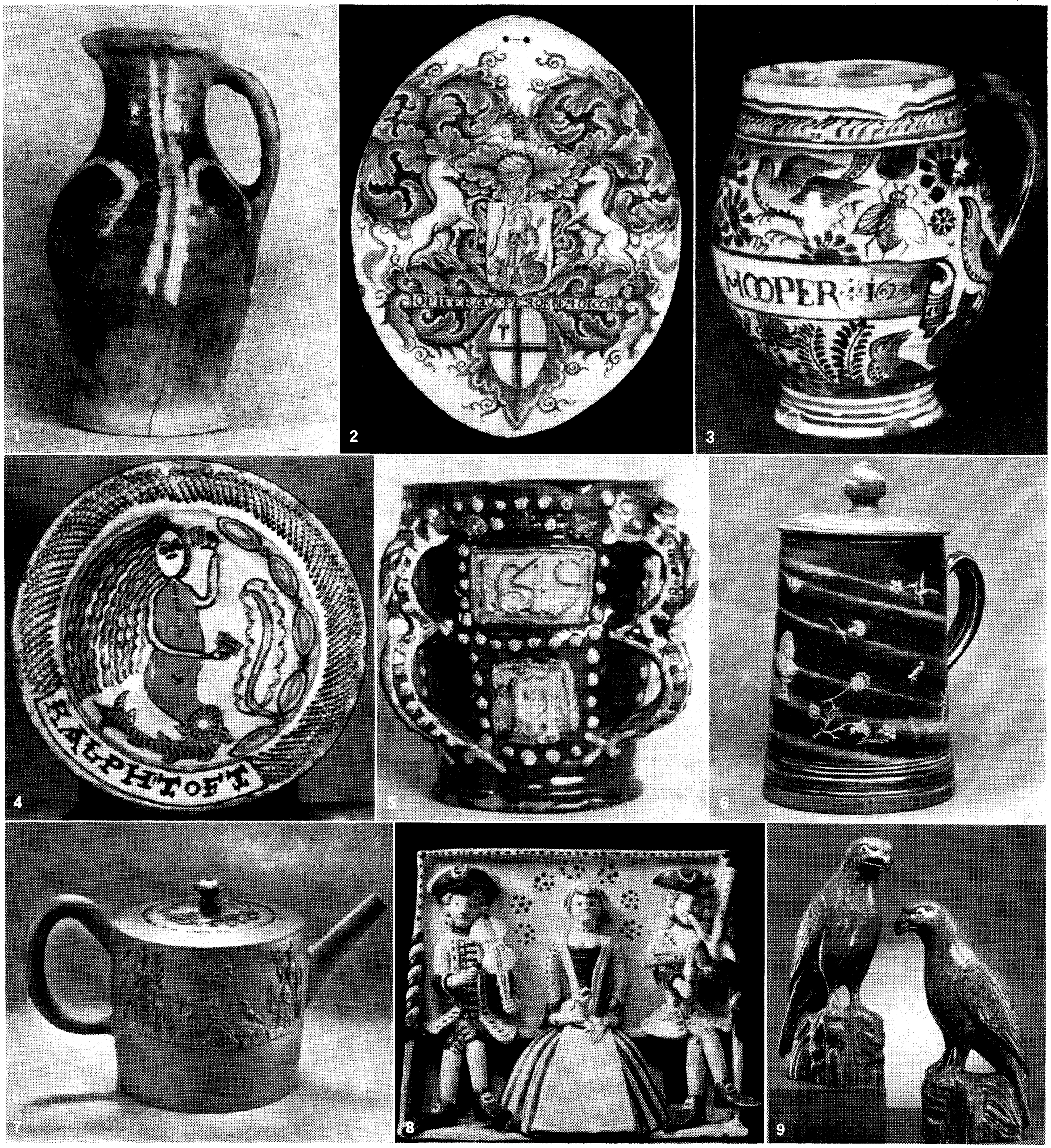
5. Group in biscuit porcelain showing children bird's-nesting, perhaps by Nicholas Lecreux. Belgian. Tournai, about ***1770***

6. Hungarian soldier with captured Turk. Swiss. Zurich, about ***1770***

7. Vase in the neoclassical style bearing a portrait of Frederick, prince of Denmark. Danish. Copenhagen, about ***1790***

8. Samoyede woman. Russian. St. Petersburg (Leningrad), about ***1800***

9. Oval plaque, "The Siege of Grave by Prince Maurice, ***1602";*** signed N. *Wicart fecit*. Dutch. Oude Loosdrecht, about ***1780***



BY COURTESY OF (1, 5) THE HASTINGS MUSEUM AND ART GALLERY, (2–4, 6–9) WILLIAM ROCKHILL NELSON GALLERY OF ART KANSAS CITY, MO (FROM THE BURNAP COLLECTION)

ENGLISH POTTERY

1. Painted mediaeval pitcher from a kiln belonging to the Hospital of St. Bartholomew, Rye, Sussex. About 1300
2. Pill slab of English delft ware made at Lambeth, London. About 1650
3. Mug inscribed "Mrs. Mary Hooper, 1629." English delft ware made at Lambeth, London
4. Dish decorated with trailed slip. Staffordshire, about 1670
5. Tyg (a vessel with several handles for communal drinking) decorated with slip. Wrotham, Kent, 1649
6. Covered tankard in brown salt-glazed stoneware by John Dwight of Fulham, London. About 1690
7. Teapot in red ware by the brothers Elers. Staffordshire, about 1710
8. Pew group in salt-glazed stoneware. Staffordshire, about 1730
9. Pair of hawks in "agate" ware made from differently coloured clays. Staffordshire, about 1750

FRENCH FAÏENCE

Bust of Apollo with pedestal. From the factory of Nicholas Fouauet, Rouen. About 1740

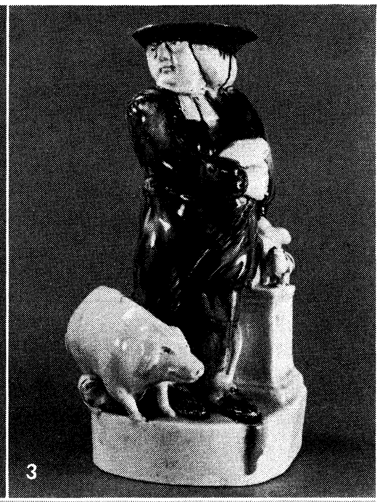
GERMAN STONEWARE AND PORCELAIN

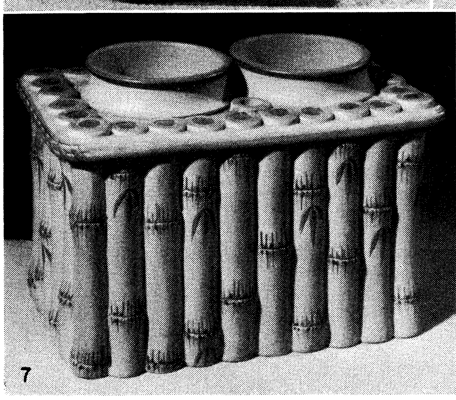
Top left: Gray stoneware tankard mounted in silver, painted with cobalt blue under a salt glaze. Westerwald. Early 17th century. English silver mounts dated 1652

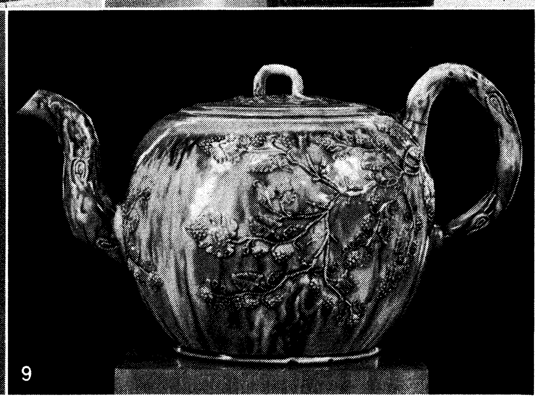
Top right: Head of Apollo in red stoneware (Böttger *Steinzeug*). Meissen. About 1712

Bottom left: Vase painted with enamel colours introduced by Johann Gregor Höroldt and marked with the monogram of Augustus the Strong, elector of Saxony and king of Poland (August der Starke). Meissen. About 1725

Bottom right: Large covered bowl painted with figures in a landscape in monochrome. Du Paquier's factory, Vienna. About 1725



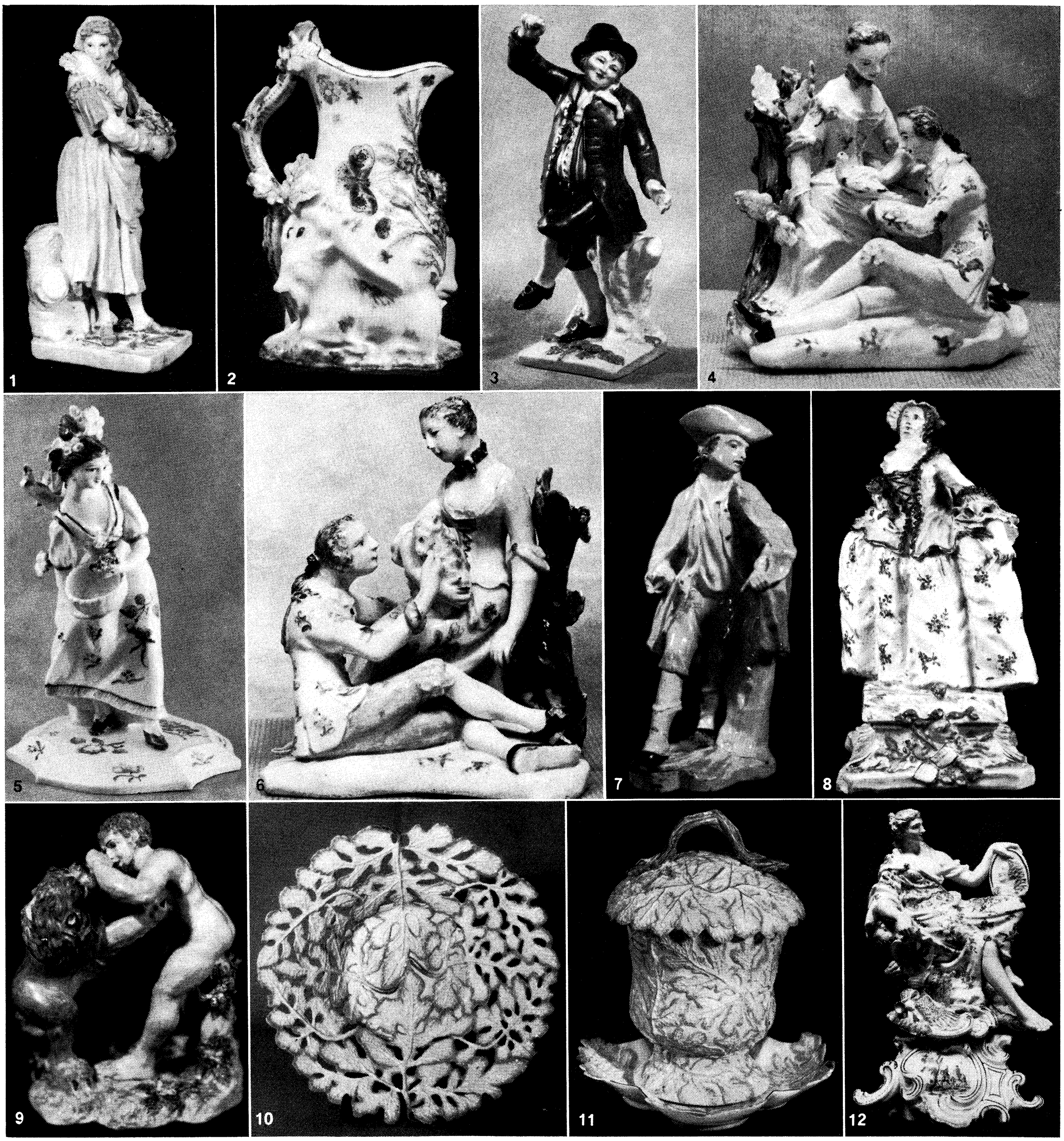




BY COURTESY OF (1–3, 9) WILLIAM ROCKHILL NELSON GALLERY OF ART, KANSAS CITY, MO. (FROM THE BURNAP COLLECTION), (4, 5) HASTINGS MUSEUM AND ART GALLERY, (6, 7) JOSIAH WEDGWOOD & SONS, LTD., (8) LADY WEDGWOOD

ENGLISH POTTERY

1. English cavalryman by John Astbury. Staffordshire, about 1730
2. Platter decorated in resist lustre of silver colour. Leeds pottery, about 1810
3. Toby jug. One of three known as the "Tithe Pig" group in which a farmer's wife is shown refusing to part with the tenth pig unless the parson takes the tenth child. By Ralph Wood of Burslem. Staffordshire, about 1770
4. Urn-shaped vase in neoclassical style. Chocolate-coloured jasper ware with relief decoration in white. Wedgwood, about 1790
5. Group titled "The Drunken Parson" by Enoch Wood of Burslem. Staffordshire, about 1800
6. Urn-shaped vase in black basalt ware. Wedgwood and Bentley, 1774
7. Bulb pot in cane ware imitating bamboo. Wedgwood, about 1788
8. Dish in cream ware made for the empress Catherine of Russia. Wedgwood, 1773
9. Punch pot by Thomas Whieldon decorated with a glaze of variegated colour termed "tortoiseshell." About 1750



BY COURTESY OF (1–4, 6–12) MR. AND MRS. SIGMUND J. KATZ, (5) MUSEUM OF FINE ARTS, BOSTON

ENGLISH PORCELAIN

1. Flower seller. Chelsea (London). Red anchor period, about 1753
2. Goat and bee jug, copied from an original model in silver. Chelsea. Period of the triangle mark, 1745–50
3. Dutch dancer. Chelsea. Red anchor period, about 1753
4. Girl and youth with a bird. London (probably Chelsea), about 1750
5. Girl with a basket, the base taken from a silver candlestick of the period. London (probably Chelsea), about 1750
6. Girl and youth with lamb. London (probably Chelsea), about 1750
7. Beggar. Derby (Derbyshire). First period, about 1750
8. The actress Kitty Clive, in a scene from Garrick's farce ***Lethe.*** Bow (London), about 1752
9. Hercules and the Nemean lion. The earlier of two versions from Longton hall (Staffordshire), 1750–55
10. Pierced dish decorated with oak leaves. Longton hall (Staffordshire), 1750–55
11. Covered jar and stand decorated with oak leaves. Longton hail (Staffordshire), 1750–55
12. Figure of Britannia. Longton hall (Staffordshire), 1750–55

POTTERY AND PORCELAIN




BY COURTESY OF (TOP LECT. TOP CENTRE) HASTINGS MUSEUM AND ART GALLERY, (OTHERS) THE TRUSTEES OF THE BRITISH MUSEUM

GERMAN PORCELAIN

Top left: **Theriakverkäufer** (an itinerant seller of medicines flavoured with sugar). Attributed to Simon Feilner. Hochst. About 1753
Top centre: Pedlar. Attributed to Feilner. Fürstenberg. About 1755
Top right: Pastoral group repeated with minor variations by other German factories of the period. Fulda. About 1765
Bottom: Shepherdess sleeping, a group by Johann Peter Melchior. Höchst. About 1770

GERMAN PORCELAIN

Tog: Figures from the *commedia dell'arte* (the Italian Comedy) by Franz Anton Bustelli; Nymphenburg. About 1760

Bottom: Cup and saucer of Meissen porcelain painted in Breslau by Ignaz Bottengruber. Signed and dated 1726

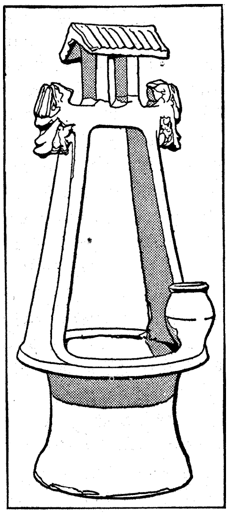
BY COURTESY OF (1 4 6–8) THE TRUSTEES OF THE BRITISH MUSEUM, (2) MR AND MRS. SIGMUND J KATZ, (3 5) VICTORIA AND ALBERT MUSEUM, (9) MUSEUM OF FINE ARTS BOSTON

ENGLISH PORCELAIN

1. Vase decorated with horses in a landscape by Jeffryes Hamet O'Neale. Worcester porcelain, about 1770
2. Bowl painted with a view of Chelsea church and water front. Chelsea. Gold anchor mark, about 1760
3. Mask jug painted with figures in a landscape and armorial bearings. Worcester, about 1765
4. Vase in the neoclassical style painted with scenes representing Damon and Musidora, probably by James Banford. Derby, about 1785
5. Teapot and cover painted in colours and gilded. Plymouth or Bristol, about 1770
6. Hexagonal vase decorated in panels, the figures by John Donaldson. Worcester, about 1770
7. Statuette of George III after a portrait by Johann Zoffany. Chelsea-Derby, about 1770
8. Shepherd and shepherdess in biscuit porcelain. Derby, about 1790
9. Figure emblematic of Water from a set of the Elements. Bristol, about 1775

the wet clay had been wrapped in matting or some coarse textile. This mat-marked pottery evidently had a long life, for it was still made in Chou and Han times.

The next important discovery belongs to the Yin dynasty (1765–1122 B.C.). On the site of the Yin tombs near An-yang in Honan were found pieces of a white pottery and of carved ivory and bone. The pottery, doubtless made of kaolinic earth, has been carved like the ivory and bone with the conventional designs and angular fret patterns which are usually associated with pre-Han bronzes. Complete vessels of this kind of carved white ware must have had a striking appearance, if indeed the fragments ever formed part of pottery vessels and were not, as has been suggested, moulds for the use of the bronze maker.



BY COURTESY OF GEORGE EUMORFOPOULOS, ESQ.

HAN WELL JAR

From the George Eumorfopoulos collection

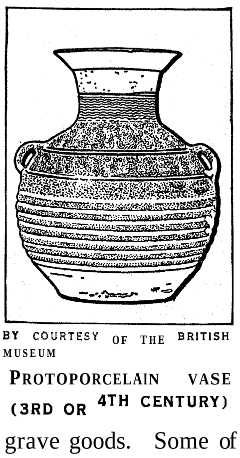
All the rest of the pre-Han pottery which is known is funeral ware of a rough and not very interesting type, generally following the forms of the more precious bronze vessels for which it was doubtless a substitute. It is frequently mat-marked, and much of it is roughly coloured with unfired pigments.

The Han Dynasty (206 B.C.–A.D. 220).—The Han pottery, though the knowledge of it is still confined to the funeral wares recovered from tombs, shows a considerable advance in ceramic technique. Many of the Han vessels, such as the wine vases, are of elegant form, and they are ornamented with artistic designs in a variety of ways, by painting with unfired pigments, by stamping, by the application of reliefs which have been separately formed in moulds, and by incising.

Glaze is now used, apparently for the first time, a transparent lead glaze of yellowish tone which is coloured green with copper oxide and variegated by the use of liquid clays or slips of different colours. The underlying body of the glazed ware is usually red and this showing through the transparent glaze gives a brown or reddish brown surface when the glaze has not been coloured green by the use of copper.

Probably this lead glaze was introduced from western Asia, where it was in use in late Roman times; for the Chinese were in touch with the Roman empire in the Han dynasty.

Many of the pottery objects recovered from Han tombs are of deep archaeological interest, for they include, besides the household and ritual vessels, models of the buildings, implements, livestock and even human beings which had belonged to the household of the deceased. Further, it is noteworthy that the potters who supplied this funeral furniture evinced much artistic skill in the way in which they conventionalized their models. Thus the granary tower and the wellhead are transformed into picturesque objects, and even the model of the kitchen stove is not devoid of ornamental qualities.



BY COURTESY OF THE BRITISH MUSEUM

PROTOPORCELAIN VASE (3RD OR 4TH CENTURY)

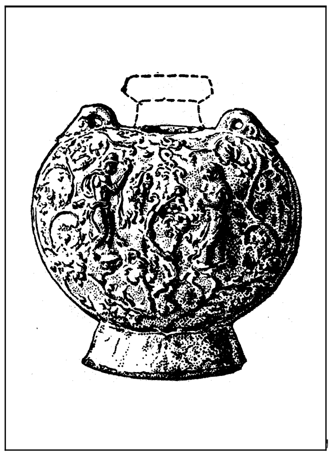
Han to T'ang (A.D. 220–618).—To the interval between Han and T'ang belongs a considerable group of figures and other beings. Animals are in many ways the most attractive of all the Chinese grave goods. Some of them are little later in date than the Han dynasty; but they evidently range over a long period, for whole sets of figurines of this class in the Toronto museum are known to have been found in tombs of the Liang dynasty (A.D. 502–557).

There are, besides, wine jars, vases, incense burners and toilet boxes of the 3rd and 4th centuries which are finely painted in unfired pigments with a style and execution not unworthy of the paintings on silk. The Han lead glaze continued in use, and it is by no means easy to differentiate the glazed pottery of the Han and of the immediately succeeding periods. There are, however, certain flask-shaped bottles with green and brown lead glaze over well-moulded reliefs which, though certainly post-Han, are probably earlier than the T'ang dynasty. Some of them are remarkable for their western types of ornament, such as dancing and piping figures, which would be at home in a Herculaneum frieze, surrounded by vine scrolls. Similar designs are seen on late Hellenistic pottery; and this doubtless was the source from which the Chinese potters drew their inspiration.

There is yet another kind of glazed ware which belongs to this interval, and which is apparently of purely Chinese origin. It is a kaolinic stoneware of hard gray body with a high-fired glaze of greenish brown tint. Specimens of this ware analyzed by H. W. Nichols of Chicago were pronounced to be a kind of proto-porcelain. In other words they are believed to contain the elements of porcelain, though in an unperfected state. M. Nakao held that the glaze of this ware is a wood-ash glaze evolved from the accidental gloss which often forms on pottery fired to a high temperature in a wood-fed furnace, as in the case of the early Korean pottery. It is practically certain that this kaolinic pottery with its glaze of feldspar and wood ashes forms a stage in the evolution of true porcelain which the Chinese had discovered by the T'ang dynasty. Indeed it is highly probable that porcelain was evolved from this material at some period in the interval between Han and T'ang. The colour of the glaze was probably caused by iron impurities in the clay, and this glaze is the oeginning of the celadon green glazes which owe their colour to iron.

The T'ang Dynasty (618–907).—In the great T'ang dynasty the Chinese empire reached its widest expansion, and China was without doubt the greatest and most civilized power in the world. It was an age of splendour for all the arts?and the potter's art was in no way behind the rest. Oddly enough, Chinese ceramic literature has little to tell of the T'ang potters. But Chinese ceramic literature is a comparatively modern growth and the secrets of T'ang pottery, laid bare only in modern times, were known in Europe almost as early as in China.

It was in fact largely as a result of the excavations made by European railway engineers that the contents of many T'ang tombs came to light, and what is known of T'ang pottery, as in the case of the earlier wares, is practically limited to the sepulchral wares. Saturally these do not show the T'ang potters in the most favourable light, but they characterize the great progress which had been made in ceramic technique and demonstrate the artistic capabilities of T'ang craftsmen. They make it clear, too, that western influences were active in China in this enlightened age, for traces of late Hellenistic, Sassanian and Persian art are frequently found in the forms and designs of the pottery of this period.



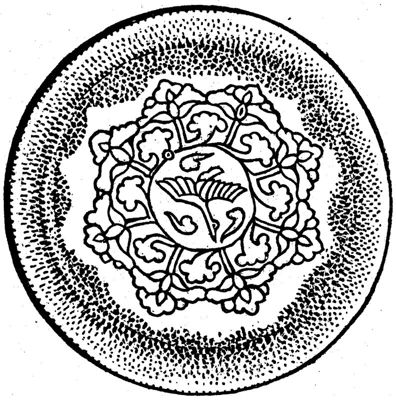
FROM THE GEORGE EUMORFOPOULOS COLLECTION

FLASK OF BUFF STONEWARE WITH BROWN GLAZE: T'ANG PERIOD OR EARLIER

On the T'ang funeral pottery the figures of human beings, birds and animals are modelled in a lively and spirited fashion, especially those of horses and camels: dancing girls and musicians. They are usually of a white or pinkish white clay, soft where lightly fired, but some occasionally are baked to considerable hardness. Some of them are unglazed and tricked out with red, black and blue pigments. Others are covered with a thin, transparent, lead glaze of faint yellowish tint, while on the more elaborate this glaze is coloured with washes, streaks or mottling of green, amber yellow or blue. The flesh parts of the glazed figures are commonly left without glaze, and in this case they are painted with the pigments mentioned above. Besides the figures, vases, ewers, bowls, cups and dishes of various kinds are found in the tombs; and among them are amphora-shaped jars of strikingly Hellenistic form and ewers of Sassanian type with a bird's head below the lip, a form common again in Persian pottery of a slightly later date.

The glazes used on the figures appear also on these vessels, sometimes in monochrome, more often in mottled colours, but they rarely cover the whole exterior of the vessel, stopping as a rule in a wavy line short of the base. The base of the T'ang vase is usually flat and shaved at the edge.

The decoration of T'ang pottery is chiefly effected by moulding in relief, by applying reliefs which have been stamped out separately, by carving the surface or by incising it with a pointed instrument.



FROM THE GEORGE EUMORFOPOULOS COLLECTION
DISH OF THE T'ANG DYNASTY

Painting with a brush was also used not only for the application of pigments on unglazed wares, but in rare instances for decorating in black under a green glaze.

The T'ang pottery so far discussed shows a considerable advance on its predecessors in the use of coloured lead glazes; but it is also apparent that great strides were now made with the harder, feldspathic glazes which were fired at a much higher temperature. The important excavations on the 9th century site of Samarra on the Tigris (see F. Sarre, Die Keramik *von Samarra,* 1925, and also below under Persian pottery) revealed quite a number of fragments of porcellanous stoneware and even true porcelain of Chinese make. From them we gather that these advanced ceramic products were not only made, but had actually become articles of overseas trade in the T'ang dynasty. They include a semi-porcelain with closely crackled. yellowish white glaze or with green and mottled glazes, or again with the sea-green glaze which we distinguish by the name of celadon; besides pure porcelain with white or ivory glaze. Other high-fired T'ang glazes are a chocolate brown, verging on black, a watery green and a brown splashed with frothy grey.

FROM THE GEORGE EUMORFOPOULOS COLLECTION
LEFT, PORCELAIN EWER WITH WHITE GLAZE, T'ANG PERIOD: RIGHT. WHITE PORCELAIN BOTTLE WITH UNGLAZED BASE, T'ANG PERIOD

But the progress of the T'ang potter is not to be measured by improved technique alone. The beauty of the vase-forms which he threw on the wheel places him in the front rank of potters, and his incised and moulded ornaments prove him to have been a true ceramic artist.

In the half century which intervened between the T'ang and Sung dynasties ceramic history records the manufacture of two interesting wares, both of which are still a puzzle to the student. One is the celebrated Ch'ai ware which was reputed to have been "thin as paper, resonant as a musical stone and blue as the sky seen between the clouds after rain." This was an imperial ware made for a few years only in the neighbourbood of K'ai-fêng Fu in Honan; and apparently no complete specimen of it remained above ground even in the 16th century. The traditional description of it suggests a kind of porcelain, and modern opinion holds that it probably belonged to the ying *ch'ing* class of ware which will be described presently. But this is only a theory and, it must be added, a theory which is by no means universally accepted.

The other is the *pi sê* (secret colour) ware made at Yiieh Chou, the modern Shao-hsing Fu in Chekiang, for the princely house of Chien. It is generally agreed that this was a porcelain or semi-porcelain with grey green glaze of the celadon type.

***The Sung Dynasty* (960–1279).**—The Sung dynasty was another Augustan age of Chinese art, and ceramic writers in after years described the Sung porcelains in reverential terms as the classic wares of China. Collectors treasured them with loving care, so that not a few have survived above the ground and we are not dependent entirely on excavated funeral goods for our estimate of the Sung potter's skill. Something too is recorded of the history of the more noted Sung factories, and slender as is the information given it has enabled the modern student to attempt a reasoned, though not yet assured, classification of the principal types, namely the Ju, Kuan, Ko, Ting, Lung-ch'iian, Chün, Chien and Tz'ŭ Chou, with a few subsidiary wares in addition.

The Imperial Ju ware was made at Ju Chou, near K'ai-fêng Fu in Honan, for a brief period at the beginning of the 12th century; but we gather that it belongs to a type of ware which was made at several potteries, *e.g.,* in the districts of T'ang Têng and Yao on the north of the Yellow river—besides at Ju Chou itself. The Ju Chou ware, however, excelled the rest and doubtless the imperial works were manned by picked Ju Chou potters. The Chinese descriptions of the Imperial Ju ware, which was already extremely scarce in the 16th century, leave us in some doubt as to its exact nature, but the most plausible theory is that it was of the ying ch'ing type. The term ying ch'ing, which means misty blue or green (the colour word ch'ing connoting both blue and green), is applied by the Chinese to-day to a soft-looking, bubbly porcelain glaze, white in colour but with a faint tinge of blue or greenish blue which sometimes develops a definite blue tint.

This tinge of colour has been traced to the presence of a minute quantity of iron in the ware. The *ying ch'ing* porcelain is a relatively low-fired ware and the body has a somewhat granular texture. It varies much in quality, from a coarse material with impure, pearly grey glaze to an exquisite eggshell porcelain thin and translucent and of a deliciously soft and melting quality. The best specimens are skilfully potted and of elegant shape, and the decoration, if any, is carved in low relief, incised with a fine point or pressed out in moulds. It is surmised that some of the finer ying *ch'ing* porcelain may have been made at the Imperial Ju Chou factory, while the rest comes from the numerous private factories working with more or less skill on the same lines. It must however be understood that the identification of this ware with the famous Ju porcelain is not yet proved.

Another type which is still problematical is the Kuan. The name itself leaves room for various interpretations, and the description of it in Chinese works, like most Chinese descriptions, is full of ambiguities. Kuan means imperial, and Kuan ware may be nothing more than imperial ware of whatever kind. But Chinese writers evidently intended the Kuan wares of the Sung dynasty to be distinctive types. They describe first of all a Kuan ware made in the neighbourhood of the capital, K'ai-fêng Fu, for a short time before 1127, when the Sung court was driven south of the Yangtze by the Kin Tartars. The identification of this northern Kuan is extremely uncertain, though there are reasons for thinking that it had the opalescent, blue-grey type of glaze which was developed to its full on the Chün Chou ware (see p. 364). The southern Kuan, made after 1127 in the precincts of the imperial palace at Hang-chou, whither the Sung court had been transferred, so closely resembled the Ko ware that many Chinese writers do not attempt to discriminate between the Ko and Kuan.

FROM THE GEORGE EUMORFOPOULOS COLLECTION

TZ'U CHOU VASE, YUAN DYNASTY
A band of lotus scroll with one of foliage below ornaments this buff grey vase which has a black finish

The Ko ware is described in some detail in Chinese books. It got its name from the elder of two potter brothers Chang who lived in the Lung-ch'üan district in Chekiang in the Southern Sung period, being in fact the ware of the "elder brother" (ko). It is evident, however, that the term Ko ware was not confined to any individual's work, but passed into general use as a generic term for a group of wares made over a long period at various places. Like the Hang Chou Kuan, the Sung Ko ware was made of a dark-coloured clay (we are told by one writer that this clay was actually brought from Hang Chou to the Lung-ch'üan district), and for this reason it has a dark brown edge on the unglazed foot-rim and a brown mouth-rim where the glaze is thin enough to allow the body material to show through it. The glaze itself was crackled, sometimes in a wide network of cracks, sometimes in a close pattern of small crackle which was likened to fish roe. The crackle was further emphasized by staining it with red or black. The colours of the Ko glaze are described as *fên* ch'ing, *hui sê,* mi sê, which may be rendered grey green, ash colour and millet colour or yellowish, and less intelligibly as tan *pai,* which was probably something of the ying *ch'ing* colour.

Well accredited specimens in Western collections have a blackish body material which gives the traditional "brown mouth and iron foot," a thick opaque glaze, lustrous and fat, with crackle stained red or black, and of bluish grey, greenish grey or buff grey colours, which tally well with the Chinese descriptions. We read of Ko ware made in the Yuan and even the early Ming periods; and in later times the term Ko glaze was current for all the grey and buff crackled glazes which figure so largely in the Chinese potter's output.

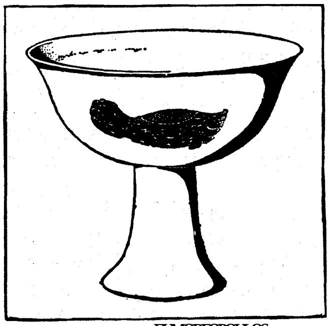
The crackle affected by the Chinese potter from the Sung dynasty onwards was deliberately sought by definite processes and was eventually got under perfect control, so that large or small crackle could be produced at will. It is unlikely that the earlier processes were very reliable, such as the plunging of the ware while still warm into cold water; but the Chinese eventually discovered that the mixing of a certain kind of stone (apparently pegmatite) with the glaze disturbed the relationship of body and glaze sufficiently to ensure crackle, and they learnt to prepare a crackle glaze which was applied in single, double or treble doses according to the size of the crackle desired

Lung-ch'üan Celadon.—The Lung-ch'üan district in Chekiang, the home of the original Ko ware, had long been noted for a beautiful ware which is familiar to us under the name of celadon.

It is a porcelain or semi-porcelain of greyish white body with a thick translucent glaze varying from greyish and bluish green to sea-green and grass-green

The most precious of the Lung-ch'üan celadons has a delicate bluish grey or greenish grey glaze over a finely potted porcelain body which is almost white. Such was the ware reputed to have been made by the younger Chang at the village of Liu-t'ien in the Southern Sung period; and collectors distinguish it by the Japanese name *kinuta,* after a famous vase in shape of a mallet (kinuta), which is preserved in a Japanese temple. Nothing could be more subtly beautiful than this soft, misty bluish grey porcelain.

It is not known how far back the industry of Lung-ch'üan dates; but the fragments of celadon found on the 9th century site of Samarra, in Mesopotamia, may well have been made there. On the other hand, we are told that the kilns were transferred to the neighbouring Ch'u-chou at the beginning of the Ming period and that they flourished there till the end of that dynasty. The output must have been large, and it formed from the earliest time an important item of Chinese export trade. Fragments of celadon are found in the ruins of ancient cities all over the Near East, and we know from actual records that celadon was imported into Egypt and carried thence along the Mediterranean coasts as far as Morocco. Fragments too have been found on the coastal sites of East Africa as far south as Zanzibar. India and the East Indies had their share of the trade, and a few pieces of celadon found their way even to western Europe in the middle ages. This justly celebrated ware, the export celadon, was a stoutly built greyish porcelain with a beautiful sea-green glaze of considerable thickness but transparent enough to allow the carved, moulded or incised designs to show through clearly.

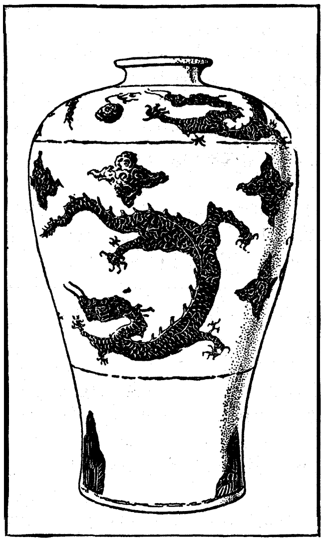


FROM THE GEORGE EUMORFOPOULOS COLLECTION

HSÜAN TÊ PORCELAIN STEM-CUP
One of the three crimson red fishes painted on the outside is shown

Besides the carved and incised designs which are of great beauty, reliefs moulded or applied were effectively used. Sometimes these reliefs—floral medallions, fishes and even figure subjects—were left uncovered by the glaze, and in this case they invariably took on a red or reddish brown colour as a result of exposure to the fire in the kiln.

This browning, caused by the presence of iron in the clay, is in all parts of the ware which were unprotected by the glaze, such as the base-rims and the large unglazed ring which is often seen on the bottoms of dishes. It was thought at one time that the presence of this ring was a sign of Ming origin, but it is very doubtful if this rule holds good; and the distinction between Ming, Yuan and Sung celadons, no easy matter, must depend on an appreciation of style and finish. Much help in this delicate task of connoisseurship can be obtained from a study of the other Sung wares, especially the Ting porcelain (see below) with its carved and engraved floral designs which closely resemble those used on the celadons. In the hands of the Sung artists these designs had a freshness and spontaneity which is dulled by repetition on the Ming wares. A special type of celadon is variegated by patches of reddish brown derived from iron. This is known as "spotted celadon," the tobi *seiji* of the Japanese.



BY COURTESY OF THE BRITISH MUSEUM

PORCELAIN VASE WITH DRAGONS

Other Celadons.—Though the industry in Chekiang is said to have died out in the 17th century, it was not to be expected that such a beautiful glaze as the sea-green celadon would be allowed to disappear. It was, in fact, made with slight variations in many other pottery centres. At Ching-tê Chên it was used over the white porcelain body for which that place is noted, and the Ching-tê Chên celadons have the ordinary white glaze, and sometimes a reign mark in blue, on their bases. A celadon glaze was used on the Kwangtung stoneware; and there are many specimens with glaze of celadon type but so different in body from the typical Chekiang ware that one must perforce look to some other centre for their origin. Consulting Chinese books provides little help in this quest. It is true that they speak of a certain T'ung ware, made near K'ai-fêng Fu in Honan, as if it were of the celadon class. But the identification of the T'ung is quite conjectural. In the absence of definite indications, the term "northern celadon" has been adopted for one large and important group. It comprises bowls, small dishes, vases, incense burners, etc., with a dry buff-gray stoneware body and an olive-green celadon glaze. The decoration is carved, incised or moulded, often with much skill and taste; and it closely resembles that of the ying ch'ing, or Ju type of porcelain, a fact which suggests a Honan origin for the ware.

This northern origin, however, is not accepted by all authorities. Nakao. for instance, held that it is only a variety of the Chekiang celadons, in spite of the very obvious difference between it and the usual Lung-ch'iian types, and he is probably right in supposing that the art of celadon manufacture was introduced into southern Korea from Chekiang, the most accessible Chinese ceramic centre. And it must be admitted that the resemblance between the so-called northern celadon and the Korean is remarkably close.

A stoneware of celadon type but with a pale and watery glaze was made at Sawankhalok in Siam as early as the 14th century; and in more recent times good celadon wares, scarcely distinguishable from the Lung-ch'uan, have been made in several parts of Japan. It may be added that the imported celadon wares were freely imitated in Persia and Egypt, but these imitations, made with the soft near eastern pottery, are easily recognizable for what they are.

Ting Ware.—Another of the classic Sung types is the ivory-white porcelain made at Ting Chou in southern Chihli. It is a singularly pure and beautiful ware with a flour-white body, slightly translucent, and a glaze of cream or ivory tint, which, however, tends to run in tears or drops on the outside of the bowls and dishes. A peculiarity of the ware, which it shares with the *ying* ch'ing, or Ju type, is that the mouth rims of bowls and dishes are often unglazed while the base is covered with glaze, thus reversing the usual conditions. The rough rims of such vessels are generally concealed by a band of silver or copper. The Ting ware was exquisitely decorated with carved or incised designs, largely floral, and in some cases, eipecially in the later periods, the more mechanical method of pressing out the designs in moulds was used with good efiect.

Besides the fine ivory-white Ting ware there are several varieties. One is known as t'u (earthy) Ting because it has a more opaque and earthy-looking body. This kind has a soft, cream-white glaze which is usually covered with faint crackle. Chinese writers also speak of Ting wares with black, red and brown or purple glazes.

The two first are probably glazes of the Honan temmoku type; but the purple Ting has so far eluded recognition. There is also mention of a painted Ting ware, which must have resembled the painted stoneware of Tz'ŭ Chou.

The beauty of the white Ting porcelain encouraged, while its simplicity abetted, numerous imitations, some of which are admitted by Chinese writers to be practically indistinguishable from the original. There was, for instance, the southern Ting, made by Ting Chou potters who moved south with the Sung court in 1127 and who seem to have settled in the neighbourhood of Ching-tê Chên. Then there were the famous imitations made by P'êng Chun-pao at Ho Chou in Shansi; and the Ssŭ Chou and Su Chou nares of Anhwei which were bought for Ting ware in the Sung dynasty "by persons who liked a bargain." There are the white wares of Hsuan Chou, and those made at the "white earth village" near Hsiao Hsien in northern Kiangsu. There were the cream-white wares made at Tz'ŭ Chou which were regarded as equal to Ting, and another of a singularly pleasing stoneware with gray or light buff body covered with a wash of white slip and a beautiful waxen white glaze closely crackled and recalling the finer t'u Ting wares. Much of this ware has been excavated on the site of the submerged town of Kiiluhsien (destroyed by flood in 1108), and many of the specimens have been made additionally attractive by pinkish gray stains acquired during burial.

The Ting Chou factories themselves, though their fame died down after the Sung period, continued in operation, and Ting ware is mentioned in court records as late as the middle of the 16th century. About this time too a celebrated potter at Ching-tê Chên, Chou Tan-ch'iian, made himself a name by his wonderful imitations of Sung Ting vessels, and apparently he had many followers who kept up the traditions of his work at Ching-tê Chên long after his death.

Chün Ware.—Yet another celebrated ware was the Chun, which was made at Chün Chou in the K'ai-fêng Fu district of Honan. It was in fact, like the white Ting and the green celadon, one of the key wares of the Sung dynasty. According to Nakao it is the type of ware which would naturally result from the firing of a kaolinic body and feldspathic glaze coloured by copper in the oxidizing flame of the typical round kiln of northern China.

The finer Chün wares have a gray porcellanous body and a thick opalescent glaze full of bubbles and minute pinholes (caused by the bursting of bubbles), and displaying a wonderful variety of colours which are the result in part of the protean changes of copper oxide in an oxidizing flame, in part of a trace of iron which is present in the body material, and in part of the play of light in a highly opalescent glaze. Copper under the conditions prevailing in the Chün Chou kilns was capable of producing a range of colour from blue to blood red, and the Chün glazes display endless combinations of these colours suffusing a basically gray glaze. Thus there are in the extremes an even lavender gray and an almost uniform purplish red, and between these a variety of splashed, streaked and mottled effects of blue, gray, purple and crushed strawberry red. Again the interior of shallow dishes is often frosted over with an opaque, greenish gray; and the Chün glaze is apt to break into irregular V-shaped lines known as earth-worm marks, which the Chinese connoisseurs regard as a sign of genuine Sung make. The Chün ware is strong and heavy, and the finer specimens consist mainly of flowerpots and shallow bowls which could serve as stands for the flowerpots or alternatively as bulb bowls. This class of Chun ware has a wash of brown glaze on the base and a ring of "spur" marks formed by the pointed stilts on which the vessel rested in the kiln. It is moreover usually incised with a series number which ranges from one to ten and apparently in'dicates the size, No. 1 being the largest. An "outsize" is indicated by addition of the character ta which means large.

It is known that the Chün factories continued active through the Sung and Yüan dynasties and as late as the 16th century. In fact it is not established when their activity ended. Consequently there is much difficulty in distinguishing the, Sung and later Chün wares; and the tendency is to call the finer specimens Sung and the coarser Yuan, too little regard being paid to the fact that much of the ware must be as late as Ming. All that can be said for certain is that the heyday of the Chün factories was in the Sung and that their reputation faded after the Yuan dynasty.

There is a peculiarly beautiful group of wares which belong to the Chün class, and, if fineness is a criterion, also to the Sung period. They have the gray porcellanous body of the numbered Chün wares, and an opalescent glaze which is, however, thinner and smoother than the usual Chun glaze. Its colour is lavender gray, but it is richly suffused, or splashed, with a lovely plum purple and this purple sometimes dominates the whole surface. The glaze flows more or less evenly down to the edge of the base rims, and it usually reappears on a small patch on the base. Sometimes the purple splashes on this ware are symmetrically disposed and even deliberately designed to suggest the forms of fishes, birds, animals or fruits, showing clearly that these patches, though doubtless at first accidental, were later brought under control. To what factory does this group belong? Is it merely a variety of the Chun Chou ware or is it something else? One of the descriptions given of the Northern Kuan ware suggests that it may belong to that obscure category; and some collectors distinguish it as Chün ware of Kuan type.

It is evident that many kilns were at work on the Chun type of ware, and probably in other districts besides Chun Chou, but we have little or no information on this point. We do, however, know that the Chun wares had many imitators. Good copies were made at Ching-tê Chên, probably as early as the Ming dynasty, certainly in the Yung Chêng period of the Ch'ing dynasty (1723–35); but there is little difficulty in distinguishing these later copies which have a white porcelain body and sometimes even a reign-mark. Other imitations made elsewhere can also be detected by variations of the body material and peculiarities of the glaze. Such are the Fatshan Chün ware made at the famous stoneware factories at Shekwan near Fatshan, in Kwangtung (*q.v.*), in Ming and later times; and the Yi-hsing Chüns which were made at Yi-hsing near the Great Lake in Kiangsu, the home of the red stoneware tea-pots. The Yi-hsing imitations have a buff or red stoneware body and a thick opalescent glaze of lavender turquoise colour with or without obviously artificial splashes of purple and crimson. While easily distinguished from the real Chün wares, they are often mistaken for another type which remains to be considered. This is the "soft Chün" (also called *ma chün* by Chinese traders), an attractive ware with light buff body and a beautiful, opaque turquoise or lavender blue glaze closely crackled and suffused here and there with purple or crimson splashes. Where it was made and when are by no means certain; but the shapes of the ware suggest in some cases the Sung and in others the Ming period, and the glaze is of the northern type. A degenerate descendant of this soft Chun is still made at Yü Chou which is the modern name of Chun Chou, and probably this was the original home of the ware.

Chien Wares.—Another large and widely distributed group of stoneware is commonly called, for want of a better general term, by the Japanese name *temmoku*. This name was first given to the black tea bowls for which Chien-an and afterwards Chien-yang, in Fukien, were noted in the Sung dynasty and even earlier. They are made of a blackish stoneware with a thick treacly glaze of purplish black shot with brown lines like hare's fur or mottled with brown like the breast feathers of a partridge. Their glaze stops in a thick irregular welt short of the base outside and forms in a deep pool on the bottom inside. The "hare's-fur or partridge" cups were commonly preferred for use in the tea-testing competitions, as their thick structure made the cup cool to handle and their dark glaze showed up the least trace of the green tea dust. In Japan they have always been fashionable in the tea ceremonies. The Chien glaze owes its colour to iron, which under varying conditions produces a reddish brown as well as a black colour. Indeed the brown and black seem to be always struggling for the mastery in the Chien glaze. Sometimes the brown completely dominates the black: sometimes it only emerges in streaks and spots, and sometimes again these spots are crystalline and have a silvery sheen.

The black ferruginous glaze is by no means confined to the Fukien factories. It was, and still is, made in many parts of China, chiefly in the north; and one of the northern wares which has this black and brown glaze over a whitish stoneware body is known to collectors as Honan *temmoku*. The northern black glazes are often of a peculiarly rich and luscious quality, and sometimes they are boldly flecked with lustrous brown and even painted with sketchy designs of flowers and birds in the same brown. On rare specimens the glaze is strewn more or less regularly with silvery crystais, the "oil spots" so greatly prized by the Japanese; while on others it comes out a uniform reddish brown, the *kaki temmoku* of the Japanese. Another ware which is commonly grouped with the *temmoku* is that believed to have been found on the site of the old Sung potteries at Yung-ho Chên near Ch'i-an Fu, in Kiangsi. In this case the body is a buff stoneware and the glaze is a rather thin blackish brown which flows evenly to the base and is often mottled with golden brown in tortoise-shell fashion or streaked and dappled with frothy grey. A further feature is painted ornament—prunus blossoms and sprays, birds, butterflies, inscribed medallions and symmetrical designs—in dull golden brown in the black or dappled glaze.

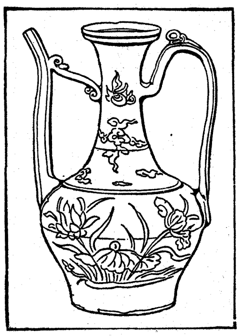
Tz'u Chou.—The last important group of Sung wares takes its name from the great pottery centre Tz'ŭ Chou, once in Honan and now in the south-west corner of Chihli. The Tz'ii Chou ware is a grey or buff-grey stoneware, which is usually coated with white slip and covered with creamy glaze. The plain cream white Tz'ii Chou stoneware has been mentioned among the Ting types, but the ware is more usually decorated with painted or incised designs.

The painted designs, floral or otherwise, are laid on with a bold brush in black or brown slip, sometimes supplemented by an ochreous red under the cream glaze. Painting in enamels—green, yellow and red—over the glaze was also used, occasionally in the Sung period and frequently in later times. The incised, or *graffiato*, Tz'ii Chou ware has many varieties. Simple incised designs are comparatively scarce, the more usual practice being to coat the vessel with white or brown slip which was then scraped away so as to leave the design slightly relieved in white or brown against a buff-grey body. A coating of transparent cream glaze over this produced cream white design on a mouse grey ground, if the slip was uhite. Where brown was used the slip usually contained the glazing material and the design appeared in brown or black glaze against an unglazed ground. Both of these *grafiato* types have great decorative value. The black and brown painted Tz'ŭ Chou is the commonest type and its merits vary with the quality of the drawing.

The Tz'ŭ Chou potteries have a history which can be traced from the 6th century to the present day. and there will always be room for debate as to the age of particular specimens. Further, most of the Tz'ŭ Chou types were made at other potteries scattered over northern China, and doubtless much that we call Tz'ŭ Chou really belongs to other potteries which worked on similar lines. This will explain variations in the body material of wares of the Tz'ŭ Chou type, and why a red body, quite unlike the original buff grey, is found on some of the most beautiful members of the group, such as the vases with black painted and *graffiato* designs under transparent green glaze or with black painted designs under a lovely peacock blue.

The potters who made these choice objects must have been among the foremost of their craft, but, though they used the Tz'ii Chou methods, their wares differ fundamentally from what we know as Tz'ŭ Chou.

Chinese ceramic records name several other Sung potteries in various parts of China, but they are hardly more than names to us and we know little or nothing of their productions. Practically all the Sung wares which we know, however, are comprised in the types already described. The forms, except where they were moulded after those of old bronzes, are simple and elegant, such as come naturally from the hands of a gifted "thrower" on the potter's wheel. The character of the classic Sung wares may be summed up in two words, simplicity and refinement.



FROM THE GEORGE EUMORFOPOULOS COLLECTION
MING EWER (1368-1644); INCISED DECORATION AND TURQUOISE GLAZE

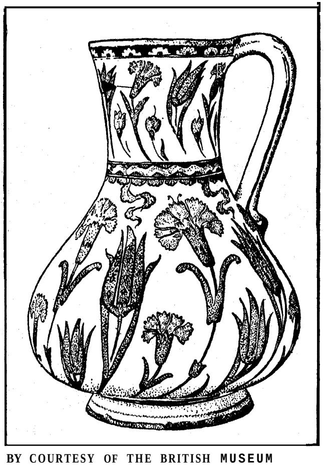
For the purpose of this brief sketch the Yuan dynasty (1279–1368) may be regarded as a continuation of the Sung. The Mongol conquerors had nothing to bring into the stock in trade of the Chinese potter except a taste for certain Western forms and designs acquired in the other extreme of their transcontinental empire. Further we are told that they were hard task-masters and that the ceramic industry, in common with many others, especially the more artistic crafts, lost ground under their unsympathetic rule.

The Ming Dynasty (1368–1644).—In 1368 tbe Yuan was replaced by the native dynasty of the Ming, which ruled China till 1644; and, when the country had recovered from the interdynastic struggles, the ceramic art took a new lease of life, though under somewhat changed conditions. The Sung monochrome wares, the celadons, Chun wares, etc., went out of favour and the old factories sank into obscurity, while the fame and importance of the great porcelain town of Ching-tê Chbn, near the Po-yang lake in Kiangsi, overshadowed all the rest. The first Ming emperors had their capital in Nanking and the proximity of Ching-tê Chên to the seat of government doubtless helped its development. At any rate from this time onwards the fine white porcelain of Ching-tê Chên was in general demand and the imperial factory there was rebuilt and reorganized to keep the court supplied with it; and Chinese ceramic writers thenceforward speak of Ching-tê Chên and little else.

The neighbourhood of Ching-tb Chên had long been noted for its excellent ceramic wares. It was ordered to supply goods to the court as early as the 6th century, and it received its present name in the Ching Tê period of the Sung dynasty (1004–07). All that the industry required in the way of material was lavishly supplied by the neighbouring hills, kaolin (china clay) for the body of the porcelain and *petuntse* (china stone) to mix with it and to form the glaze, wood ashes to soften the glaze, and cobaltiferous ore of manganese to make the blue for the underglaze painting and the blue glazes. The staple product of Ching-tê Chên is the fine white porcelain which has made China a household word throughout the world; and as this ware lent itself peculiarly well to painted decoration, the vogue for painted porcelain rapidly replaced the old Sung taste for monochromes. They fall into three chief groups, namely blue and white, enamelled wares and three-colour glazed wares, all of which are essentially pictorial in their decoration.

Blue **and** White.—The beautiful cobalt blue is one of the few ceramic colours which will stand the high temperature required to melt the porcelain glaze, and which consequently can be used under the glaze. Thus the blue colour, painted on the body of the ware and covered with a transparent sheet of glaze, gives a perfectly protected picture which will last as long as the porcelain itself. The idea of painting porcelain in this fashion was not new in the Ming dynasty. It was known to the Sung potters, but it was only in the Ming dynasty that blue and white became fashionable. Kor is the idea necessarily of Chinese origin, for blue painting was certainly known to the Near-Eastern potters as early as the 9th century, and we have as yet no indication of its use in China at so early a date. In the Ming dynasty, however, the Ching-tê Chên potters made it specially their own, and their blue and white was not only supplied in large quantities to the imperial court but was exported all over the eastern hemisphere.

During certain reigns—Hsiian Tê (1426–35), Chbng Tê (1506–21) and Chia Ching (1522–66)—the native supplies of cobalt blue were supplemented by a superior blue imported from the Near East and known as Mohammedan blue. This imported material was scarce and costly and was at first reserved for the imperial factory, and even so it was usually diluted with the common native cobalt. Later on supplies of it found their way into the hands of the private manufacturers. According to Chinese accounts it varied much in tone, but the kind best known to us is the Mohammedan blue of the Chia Ching period which is a dark violet blue of great strength ard intensity. In general the Ming blue is painted in one of two ways, either in finely pencilled line drawing or in strongly outlined designs filled in with flat washes. The better class of Ming porcelain, made 'for imperial and native use, was potted thin and finely shaped; and this is now rare and only to be acquired from Chinese collections. But there is a commonzr class which was more strongly and roughly fashioned to meet the exigencies of the export trade, and this has been found in considerable quantities in India, the East Indies, Persia, Egypt and even in Europe. But all the Ming blue and white, whether made for home or foreign consumption, is distinguished by a freshness and freedom of design which make the commonest specimen a desirable possession.



BY COURTESY OF THE BRITISH MUSEUM
TURKISH POTTERY JUG

Another colour used, like the cobalt blue, under the glaze, is a red derived from copper. It was a difficult colour to control but it was used with success in several Ming reigns, notably the Hsüan Te (see page 363) and Ch'êng Hua, both as monochrome and in designs painted in the same way as the blue and white.

Ming Enamelled Wares.—Pictorial designs having become fashionable, means were found to paint them on the glaze as well as under it. The chief advantage in on-glaze painting lies in the wider range of colours available. The over-glaze colours, commonly distinguished as enamels, are made of coloured glass ground to powder and liquefied so as to be usable on a brush. They are "fixed" in a small stove, or muffle, at a low temperature which is sufficient to melt the enamel powder and make it adhere to the glaze without actually melting the latter.

The colours used are leaf green and turquoise green derived from copper, a brownish yellow derived from iron, and aubergine purple derived from manganese, besides which a dry black pigment was obtained from manganese and a thin tomato red (halfway between a pigment and an enamel) from iron. The Ming red is apt to become iridescent and lustrous; both it and the black are used for painting outlines, and the latter was sometimes washed on and covered with transparent green to form a composite black. Gilding was also used. With this palette the Ming potters produced richly coloured porcelain, decorated with pictorial designs and formal brocade patterns. In some cases the enamels were combined with underglaze blue and this colour scheme, though known in the I jth century, was so popular in the Wan Li period (1573–1619) that it has come to be known as the wan *li wu ts'ai* or Wan Li polychrome. Another type, known as the "red and green family," is characterized by the absence of blue and the predominance of red and green, and again there are effective combinations of two colours such as red and yellow, blue and yellow, blue and green, red and green, red and gold and more rarely green and gold.

Besides being painted on the glaze the enamel colours were sometimes painted on the biscuit, *i.e.,* the fired but unglazed porcelain body; but this technique was commoner in the succeeding dynasty and will be discussed later.

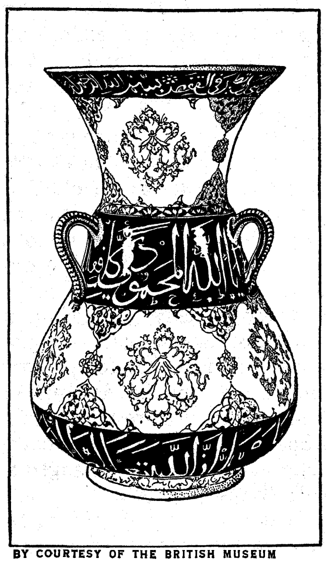
"Three-colour" Ming Wares.—There are few kinds of ceramic ware, Chinese or otherwise, that make such a brave show as the Ming three-colour (*san ts'ai*) porcelain. Though nominally combinations of three, the glazes which make up the colour scheme of this group are dark violet blue, turquoise, aubergine purple, yellow and a neutral white; and they are used in washes over designs set in single-colour ground which is usually dark blue or turquoise. To prevent the colours from overrunning each other the designs are outlined by incised lines or by threads of clay, or they are carved in open work. The glazes themselves, though harder than the enamels discussed in the last section, do not require the full heat of the porcelain kiln to melt them, and consequently the ware has to be "biscuited" (subjected to a preliminary firing) and then, when the glazes have been applied, fired again in the cooler parts of the kiln.

They are, in fact, what the French call them, glazes *du demi-grand feu.*

The decoration of the three-colour ware is bold; it includes large floral subjects, lotus and cranes, peonies and peacocks, and a few set figure subjects such as the Eight Immortals paying court to the God of Longevity, Wang Chih watching the game of chess, etc. The details are often built up in slight relief, certain parts such as faces and hands of human figures being left unglazed. The glazes are thick and inclined to be opaque. Much of the three-colour ware dates from the 15th century. In the 16th century the glazes tend to become sleeker, smoother and more transparent, and incised decoration is used.

The three-colour decoration was not confined to porcelain. Excellent specimens of it are seen on both stoneware and earthenware bodies. Indeed some of the most beautiful three-colour vases have a buff stoneware body and bold floral designs in minutely crackled glazes which include a peacock blue of peculiarly attractive tone. Where this group of fine pottery was made is not known; but it is found in widely separated parts of China and may have been made in several factories.

Other **Ming** Wares.—Though monochrome porcelains no longer held the premier position, they were still made in considerable quantity and some of them received special notice from Chinese writers. The sacrificial red (chi hung) of the Hsiian Te and Ch'êng Hua periods, a brilliant underglaze red derived from copper, was most noted; and next came the chi *ch'ing,* an intense blue glaze of the Hsiian Te period; and a lovely blue glaze of slightly mottled texture is found on some of the Chia Ching porcelains. There were, besides, celadon green, lustrous black and brown glazes; and all the demi-grand feu glazes of the three-colour porcelains were used individually as monochromes, the turquoise blue being especially effective.



BY COURTESY OF THE BRITISH MUSEUM

LAMP FROM THE MOSQUE OF OMAR

Beautiful, too, are the pure **white porcelains (white was the colour required in certain forms** of ritual and also by the court during periods of mourning) ; and special mention is made of the exquisite white "egg-shell" bowls of the reign of Yung Lo (1403–24) and of the white altar cups of the Hsiian Te and Chia Ching periods. If any decoration was added to these white wares it was faintly carved, incised or traced in white slip under the glaze, a subtle form of ornament known as an hua or secret decoration. Another and more conspicuous form of slip decoration is traced in white on blue or green glazes in a manner resembling the modem *pâte sur pâte.* Reliefs in white biscuit and remarkably fine open work distinguish some of the later Ming porcelains, the open work being of such superhuman delicacy that it was called *kuei kung* or devil's work. A quantity of stoneware and earthenware was made all over China in the Ming period. The best known are the tile work and architectural pottery which are often finely modelled: they are usually glazed with green, yellow, aubergine purple, turquoise or blue. On parts of the famous Nanking pagoda, built in the beginning of the 15th century, white porcelain was also employed for the same purpose. Many vases and vessels of everyday use were also made as by-products of the tile works which existed in all large centres of population to supply local needs; but it is hard to distinguish the common pottery of the Ming from that of the earlier and later periods, except where there is a close analogy with some known type of Ming porcelain to help us.

In the early years of the 16th century direct contact was established between Europe and China; and Chinese porcelain, together with silk and tea, soon became an important item of European trade. From this time onwards we note the influence of European taste affecting the Chinese porcelain to a steadily increasing extent.

The **Ch'ing** Dynasty **(1644–1911).**—The Ch'ing dynasty of the Manchus replaced the Ming in 1644; but it was not till about 1680 that its rule was firmly established over a pacified country. A succession of three able and enlightened emperors—R'ang Hsi (1662–1722), Yung Chêng (1723–35) and Ch'ien Lung (1736–95)—gave China a long period of good rule and the ideal conditions for the development of the arts, which indeed enjoyed at this time an unusual amount of imperial patronage. The imperial porcelain factory at Ching-tê Chên was managed by a series of exceptionally capable directors. Ts'ang Ying-hsüan, appointed in 1682, remained in charge till the end of the K'ang Hsi period. Nien Hsi-yao was appointed by the Emperor Yung Chêng and in 1728 he was given as an assistant the celebrated T'ang Ying, who succeeded him in 1736 and held the post with great distinction till 1749. T'ang Ying left behind him several treatises on the manufacture under his control, and in addition to these we have the letters of the Jesuit father d'Entrecolles which were written from Ching-tê Chên in 1712 and 1722, giving us an intimate picture of the life and industry of the great porcelain centre with its 3,000 furnaces.

The period from 1680 to 1749 must be regarded as the most fertile in the annals of Chinese ceramics. The porcelains of this time are distinguished by fine finish and perfect command of material and technique. They do not, however, differ basically from those of the Ming potters, who had little to learn in the essentials of their craft; and on the whole they suffer by comparison with the Ming in the matter of originality and freshness. The Ch'ing wares indeed are often a trifle stale and mechanical. Still they have enjoyed a long period of popularity in Europe, and their relative weakness has only recently become apparent; for we have only recently made acquaintance with the better types of Ming porcelain.

Ch'ing Blue and White.—Old Nanking is a household phrase in Europe for Chinese blue and white. None the less it is a misnomer, for while much of that ware was transhipped from Nanking, none of it was actually made there. Old Nanking is in fact the blue and white porcelain. of Ching-tê Chên and chiefly that made in the K'ang Hsi period and imported into Europe by the Dutch and other East India merchants. It was justly famous, for never was more care expended on the preparation of the ware and the refining of the blue. The best K'ang Hsi blue is pure sapphire, without the tinge of violet or grey so often observable in the Ming blue; and it is usually laid on in graded washes which give it its splendid, vibrating depths. As to the painted designs they are mainly Ming themes, when they are not of the formal arabesque type; but some of them are of outstanding beauty, such as the design of ascending and descending branches of flowering prunus reserved in white in a ground of marbled blue which is netted over with lines suggesting cracked ice.

The prunus blossom falling on the breaking ice is a symbol of returning spring; and this motive is a favourite one for the decoration of the jars in which gifts of fragrant tea and sweetmeats were sent at the new year—a festival which falls in China three to seven weeks later than in our calendar. The vogue of blue and white seems to have died down at the end of the K'ang Hsi period, for after that time the ware in general sank into mediocrity, though exceptions must be made of two types. One is the close imitations of Ming blue and white made in the Yung Chêng period; and the other is the so-called "soft paste" blue and white, a ware prepared with "soapy rock" (hua shih), a kind of pegmatite, and exquisitely painted with the finest brushwork and the purest blue under a soft-looking crackled glaze. Another name given to this porcelain is "steatitic," in the belief that the hua shih was soap-stone or steatite. It was an expensive ware and chiefly used for small objects such as snuff bottles and the furniture of the writing table, in which the Chinese literati take special delight.

Famille **Verte.**—This is the name given to the K'ang Hsi porcelain decorated in transparent enamels. These enamels are in the main the same as those used in the Ming period, but there are a few differences. The iron red is a coral rather than a tomato red, the yellow is clearer than the brownish Ming yellow, there are additional shades of green, and the Ming turquoise green is replaced by a beautiful violet blue enamel.

The enamels are either painted over the glaze or are washed over black-outlined designs painted direct on the unglazed porcelain or biscuit. The latter process was not unknown in the Ming period, but most of the existing specimens, though often miscalled Ming, belong to the Ch'ing dynasty. Some of the finest Ch'ing porcelains are enamelled on the biscuit, such as the sumptuous vases with grounds of green-black (*famille noire*), figures and groups.

Not unlike the porcelain enamelled on the biscuit is that decorated with washes of coloured glazes, chiefly green, yellow and aubergine. This is the Ch'ing version of the Ming three-colour ware; but the Ch'ing glazes are sleek and transparent. Sometimes they are laid on in patches making a motley decoration which is known in the trade as "egg and spinach" glaze.

Ch'ing Monochromes.—The Ch'ing monochromes comprise the Ming types, close imitations of the old Sung glazes and many novelties.

Among the best known is the *lang yao* red, which follows the Ming chi hung but has a character of its own, varying from bright cherry red and deep ox-blood (sung de boeuf) colour to a dappled glaze of crushed strawberry tint. This red is called after a potter family of the name of Lang; and, though imitated in subsequent reigns, it was never so well controlled or so fine in colour as on the K'ang Hsi porcelain. Another success of the K'ang Hsi period was the "peach bloom" glaze, pinkish red in colour but flecked with russet spots and broken by passages of green. Between the peach red and *lang* yao are many shades of maroon and liver colour. Other K'ang Hsi glazes are the mirror-black, the powder-blue and the pale lavender or clair de *lune;* and Chinese writers mention turquoise, eel-skin yellow and snake-skin green as specialties of the period.

We need not dwell on the many other monochromes—whites, celadons, lustrous browns, aubergine purples, violet blues and so forth; but there is a group of composite glazes which requires notice.

They are formed by washes of enamel over a stone-coloured crackled glaze; and they include "apple-green," camellia leaf green, sage green and mustard yellow. Coral red was also used in monochrome, but this and many enamels of the famille rose types belong chiefly to the Ch'ien Lung period, as also do the splashed or *flambé* reds which came at first by accident but which T'ang Ying succeeded in getting under perfect control.

Famille Rose.—In the third decade of the 18th century a revolution took place in the enamelled porcelains. A new palette of colours was introduced, opaque enamels among which rose pinks (derived from gold) are most conspicuous. The Chinese called these new colours *juan* ts'ai (soft colours) or yang ts'ai (foreign colours), and we have adopted for them the French name famille rose. The famille rose displaced the famille verte, and it brought with it a new and more effeminate type of decoration with delicate designs executed with a miniature-like refinement. The colours are seen at their best on the Yung Chêng porcelain with a few sprays of flowers thrown artistically across the white surface. The more elaborate ruby-back dishes and table services with crowded figure-subjects and complicated borders are less satisfactory; but these were painted in the Canton enamelling establishments and were destined for the European trade. At Canton, too, were decorated large quantities of Ching-tê Chên porcelain with coats of arms and other European designs directly ordered by the foreign merchants.

The famille verte enamels, though eclipsed by the *famille* rose, were not entirely suppressed; and they emerged again in a mixed palette of transparent and opaque colours. These mixed enamels were effectively used by a school of painters who worked in the style of one Ku Yüeh-hsüan, a maker and decorator of glass in the early years of Ch'ien Lung's reign. Good specimens are rare, for they are prized by Chinese collectors. Other specialities of the Ch'ien Lung period are "lace-work" porcelain with designs deeply incised and forming semi-transparencies; and "rice-grain" porcelain in which the designs are actually cut out of the side of the vessel though allowed to fill up with glaze. A third type, known as *graviata,* has a covering of opaque *famille rose* enamel which is diapered with incised scroll-work.

The monochromes of the Yung Chêng and Ch'ien Lung periods include those of the K'ang Hsi with numerous additions, some of which have already been mentioned. Great ingenuity was exercised by the Ch'ien Lung potters in the imitation of natural substances in glaze; the effects of tea dust, iron-rust and bronze are cleverly produced, and enamelled metal, shells, birds' eggs, grained wood, jade, ivory, etc., are copied so closely as to deceive the eye But tbese *tours de* force are symptoms of an art which had passed its maturity; and after the 18th century the porcelain has little interest, being mainly of an imitative kind. Exceptions may be made of the Peking medallion bowls, the finer snuff bottles of the Tao Kuang period (1820–50) and some of the imperial porcelains which maintained a high standard of technique. The devastation of Ching-tê Chên during the T'ai-p'ing rebellion in 1853 was a crowning disaster to the ceramic industry of China.

Provincial Porcelains and Pottery.—The bulk of the Ch'ing dynasty porcelains which have reached Europe is of Ching-tê Chên make; but there were many provincial factories which supplied local needs and which also catered for the sea-borne trade to India and the East Indies. These provincial wares are generally of a coarse type; but a shining exception is the white porcelain made at Tê-hua in the province of Fukien. This is the blanc de Chine of the old French catalogues, which was freely exported from Amoy in the 17th and 18th centuries, and which served as a model for most of the early European porcelains. It is a beautiful, translucent ware with a soft-looking, melting glaze of milk or cream white, sometimes warmed with a pinkish tinge; and it was chiefly used for ornamental objects such as vases, libation cups, incense burners, figures and groups, less often for table wares. It is decorated, if at all, with slight, applied reliefs, moulded or incised designs, rarely with painted enamels. The Tê-hua factories are known to have existed in the last half of the Ming dynasty, and they are still active to-day; and as the character of the ware has changed very little, the dating of specimens will always be difficult.

Immense quantities of earthenware and stoneware have been and are still made in every part of China. We know little of the individual potteries, but there are two centres which must be mentioned. Yi-hsing, on the west side of the Great Lake in Kiangsu, has been noted since the 16th century for a fine stoneware, chiefly red but also buff, grey and of other colours formed by clever blending of the local clays. The red tea ware of Yi-hsing came to Europe with China tea as early as the 17th century. It was classed at that time with the American buccaro ware; and it was copied closely by Dutch, English and German potters, notably by Bottger at Dresden and by Dwight and Elers in England. The Yi-hsing tea-pots were cleverly fashioned, often in fanciful shapes, and decorated with reliefs, moulded and incised designs and in some cases with glazes and even enamels.

The second centre lies in the province of Kwangtung, the principal potteries being at Shekwan near Fatshan, a few miles west of Canton. The Shekwan ware is a stoneware verging on porcelain; and the standard type has a thick flocculent glaze of brown mottled with blue and grey and sometimes with vivid red. Glazes of the Sung Chün type and celadon green, as already mentioned, besides *flambé* red were also used; and some of the Shekwan stoneware dates back to the Ming period, though the bulk of it is of comparatively recent date.

The reader is reminded that true Chinese decoration is never meaningless. Its meaning may be directly expressed in semi-religious emblems such as the Eight Buddhist Symbols, the attributes of the Eight Immortals, the Eight Precious Things, etc.; or indirectly by motives which suggest good wishes, such as the peach, crane, tortoise and pine (long life), the bat (happiness), the pomegranate (fertility). Again combinations of flowers, animals, etc., can be read rebus-fashion into auspicious phrases; for the Chinese language abounds in homophones and the Chinese delight in puns. They also delight in themes of religious and historical import; and the understanding of their decorative designs involves a deep study of their religion, history and folk-lore.

Numerous marks and seals are used on Chinese pottery and porcelain; but for these again the reader must consult special books. The most important and the most frequent of the marks are the reign-names (*nien* hao) of the emperors; but there are also potters' names, phrases of good omen, symbols and the names of halls and workshops, which it would be futile to enumerate without giving the actual marks and their readings.

Bibliography.—*General:* F. Brinkley, China, Its *History,* Arts and *Literature* (1904); W. Burton and R. L. Hobson, *Marks on Pottery* and *Porcelain* (1912); S. W. Bushell, *Chinese Art* (2 vols., 1906), *Description of* Chinese Pottery and Porcelain (1910), being a transla-

tion of the *T'ao shuo, Oriental Ceramic Art* (1899); *E.* Hannover, *Pottery and Porcelain,* vol. *II., The Far East* (1925); *R.* L. Hobson, *Chinese Pottery and Porcelain* (2 vols., 1915), *Catalogue of the Eumorfopoulos Collection* (6 vols., 1925–28), *Guide to the Pottery and Porcelain of the Far East* (1924); St. Julien, *Histozre et Fabrication de la Porcelaine Chinoise* (1856), being a translation of the greater part of the *Ching tê chên t'ao lu,* with notes and additions; E. Zimmermann, *Chinesisches Porzellan* (Leipzig, 1923).

Early Periods: J. G. Andersson, *Bulletin of the Geological Survey of China,* No. 5 (1923), *Memoirs of the Geological Survey of China,* Series *A,* No. 5 (1925); T. J. Arne, *Palaeontologia Sinica* (1925), Series D, vol. I., No, 2; C. Hentze, *Les Figurines de la Ce'ramique Funéraire* (Hellerau, 1927); A. L. Hetherington, *Early Ceramic Wares of China* (abridged ed., 1924); B. Laufer, *Chinese Pottery of the Han Dynasty* (Leyden. 1909), *The Beginnings of Porcelain in China* (Chicago, 1917); O. Rücker Embden, *Chinesische Friihkeramik* (Leipzig, 1922).

Later perzods: R. L. Hobson, *The Wares of the Ming Dynasty* (1923), *The Later Ceramic Wares of China* (1925); *A.* E. Hippisley, *Catalogue of the Hippisley Collection,* Smithsonian Institute, Washington (1900).

KOREA

The geographical position of Korea makes it a natural link between China and Japan. In close contact with China the Koreans were absorbing Chinese influences from the Han dynasty onwards; and Chinese graves of the Han period excavated in Korea prove by their contents that the Koreans must have been familiar with the arts of their great western neighbour. But in actual fact the early Korean pottery, though doubtless its essentials were learnt rrom the Chinese, developed on lines of its own. It is a hard, slate-grey ware, unglazed except for an accidental smear of glossy brown which probably came from the wood ashes in the kiln, and ornamented with large perforations, rather crude reliefs and simple incised patterns. This is the ruling type found in the tombs of the Silla period, which is generally regarded as extending from the 1st to the 10th century, though the Silla state did not actually become paramount till the 7th century. Naturally the Silla pottery varies considerably in such a great space of time, and some of it is potted thin, fired hard and of a neat and almost ornamental appearance.

The Korai Period **(918–1392).**—But the heyday of Korean ceramics belongs to the succeeding Koryu or Korai period, when the Korean potters suddenly developed a skill which was the admiration of the Chinese themselves. There can be little doubt that this sudden change was wrought either by Chinese refugees or by Koreans who had gone to China to study. For the home of the new industry was in southern Korea, in the Zenra district; and, as Dr. Nakao has pointed out, this district is connected by the most convenient sea route with the coast of Chekiang. the home of the Chinese celadon in the imitation of which the Koreans specialized. The characteristic Korean ware of the Korai period is a porcellanous stoneware with a celadon glaze which at its best resembles blue green ice, but which varies in tone to olive green and brown. A Chinese writer, Hsü Ching, who visited Korea in 1125 compared this ware in one passage with the secret-colour (pi *sê*) ware of Yüeh Chou and the contemporary Ju Chou porcelain, and in another passage with the celadon of Lung-ch'iian. The same writer adds that in form and style it resembled Ting Chou porcelain, a statement of which we quickly realize the truth in comparing the etched, engraved and moulded designs in the Korean bowls with those of the ivory white Ting ware. Incidentally it may be mentioned here that a white porcelain of Ting type and a bluish white porcelain of *ying ch'ing* type have both been found in Korai tombs; but whether they were, all or some, made in Korea itself or imported from China are questions not yet decided. The finest Korai ware is undoubtedly the blue green celadon made in the best period which may be placed between 1050 and 1170; and it is either plain or delicately decorated with etched or carved designs. Sometimes the glaze is more grass green like the typical Lung-ch'iian celadon or olive green like the so-called northern celadon (see above).

Indeed there are specimens which could hardly be distinguished from this latter ware, were it not for the typical Korean finish of the base which is shallow and covered with glaze and almost always scarred with the marks of the spurs or sand on which the piece was supported in the kiln. This rough finish of the base and a tendency to lose shape in the firing are two defects which are apt to mar even the best Korean ware.

It was probably in the last half of the 12th century that a typically Korean method of decorating the celadon ware was first used, namely inlaying the incised designs with black and white clays. Discreetly used this decoration produced a very charming effect; but it was overdone and soon became hackneyed. The easy but mechanical method of stamping the designs instead of drawing them with the stylus was adopted, and a stiff and crowded ornamentation resulted. To this inferior class belongs the so-called "Mishima" ware with its radiating cord patterns which recalled to the Japanese the lines of their Mishima almanac.

Other less usual kinds of decoration on the Korai ware are painting in underglaze red, painting in bold, but often rather crude, designs in brown (rarely in white) in the style of the Chinese Tz'ŭ Chou pottery, and blending variously coloured clays so as to make a marbled body. Black- and brown-glazed wares of the "Honan *temmoku*" class are also found in Korea, but, as with the ivory white and *ying ch'ing* types, their native origin remains to be proved. By the end of the 13th century the Korai pottery had become definitely decadent: the beautiful celadon glaze had turned brown and cement-coloured, and the inlaid and brown-painted wares were coarse and clumsy.

The Korai dynasty was followed by the Yi which lasted from 1392 to 1910. The capital was removed from Song-do to Seoul and the name of the kingdom was changed to Chosen. But the country was impoverished by many calamities and the final blow to its prosperity came with the invasion of the Japanese under Hideyoshi at the end of the 16th century. From this time Korea was virtually closed to the outside world and became a veritable hermit kingdom. We know little of the early Yi pottery except so far as it is reflected in Japanese imitations. From these we would infer that it included a rough kind of red or grey pottery with translucent glaze varying from brown to light grey tinged with pink; coarse *mishima*, and brown-painted wares which the Japanese call *e-gorai* (painted Korean); a creamy buff ware with closely crackled glaze; and grey ware with opaque milk white glaze of thin paint-like appearance which the Japanese call *koma-gai.* For the rest, specimens of the 17th to 19th century wares in our collections comprise porcellanous stoneware with crackled grey or buff glaze, plain or painted with sketchy designs in dull underglaze blue; and white porcelain painted in underglaze blue and red, with occasional relief decoration and open work.

BIBLIOGRAPHY—*Kanroku Korai-yaki Gwacho* (Album of Korean Pottery) (1910); N. Nakao, "Old Korai China," *Manchurian Daily News* (monthly supplement, Aug–Oct. 1925); *B.* Rackham, *Catalogue of the Le Blond Collection of Corean Pottery* in the Victoria and Albert Museum (1918).

JAPAN

Japan, like every other country, has its primitive pottery, a rough hand-made material sometimes mat-marked like the primitive Chinese. A more advanced type is found in the dolmen burials which date from the 3rd century B.C. to the 7th A.D. The dolmen-builders were invaders from the mainland, doubtless from Korea, and the dolmen pottery closely resembles the Korean wares of the Silla period. The development of the potter's art in Japan was slow—perhaps it was retarded by the preference for other materials, such as lacquer, for the articles of every day use—and it seems at first only to have moved forward under the stimulus of foreign influences. The first foreign influence was Korean. The next was Chinese, and this must have been felt as early as the 8th century, for the treasure of the Emperor Shomu, preserved at Nara, includes a few specimens of motley glazed pottery of T'ang type. In the 13th century Kato Shirazaemon is said to have gone to China to study the work of the Sung potters, and to have set up kilns in Seto on his return. Reputed specimens of his work are tea jars and tea bowls with thick treacly glazes of black, amber brown, chocolate and yellowish grey colour. This type of pottery took a firm hold in Japan and variations of the Seto glazes were subsequently made in many factories throughout the country. A second and more potent wave of Korean influence flooded Japan after Hideyoshi's campaigns in the 16th century, from which he brought back a large number of Korean captives. It happened too that about the same time the famous aesthete Senno Rikiu organized the tea ceremony, which has played ever since an important part in Japanese social life. The masters of the tea ceremony decided that pottery was the most fitting material for the tea vessels; and the Japanese potters soon learnt from the Koreans how to meet the demand satisfactorily. Hence the numerous imitations of Korean Yi dynasty wares to which allusion was made in the last section. Indeed many of the best known Japanese potteries, such as those of Karatsu, Satsuma, Shigaraki, Takatori and Hagi, owe most of their importance, and also very often their origin, to Korean teachers. From the 16th century onward Japanese pottery developed rapidly and many new and original types were invented, of which the *raku* ware is one of the most important

Though the credit for the invention of *raku* ware is given to a Korean family settled in the Kioto district, the ware itself is essentially Japanese. It is a soft, hand-made earthenware, requiring only a slight firing, and covered with a peculiarly waxen, treacly and semi-opaque glaze of various colours of which the black and salmon are the earliest and the yellow, green, cream white and mixed colours later.

Another successful Japanese creation is the antithesis of the *raku* ware. It is a hard reddish brown stoneware unglazed as a rule, except for an accidental smear, and evidently well suited for figure modelling. Its habitat is the province of Bizen, where the industry can be traced back to the 14th century. A fine, hard, buff pottery with closely crackled cream glaze is another Japanese specialty. It is a development of the Korean *koma gai,* or white ware; and it reached its finest expression in Satsuma. Here and at numerous factories in Kyoto it was used as the vehicle for enamelled decoration.

The art of enamelling on porcelain was learnt from China, the story being that Sakaida Kakiemon, an Arita potter, was instructed in it by a Chinese ship's master about the middle of the 17th century. One of the most-celebrated Japanese potters, whose art-name is Ninsei, adapted its use to the cream glazed pottery and developed a special style of enamelling in purely Japanese taste. Ogata Kenzan, another of the great Japanese ceramic artists, at the end of the 17th century found a way of using enamelled decoration on the soft *raku* glazes. From this time onwards Chinese influence was discounted in the pottery which displays much originality and a true national style.

Japanese Porcelain.—Meanwhile the manufacture of porcelain had started in Japan. Needless to say the technique was learnt from the Chinese, a potter named Gorodayu go Shonzui visiting Ching-tê Chên itself to study in the 15th century. Shonzui's difficulty on his return to Japan was to find suitable raw material and he was forced to work with imported Chinese clays. Not till the beginning of the 17th century did the discovery of the important deposits of porcelain stone on Izumi Yama, in the Arita district of Hizen, permit the establishment of the Japanese porcelain industry on a firm basis. The Arita district was the chief centre of the manufacture; and it was here, at the seaport Imari, that the Dutch traders obtained the "Old Imari" porcelain with which they flooded Europe. Here too Kakiemon practised his new-found art of enamelling, in a style which is for ever associated with his name. The Kakiemon enamels were soft orange red, grass green and lilac blue, supplemented by pale primrose yellow, turquoise green, gilding and occasionally by underglaze blue; and his decorations are slight and in the best Japanese taste. A few blossoms, a floral medallion, a flowering prunus tree, a banded hedge with birds, quails and millet, a tiger and bamboos, a dragon and sometimes children are motives of the nicely balanced Kakiemon designs which have been imitated wherever porcelain has been made.

The "Old Imari" of the Dutch importers included another highly specialized but less artistic kind of porcelain. It was painted with masses of heavy impure blue supplemented by red and gold and to a less extent by enamel colours. The designs are irregular and confused, asymmetrical panels enclosed by mixed brocade patterns. Over-loaded, but not without decorative value, they appealed strongly to the Dutch taste.

Many factories were started in the Arita district, those of the princely houses of Hirado and Nabeshima being the most noted; and the industry soon spread to other provinces. It was early established in the Kutani district of the province of Kaga and at a little later period at Seto in Owari, Mino, Kioto and many other places. The Kaga potteries in the 19th century popularized a special kind of decoration in red and gold; but on the whole Japanese painted porcelain follows closely on Chinese lines, and the highest ambition seems to have been to make wares which could be mistaken for Ming porcelain. The Koto factory on the shore of Lake Biwa was noted for its enamelled porcelain in the middle of the 19th century; and good imitations of Chinese celadon were made in the Arita district at an early date and at Sanda and Kioto since the end of the 18th century. In the early 19th century remarkably fine porcelain of "egg-shell" thinness was made at Mikawachi, in Seto, Shiba and Mino.

Since the reopening of Japan to the foreigner in 1868 vast quantities of pottery and porcelain have been made for the Western market. These wares, usually overloaded with ornament, do not represent true Japanese taste, which requires that a piece of pottery be made strictly to serve its useful purpose and decorated soberly in a style appropriate to its form and use.

It is not practicable within the compass of this article to describe the work of individual potters, and the mere mention of famous names, such as Banko, Hozan, Dohachi, Eisen, Rokubei and Zengoro Hozen, cannot serve any useful purpose. The potteries are very numerous, being for the most part small family concerns; and as each had its individual mark or seal and a proper pride in using it, the list of Japanese potter's marks is a formidable one, for which the reader must consult works cited below.

BIBLIOGRAPHY.—F. Brinkley, *Japan, Its History, Arts and Literature* (1904); A. W. Franks, *Japanese Pottery,* Victoria and Albert Museum Art Handbook (1906), *Catalogue of the Franks Collection of Oriental Pottery and Porcelain* (1879); E. S. Morse, *Catalogue of the Japanese Pottery in the Museum of Fine Arts* (Boston, 1901).

PERSIA AND THE NEAR EAST

The ceramic history of the Near East between late Roman and Islamic times is still obscure. Little Sassanian pottery of any importance has been identified, and the excavations at Constantinople which should tell the Byzantine side of the story have hardly begun. But the continuity of ceramic tradition in these regions is not for a moment in doubt. The most familiar of all the Persian glazes is the blue-green which appears on late Babylonian, Parthian and late Roman wares; while in Egypt there is no real break in the sequence of potters from early dynastic times to the present day, though the chain of evidence is very weak in the period immediately preceding the coming of Islam.

The "Gabri" Types.—What is reputed to be the earliest type of mediaeval Persian pottery has been called "Gabri" because it was believed to have been made by the pre-Islamic, fire-worshipping (Gabri) peoples. It is an earthenware with a reddish body which is usually concealed by a coating of white slip (liquid clay) and covered with a transparent lead glaze. The commonest form of decoration was effected by cutting or scratching a design through the slip coating so as to expose the red ware below; and by varying the naturally yellowish colour of the glaze by washes of green and purplish brown, derived respectively from copper and manganese. This technique is probably of Byzantine derivation, but it has been used since in every civilized country and at all periods. The Gabri ware, though often crude and bucolic, is attractive for its bold designs and warm colouring, and in the best specimens the rendering of animal forms among floral scrolls and of ornamental inscriptions is highly artistic.

In point of date some of it may go back to the early days of Islam (7th century), but the bulk of it may safely be placed between the 10th and 13th centuries. In Egypt the same technique was largely used on the armorial pottery of the 15th century. Gabri ware has been excavated chiefly in northern Persia, at Zendjan, Rhages and Hamadan; and a kindred ware reputed to come from Amul, south of the Caspian, is distinguished by the additional colours, yellow and ochreous red. A rare type reputed also to be of Amul make has painted designs in white on a background of black slip. A red ware with painting in coloured slips, as well as with incised ornament, has been found in some quantity as far east as Samarkand.

Samarra.—A shining exception to the usual haphazard excavation is the work done by Profs. Sarre and Herzfeld in the ruins of Samarra on the Tigris, a site which was occupied for about 50 years in the 9th century. The finds made here are of the utmost historic importance, and they include a variety of interesting pottery types. One is a thin reddish buff earthenware decorated in low relief with formal designs under a green lead glaze and strongly reminiscent of the lead glazed wares of the late Roman period. Another and more characteristic type is a close-grained, buff pottery with an opaque greyish white glaze which is sometimes painted with a dark cobalt blue, sometimes with lustre pigments of golden brown, green or blood red tones. The blue-painted ware is varied at times with patches of green and manganese brown. The same Samarra body is found with monochrome white, green and yellow glazes, and also with glazes splashed and mottled with green and yellow in the style of the Chinese T'ang wares with or without incised designs. Indeed it is clear that the Samarra potters deliberately set themselves to copy Chinese wares, fragments of which in company with white and celadon porcelain have been found on the site. But the most important of the Samarra fragments are those decorated with lustre.

Lustre painting is perhaps the chief contribution of the Near East to ceramic decoration. When and where it was first used are still debated questions, but one fact at any rate is established by the Samarra finds, namely that the process was fully developed in the 9th century. The lustre is applied in the form of a metallic salt (derived from copper or silver) which is painted on the glazed ware and developed at a low temperature in a special kind of kiln. This process deposits a film of metal on the surface of the ware, in colour golden brown, greenish or red, and when the film is thin enough to allow the light to penetrate it, it glows with beautiful rainbow reflections. The blue-painted and the lustred pottery of the Samarra type have been found at Susa certainly, and, according to report, at Rhages also; and examples of the lustred types have all been found in the waste heaps at Fostat in Egypt.

Rakka Ware.—Extensive pottery remains. including a number of kiln wasters, have been dug up at Rakka, in Syria, a place situated on the Euphrates about 100 m. E. of Aleppo. Rakka is a very ancient site and one which had considerable importance between the 8th and the 14th centuries. It includes ruins of several cities, one of which was the residence for a time of the Caliph Harun Al-Rashid. The pottery found at Rakka is of a type which became general in the Near East after the 10th or 11th century. It has a sandy, white or buff white body, loosely constructed and friable, and it is covered with a clear silicious glaze which became opaque when tinted with certain colours. A bowl of Rakka ware figured in Chatfield Pier's book is said to have a dated inscription of the year 831: it is painted in black under a pale blue glaze. Other Rakka wares are decorated with a characteristic brownish lustre; and some of these may date back to the 10th or 11th century. Others again have designs in bold relief which is lustred, or covered with opaque turquoise or translucent bluish green glaze. But the most characteristic type is painted in black under a pale blue glaze or in blue and black under a clear glaze.

Sometimes the glaze is coloured a fine purplish brown with manganese. The blue and black painted ware is common to Syria and Egypt, whence its name Syro-Egyptian, and the bulk of it was made between the 13th and the 15th centuries.

Kiln sites have also been found at Rakka with remains of another kind of ware which appears to belong to the 11th or 12th century. It is white with engraved designs under a clear glaze which is sometimes coloured with dabs of blue. Probably other colours also were used, for specimens of this type reported to come from Rhages have the same features with the addition of green, yellow and manganese purple.

Rhages Ware.—To return to Persia, the ruins of Rhages have long been a happy hunting ground for pottery seekers, and they have produced wares of great variety and of many periods. There is little doubt that Rhages was an important centre of the ceramic industry, though very few waste pieces have been found to indicate the presence of kilns. The city, once the capital of the Djebal, was laid waste by the Mongols in 1220, and, though not completely abandoned till the 17th century, it never recovered from this disaster. The classic period of Persian pottery is from the 12th to the 14th century; and among the fragments found at Rhages are some of the most beautiful Persian wares. They are mostly made of the sandy white material; and the glaze is usually opaque and of a creamy tone, and much of it is finely painted with golden brown lustre with or without touches of blue. Another beautiful type, specially associated with the name of Rhages, is painted in enamel colours heightened by leaf gilding on a cream white or turquoise blue glaze. The Rhages enamels include blue, turquoise, manganese purple, red, green, mixed colours and white, and, with the exception of the blue, they generally have a mat appearance which gives a subdued splendour to the colour scheme. The designs on this Rhages enamelled ware are pencilled with miniature-like fineness recalling to a great extent the beautiful workmanship in the manuscript illuminations of the early 13th century. Indeed it has been thought that the court miniaturists may have assisted at the work In some cases, especially with the more formal designs, parts of the pattern are built up in relief and these incrustations are jewelled with enamels and gilding.

Again the red, white and gold are effectively used in tracing formal designs on a fine dark blue glaze or on an opaque turquoise glaze which frequently covers moulded reliefs. Enamel colours too are sometimes used on the unglazed water jugs of porous buff earthenware, which are found all over the Near East and which are often decorated with artistic relief ornament.

The ruins of Sultanabad, in Kazvin, have also given us much fine pottery of the classic period, wares painted in lustre with or without blue, decorated in strong relief under blue, turquoise or green glazes, and painted in blue and brown under a clear glaze. The most characteristic Sultanabad type is a variety of the last mentioned, with animals, birds or human figures set in a background of close foliage, outlined in black and washed in with blue. The central motives are frequently speckled with black dots, and parts of the ornament are slightly raised.

The beauty of these specimens is further enhanced by the warm grey tone of the glazed ware in the remaining spaces. Chinese influence is frequently observable in the drawing of the figures, and pure Chinese motives such as the dragon and phoenix also appear. These features indicate a date in the second half of the 13th century after the Mongol conquest. Excavations at Khar have produced pottery of the best Rhages types, and it is probable that many other sites could be found equally productive, for there is no doubt that pottery centres were widely distributed throughout Persia and that Rhages and Sultanabad are only two of many.

Persian **Tiles.**—One of the most attractive forms of Persian pottery, the beautiful lustred wall tiles, have been found at Rhages Veramin, Koum, Natinz. Meshed and Kashan, and it is reasonable to suppose that such things were manufactured on the spot. But the wall tiles illustrate almost every phase of Persian ceramic art. Some of the earliest have ornamental inscriptions in strong relief and a coating of monochrome glaze, light blue or green. Next came the splendid lustred tiles, cut into star shapes and decorated with a complete design on each, chiefly consisting of ornamental foliage which sometimes encloses animals, birds and even human figures. An inscribed border usually completes the tile, and many of the inscriptions have the added interest of dates in the 13th and 14th centuries. The designs are sometimes painted direct in the lustre pigment, sometimes reserved in a lustred ground: details are etched with a needle point and parts of the design, especially the borders, are often touched with blue and occasionally with turquoise. It was soon discovered by the craftsmen that a slight relief gives additional play to the lustre, and reliefs were freely used, especially on the larger mihrab tiles. In place of lustre we also find traceries of red, white and gold on dark blue or turquoise glaze as on the Rhages wares. Another characteristic Persian mural decoration is in a mosaic composed of glazed pottery, sawn in intricate patterns and embedded in mortar. There are fine examples of this work on buildings of the 14th century. Later the same general effect was produced by the easier method of painting the design in coloured glazes leaving the outlines dry to represent mortar.

Before leaving the classic period of Persian pottery mention should be made of the fairy-like effects obtained in the sides of bowls and vases by open work designs into which the glaze has been allowed to run, forming transparencies. This beautiful decoration is seen on white wares which may be as old as the 11th century and on the pottery found at Rhages, Sultanabad and Fostat. It reappears at a later date on the so-called Gombroon ware.

Later Persian Wares.—In the post-classical period, from the 15th century onwards, the fashions in Persian pottery underwent considerable change. Few of the older styles survived, and those which did are barely recognizable. The body of the ware is the same sandy white material; but it is more highly vitrified and quite often it is translucent in the thinner parts, a condition only occasionally noticeable in the early wares. It is in fact a kind of soft porcelain. Chinese influence is very strong in the decoration. Celadon greens and other colours are copied as monochromes or painted with traceries of white slip: the painted designs in blue and black, or in blue alone, under a clear glaze, so closely follow the Ming blue and white that they are often mistaken for it. The Persian potters even marked their wares with imitations of Chinese seals. Survivals of the old Persian types include decoration scratched through a black slip under a pale blue glaze, painting in black under a blue glaze, and lustre ware, but in every case the character of the designs has changed. As to the lustre ware it would perhaps be more correct to describe it as a revival, for we have no examples made during the century which preceded the reign of Shah Abbas (1587–1629). On the revived ware the lustre is greenish or reddish brown in colour and its reflections are generally coppery, but sometimes of a beautiful ruby tint. It is applied over a white, or a vivid blue, glaze, rarely over yellow; and the designs are freely drawn trees and plants, among which the cypress occurs frequently, animals and birds and formal patterns, arabesque scrolls, leaf medallions and cable borders. The old device of reserving the design in a ground of lustre does not seem to have been used. Though this ware is generally known as Shah Abbas lustre, the only published specimen with a date was made in the year 1651 (or 1673 according to the reading), and a jug in the British Museum has a metal mount of about 1700. The ware in fact seems to be a 17th century revival but there is no evidence that it continued beyond that period.

The effective use of pierced ornament filled with transparent glaze on the earlier wares has already been noted. After a long interval it reappears on the white translucent ware of the later periods. The incised patterns are of a simple kind and they are supplemented as a rule with a few sprays or arabesques in blue and black. This singularly light and elegant pottery has been called Gombroon ware, because it was believed to have been shipped from the poft of Gombroon; but it was probably made in many places, and the material differs in no respect from the contemporary ware made all over Persia. The few known dated examples are of a rather coarse type and belong to the early years of the 19th century; but the ware was largely made in the 18th and some of it may date back to the 17th century.

The late Persian types are no easier to localize than the earlier. Chardin, who travelled in Persia in the 17th century, tells us that faience in Chinese style was produced all over the country, but that the best came from Shiraz, Meshed, Yezd, Zorende and Kerman. There is an interesting product of Yezd in the British Museum, a kettle-shaped ewer of fine white ware well painted in blue in Chinese style and inscribed "The Work of Mahmûd Mi'mar of Yezd. The decorator of it the poor Zari. 1025" (=A.D. 1616). Hannover describes a pottery decorated in blue, green and a red similar to that used on the Turkish wares (see below), which he believed to be of Kerman make. Kubatcha in the Caucasus is also credited with the manufacture of a ware painted in similar colours or in a greyish blue under a glaze which tends to crackle. A typical specimen of this ware is a dish with a female bust surrounded by floral ornament, while others have rather coarsely painted designs in the style of Chinese blue and white; but all that can be said with certainty is that pottery of this kind has been found in the neighbourhood of Kubatcha. With even less reason a considerable group of post-classical pottery with black designs under a transparent blue glaze, which is inclined to crackle, have been assigned to Kubatcha; but there is little doubt that this type was made in various parts of Persia and certainly at Damascus. Specimens exist with dates around the year 1500.

The later tile work tends to be pictorial, with hawking figures on horseback and the like in slight relief in a ground of landscape and flowers. One of the best examples of the 17th century tile work is in the Victoria and Albert Museum, a large panel made up of many plaques and representing a princess and court ladies in a garden of flowers and cypress trees.

In the middle of the 18th century overglaze enamel painting in the colours of the Chinese *famille* rose came into use on tiles and on ordinary pottery. But the late 18th century and the 19th century Persian wares are in the main coarse versions of older types.

Mention has already been made of the early lustred pottery, the *graffiato* wares, and the blue and black painted wares of Syrian type found in Egypt, and of the continuity of the potters' art there from early dynastic times to the present day. Most of the early Persian and Syrian types were made in Egypt in the neighbourhood of Cairo; and the finds at Fostat are specially rich in lustre wares of all kinds, in pottery painted in black and blue under a clear glaze, and in monochromes which imitate Chinese porcelain.

Turkish and Damascus Wares.—Little is known of the potteries of Asia Minor in the middle ages, but in the 16th century under Ottoman rule they became famous for a pottery which is unsurpassed for its bold designs and powerful colouring. It is directly descended from Persian wares, but it has decided characteristics of its own which reflect the taste and temperament of the Ottoman peoples. It has the standard Near Eastern body of sandy whitish material, but in all the better specimens this body is dressed with a slip of fine white clay. On this the decoration is painted in black outlines which are filled in with brilliant blue, turquoise, green, and either manganese purple or thick red, under a clear glassy glaze. The colours are laid on with a full brush, and the Turkish designs have a distinctive character. They consist chiefly of sprays of certain flowers such as the narcissus, tulip, carnation, rose, fritillary, etc., naturalistically treated, or of arabesques of feathery leaves; and the dishes have borders of spiral clouds.

The transition from the old Persian types to the full-blown Turkish ware is abrupt; but a link may be found in the pottery of Damascus.

Outside this important city, kiln sites have been found with remains of a pottery of the 14th century Syro-Egyptian type, painted in blue and black under a clear glaze; and there is a vase with lustred decoration on a blue glaze, bearing legend "painted by Yussuf of Damascus" which implies a knowledge of the lustre technique among the Damascenes. Pottery painted in black under a blue glaze has been found in some quantity near Damascus and tiles of the same kind of ware adorn buildings in the city. Some of these have delicate Persian scroll-work suggesting a date not later than the 15th century, while other specimens have the large feathery leaf designs which appear on the Turkish wares. Finally Damascus has been credited with the manufacture of the most refined of the wares of Turkish type, distinguished from the rest by soft colours which include a dull lilac in place of the thick Turkish red, a delicate turquoise blue and sage green, and also by a certain Persian flavour in its arabesque ornaments. It must be admitted, however, that the claims of Damascus to a monopoly of this ware are more than doubtful.

The most outstanding feature of the pure Turkish pottery is a brilliant red colour, made with Armenian bole, which is laid on in palpable relief. Its manufacture must have been widely spread over the Turkish dominions, for the ware is found effectively decorating the walls of mosques and public buildings from Adrianople to Cairo. Important centres of the manufacture were at Constantinople, Nicaea, Broussa and possibly in the island of Rhodes, though the old tradition that the ware came exclusively from Rhodes has been proved erroneous. The dating of the Turkish ware is established by the tiles on various buildings of which the history has been preserved, by a few specimens with European metal mounts and by still rarer pieces with dated inscriptions. From these sources we learn that the best period was in the 16th century, and that the quality of the ware had deteriorated by the last part of the 17th century, when the designs had become coarse and hackneyed and the ware itself dirty and yellowish. A beautiful mosque lamp of the finest Turkish ware in "Damascus" style in the British Museum bears the date 1549. A ware of such individuality could not fail to affect the pottery of other regions, and its influence can be traced on the Persian pottery of the 17th century, and particularly on the kind which is called Kubatcha.

Kutahia in Anatolia was till quite recent times a busy ceramic centre. From the 17th century onwards a pottery of Turkish type was made here, but painted with small patterns—palmettes, scrolls and flowers, scale and leaf diapers, etc.—in lively colours including blue, turquoise, green, yellow and the Turkish red. It is a crisp ware, thinly potted and sometimes engraved with criss-cross patterns in the paste. Dated specimens of the years 1719 and 1787 are known. A much more artistic ware painted in shades of blue has also been attributed to Kutahia; but this attribution rests on the reading of an inscription of a ewer in the Godman collection (Cat. Pl. LV., No. 35) which is given as follows: "This mass cruet commemorates the servant of God, Abraham of Kutahia, Anno Armen: 959" (=A.D. 1510). The date is interesting, but if the reading is correct it still leaves open the question whether the ewer was made at Kutahia or elsewhere.

BIBLIOGRAPHY.—A. J. Butler, *Islamic Pottery* (1927); O. von Falke, *Maiolica* (1907); H. Gallois, *Islamische Kunst in het Gemeente-Museen* (The Hague, 1924); E. Hannover, *Pottery and Porcelain*, vol. I. (1925); D. Kelekian. *Catalogue of the Kelekian Collection* (Paris, 1910); E. Kuhnel, "Datierte Persische Fayencen," *Jahrbuch der Asiatischen Kunst* (Leipzig, 1924); R. Meyer Riefstahl, *The Parish Watson Collection of Mohamnzedan Pottery* (1922); G. Migeon, *Manuel d'Art Musulman* (1927); G. Migeon and Armenag Bey Sakisian, *La Céramique d'Asie Mineure et de Constantinople du XIVe au XVIIe siècles* (1923); M. Pézard, *La Céramique archaique de l'Islam* (1920); G. Chatfield Pier, *Pottery of the Near East* (1909); F. Sarre, *Die Keramik in Euphrat- und Tigris-Gebiet* (1921), *Die Keramik von Samarra* (1925); H. Wallis, *Persian Ceramic Art* (in the Godman Collection) (1891). (R. L. Ho.)

UNITED STATES

It is difficult to write an accurate comprehensive story of pottery and porcelain in the United States. There are several reasons. First, local history is inadequate. In some parts of the country where the potters did not belong to the group considered socially important, it is almost impossible to trace accurately their activities because they were seldom mentioned in newspapers or records. In other sections, the potters were among the leaders so that complete records are available. As a result, it is sometimes incorrectly supposed that certain parts of the country had practically no pioneer potters. The second reason is that until the 20th century, ceramic history centred attention on foreign developments. The third reason is that nowhere is terminology clear-cut, due to the fact that pottery began before there were printed records and has continued to spread and develop in many directions ever since so that each new development has been a gradual merging of one phase of expression into another. Such changes often took place simultaneously even in different parts of the same country. Twentieth century commercial practice added to the confusion of terms. Often manufacturers gave to their ware trade names which erroneously suggested classification within groups popularly considered valuable. Because of looseness in terminology, it was usually impossible to determine unquestionably where one classification ended and another began, or to list characteristics which could remain unchallenged as distinguishing qualities of a given group.

Historically, development of pottery and porcelain in the United States was practically a duplication of the progress of ceramic history of the world except that, due to an accumulated ceramic knowledge and new scientific and industrial processes, ceramic development in the United States took place within about 300 years, while the world development had been going on for many centuries. The history of American pottery and porcelain can be divided into three distinct periods. The first comprised pioneer pottery made by individual potters for utilitarian purposes. By gradual change, ceramics became an important industry supplying quantities of inexpensive ware made by mass production methods, and about the middle of the 19th century the decoration and making of pottery and porcelain began as an art,

Pioneer Pottery.—Pioneer pottery resulted from the use of natural local materials made simply and directly into articles needed in the everyday life of the group wherein the potter lived. As a result, the ware had a ruggedness, directness and simplicity which are usually lost as soon as civilization reaches the point where needs are less demanding.

Potteries were operated by three and four generations of the same family. The principles and problems of the potter's life were similar to those of a carpenter or blacksmith—only materials and equipment were different. Often the potter mas part farmer or tradesman. Usually, the red firing clay was baked at a comparatively low temperature so that the ware was porous and easily broken. Glazes were lead or a mixture of lead, flint and clay. Workshops were fitted with a wheel and a kiln. Near by was a clay pit with a paddle turned by a mule or horse for mixing. In most cases, ware was thrown on the wheel but occasionally it was pressed into or over moulds of fired clay or wood. Often pieces were decorated with quaint designs, mottoes or patriotic inscriptions. The drawing was childlike, the craftsmanship varied.

Decoration was done in various ways. In one method, slip (liquid clay) of a different colour was painted on by means of a brush or slip cup. This was called "slip painting." Sometimes a piece was partially or completely covered by slip and later, when the piece was "leather-hard," the design was scratched through the slip. This method was known as "sgraffito." At other times a design was cut or scratched into the clay without the coating of slip. Such objects as churns, crocks, pitchers, plates and toys were made. The colours mere terra-cotta, white, dark brown and yellow, with touches of green and blue. Often the ware was distributed by boat, especially throughout the Ohio and Mississippi valleys as far south as New Orleans. At other times it was sold in local stores or peddled from door to door. Some pieces are valuable historically because important events were recorded and dated. Examples of this ware can be found both in museums and in private collections. One of the best displays is in the Pennsylvania museum in Philadelphia.

The term "pioneer" potter refers more to a point of view or a stage of development than to chronology During the colonization period, pottery enterprises spread. In each case, the simplest use of local clays made into utensils was the most logical beginning.

By the early 17th century, many pioneer potteries were established, though the exact date and location of the first potter is not known. In 1641, John Pride was working in Salem, Massachusetts. There are indications that potteries were in Jamestown, Virginia, at the time of Captain John Smith and it is known that as early as 1650 several potteries had been established in Virginia. It appears that in 1684, a pottery was functioning in Burlington, New Jersey. Dr. Daniel Coxe of London, once governor of New Jersey, caused the pottery to be built. In eastern Pennsylvania, Germans settled as early as 1735, then spread southward and westward. Beginning about 1750, over 11j potteries were recorded in eastern Pennsylvania alone, making colourful slip-painted and sgraffito ware according to the German tradition. All were small. The Bell pottery of Waynesboro boasted six wheels. It was considered large. Peter Craven, the first of the Jugtown potters in North Carolina, is said to have come from Staffordshire, England, about 1750. From that time to the present date Jugtown potters have supplied the needs of that community. The ware is shaped on the wheel and glazed with simple glazes. The first pottery known west of the Alleghenies was built at Morgantown, West Virginia, by Foulke, about 1784, and continued until 1890 William McFarland went from Kentucky to Losantiville, later called Cincinnati, and many others followed to various parts of Ohio, Indiana, Illinois, Minnesota, Missouri and farther west. The Moravians were established in North Carolina about 1840. They were the same race and religion as the German settlers of Pennsylvania. Their ware was similar. One potter was named Brother Aust. He must have been successful because the authorities of the colonies complained that people came from a radius of 50 to 60mi. to buy. He was ordered to discontinue sales to outsiders "on account of the crowd it draws."

Refinement of Ware.—As communities became more estabfished and there were time and money for more than bare essentials, pottery began to leave the pioneer stage. This took place as a gradual natural growth, affected tremendously by the development of the machine age and greater use of available scientific knowledge. These changes brought about increased refinement of clays, more expert workmanship, higher fire--effecting harder bodies and glazes—mould production, improved machinery and new decorative processes. Thus, generally speaking, one may say that pottery began with pioneer ware—soft, crude and red—and progressed by successive steps through Rockingham ware to a gray stoneware often glazed with salt, and on to white china and porcelain.

During the early part of the 18th century potteries sprang up in many places and great development followed. Two families, headed by John Remmey and William and Peter Crolius, established themselves at "Pot Baker's Hill" or "Potters' Hill," New York city, in 1745. The two families worked and lived as neighbours for several generations. Both families included members influential in public life. Connecticut, the birthplace of the beanpot, led in quantity production of poftery and earthenware from 1771 to 1850. In 1793, Captain John Norton, who had learned his trade in Litchfield, Connecticut, founded a pottery in Bennington, Vermont. It functioned over a century. The ware of this period was glazed in several ways; one was by throwing salt into the fire so it would volatilize and coat the piece with sodium silicate, thus making what is known as "salt glaze ware." In a second method, a stoneware clay was coated with Albany slip, a low-burning red clay. By firing the coated piece to a high temperature, the slip melted into a beautiful brown glaze.

Beginning of White Ware.—Next came interest in a whiter ware. During the last part of the 17th century and throughout the 18th, England, France and Germany were striving to produce ware equal to porcelains from China. In the Bodleian Library at Oxford an old record indicates that "white Chiney Ware" was made at the pottery established by Dr. Daniel Coxe near Burlington, New Jersey. It may have been the first white ware made in the United States. In 1745, William Cookworthy (*q.v.*), an important potter of England, wrote referring to a "china earth" discovered in Virginia. He said, "I have lately with me the person who hath discovered the china earth. He had samples of the china ware of their making with him, which were, I think, equal to the Asiatic. 'Twas found in the back of Virginia. He has gone for a cargo of it, having bought the whole country from the Indians." Some authorities believe the samples referred to were made in the United States; others think they were made in England from clay imported into England from the United States. In a patent taken out in 1774 by Edward Heylyn and Thomas Frye of the Bow Pottery in England for the making of "china ware" it was stated that the material was "an earth, the product of the Chirokee nation in America, called by the natives 'Unaker'." Samples found at the Wedgewood factory and tested by William Burton proved that "Unaker" was a china clay.

During the 18th century, after Philadelphia had become the social capital of the United States, there was a demand for better ceramic wares to supply the needs of a well-to-do class. With this background, more refined ware began to succeed. In 1765, Josiah Wedgewood was worried because potteries were being established in the American colonies. Referring to the colonial market, he wrote, "We cannot make anything too rich and costly."

For about 100 years, potters tried to make chinaware before they were able to record commercial success. During that time, numerous fortunes were lost. Many of these efforts took place in or near Philadelphia. Alexander Trotter was mentioned in 1808 as a leading manufacturer of Queensware (earthenware). Another Philadelphia potter was Abraham Miller, member of a family of potters, an expert modeller, member of the State senate, and a leading member of the Franklin Institute. In 1824, he exhibited a silver lustre pitcher and a specimen of porcelain. In 1842, he showed decorated plates, vases and ornamental flower pots. By the time he died in 1858, excellent American porcelain was being made, equal in quality to the best produced in England. Around 1850, American potters began to succeed in producing a vitrified earthenware and parian—a hard, unglazed white ware, which required fewer skilled workmen and presented no problems with glaze and colour. Later, a modified parian appeared as a very thinly cast glazed ware. It was called Belleek. Although small amounts of high grade white ware had been made, it was not until about 1825 that porcelain was manufactured in any quantity. About 1820, William E. Tucker, a member of a Quaker family of educators in Philadelphia, undertook to decorate imported white ware by the overglazed process. Soon he became interested in making his own ware for decorating. The beginnings were crude, but several medals were earned. In 182 j, he succeeded in making hard-paste porcelain. Eventually, there were financial struggles and changes in partnerships until, in 1832, Joseph Hemphill joined the firm, bringing financial backing and a great capacity for business. Soon Tucker died and Hemphill imported capable workmen from Europe. As a result, the firm experienced a period of producing excellent ware of expert workmanship and a better quality of design.

Moulds for Quantity **Production.**—In 1859, the demand for cheaper domestic ware had grown sufficiently to enable potters to establish themselves on a sounder financial basis. Mould making was being carried on as a trade by men who made and sold moulds, though exclusive rights were not yet practised. Small potteries often purchased their moulds from a mould maker or a defunct potter. Probably no one person contributed as much practical information toward this change in production as William Bloor. In Trenton, New Jersey, from 1854 to 1859, he was associated with James Taylor and Henry Speeler who established the first pottery factory in Trenton in 1852. In 1856, a medal was awarded the firm by the Franklin Institute of Philadelphia. In 1859, he went to East Liverpool from whence he had come in 1854. There, in 1860, he manufactured on a commercial scale the first white ware to be made in East Liverpool, Ohio, now one of the great pottery centres of the world. The ware was translucent and well vitrified. Most of it was made in moulds and skilfully decorated with designs painted by expert workmen. This success had a great influence on the production of moderately priced white ware. In 1865 he returned to Trenton, which at that time was America's pottery centre and helped establish the firm which later became the Eutreria pottery where a high quality Belleek china and fine ivory porcelain were made.

In 1870, he went back to East Liverpool where he supplied the potteries with materials from mines he had discovered and owned in New England, Maryland and Missouri. Later, he helped establish the Dresden pottery of which firm he was a member when he died in 1877. In the *Journal of the American Ceramic Society* it is stated of Bloor: "Giving information freely to competitors in Trenton and East Liverpool, the transition from yellow ware to white ware was quickly made under Bloor's tutelage. Americans were ready and able to purchase white ware made on Bloor's formulas and by Bloor's methods. Thus the white dinnerware industry of Trenton and East Liverpool was started by Mr. Bloor."

One pioneer in the manufacture of pottery in Trenton, New Jersey, told how he had travelled over the States of New York, Pennsylvania, Delaware and Ohio, searching for the best place to manufacture pottery. He had chosen Trenton because it was between the two great markets—New York and Philadelphia—and because the section was healthy, abounding with fine clay and convenient for the collection of other materials by canal or river.

Referring to development during a few years following 1861, he wrote: "If the business increases at the same ratio, Trenton is destined to be the Staffordshire of America and in 50 years hence but little ware will need to be imported." In 1890, Mrs. Benjamin Harrison wished to buy domestic tableware for the White House but could find nothing suitable. It was not until 1918 that Lenox, Incorporated, Trenton, New Jersey, supplied the White House with the first American-made table service.

Imported Workmen. — Far-sighted manufacturers often brought skilled workmen from France, England and Germany to improve the quality of their ware. About 1835, Joseph Hemphill of Philadelphia imported experts from Sevres who produced pieces more or less copies of Sevres ware. In 1843, Julius Norton, the third generation of potters at Bennington, Vermont, brought over John Harrison, modeller from Copeland; he brought many of the latest moulds and designs being used in England. About the middle of the 19th century, Charles Cartlidge and Company of Green Point, New York, brought Josiah Jones from the Staffordshire pottery in England. He was a designer, modeller and ceramist. Soon after his arrival he imported Elijah Tatler, a decorator of great ability. In 1853, the firm sent ware to the International exhibit in New York. It included tea and dinner sets in bone china, as well as earthenware and statuettes, modelled by Jones. There are good specimens of these in the Metropolitan museum and the Pennsylvania museum.

Handicaps. — From the beginning, unfamiliarity with new materials was a definite handicap to the potter. One who had been a master workman in the old country might find himself bankrupt in the new country before he became accustomed to materials. Since there was little scientific ceramic knowledge he had to discover correct materials and proportions by the trial and error method before his funds were depleted. While the problems of new materials were being overcome, and better ware was being developed, a more sophisticated social life was evolving so that the potter had to deal with a public prejudice against American-made ware. Sometimes the cause of the prejudice was due to the fact that American-made ware was more crude, but often people considered it elegant to use imported ware. The European manufacturers encouraged that feeling. At times there was sabotage among the American workmen, sympathetic with the mother country. At other times the markets were temporarily flooded with ware to be sold at a price the local manufacturer could not meet, so that the potter had to go out of business or move to a section where there was less competition.

Toward the end of the 19th century, there were other handicaps. Both in Europe and the United States, emphasis had been placed upon improved techniques for mass production at the expense of sound design. As a result, many pieces were created primarily as demonstration of technical skill with little thought of good design. Eventually there was a reaction, especially in Europe where simpler and better design began to replace the extravagantly ornate. The designers in the United States still clung to the type of design traditional with the designers, who were usually old countrymen. Conservatism and prejudice against ware made in the United States lasted well into the 20th century.

Ceramics Becomes Scientific. — Up to the end of the 19th century, ceramic information had been guarded and handed on from generation to generation. New discoveries were kept secret and experimentation was carried on by rule of thumb. While working on the minerals from 1884 to 1894, Edward Orton, Jr., discovered a dearth of literature concerning the science of ceramics. Being a public spirited. practical man, he succeeded in getting sufficient support for a law authorizing the establishment of a ceramic department at Ohio State university in Columbus in 1894. It was the first school in the United States for the scientific study of ceramic engineering. Not long after that the New York State College of Ceramics was established at Alfred, New York, with Charles F. Binns as its director. Dr. Binns had had life-long acquaintance with ceramics since his father was a factory superintendent in England and he himself was for some time superintendent in the Royal Porcelain Works at Worcester, England. Soon other States had established similar departments. At these schools scientific methods were developed for compounding efficient bodies and glazes and for solving problems encountered by the potters. The ceramists turned more and more to the fields of chemistry, physics, geology, mineralogy, microscopy and other sciences to discover what those fields might contribute.

Under the leadership of Edward Orton, Jr., the American Ceramic Society was founded in 1898 to co-ordinate ceramic interests and further progress. Its work was carried on by meetings, by collecting, publishing, and distributing available ceramic information and by encouraging research. Thus ceramic knowledge became accumulative so that early in the 20th century a person successfully completing a four-year ceramic course had the opportunity of a better understanding of the science of ceramics than a master under the old system could have had after working a lifetime.

As trained ceramists were gradually absorbed into the potteries, they greatly influenced production — making better-wearing bodies and glazes and developing cheaper factory methods. However, because emphasis was put on science and technique, at the expense of good design in form, colour and decoration, the country was soon producing ware which was of the best technically but the designs were often copies of European patterns or a conglomeration of patterns produced under a variety of conditions. As a result, the ever-developing taste of the American public continued to be prejudiced in favour of imported ware, but this time for a different reason. It was no longer the quality of the ware or workmanship which was responsible for the prejudice but instead lack of beauty and distinction and the absence of that intangible quality which comes from the hand of a skilled creator but is lost by one who copies — regardless of how accurately the work is done.

Pottery and Porcelain as an **Art.**—About the middle of the 19th century, European women were interested in doing over-glaze decorating. The idea spread to America where it became fashionable for women to go to Europe to study the subject. In 1879. the Cincinnati Pottery Club was formed by a group of women for the purpose of encouraging sound pottery production. They did under- and over-glaze decoration and made porcelain. Much credit is due this pioneer work. In 1891 the National Ceramic Association was founded. Ten thousand women were actively engaged in the United States working at ceramics. Five thousand earned a living doing over-glaze painting. The association was organized in Chicago where there were 1,000 pottery decorators. The object was to advance the art and secure the finest possible exhibition for the World's Fair. In 1892 Mrs. S. S. Frackelton of Milwaukee, Wisconsin, organized the "National League of Mineral Painters." Its aim was to bring into closer relationship the over-glaze painters in order to define lines of study and to aid in the development of a national school of ceramic art. At one time the membership became as high as 500 women. They exhibited in many places and took part in international expositions, often winning recognition for exceptional achievement. Later, Mrs. Frackelton did excellent work with salt glaze in an effort to use a humble material as a medium for artistic expression. She received honours at home and abroad. Many of the decorators became interested in creating the forms they were to decorate. Some of those creating the forms continued to expand until a business or profession was established. As a result of the activity of the Cincinnati Pottery Club, the Rookwood pottery developed. The Pewabic pottery was established by Mrs. Stratton in Detroit. Mr. and Mrs. A. Robineau in Syracuse, New York, turned to porcelain, carved decoration, crystalline and other glazes. Also, they were in charge of a ceramic department at the University of Syracuse. Charles F. Binns in his work at the New York State College of Ceramics lent valuable support to the expression of ceramics as an art. Besides helping to organize the science of ceramics, he made excellent stone ware of the quality of the Chinese. He knew factory methods and mas an expert craftsman who often explored the historical background of ceramics. Because of his broad interests and high standards, he was an inspiring teacher in the field of ceramic art. Many excellent ceramic artists were trained by him and valuable research was done under his direction.

It was only natural that the increased interest in the art expression of ceramics should result in new scientific developments among the artists and improved design for individual and manufactured ware. To study and further these ends, a section of the American Ceramic Society was organized which was known as the Art Division of the American Ceramic Society. Work of the division is carried on through regular meetings, exhibitions and research reports and other articles published in the *Journal of the American Ceramic Society*. The most important regular exhibition is organized annually at the Syracuse Museum of Fine Art as a Robineau Memorial Ceramic Exhibition. It was started in 1932 by Ann Wetherill Olmstead, director of the museum. Because of Miss Olmstead's work, American potters were invited to send an exhibition to museums in the Scandinavian countries, to England. and to many important museums and galleries of the United States. As a result of various efforts the quality and appearance of work done by studio potters improved greatly during the first half of the 20th century and the design of ware for reproduction methods is given increasing attention.

After about 150 years of technical, financial and artistic struggle, it is encouraging to find that in 1940, the best of the United States pottery and porcelain is as good in quality and design as any made. Ceramic artists in many parts of the country work as designers, studio potters and teachers; the number increases steadily and standards constantly improve as the general public learns to understand the beauty of fine ceramics.

Many States have tax-supported ceramic schools. Art schools advocating better designs for industrial use encourage the ceramic department to study mass production possibilities and methods along with the craft of the potter. Pottery work is taken more and more seriously in public schools. The national, State and local governments are sponsoring the making of pottery as an art expression. A U.S. ceramic experiment station is in the Tennessee Valley.

See also NORTH AMERICA: *Prehistory and Archaeology.*

BIBLIOGRAPHY.—*Books,* John Ramsay, *American Potters and Pottery* (1939); Edwin Atlee Barber, *Tulip Ware of Pennsylvania-German Potters* (1903); Jennie Young, *The Ceramic Art (1873)*; *Magazines,* Charles Fergus Binns, "Pottery in America," *The American Magazine of Art* (Feb. 1916); Frederick H. Rhead, "America as a Ceramic Art Center," chap. I, *Fine Arts Journal* (April 1910); Evelyn Marie Stuart, "America as a Ceramic Art Center," chap. II, *Fine Arts Journal* (May 1910); Clara Ruge, "American Ceramics—% Brief Review of Progress," *International Studio* (Vol. 28, Mar.–June 1906 pp. supp. 21–29), many numbers of the magazines: *Antique: Design,* November numbers; Bulletin *of American Ceramic Society.* (M. M. F.)

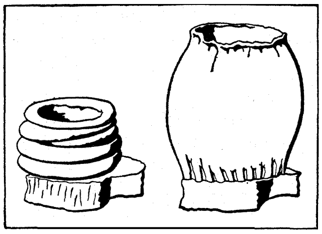
POTTERY, PRIMITIVE. Receptacles of some kind are essential to man, however primitive, and are made of basketry, skins, gourds and other suitable natural objects. But over all these pottery has an advantage. for it can be brought into contact with fire and not be destroyed, and it is therefore valuable for cooking purposes.

Pottery-making is not universal, however; partly because its construction is not easily carried on under certain cultural conditions, *e.g.,* a nomadic life; partly because it depends upon suitable materials being available, though sometimes potters obtain their clay from other districts. It is absent from large regions of America, and in certain islands of the west Pacific has become a lost art. The knowledge of pottery-making was, at one time, believed to mark a stage in the cultural development of mankind, but its presence among such peoples as the Andamanese, Eskimo, Bushmen and Hottentots: and its absence among the advanced Polynesians, make this questionable.

The manufacture of pottery falls into five stages: preparing the *body* or raw material; shaping the pot; drying and firing it; decorating it; and varnishing or in some other way rendering it non-porous. This last is often lacking in the pot-making of primitive peoples, but the other four processes are found in the manufacture of the simplest wares.

As regards the raw material, it seems that the clay is frequently dug and seasoned for a while before using. Clays vary very greatly. Those which are highly plastic and hold the water, though convenient for working. are liable through excessive shrinkage to crack in the drying or firing of the pot and must therefore be ***opened*** by mixing them with non-plastic materials. Sand is often used to this end, or carbonaceous materials such as chopped grass, cinders, dried cow or donkey dung; frequently old potsherds are ground up for this purpose. In mixing the *body,* the proportion of clap, *opener* and water necessarily varies greatly and is judged empirically by the potter.

Shaping. — The body having been prepared, the next stage is the shaping. There are three main ways of doing this: by hand, with the aid of a few simple implements; by moulding; and by throwing on the potter's wheel. Of these, the first is by far the most common. There are two hand techniques — modelled and coiled. The simplest way in which a pot is modelled is that used by the women of the Baronga in South Africa. Having kneaded the body into a very soft ball, the woman "makes a hole in it, which she enlarges by degrees, hollowing it out and gradually giving it the shape she wishes. . . . It is astonishing to see the beautiful symmetry of these utensils." (H. Junod, *The Life of a South African Tribe.)* If the pot is to be a big one, the initial lump of clay may not be enough and more is added to build up the walls of the vessel. Frequently the pot is modelled in parts, which are then welded together.



FROM DALE & SMITH, "THE ILA SPEAKING PEOPLE OF NORTHERN RHODESIA" (MACMILLAN)

FIG. 1.—STAGES IN PRIMITIVE POTTERY PRODUCTION

Left, rings of clay piled up. Right, walls completed by scraping the clay upwards

In the coiling technique, the raw material is rolled out into a slender rope which is coiled upon itself (fig. 1).

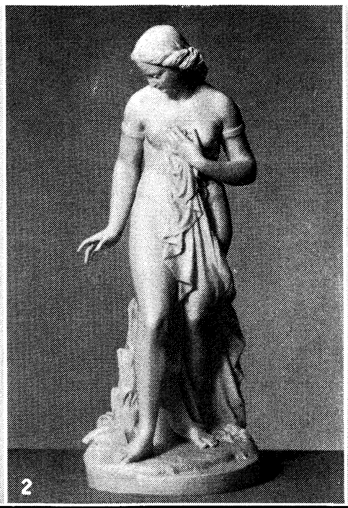
The coils are carefully worked together with the fingers and the unevennesses smoothed away, so that, when the pot is finished, no trace of them is visible except occasionally in faint ridges on the inner surface. The modelled and coiled techniques may be combined; the base of the pot is modelled from a lump and the coils built up on this.

Certain tribes used baskets for moulds. These were subsequently burned in the firing. A similar method is used by shaping the belly of the pot over a ring of vegetable fibre, then adding the neck and base. In these examples a mould is destroyed with every pot made. More advanced is the method by which one mould is made to serve several times. Among the Hausas of Nigeria, a pot is inverted and over this a sheet of clay is spread so as to form a bell-like dome. This is then removed from the mould and the shoulders and neck modelled by hand (fig. 2). A moulded pot may be made in two or more sections, then joined.

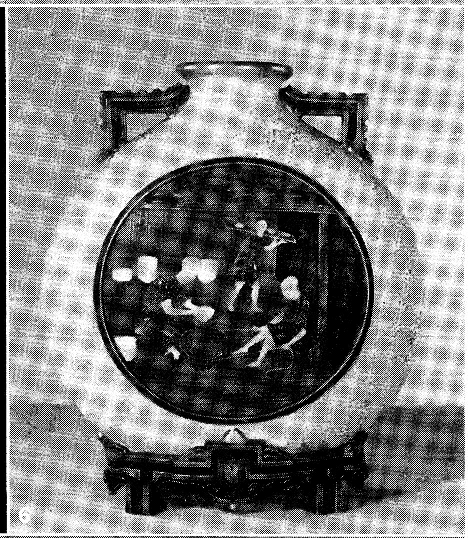
Shaping a pot by means of throwing on the wheel is little known among primitive peoples, because primitive potters can make by hand pots which rival those thrown and because it takes years to learn to throw expertly.

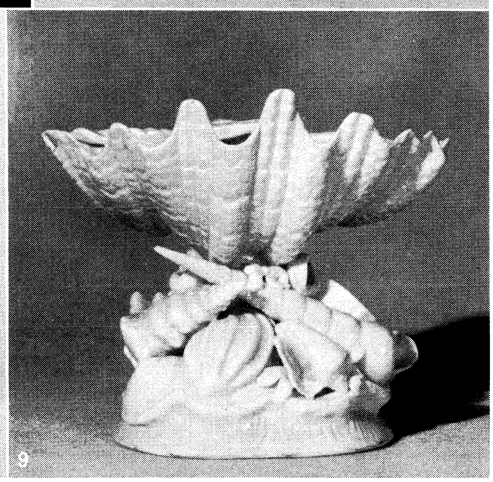
Drying and Firing.—When a pot is finally shaped, it is necessary to render the clay hard by firing it. The material of which a vessel is composed contains a certain amount of free water which can be removed by leaving it to dry or be sun-baked for a time; but it also contains a quantity of combined water which is only liberated at a temperature of from 350°–400° C. If only sun-baked, the vessel when filled with water would absorb this and after a short while collapse into a shapeless mass. But when the combined water has been liberated the clay is completely decomposed; it is impossible for it to become malleable again and it will hold water safely. Except, therefore, for certain pots which are destined only to contain grain and other dry goods, all vessels must be fired.

After being shaped the pot is set aside to dry for some hours, usually where there is a free current of air. Except in a few cases, ware is fired but once. Usually the firing is done in the open. The pyre is carefully built and the pots stacked so that the heat may circulate freely. A genuine kiln has only been recorded from the region of the Lower Congo. It seems to be a beehive shaped structure. The more common primitive practice is to bake the ware in a hole in the ground. The "oven" is fairly elaborate, for charcoal is used and openings are therefore cut through the soil to the chamber that bellows may be employed to sustain the





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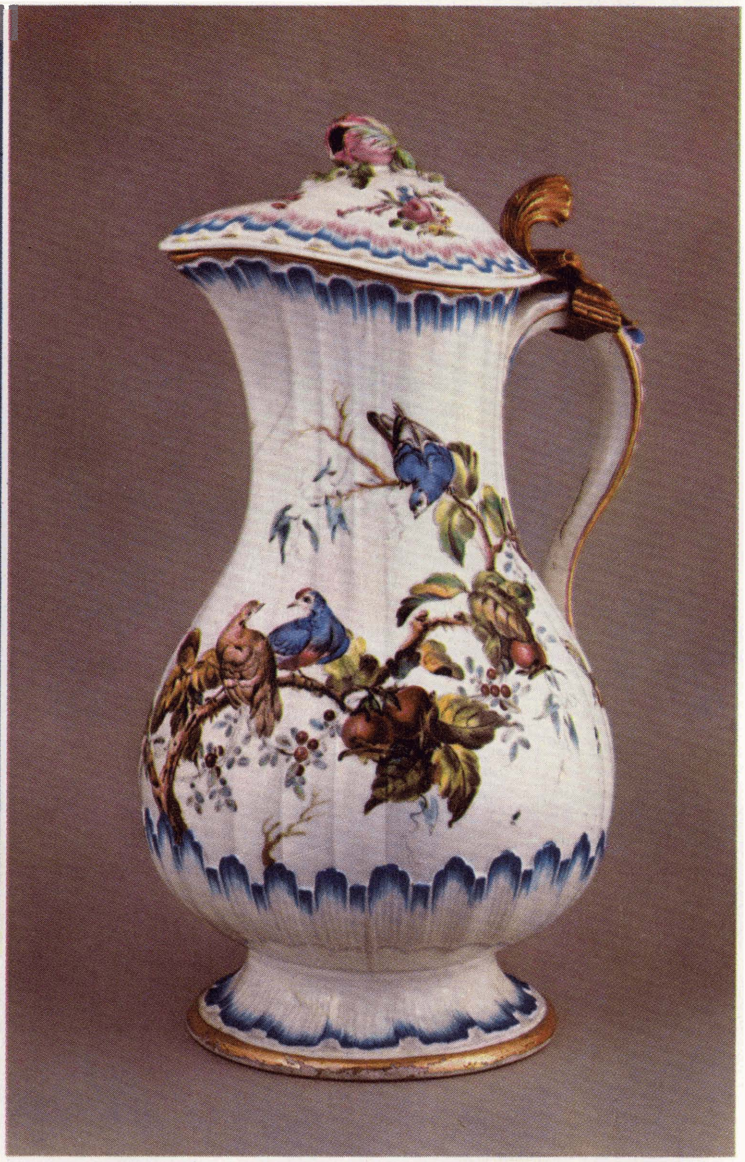
19TH-CENTURY WARES

1. Dish by William de Morgan, probably painted at Merton abbey, 1882–88
2. Figure of Musidora, model by W. Theed, in Parian porcelain. Copeland (Stoke-on-Trent, Staffordshire), 1857
3. Dish painted by Emile Lessore. Earthenware. Wedgwood (Etruria, Staffordshire), about 1861
4. Pilgrim flask with *pâte-sur-pâte* (paste-over-paste) decoration by Marc Louis Solon. Minton (Stoke-on-Trent), 1875
5. Standing dish, part of a Shakespeare service, with figures in Parian porcelain representing Bottom and Tinker from *A Midsummer Night's Dream*. Made by Kerr & Binns, designed by R. W. Binns. figures modelled by W. B. Kirk, painted medallions by Thomas Bott. Worcester, about 1853
6. Pilgrim flask showing Japanese influence, probably modelled by James Hadley. Worcester, about 1872
7. Duplicate, made in 1876, of a teapot belonging to a service made about 1865. Painting by T. Callowhill, gilding and jewelling by S. Ranford. Worcester
8. Vase of salt-glazed stoneware, decoration probably by Edwin Martin. Martin Brothers (Southall, Middlesex), 1903
9. Shell ornament probably modelled by R. W. Armstrong. D. MacBirney & Co. Beleek, Ire., about 1868



BY COURTESY OF (TOP LEFT) THE TRUSTEES OF THE BRITISH MUSEUM, (OTHERS) VICTORIA AND ALBERT MUSEUM

FRENCH AND
ITALIAN PORCELAIN

Top left: **Dootor** Balcordo from the ***commedia dell'arte.*** **Itallan.** Capo-di-Monte (near **Naples).** About 1750

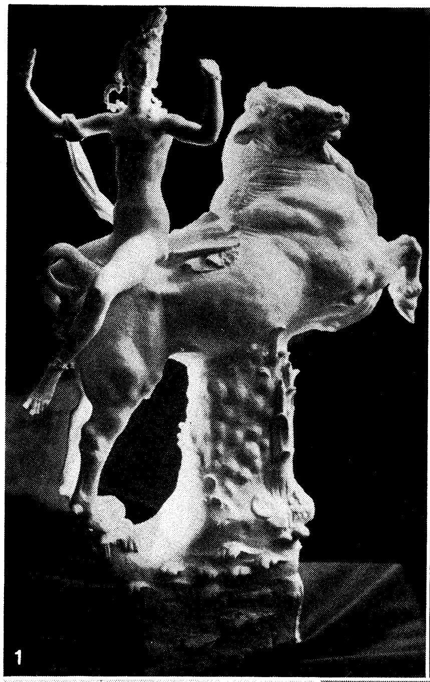
Top right: Jug and cover decorated wIth birds and **frult,** the cover wIth ormolu (simulated **gold) hinge** and thumb **grlp.** Frenoh. Mennecy. **Mld-18th** century

Bottom: ***Cachepot*** with a yellow ground decorated In the style of Sakalda Kaklemon of **Arlta** (Japan) In reserved panels. Ormolu mounts of the period of Louis **Quinze.** Frenoh. Chantllly. About 1730

FRENCH AND ENGLISH PORCELAIN

Top: Sèvres *cabaret* painted in panels with birds in a landscape by Aloncle against a celeste blue ground. French. Date letter for 1764
Bottom left: Pedlar. English. Bow. About 1753
Bottom centre: Silver-pattern dish painted with exotic birds. English. Chelsea; gold anchor period. About 1760
Bottom right: Urania, from a set of the Muses By the *Muses Modeller.* English. Bow. About 1750

POTTERY AND PORCELAIN



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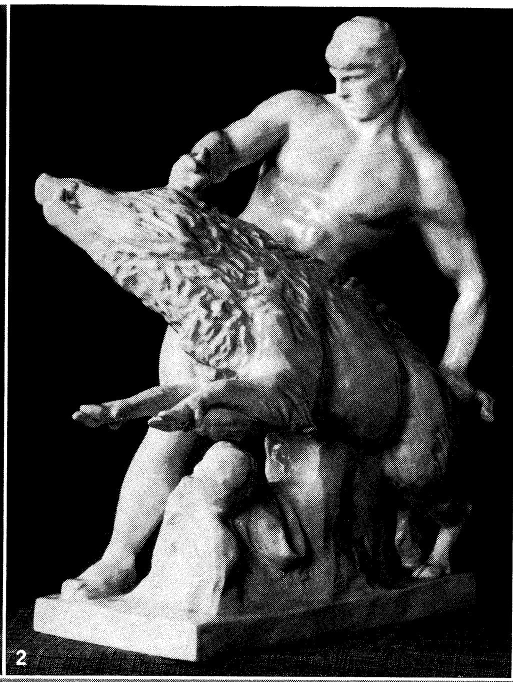

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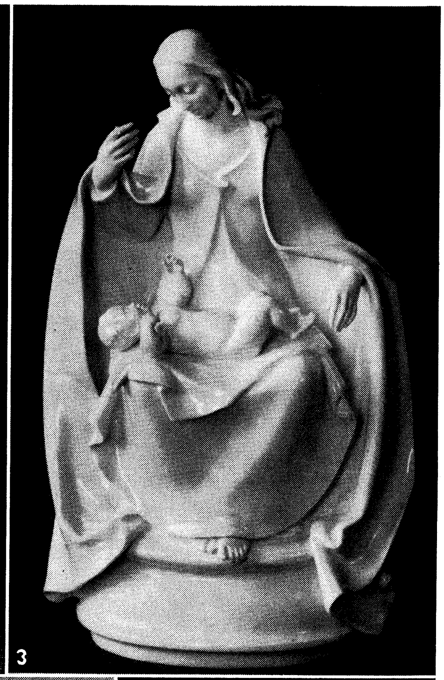

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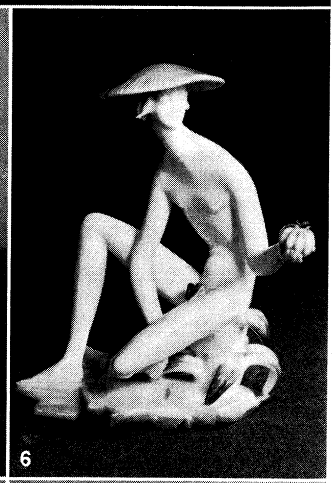

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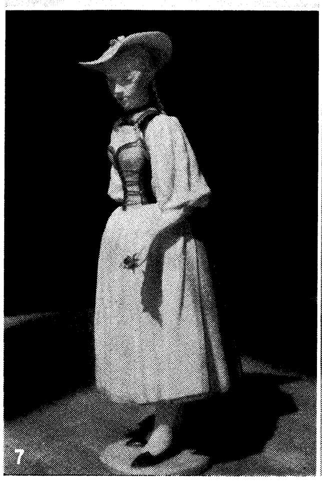

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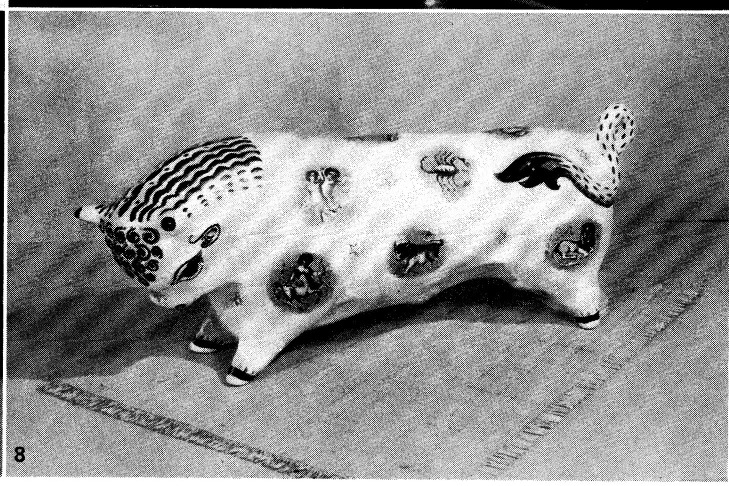

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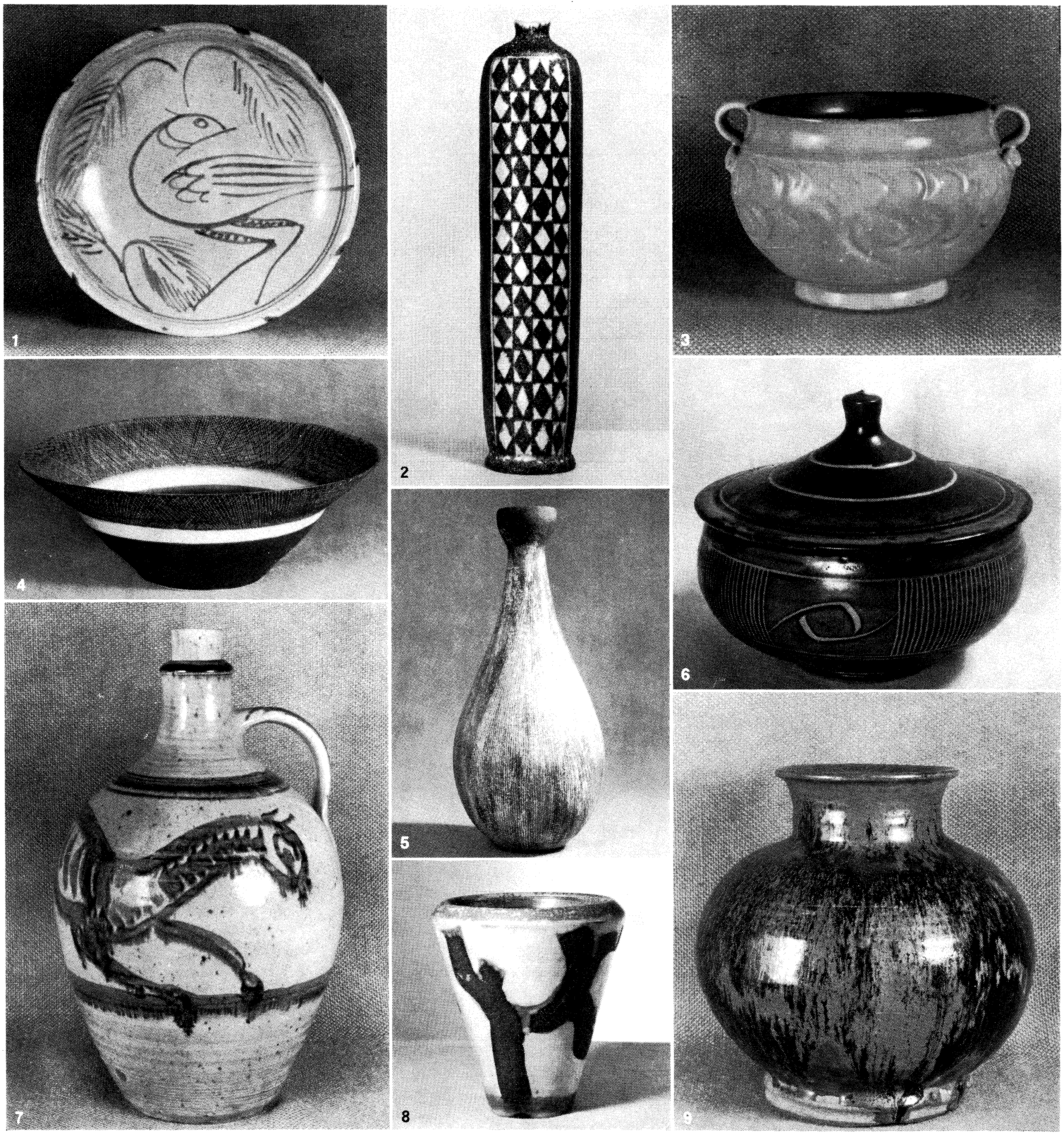
20TH-CENTURY FACTORY PRODUCTION

1. Figure of Europa by Paul Scheurich. German porcelain. Meissen, 1931
2. Hercules and the Erymanthean boar. German porcelain. Meissen, 1922
3. Madonna and child by A. Nick. German porcelain. Meissen, 1932
4. Portrait bust by Emil Paul Borner. German porcelain. Meissen, 1928
5. Urn made for presentation to Sir Winston Churchill showing a view of Worcester cathedral painted by Harry Davis. English porcelain. Worcester, about 1951
6. Figure entitled "Malaye" by Mathilde Saksch-Szendro. German porcelain. Wiener Porzellan Manufaktur, 1925
7. Figure of a young Bernese woman by Resl Lechner. German porcelain. Nymphenburg. Contemporary
8. "Taurus" by Arnold Machin. English earthenware. Wedgwood, 1945
9. "Augsburg Patrician" by Resl Lechner. German porcelain. Nymphenburs. Contemporary



BY COURTESY OF (1–5 7–9) VICTORIA AND ALBERT MUSEUM, (6) BERNARD LEACH

20TH-CENTURY STUDIO POTTERY

1. Stoneware dish by Michael Cardew. English. Wenford Bridge, Cornwall, 1950
2. Vase by Guido Gambone. Italian. Florence, about 1954
3. Stoneware bowl by Charles Vyse. English. London, about 1950
4. Porcelain bowl by Lucy Rie. English. London, about 1955
5. Stoneware vase by Hans Coper. English. London, about 1954
6. Stoneware covered bowl by Bernard Leach. English. St. Ives, Cornwall, 1950
7. Cider jar by Michael Cardew. English. Wenford Bridge, Cornwall, 1950
8. Vase by Wilhelm Kåge. Swedish. Gustavsberg, 1953
9. Stoneware vase by William Staite Murray. English, about 1935

ENGLISH
PORCELAIN

Left: Figure of a woman, perhaps from the Italian comedy. Chelsea. About 1755
Bottom: "Leda on a Dolphin." Chelsea. About 1755

ENGLISH

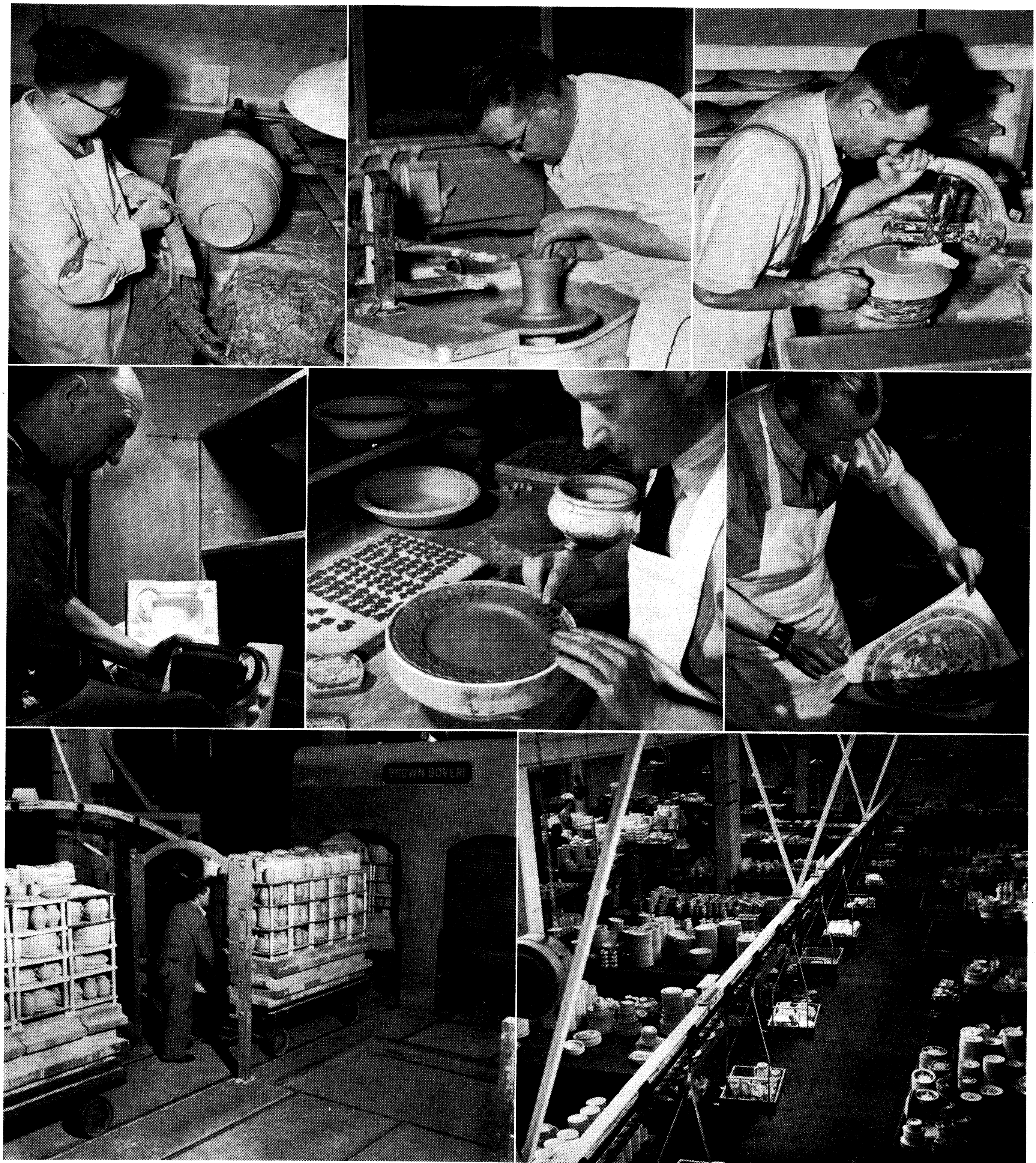
POTTERY

AND

PORCELAIN

Right: Earthenware figures decorated with coloured glazes. Made by John Astbury in Staffordshire about 1730
Bottom: "Earth" and "Water" from a set of the "Elements" mounted in ormolu. Modelled by "Mr. Tebo." Bow. About 1760. A rare example of English figures with the original mounts

BY COURTESY OF (RIGHT) WILLIAM ROCKHILL NELSON GALLERY OF ART, KANSAS CITY, (BOTTOM) HASTINGS MUSEUM AND ART GALLERY



BY COURTESY OF JOSIAH WEDGWOOD & SONS LTD., BARLASTON, STAFFORDSHIRE

INDUSTRIAL POTTERY MANUFACTURE

Top left: Turning. Lathe turning is used to reduce the thickness of the clay, to shape the piece evenly and symmetrically and to cut in ornamentation

Top centre: Throwing, or shaping, on a potter's wheei, a method which has remained essentially unchanged for 5,000 years

Top right: The jigger, a machine which automatically shapes plates and dishes

Centre left: Moulding. Articles which cannot be formed on the wheei are frequently cast in piaster of paris moulds

Centre: Decoration. The application of small moulded ornament to the ledge of a plate

Centre right: Transfer printing. Pottery is often decorated by transfers taken from an engraved copper plate

Bottom left: Firing. A modern tunnel kiln in operation

Bottom right: Storage. A view of the Wedgwood warehouse, England, showing the assembly of services

BY COURTESY OF (1, 5, 7, 9) THE ART INSTITUTE OF CHICAGO, (2, 4, 6, 8) BROOKLYN MUSEUM, (3) THE NEW YORK HISTORICAL SOCIETY

EARLY U.S. POTTERY

1. Plate with typical early decoration of painted, or trailed, slip (liquid clay). New England, 18th or 19th century
2. Pair of red earthenware pie plates with sgraffito decoration, the design scratched through the slip. Pennsylvania German style; signed by David Spinner, early 19th century
3. Stoneware churn by Clarkson Crolius, Sr. New York city, about 1800
4. Sgraffito bowl of red earthenware. Pennsylvania, dated 1775
5. Earthenware cake mould with slip decoration. Probably Pennsylvania, about 1810
6. Glazed stoneware jug with incised design of eagle by Daniel Goodale. Hartford, Conn., 1818–30
7. Stoneware jar by George Muk. Bladensburg, Md., 1848
8. Stoneware jar. Morgan Pottery, Cheesequake, N.J., about 1775
9. Water cooler of salt-glazed stoneware with sgraffito decoration of eagle by Martin Crafts. Nashua, N.H., 1838–52

NOTE: THE PHOTOGRAPHS ON THIS AND THE FOLLOWING PAGES WERE CHOSEN WITH THE ASSISTANCE OF MEYRIC R. ROGERS. THE ART INSTITUTE OF CHICAGO. MANY OF THE PHOTOGRAPHS APPEAR IN HIS BOOK "AMERICAN INTERIOR DESIGN," NORTON, 1947

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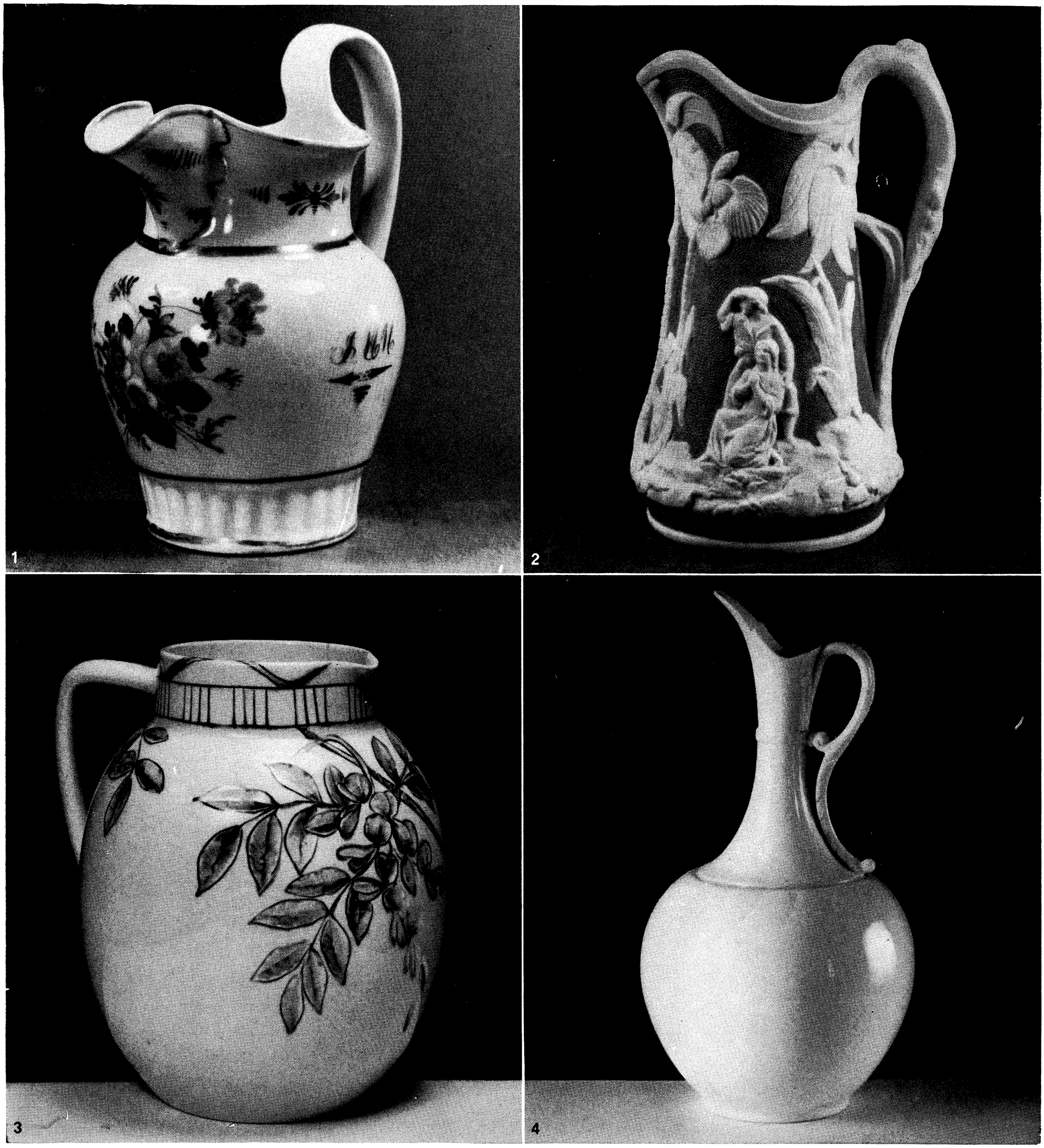
18TH- AND 19TH-CENTURY U.S. POTTERY AND PORCELAIN

1. Sauceboat of white earthenware with underglaze blue. Philadelphia, 1769–72
2. Porcelain vase by Henry Mead. New York, 1816
3. Pitcher of yellow earthenware with Rockingham glaze. Salamander works, Woodbridge, N.J., 1845
4. Redware pitcher, slip covered with green and manganese mottled decoration. Attributed to Bell pottery, Strasburg, Va., 1843–1900
5. Pair of earthenware plates with blue transfer decoration of American eagle and shield. Probably Jersey City Pottery company, 1840–50
6. Meat or vegetable dish. Earthenware with sgraffito "tulip and bird" design, a favourite motif of Pennsylvania potters. About 1830
7. Figure of a poodle in yellow ware with mottled brown glaze. Probably Bennington, Vt., about 1849–57
8. Cup and saucer by Ceramic Art company, Trenton, N.J., about 1889



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U.S. 19TH-CENTURY POTTERY AND PORCELAIN

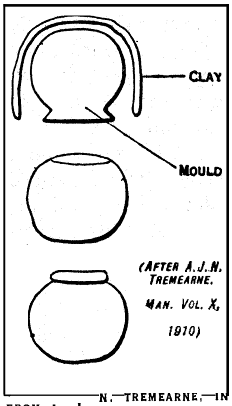
1. Porcelain pitcher by William E. Tucker. Philadelphia, about 1830
2. Pitcher of parian ware, unglazed soft porcelain. Design in moulded relief. United States pottery, Bennington, Vt., 1852–58
3. Incised earthenware pitcher decorated by Laura A. Fry. Rockwood pottery. Cincinnati, O., 1883
4. Vase in the shape of a pitcher, white earthenware, by Joshua Poole. East Liverpool, O., 1888– 98

BY COURTESY OF (1) THE SYRACUSE MUSEUM OF FINE ARTS, (2, 4, 5) THE ART INSTITUTE OF CHICAGO, (3) AMERICAN CERAMIC SOCIETY, (6) LENOX, INC., (7) AMERICAN LIMOGES CHINA COMPANY

20TH-CENTURY U.S. STUDIO AND COMMERCIAL WARE

1. Scarab vase of white porcelain with excised carving by Adelaide A. Robineau (1865–1929)
2. Stoneware vase with blue glaze over white engobe (slip) by Leon Volkmar, 1922
3. Stoneware vase and bowl by Charles F. Binns (1857–1934)
4. Redware bowl by Gertrude and Otto Natzler, about 1945
5. Stoneware vase, mottled white glaze with turquoise rim, by Maija Grotell, about 1945
6. Service plate of fine china, designed by Frank G. Holmes, Lenox, Inc.
7. Set of service ware in "Manhattan" shape by Viktor Schreckengost, American Limoges China company

necessary heat. The time taken for firing varies greatly, from about half-an-hour to two days. Pots which have been fired for only a short time are less durable than others. There is great diversity of shapes and an amazing similarity in wares widely separated from each other in time and space. Some elaborate forms have a utilitarian purpose, others a religious significance, while others appear to be the outcome of the artist's desire to create something beautiful. In many cases, the pots are modelled in imitation of natural or manufactured objects, which before the introduction of ceramics served the people as vessels.



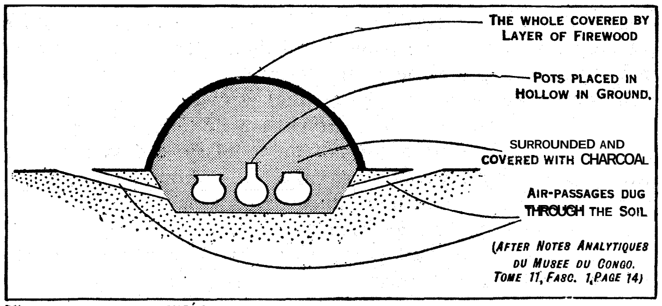
FROM A. J. N. TREMEARNE, IN "MAN"

FIG. 2.— POTTERY-MAKING

1. Clay spread over inverted pot, 2. Clay removed from mould and shaped, 3. New pot with roll of clay for mouth modelling

Decoration and **Colour.**—In most primitive pottery decoration is done by means of incised lines, made with a pointed stick, thumbnail or coil of rope. Sometimes wooden stamps are used or the "beater" with the aid of which the pot is modelled is carved or wrapped about with string and the designs may be but the marks thus left on the surface. Where pots are moulded over baskets, the clay will be decorated by the impress of these. The most usual designs are bands of chevrons or other rectilinear skeuomorphs, though animal and plant, and occasionally human motifs, do occur. To increase the effect,the incisions are often filled with powdered lime or some other substance which shows up against the dark background of the vessel. Less common are ornaments applied to the surface such as knobs, scrolls and figurines. Raised designs are also produced by pressing out the wall of the pot from within. Another method, of restricted distribution, is that of scraping away the surface so as to leave the figures in relief.

The colour of a vessel is to a great extent dependent upon the composition of the body and the method of firing. Of materials present in bodies, iron is usually the only colouring element. This, on being subjected to heat under oxidizing conditions, is changed into a red iron oxide and gives a shade varying from yellow to an orange or red; under reducing conditions producing a colour which ranges from light bluish gray to a deep, sometimes metallic, black. Usually among primitive peoples no effort is



BY COURTESY OF THE MUSÉE DU CONGO

FIG. 3.— DIAGRAM SHOWING PROCESS OF BAKING POTTERY

made to produce certain shades by regulating the conditions of the firing. A dark colour is often the result of a pot's being smoked; this may be an unintentional incident of the firing. but among the Ashanti it is brought about by setting the vessel, while still red-hot from the furnace, on a heap of dry tinder. This it ignites. Water is then poured on and the pile is left smoking. The smoke permeates the heated clay and deposits on and sometimes through it a mixture of finely divided tar and carbon, rendering it non-porous. Decoration by means of slip is occasionally found, but true painted pottery is extremely rare among primitive peoples.

Varnishing. — Fired pots are nearly always porous. They are therefore frequently varnished and this varnish is often decorative as well as useful. Many different methods are employed to treat the suriace with a resin, gum, fat or gelatinous substance. Similar in artistic effect to varnishing but without so great utilitarian value is the practice of polishing or burnishing the ware, but this is only possible where the clay is of a fine body. Though vessels are the most common pottery products of primitive peoples, other things are sometimes made, such as tobacco pipes, drums, toys and figurines.

Sociological and Religious Aspect. — Little attention has as yet been paid by ethnologists to the religious and sociological aspects of pot-making. Generally the craft is confined to one sex, usually the iemale, except where the potter's wheel is used, which is always operated by men. In so far as domestic utensils are naturally matters which concern women it is not strange that they should be the potters, but this does not explain why, in many cases, men are definitely prohibited from potting nor why their very presence during the manufacture is inimical to it. Thus among the Sema Nagas of Assam a man may not even speak to a woman thus engaged nor approach her work. The making of ceramics is often the prerogative of certain families or a certain district and any infringement of this may easily cause trouble. Even where this is not so, certain villages become famous for their wares. Theories oi origins are necessarily speculative, but in evolving them it must not be iorgotten that clay shaped and burnt does not produce a pot. The body must be properly prepared, the vessel properly dried and fired under suitable conditions. The accidental discovery of pottery, thereiore, is not so easy as has sometimes been implied.

BIBLIOGRAPHY.—O. T. Mason, *Woman's Share* in *Primitive Culture*, ch. v (1894) and *The Origins of Invention*, ch. v (1895) ; Handbook to the Horniman Museum, *The Evolution of the Domestic Arts*, part ii (1924) ; Louis Franchet, *La Ceramique Primitive* (1911) ; James R. Partington, *The Origins and Development of Applied Chemistry* (1935).

POTTHAST, AUGUST (1824–1898), German historian, was born at Hoxter on Aug. 13, 1824, and was educated at Paderborn, Münster and Berlin. He assisted G. H. Pertz, the editor of the *Monumenta Germaniae historica*, and edited the *Regesta pontificum romanorum, 1198–1304* (1874–75). From 1874 to 1894 he was librarian of the German Reichstag. Potthast piled the monumental and indispensable *Bibliotheca historica medii aevi* (1862; new enlarged ed., 1896), a guide to the sources of European history in the middle ages. The work, in the form of an index, gives particulars of practically all the historical writers of Europe and their work between 375 and 1500. Potthast died on Feb. 13, 1898.

POTTO, the name of the West African slow lemurs, *Perodicticus* and *Arctocebus,* popularly miscalled sloths. The aborted condition of the index finger is their most distinctive feature. The ordinary potto (*P. potto*) is about the size of a squirrel, with large staring eyes and a stump of a tail; its colour is rufous brown. It occurs from Ghana to the mountains of Kenya. The awantibo (*Arctocebus calabarensis*), nearly allied, of Old Calabar, has no tail. See PRIMATES.

POTTSTOWN, a borough of Montgomery county, Pa., U.S., on the Schuylkill river, about 38 mi. N.W. of Philadelphia, is the trading centre for a prosperous farm, dairy and industrial region. Hill school, a college preparatory school for boys, is located there. The borough has a council-manager form of government, in effect since 1945. Steel fabricators and the manufacture of tires, tubes and related products, are the largest industries. Other manufactures include universal joints and axles, pipe fittings, gray iron castings, boilers, dresses and shirts, dairy and bakery products, paper boxes, and clay and concrete pipes.

In the immediate area of Pottstown iron was manufactured by 1717. The first cold-blast iron furnace in America was erected by Thomas Potts and Thomas Rutter in 1720, and the Coventry forge produced the first commercial steel in Pennsylvania in 1732. The prosperity of Pottstown was based mainly on the production of iron and steel until about 1918, when fabrication replaced the reduction of ores.

John Potts, ironmaster and merchant, laid out the town in 1752 under the name of Pottsgrove. Arthur St. Clair was a resident of Pottsgrove when he was elected president of the Continental congress. In 1815 the town was incorporated as the borough of Pottstown. For comparative population figures see table in PENNSYLVANIA: *Population.* (L. A. GR.)

POTTSVILLE, a city of Pennsylvania. U.S., on the Schuylkill river, 93 mi. N.W. of Philadelphia; the seat of Schuylkill county. It is a picturesque town at the gap of the Schuylkill river through Sharp mountain and has many narrow and extremely steep streets. The shopping centre is extensive and attractive, serving a retail-trade area with a population of more than 100,000. Pottsville is located on the southern edge of the Pennsylvania anthracite coal region, and after the opening of the Schuylkill canal in 1824 the prosperity of the city was closely related to anthracite prosperity. The steady decline of the anthracite industry in the mid-20th century brought problems of chronic unemployment and of loss in population. (For comparative population figures *see* table in PENNSYLVANIA: *Population.*) The Greater Pottsville Industrial Development corporation experienced some success in bringing new industries to the area. Besides extensive mining industries and railroad shops, manufactures produce aluminum extrusions, plastics. dresses and shirts. an assortment of steel products, shoes, beer, concrete products and paper boxes.

Permanent settlers came to the site of Pottsville about 1795 and soon established a furnace for the production of raw iron. John Potts acquired and expanded the local iron furnace and set the stage for an important iron and steel industry that lasted until the 1920s. He laid out the town of Pottsville in 1816. It was incorporated as a borough in 1828, became the county seat in 1851 and was chartered as a third-class city in 1911. In the 1860s and 1870s Pottsville was a rallying point of the Molly Maguires (*q.v.*). (L. A. GR.)

POUGHKEEPSIE, a city of New York, U.S , on the east bank of the Hudson river, midway between New York city and Albany, the seat of Dutchess county, a rich dairy-farming area The city is the shopping centre of the mid-Hudson valley and contains many diversified industries. Among the largest are an electronic business machines company, a dairy machinery company and a printing and lithographing company. Other manufactures include clothing. cigars, chemicals, cough drops and ball-bearings. Among the nationalities represented in the city are Italians, Poles, Irish, Germans and Dutch.

Vassar, a private college of liberal arts for women (founded 1861), has a cosmopolitan student body and a distinguished faculty. Its founder, Matthew Vassar, conceived the idea "to build and endow a college for young women which shall be to them what Yale and Harvard are to young men." The college was incorporated as Vassar Female college, but under the influence of the intrepid feminist Sarah J. Hale, editor of *Godey's Ladies Book,* "Female" was deleted in 1867. From 1925 Vassar has conducted a Summer Institute of Family and Community Living for parents and their children, social workers and teachers. Also in Poughkeepsie is the Dutchess Community college, a junior college affiliated with State University of New York, opened in 1958. Extensive medical facilities are offered at Vassar and St. Francis hospitals and at the Hudson River State hospital for mental illness.

The Hudson river near Poughkeepsie for many years was the scene of the annual Poughkeepsie regatta of the Intercollegiate Rowing association, one of the most famous rowing events in the world Established in 1895, it was held annually until 1949 except for 1898 when it was at Saratoga lake and for 1917–19, 1933 and 1942–46, when no competition was held. In 1950 the regatta was moved from Poughkeepsie to Marietta, O., and later to Onondaga lake. Syracuse. N Y. (*see* ROWING)

The name Poughkeepsie was derived from Indian words meaning "the reed-covered lodge by the little water place." The town was settled by the Dutch in 1687 and served as the capital of New York state temporarily in 1778. A thriving river port in the early 19th century, from which ships carried grain to New York, it suffered a decline after the completion of the Erie canal and turned to industry and commerce. Poughkeepsie was incorporated as a city in 1854 and in 1952 adopted the council-manager form of government. For comparative population figures *see* table in NEW YORK: *Population.* (E. M. A.; X.)

POULENC, FRANCIS (1899–), French composer, was born in Paris on Jan. 7, 1899. His first important work, the *Rapsodie Nègre,* played in Paris in 1917, excited much interest as the work of so young a composer. It was followed by *Le bestzaire* and *Cocardes* (1919) and *Quatre poèmes de Max Jacob* (1921) for solo voice and chamber orchestra. In 1920–21 he wrote the comic opera. *Le gendarme incompris,* for one violin, one violoncello, one double-bass, one clarinet, one trombone and triangle. His works include a ballet, *Les Biches* (1924); a cantata, *Figure humaine* (1943); and the comic opera, *Les Mamelles de Tirésias* (1944).

POULTRY AND GAME PREPARATION. The term poultry includes fowls, ducks (domestic), turkeys, guinea fowl and geese; the word game is usually applied to wild duck. partridges, grouse, pheasants, quails, deer (venison) and other edible wild birds and beasts. Rabbits, hare and pigeons are usually classed with game.

Poultry and game may be cooked in a variety of ways: roasted; boiled; grilled; stewed in various forms; boned and made into galantines; baked in pies, puddings, *vol-au-vents,* pasties, etc.; combined with cereals, jellies and special sauces, or pounded and used for spreading on pastry or bread and butter. *See* also MEAT COOKERY; PASTRY. HOME MADE.

Preparation of Game and Poultry. — Poultry and feathered game should be plucked and then singed to remove any stray hairs or feathers. It is easier to pluck poultry when warm. The neck is cut off at the shoulder, leaving the skin. There are two ways to draw poultry. The English loosen the skin around the vent with the point of a knife, lay the bird on a board, back uppermost, make a small incision in the skin of the neck lengthwise, insert the fingers through the opening and draw out the entrails. being careful to avoid breaking the gall. Americans cut a slit from the vent of about two inches and draw out the entrails from there. The gizzard, from which the inner bag has been removed. heart and liver are saved for giblet gravy or used in the stuffing. The bird is then washed thoroughly inside and out with cold water. Chop off the ends of the claws and fold back the pinions in the form of a triangle; turn the bird over and bend back the legs toward the neck. Either pin in place nith a skewer (if a small bird) or use a trussing needle and stitch through the bird under the knee bones, at the same time securing the flap and pinions. Birds which need larding should then be covered with bacon fat.

Roasting. — Birds which require stuffing should be filled with a suitable forcemeat (chopped meat, spiced and seasoned) which ought, if possible, to include the pounded liver of the bird. Turkeys and large fowls (capons) are frequently stuffed with veal and ham forcemeat flavoured with lemon peel and nutmeg or with chestnuts; geese and ducks with sage and onions chopped finely and mixed with other forcemeat ingredients, and ducks are occasionally stuffed with prunes and apples. Roast wild duck, widgeon, teal and most small game birds are generally served without stuffing,though pheasants may be stuffed with chestnuts. To keep game birds moist while cooking, a small piece of butter or rump steak is often placed inside the bird. Small birds should be protected with a buttered paper or larding. To roast very small birds, *e.g.,* larks, place them on a skewer.

The best way to roast a haunch of venison is to wrap it in buttered paper and seal this over with a flour and water paste. Ordinary dripping is used for basting poultry and venison, but butter is preferable for basting game birds. About 10–20 minutes before poultry and game have finished cooking remove buttered paper or larding and dredge with flour.

A good gravy with roast poultry or game is essential. Stuffed birds need a thickened gravy. Bread, cranberry, mushroom or chestnut sauce may be served with turkey, and sausage or bacon is a common addition. Roast fowl, pheasant, partridge and grouse are all usually accompanied by rashers of bacon and bread sauce. Water cress is used as a garnish. Fried bread crumbs are served with partridge, pheasant and grouse. Red currant jelly should always accompany roast venison and hare. Apple sauce is substituted for bread sauce in serving roast goose.

Poultry is boned and stuffed to form a galantine. Remove the head and feet; then draw the bird. Divide the skin down the back with a sharp knife and turn down the flesh from the ribs, breast and side bones, leaving these as bare as possible. Pull legs and wings carefully out at the sockets, cutting the sinews through with a knife, and turn these inside out with the rest of the outside skin. Free the skeleton and turn the skin outward again. Stuff the bird to restore its original shape.

Other Methods of Cooking. — All poultry may be boiled in the same way as butcher's meat, *i.e.,* in a well-flavoured stock (*see* FOOD PREPARATION) and served with different sauces; *e.g.*, boiled chicken and egg sauce. Generally, game is not boiled. Both game and poultry are used for making entrées and these may take the form of elaborate stews (brown stews flavoured with special condiments. such as mushrooms, truffles. orange peel, vegetables, etc.); salmi of game; timbales (molds of cold poultry and game); creams (purées with cream and egg liaison); fricassees; *blanquettes;* spatchcock of game (split bird grilled and served with melted butter to moisten); jellies (cold game and poultry purées formed into shapes and masked with aspic or white sauce, or both mixed togetherj; minced game and poultry formed into *rissoles* or croquettes and dipped in batter, rolled in pastry or dipped in egg and bread crumbs and fried in deep fat.

In the making of soups, game and poultry are also used as foundations, and any game or poultry may be used for making raised pies, ordinary pies, pasties and vol-au-vents. Where sufficient giblets are available these may also be used for pie making. To prepare giblets. first scald them and remove any outer skins, such as tough skin adhering to gizzards, etc., take out crop and remove gall. Cut into convenient pieces and partially stew before adding to the pie.

Rabbits and Hares.—For roasting, rabbits and hares are first cleaned and then filled with stuffing; after which they are se n up. Extend the forelegs straight along the sides and skewer through the body. Bring the hind legs forward and bend back the head onto the shoulders and fix into place by passing a skewer through the mouth into the body. For stewing, brown the meat in the same way as for meat. Rabbits may also be curried. For jugged hare! skin and clean the hare. joint it and remove the liver; place in an earthenware pot and add a bunch of sweet herbs, onion stuck with cloves. blade of mace, piece of lemon rind, celery seed or stalk of fresh celery. carrot and a few button mushrooms. Cover with stock. Cook slowly until the flesh is tender. Strain off the gravy and thicken with flour. pounded liver and some of the blood of the hare. Stir in one tablespoon of red currant jelly, one tablespoon of Worcester sauce and a dessertspoon of mushroom catchup. A wineglass of port wine is frequently added to this dish. Serve with fried or poached forcemeat balls and red currant jelly.

POULTRY AND POULTRY FARMING. In practically all countries poultry farming for the purpose of producing meat and eggs for table use is carried on to some extent. In fact, few other agricultural enterprises are so widespread, and in the United States: Canada, England, Ireland, Denmark! Australia, China and some other countries, the poultry industry is one of the leading branches of agriculture. Within each country the egg and chicken business is by far the most important branch of the poultry industry.

In the United States turkey production is a relatively important enterprise although in most countries it is carried on to a limited extent only. The raising of ducks for eggs is an industry of moderate importance in England, the Netherlands and Belgium and for meat production primarily in the United States. Geese are raised exclusively for meat, goose production being of limited importance in practically all countries except Germany and in one or two other European countries. The raising of guinea fowl for meat production is of relatively little importance in any country.

In all countries most flock owners of chickens are primarily interested in egg production because more income is obtained from egg production than from chicken-meat production. In certain sections of some countries, especially France, England and the United States, however, producers receive practically all of their poultry receipts from market poultry.

Domestic breeds of chickens are descended from the jungle fowl (*q.v.*) of India. The numerous modern breeds of chickens known throughout the world may be conveniently classified into the following five classes, on the basis of their origin: English, Asiatic, American. Mediterranean and Continental European. The breeds belonging to the Mediterranean class are for the most part somewhat smaller in body size and more active than the breeds belonging to the other classes. Also, Mediterranean breeds lay white-shelled eggs, become broody, that is. inclined to try to incubate their eggs, relatively seldom, and have white ear lobes whereas most of the breeds belonging to other classes lay brown-shelled eggs. are likely to become broody, and have red ear lobes. The Mediterranean breeds are not as well suited for meat production as most of the other breeds. The Asiatic and some of the Continental European breeds have feathered shanks whereas other breeds have nonfeathered shanks.

Principal Breeds and Varieties.—Although there are more than 100 breeds and varieties of chickens, the number kept primarily for meat or egg production or both is very limited. several breeds and numerous varieties having been developed because of some unique structural character, such as an odd shape of comb or the presence of a crest on the top of the head, or because of the beauty of the plumage pattern. All birds belonging to the same breed have the same shape. Varieties within a breed differ with respect to colour of plumage. There are numerous Bantam breeds, kept by some poultrymen as novelties. Only the more popular breeds and varieties of outstanding economic importance can be discussed here.

Australorp.—This breed originated in Australia and was developed primarily as an egg producer, although its medium size makes it a good meat bird. The comb is single, the skin white and the plumage black. It is kept to some extent in the United States but is more popular in Australia.

Cornish.—A breed of poultry developed in England and imported into the U.S. in 1887. It gained considerable popularity partly because of its excellent meat properties and its yellow skin. It has close feathering and a compact. heavily meated body, the breast being very deep and broad. The Cornish lays a brown-shelled egg and is a broody fowl. It has a pea comb. In spite of its excellent meat properties. the Cornish has never demonstrated that it is a very great layer. There are three varieties. the dark, the white and the white-laced red. White Cornish males are frequently mated nith White Plymouth Rock and other females for the production of broiler chicks They will carry some of the good meat characteristics of the Cornish and increased vigour resulting from the crossing.

Dorktng—The Dorking is an English breed. Dorkings have long, broad. deep and low-set bodies and five toes, most other breeds having four toes. The Silver Gray Dorking has a single comb and white skin, is an excellent meat bird and is used to a considerable extent in England for crossing with some of the game breeds.

Leghorn.—Of the 12 different varieties of Leghorns, only the Single-Comb W'hite is kept extensively in any country. The Leghorns belong to the Mediterranean class. White Leghorns have been bred to a high level of egg production in England, Canada, Australia and the United States and for years have occupied a very prominent place on commercial poultry plants devoted to market egg production. Its white-shelled egg and yellow skin enhance its popularity, although Leghorns do not make as good table birds as most of the larger sized breeds. For market egg production, exclusively. and for economy of production the Single-Comb White Leghorn is pre-eminent.

New Hampshire.—The New Hampshire is an American breed, with single comb and yellow skin, and used in the United States and Canada as an egg and meat producer. In both sexes the plumage over most of the body is chestnut red, and there is some black in wing and tail feathers; in the male the hackle and saddle feathers are reddish bay.

Orpington.—This is a single-combed English breed of which there are four varieties: Buff. Black, White and Blue. The Buff and White varieties have enjoyed more popularity in England than the other varieties. The Orpington is an egg producer of moderate ability as compared with the Leghorn and the more popular American breeds. The white skin is largely responsible for the raising of the Buff variety in the middlewestern section of the United States, where a dressed carcass with a light-coloured finish is sometimes desired.

Plymouth Rock.—Among seven different varieties of this American breed. only the Barred and the White varieties have assumed a place of economic importance. The comb is single and the skin is yellow. In the Barred variety the black and white bars should be of equal width in males, and the white bars should be one-half as wide as the black bars in females. The Plymouth Rock is a bird of good size, with good fleshing properties, and when properly bred lays well.

White Plymouth Rocks have become popular for broiler production because of the white plumage. The females are frequently mated with Delaware or White Cornish males for the production of crossbred broilers with white or nearly white plumage. Crossing stimulates growth rate and increases vigour.

Rhode Island Red.—The Rhode Island Red is another American breed, the Single-Comb variety being much more popular in England, Canada and the United States than the Rose-Comb variety. The skin is yellow. The plumage should be rich dark red over all parts of the body, there being black in the tail and parts of the wing feathers. The Single-Comb Rhode Island Red has been bred extensively for egg production and in the United States especially, some strains lay as well as some of the best strains of Single-Comb White Leghorns.

Sussex.—This English breed contains the Light, Speckled and Red varieties, the Light variety being by far the most popular in England although but few of any Sussex varieties are kept in other countries. The comb is single and the skin is white. In plumage colouration the Light Sussex is similar to the Light Brahma. Sussex fowl have long been noted for the excellence of their flesh and are kept extensively in England for the production of roasters. After about 1925, English poultry breeders made considerable improvement in the laying qualities of the Light Sussex.

Wyandotte.—Among several varieties of this American breed, the White Wyandotte is the only variety bred extensively in England, the United States or other countries. Wyandottes have rose combs and yellow skins. Like several other American varieties, they are a good general-purpose fowl, suitable for both meat and egg production. In England, egg production has been developed to a higher level among White Wyandottes than in other countries. In the United States White Wyandotte has largely been supplanted in popularity by the other previously mentioned American varieties.

Other Breeds and Varieties.--Of hundreds of other breeds and varieties of chickens kept in various countries, only a few can be mentioned. The Ancona is a Mediterranean breed with mottled plumage. The Dark Cornish is of English origin and has a very broad, compact body, ideal as a roaster type but a poor layer; it is sometimes used for crossing with other breeds. The Faverolle is a French breed with feathered shanks; in England the Salmon Faverolle is crossed extensively with the Light Sussex for roaster production. Old English and Modern Game breeds make excellent roasters but are poor layers and are kept largely by fanciers. The Jersey White Giant is the largest of the American breeds, developed primarily as a meat breed and is not noted for egg production. The Light Brahma has always been the most popular representative of the Asiatic breeds but is kept to a limited extent only. The Black Minorca is the largest of the Mediterranean breeds but has never been kept to any great extent in any country. The Black Sumatra is a native of Sumatra and is a fancier's breed exclusively.

Breeding for Meat and Egg Production.—Success in raising chickens for meat and egg production is largely a matter of good stock plus good management. Good stock can be secured only from carefully selected, well bred parents that are properly mated.

Meat Production Standards.—For profitable meat production, chickens must grow at a rapid rate and make good gains in body weight for the feed they consume. Usually the fewer pounds of feed consumed per pound of gain in body weight, the greater the profit in meat production. The characteristics which birds raised for meat production should possess include: (1) good health and vigour; (2) fast wing feathering at hatching time and fast tail feathering at ten days of age; (3) well feathered over the back by eight weeks of age; (4) rapid growth to marketing time; (5) well-proportioned body, with good length and width and fair depth in proportion to shank length, body depth being uniform from front to rear; (6) good fleshing on breast and thighs. The selection of breeding stock on the basis of these six characteristics implies that the poultry breeder must carry on a definite selection program from hatching time to the time of mating.

Commercial poultrymen interested in poultry meat production exclusively frequently resort to crossbreeding with beneficial results, since crossbreeding tends to stimulate growth during the first 10 or 12 weeks, and mortality is usually less than among purebred chickens. However, the actual results secured from crossbreeding depend largely on the breeding quality of the parental breeds crossed. In England, and to a lesser extent in some other English-speaking countries, new breeds have been developed by crossbreeding for the purpose of enabling the sexes to be separated at hatching time according to differences in the colour of the down. This makes it possible for meat producers to purchase male chicks only and market egg producers to purchase female chicks only.

Egg Production Standards.—In addition to the six characteristics for meat production given previously, a pullet, or young hen, to lay well, should possess the following four outstanding characteristics: (7) early sexual maturity; White Leghorns should commence to lay at about 150 days of age and Light Sussex, New Hampshires, Plymouth Rocks, Rhode Island Reds and other general-purpose birds at about 170 days of age; (8) pullets of all varieties should lay at a rate of at least 50% production, or a minimum of 15 eggs per month; (9) there should be little or no broodiness; White Leghorns usually do not exhibit much broodiness, but general-purpose varieties must be bred for nonbroodiness or there will be numerous interruptions in laying; (10) pullets of all varieties should continue to lay for a period of approximately ten months from the time they start to lay.

In order to develop a strain of birds noted for a high level of egg production, the poultry breeder must adopt a rigid program of selecting his breeding stock from year to year. The program of selections should be based on minimum standards for early sexual maturity, rate of laying, nonbroodiness and persistence of production. Selecting birds with good pedigrees for future breeding purposes is an additional help in developing a good laying strain. The best help of all in selecting females for breeding purposes is to select them from among the families of full sisters that are outstanding in laying performance. Males for future breeding purposes should also be selected from the outstanding families but too close inbreeding should be avoided.

Additional Standards of a Good Strain.—In addition to the ten desirable characteristics previously mentioned, a good strain of chickens should also possess the following essential characteristics: (11) good egg size, eggs attaining approximately standard weight (2 oz. each) within about 60 days from the time a pullet commences laying; (12) eggs of good interior quality; (13) hatchability of at least 75% of all eggs incubated; (14) low mortality among growing chickens and laying stock; the strain should possess the ability to resist disease to a marked degree; (15) long productive life.

Renewing the Flock.—Whether chickens are raised for meat production or pullets are kept for egg production, the entire flock or part of it has to be renewed every year. Commercial producers of broilers and fryers renew their flocks several times a year, depending upon the number of lots produced annually. Market egg producers should plan each year to replace about two-thirds of the layers with a fresh lot of pullets because birds usually lay about 20% fewer eggs in their second than in their first laying year.

In practically all English-speaking countries it is possible for the great majority of poultry producers to secure from hatcheries the chicks necessary to renew their flocks. Hatching chicks in incubators rather than under broody hens makes it possible to secure larger numbers earlier in the season, which is a distinct advantage. The egg capacity of incubators used by a commercial hatchery operator may run up to several thousand eggs, these incubators being heated for the most part by gas, coal, oil or electricity.

Hatchery operators may be divided roughly into two groups: (1) those who produce their hatching eggs with their own breeding flocks; and (2) those who secure their hatching eggs from flocks owned by others. The hatchery operator who produces his own hatching eggs naturally has complete control over his flock and is thus in a position to do a great deal toward improving the quality of chicks hatched for customers. The most progressive hatchery operators who secure their hatching eggs from various flock owners adopt a system of close supervision concerning the management of the flocks and see to it that the females are carefully selected and are mated to males with as good breeding as possible.

Since many of the chickens raised in different countries each year are secured as chicks from hatcheries, it is quite apparent that they occupy a very important place in the poultry industry. The quality of chicks produced by hatcheries determines very largely the results secured by those who purchase the chicks for meat or egg production.

Rearing Chickens.—If a few chickens only are to be raised, they may be brooded with hens, but if a few hundred or more are to be raised, they should be brooded artificially. Moreover, brooding chicks artificially makes it possible to raise a larger number at one time than with natural brooding so that a larger number of pullets of the same age may be placed in the laying house in the fall of the year.

There are several different types of brooders for artificial brooding, varying according to size, design and the kind of fuel used to supply heat. Brooders differ in size from those accommodating about 50 chicks to those accommodating several thousand chicks.

Most makes of brooders are portable and can be moved from place to place. Many of the portable brooders are equipped with canopies or hovers for conserving the heat to a limited area near its source. There are colony brooders for lots of about 60 to a few hundred chickens, continuous brooders for brooding chickens by the thousands, and battery brooders for brooding in strict confinement. The kind of fuel used to supply heat in colony brooders may be kerosene, coal, wood, oil, gas or electricity. Continuous brooders are heated by burning coal, gas or oil. Battery brooders are usually heated electrically.

When only a few chickens are to be raised, some kind of lamp brooder is often justified, because the initial expense is relatively low. On the other hand, if a few hundred or more chickens are to be raised, one of the other types of brooders would undoubtedly be justified.

Most poultrymen use electric, oil-burning or coal-burning portable brooders. Best results are usually secured when not more than 250 chickens are brooded together.

For the first few days, the temperature under the hover of the brooder should be about 95° F. at about two inches above the floor. The temperature should be lowered about 5° each week depending upon the time of the year and the outside temperature. The temperature of the brooder house should be about 70° F. The most critical period in brooding is the first two weeks; thus the most careful attention should be given the brooder during this time. Drafts in the brooder house should be avoided and the litter should be kept dry to prevent the spread of disease. When the chickens are well feathered, they require little heat. Plenty of waterers and hopper feed space should be provided, larger sized waterers and dry mash hoppers being provided as the chickens grow.

A 10 ft. × 12 ft. or a 12 ft. × 12 ft. colony brooder house is large enough for brooding 250 chickens up to about eight weeks, when the sexes should be separated. The pullets may be moved to range shelters to be reared on range, and the cockerels may be kept until they attain broiler, fryer or roaster stage.

Feeding Chickens.—Chicks should be given a finely ground starting mash feed containing 20% to 22% protein as soon as possible after hatching and placing in the brooder house. When the chicks are about eight weeks old the protein may be reduced to about 16% by changing the composition of the mash or by feeding some whole grain with the starting mash. A hundred chicks will eat 10 to 20 pounds of feed the first week and 10 to 20 additional pounds each week during the next eight or nine weeks, depending on the breed of chicks being raised, the energy content of the ration and the rate of growth desired.

Chicks deprived of sufficient sunshine or vitamin D will develop rickets, characterized by poor growth, ruffled feathers, a wobbly gait, sitting down much of the time, crooked breast bone and bones of low ash content. An improper balance of calcium and phosphorus in the ration and a deficiency of manganese may result in perosis—enlarged hock joints and crooked legs. A deficiency of riboflavin will result in a curled toe paralysis and a deficiency of pantothenic acid in chick dermatitis.

Chickens are generally changed from the growing ration to a laying ration when 16 to 20 weeks old. This may be a 16% protein all mash ration; a 20% protein mash to be fed with a limited amount of grain; or a mash concentrate (24% to 32% protein) fed free choice with grain. The mash feed is kept before layers at all times. The grain is usually a mixture of two or more of the following; corn, wheat. oats and sorghum grains. Oyster shell or limestone grit should be kept available at all times. A hundred laying hens will eat about 17 to 30 lb. of feed daily, depending on size of birds, rate of production and weather conditions. A hundred layers of small egg type birds in the same rate of lay as 100 heavy meat type chickens will eat 4 to 5 lb. less feed daily.

The ration fed will influence the number of eggs laid and their quality and hatchability. A deficiency of vitamin D or calcium will result in thin egg shells. The consumption of grass will result in darker yolks and succulent feed in thinner whites. A deficiency of riboflavin, vitamin B_{12} and vitamin D will result in eggs of poor hatchability.

A few chickens may be maintained largely on table scraps, milk, corn, grass and bugs and worms from range. Larger numbers of chickens and those kept in confinement will need to be fed a complete ration. It is usually advisable to start chicks on a commercial chick starter. Later a commercial concentrate may be purchased for feeding with home grown grains. It is difficult for the poultryman to buy, accurately weigh and properly mix the small amounts of vitamins, trace minerals, antibiotics, amino acids, coccidiostats and other drugs used in modern mash feeds. *(See* also FEEDS, ANIMAL.)

Housing the Laying Stock.—The purpose of housing is to give the layers protection and keep them comfortable so that they will be efficient egg producers. In extremely hot weather the layers are very likely to suffer considerably if they cannot secure relief in a cool house. The chicken has no sweat glands to assist in keeping the body cool. In extremely cold weather, chickens not only suffer from the cold in a poorly built house but use too much of the energy contained in their feed to conserve body heat instead of producing eggs. The primary objective in housing laying stock, therefore, is to protect the birds against excessively high and low temperatures and especially against sudden changes in temperature. In addition, the proper housing of the layers makes it possible to manage them more efficiently. The size of the house needed varies according to the size of the flock. For flocks of 15, 25 and 50 birds, houses should have about 70, 100 and 180 sq.ft. floor space, respectively. A flock of 125 birds should have about 400 sq.ft. floor space. A flock of several hundred birds may be housed in a pen.

It costs less, on the average, to build a square house than a long narrow one, which is likely to be drafty. Houses for small flocks should be at least 10 ft. deep, and houses for large flocks should be 30 to 40 ft. deep. Large flocks may be kept in houses that are two, three or four stories high. A multistoried house reduces the labour required to manage a large flock, as compared with a single-storied house. A multistoried house simplifies ventilating problems to some extent and makes it possible to maintain more uniform temperatures in summer and winter.

A concrete floor is more durable and much more sanitary than a board floor. Insulating the walls and roof. especially the latter, helps greatly to keep the house cool in summer and warm in winter. The proper ventilation of the house is necessary in order to remove excessive moisture and provide fresh air but, at the same time, drafts should be avoided. Sunlight in the laying house is desirable not only because it brightens up the house but also because it tends to keep the house dry and is a good germicide, being effective in destroying disease organisms.

Moreover, sunlight is a good source of vitamin D. A good absorbent litter helps to keep the floor dry. How frequently the litter should be removed depends largely on the number of birds in the house, weather conditions and the extent to which the house is properly ventilated.

Diseases and Parasites of Poultry. — Chickens and other species of poultry are subject to both external and internal parasite infestation. Lice, the most troublesome external parasites, may be controlled by dusting with sodium fluoride or DDT or by a liquid fumigant, nicotine sulfate or lindane sprayed on the perches. The red or roost mites live in cracks and crevices on the perches and in the nests. They may be destroyed by spraying the nests and perches with Carbolineum or oil.

The chief internal parasites affecting poultry are various species of round worms and flat segmented tapeworms. Birds become infested by picking up the embryonated worm eggs from infected soil and litter. Resistance to worm infestation increases with age. The best preventives are feeding a well-balanced ration and keeping the chicks away from infected range, soil and mature birds during the first few weeks after hatching.

Protozoa *(Eimeria)* cause an intestinal disease in growing chickens — coccidiosis — characterized by bloody droppings. The trouble may be prevented by feeding a coccidiostat at a low level in the starting and growing mash. In case of an outbreak of the disease, it may be corrected by feeding one of the sulfa drugs at the recommended level or placing it in the drinking water

There are a few molds that may cause a diseased condition in poultry. Apergillosis affects the lungs and air sacs; thrush the mouth and gullet; and favus the face. comb and skin of the bird. The latter may be spread to man through skin abrasions.

The principal bacterial diseases affecting poultry are pullorum disease, fowl typhoid, cholera and tuberculosis. Pullorum disease may be transmitted to chicks through the egg. A blood agglutination test is used to detect carriers of pullorum in the breeding flock. Incubator fumigation may be used to prevent the spread in the machines. The disease causes high mortality during the first two weeks after hatching and is characterized by a diarrhea or spots in the lungs. In case of an outbreak, it may be checked by feeding a sulfa drug or a nitrofuran in the mash or incorporating the drug in the drinking water. Fowl typhoid and cholera cause disease among older birds. The troubles may be checked by the same drugs used to check an outbreak of pullorum. Fowl tuberculosis affects birds more than a year old. The birds become thin and die. Hard gritty lesions may be found on the liver, spleen and intestines. Fowl tuberculosis may spread to swine and possibly other farm animals. The best control procedure is to dispose of the flock, clean up the premises and restock with chicks.

Virus diseases are the principal causes of mortality and poor production in laying flocks. The principal ones are leucosis, fowl pox, Newcastle disease and infectious bronchitis. All except leucosis may be prevented by preventive vaccination by means of a dust, spray, addition to the drinking water, or individual inoculations. Leucosis may affect almost any tissues of the body and generally birds between 6 and 18 months of age. Symptoms include paralysis, blindness, bone and muscle tumors, emaciation, big livers and visceral tumors. Birds may be selected on a family basis for resistance to leucosis.

Marketing Eggs. — Nearly all eggs at the time they are laid are of high quality. They represent the kind of eggs that most consumers would like to purchase the year round. The proper steps to preserve fresh-laid egg quality are far more important than most producers realize. The proper preparation of eggs for market and marketing them to best advantage are just as important, in many respects, as producing them efficiently.

Since the germ of a fertile egg begins to develop at about 82° F., eggs for market should be kept at a temperature lower than this, a temperature of 55° F. being desirable. All producers of market eggs should keep the males away from the females except during the breeding season.

Unless eggs are gathered frequently and cooled promptly in warm weather, they commence to deteriorate. The higher the temperature and the drier the air of the room in which eggs are held, the more rapid the deterioration. Some of the most striking changes that take place in eggs subjected to high temperatures and dry atmosphere are: (1) water evaporates through the porous shell; (2) the thick white tends to break down into thin white; (3) the yolk membrane becomes weaker; and (4) the yolk becomes more flaccid.

The excessive heating of eggs, whether from being exposed to the sun's rays or held for a long time in a warm room, results in a complete breakdown of the thick white, giving the entire white a watery appearance.

Clean litter and clean nests, one for every five hens, are essential for the production of clean eggs. The eggs should be gathered in wire baskets three or four times daily in warm weather and stored in a room in which the temperature is about 55° F. and the relative humidity about 75%.

Flock owners nho have only a few layers often sell all of their surplus eggs direct to consumers. This is especially true of flock owners in villages or those living in areas adjacent to towns and cities. In the case of farm and commercial flock owners the eggs may pass through any one of several different marketing channels before reaching the consumer. Selling market eggs on a graded basis is in the best interests of producers, dealers and consumers. Eggs are graded according to size, shell cleanliness, size of air cell and the quality of the yolk and white.

The method of packing eggs in different countries varies. In several European countries, for instance, long wooden boxes are used for packing eggs in straw whereas in Canada and the United States different kinds of containers are used, including cartons holding ½ doz. or 1 doz., and fibre or cardboard boxes holding 15 or 30 doz. From the surplus producing areas in a country, eggs are shipped in refrigerated cars or trucks to wholesalers who sell them to retailers.

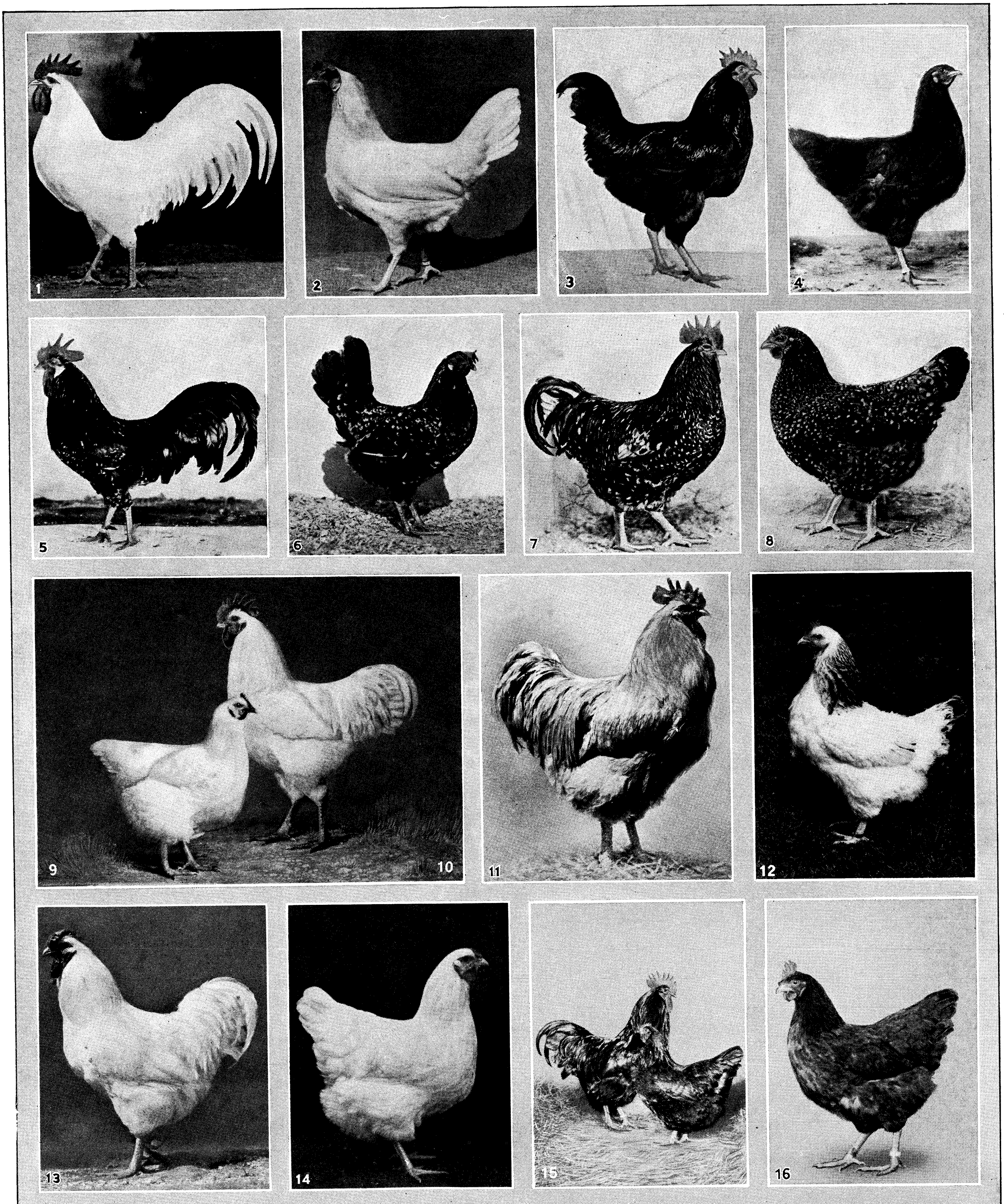
Co-operative egg marketing methods have been developed extensively in various English-speaking countries, especially the United States and Australia as well as in such countries as Ireland and Denmark.

Prior to World War II some countries, including China, Denmark, Australia, New Zealand, South Africa and Ireland, exported considerable quantities of eggs annually to Great Britain, which is primarily an importing country. (See also EGG.)

Marketing Chickens. — Chickens are sold alive at various ages, ranging from those about six weeks old, weighing about one pound each, to those that are several years old. They are all called chickens when one wishes to distinguish them from turkeys, guineas, ducks and geese. From the market standpoint, however, the term chicken is usually used to distinguish growing birds, except stags and capons, from cocks and hens, the latter usually being referred to as fowl. Stags are older chickens; they have more prominent spurs, and the flesh is not so tender. Capons are male birds that were castrated while young, the flesh being relatively tender even when the birds are almost fully grown.

While the marketing of live chickens is an important industry in many countries, the proportion of dressed poultry marketed by live-poultry buyers increased considerably after about 1930. In all countries the great bulk of market poultry is sold to consumers either in the dressed, drawn or cut-up form. A dressed bird is one that has been killed and plucked. A drawn bird is a dressed bird from which the head, feet and entrails have been removed. A cut-up chicken is a drawn bird that has been cut up into parts suitable for frying.

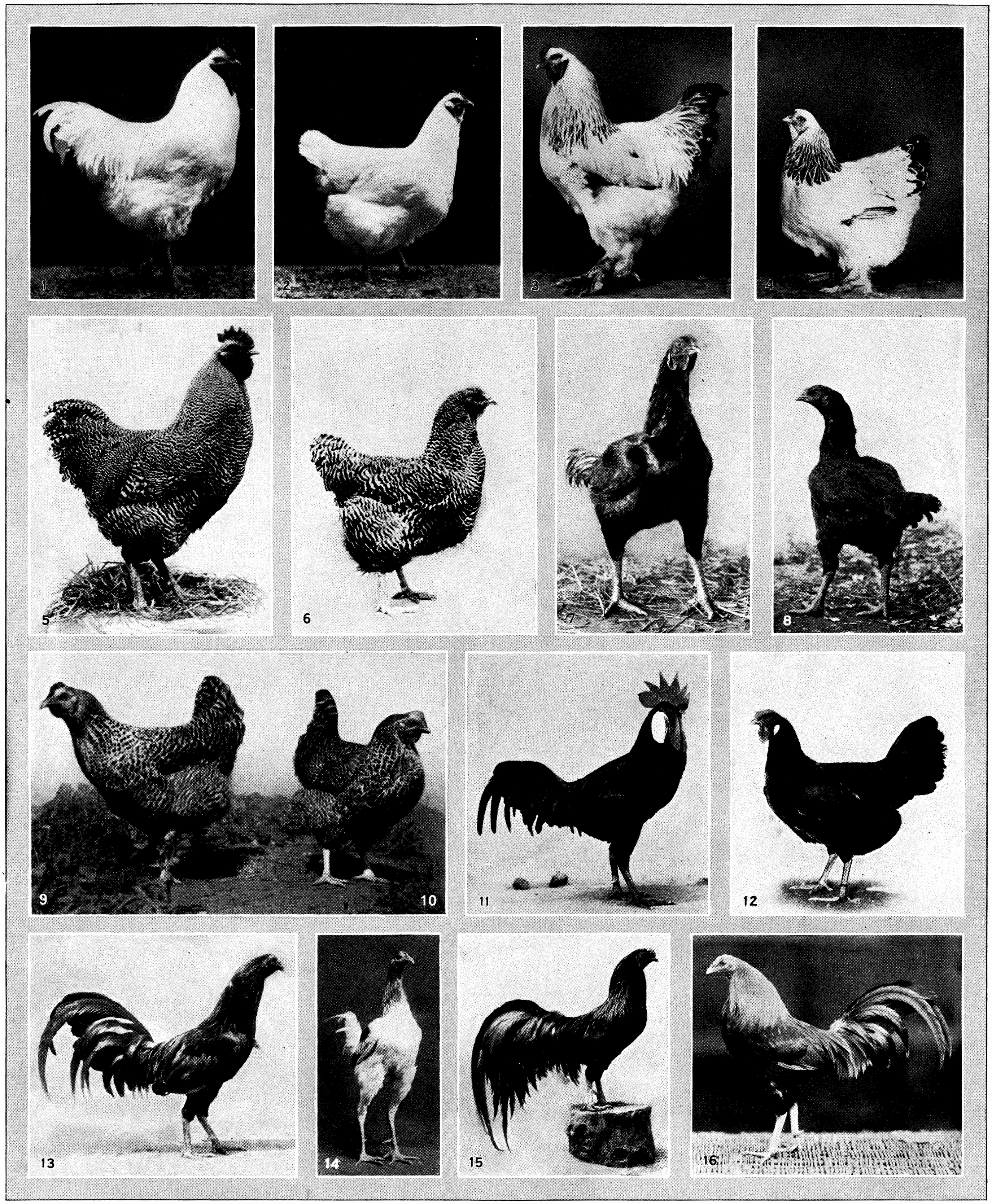
Feed should be withheld from birds for about ten hours before they are killed and plucked. The different methods of plucking chickens include dry plucking, hard-scald plucking, semiscald plucking, wax plucking and machine plucking. Dry plucking must be done the moment tha bird is killed, while the body is still warm. The hard-scald method involves immersing the bird for a few seconds, except the head and feet, in water kept at a temperature of 180° to 190° F. If the water is too hot or the birds remain in the water too long, the skin will have a scalded appearance. For semiscalding, the temperature of the water should he approximately 127° F. for broilers, 128" F. for fowl, and the birds should be kept in the water for 30 to 35 sec. Wax plucking is a somewhat involved process in which a special kind of melted wax is used



BY COURTESY OF (1, 2, 4, 5, 6, 7, 8, 11, 13) THE U.S. DEPARTMENT OF AGRICULTURE, (3, 12, 14) "POULTRY FARMER," LONDON, (9, 10, 15, 16) "AMERICAN POULTRY JOURNAL," CHICAGO

EUROPEAN AND AMERICAN BREEDS OF POULTRY

1. White Leghorn cock
2. White Leghorn hen
3. Rhode Island Red cockerel
4. Rhode Island Red pullet
5. Ancona cockerel
6. Ancona hen
7. Speckled Sussex cock
8. Speckled Sussex hen
9. Jersey White Giant pullet
10. Jersey White Giant cockerel
11. Buff Orpington cock
12. Light Sussex hen
13. White Wyandotte cock
14. White Wyandotte pullet
15. Australorps, cock and hen
16. New Hampshire Red pullet



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EUROPEAN AND AMERICAN BREEDS OF POULTRY

1. White Plymouth Rock cock
2. White Plymouth Rock hen
3. Light Brahma cock
4. Light Brahma hen
5. Barred Plymouth Rock cockerel
6. Barred Plymouth Rock pullet
7. Dark Cornish cockerel
8. Dark Cornish pullet

9, 10. Cross-bred pullets of Barred Plymouth Rock male and Rhode Island Red female cross

11. Minorca cockerel
12. Black Minorca pullet
13. Old English Black and Red game cock
14. Modern game cock
15. Sumatra game cock
16. Old English game cock

to facilitate the removal of feathers, pinfeathers and hair. Plucking machines are used extensively in the United States and England. Some of the machines are equipped with a revolving disk or cylinder for dry plucking and others are equipped with a revolving cylinder to which rubber fingers are attached for plucking by the semiscald method.

After the birds have been plucked, the heads, feet and vents are cleaned thoroughly in order to give the dressed carcasses an attractive appearance. After the birds are dressed, they should be cooled thoroughly by immersing them in cold water for about an hour, or they may be held for about a day in a room for dry cooling at a temperature of 32° to 34° F. If the dressed birds are to be packed in boxes or other containers for shipment to market, the heads are wrapped in parchment or kraft paper waxed on one side.

In some countries, especially the United States, dressed birds are drawn in poultry-packing plants and after being inspected and cleaned are prepared so that they are ready to be placed in the consumer's oven for roasting; or they may be packaged and frozen at 0° F. or lower.

The practice of selling fresh-killed chickens cut in pieces suitable for frying has gained considerable impetus in the United States and Canada. Buying cut-up chicken is popular with many housewives, because practically no labour is necessary in preparing the poultry for the frying pan.

Raising Ducks for Meat and Eggs.—Duck raising is practised on a limited scale in practically all countries. for the most part as a small farm enterprise; but in such countries as England and the Netherlands they are kept extensively for egg production, and in the United States a considerable number of commercial plants have been developed for meat production exclusively. The Runner duck, formerly called the Indian Runner, and the Khaki-Campbell are especially adapted for egg production, whereas the larger sized Pekin breed is a meat producer of exceptional merit. Some strains of Runners and Khaki-Campbells will lay better than many strains of chickens. Pekin ducks grown commercially for meat are marketed from about 8 to 12 weeks of age. when they weigh from about 43 to 7 lb. each. In England the Aylesbury is the kind kept for meat production. The Muscovy duck, of South American origin, is kept on farms for meat production to some extent because it does not quack.

Turkey Raising.—Turkeys are raised mainly for meat production. The trend in turkey breeding has been toward fewer breeds in recent years. White varieties are becoming more popular than coloured ones because they are preferred by consumers. They do not show the dark pin feathers found in the Bronze and other coloured varieties. Hotels, restaurants and institutions prefer large birds, 1j to 30 lb. when ready for the oven. Most families prefer a smaller, 5 to 15 lb. turkey when ready for the oven.

The incubation period for turkey eggs is 28 days. Turkey poults are generally started on a 26% to 28% protein all mash ration. They may be moved to range when eight to ten weeks old or reared in confinement. Small breeds of turkeys are generally ready for market when about five months old and the large breeds when about six or seven months old. Some large breeds of turkeys are sold when partially grown as turkey broilers weighing 6 to 10 lb. and when 10 to 16 weeks of age.

The principal turkey diseases are pullorum, blackhead and sinusitis. Pullorum may be controlled by the same procedures used for chickens (*see* above). Blackhead is a protozoan disease that may affect turkeys of all ages. Mature chickens and turkeys may be carriers. A histostat may be fed as a preventive or treatment for blackhead Sinusitis may be checked by isolation of sick birds and injection of an antibiotic into the swollen sinus.

Goose Raising.—Goose raising is a farm enterprise of limited proportions in practically all countries, although in Germany, Austria, parts of France and certain sections of other countries, goose raising on a commercial basis is carried on extensively. The Toulouse, predominantly gray in colour, and the Embden, a white breed, are the two outstanding meat-producing breeds. In some commercial plants, market geese are fattened by a special process, the forced-feeding of noodles sometimes being practised, resulting in a considerable enlargement of the livers.

Some goose raisers make a practice of plucking feathers from the live birds, usually just before the birds molt, up to one pound of feathers being obtained from a bird.

Guinea Raising.—Guineas are raised as a sideline on a few farms in various countries. In some cities there is a relatively good market for them, and they are often used as a substitute for game birds, such as quail. grouse, pheasant and partridge.

Pigeon Production.—Pigeons are kept for squab production, messengers and exhibition. The Homer is the most popular breed for squab production. A pair of pigeons will raise six pairs of squabs annually. The incubation period for most pigeons is 17 days. Pigeons are generally fed cereal grains and legume seeds. Squabs are generally marketed when three to four weeks old.

See also GAME BIRDS.

BIBLIOGRAPHY.—H. E. Botsford, *The Economics of Poultry Management* (1952); W. A. Lippincott, *Poultry Production,* 8th ed. rev. by L. E. Card (1952); A. R. Winter and E. M. Funk, *Poultry Science and Practice,* 5th ed. (1960); Morley Allan Jull, *Poultry Breeding,* 3rd ed. (1952), *Raising Turkeys, Ducks, Geese, Game Birds* (1947); *A. L.* Romanoff and A. J. Romanoff, *The Avian Egg* (1949); William Raiford Ewing, *Poultry Nutrition,* 4th ed. rev. (1951); H. E Biester and L. de Vries, *Diseases of Poultry,* rev. 3rd ed. by H. E. Biester and L. H. Schwartz (1952); E. W. Benjamin, *Marketing Poultry Products,* 4th ed *by* E. W. Benjamin, H. C. Pierce and W. D. Termohlen (1949); L. B. Darrah, *Business Aspects of Commercial Farming* (1952); R. C. Hartman and G. S. Vickers, *Hatchery Management* (1950); *S.* J. Marsden and J. H. Martin, *Turkey Management,* 6th ed. (1955); S. K. Haynes, *Practical Pigeon Production* (1944). (M. A. J.; A. R. WR.)

POULTRY FEEDS: *see* FEEDS, ANIMAL.

POUND, SIR (ALFRED) DUDLEY (PICKMAN ROGERS) (1877–1943), British naval officer, first sea lord and admiral of the fleet during World War II, was born on Aug. 29, 1877, on the Isle of Wight, the son of an English father and an American mother. He entered the navy in 1891. As a lieutenant he specialized as a torpedo officer, and in 1913 was appointed as an instructor at the new naval staff college. Having been promoted captain in 1914, he served as assistant to Admiral Lord Fisher. At the battle of Jutland he commanded H.M.S. "Colossus." During the last years of the war he reorganized the operations division at the admiralty into the plans division, of which he was director from 1922 to 1925. He then served two years in the Mediterranean under Admiral Sir Roger Keyes, returning to the admiralty as assistant chief of naval staff with the rank of rear admiral (1927–29). From 1929 to 1931 he commanded a battle cruiser squadron and from 1932 to 1935 was second sea lord. He was commander in chief of the Mediterranean fleet (1936–39) at the time of the Spanish civil war. In May 1939 he was recalled to become first sea lord and chief of naval staff, which office he held until three weeks before his death on Oct. 21, 1943. In July 1939 he was promoted admiral of the fleet.

As first sea lord Pound shared the responsibility with the first lord. Winston Churchill, of mobilizing the fleet and conducting the naval war at a critical period. Unlike the air ministry and the war office. the admiralty was an operational centre, so that Pound was personally involved in such events as the hunt for the "Graf Spee," the Norwegian campaign, the fall of France and the early U-boat campaign. The most successful collaboration between the planning staff at the admiralty and the commander in chief at sea was the sinking of the "Bismarck." Pound combined exceptional administrative ability and capacity for work with an imperturbable temperament. (C. C. L.)

POUND, EZRA LOOMIS (1885–), U.S. poet, critic and one of the most influential single agents in the development of 20th century English writing, was born in Hailey, Ida . Oct. 30, 1885. His family traditions were those of the northnestern frontier, where a man thrived by discerning the most direct procedure and pursuing it boldly. By the time he had settled in Europe (1907) after an education in romance philology at the University of Pennsylvania and Hamilton college, he had developed his unique conviction that poetry is a craft demanding active intelligence, and begun his lifelong labour of educating and assisting his contemporaries. As foreign editor of Poetry (Chicago) he brought to its pages Robert Frost, W. B. Yeats and the first published work of T. S. Eliot. He forced Wyndham Lewis's *Tarr* and James Joyce's *Portrait of the Artist as a Young Man* (1916) and *L'lysses* (1922) into print, founded the Imagist movement and in 1922, by a brilliant feat of editing, extracted Eliot's *Waste Land* from a sprawling manuscript twice its published length.

His major poems are *Homage to Sextus Propertius* (1917), *Hugh Selwyn Mauberley* (1920), and *The Cantos*, a long work in progress, dating from the early 1920s, that undertakes to assemble. sharpen and order the traditions and signposts of fructive intellectual history. His translations include the Anglo-Saxon *Seafarer* (1912), the Chinese *Cathay* (1915) and *Classic Anthology* (1954), and the Confucian books (1947–50). His *Letters* were published in 1950, and a selection of his *Literary Essays* in 1954.

From 1946 to 1958 he was confined in St. Elizabeth's hospital in Washington after being ruled mentally unfit to answer indictments for treason growing out of broadcasts he gave on the Italian radio, 1940–45. Following his release from St. Elizabeth's, Pound returned to Italy.

BIBLIOGRAPHY.—H. Kenner, *Poetry of Ezra Pound* (1951); *R.* Aldington, *Ezra Pound and T. S. Eliot* (1954); Clark Emery, *Ideas Into Action* (1959). (HH. *K.*)

POUND, ROSCOE (1870–), U.S. jurist and educator, a leading exponent of the reform of judicial administration, was born in Lincoln. Neb., Oct. 27. 1870. He studied at the University of Nebraska (A.B. 1888. A.M. 1889, Ph.D. 1897), attended Harvard law school (1889–90), and practised law in Nebraska from 1890 until 1907. After teaching at the Nebraska, Northwestern and The University of Chicago law schools (1899–1910), he taught at Harvard law school (1910–47), where he served as dean (1916–36). After his retirement in 1947 he was active in numerous legal, editorial and educational positions.

Pound's activities in bar association work led to close co-operation between law teachers and the organized bar. Many fields of the law, including jurisprudence. Roman law, equity and criminal law, were enriched by his writings and teaching. He directed the Cleveland Survey of Criminal Justice in 1922 and was a leader in the cause of efficient court administration.

Pound wrote nearly 1,000 pieces. including 250 books and major papers, and 250 opinions as commissioner of appeals of the supreme court of Nebraska! 1901–03. He also did research and riting early in his career on botanical geography. Among his books are *The Spirit of the Common Law* (1921); *Criminal Justice in America* (1930); *Organization of Courts* (1940); *The Task of the Law* (1944); *New Paths of fhe Law* (1950); and *The Lawyer from Antiquity to Modern Times* (1953).

See P. L. Sayre, *The Life of Roscoe Pound* (1948); and F. C. Setaro, *Bibliography of the Writings of Roscoe Pound* (1942). (L. HL.)

POUND (1) An enclosure in which cattle or other animals are retained until redeemed by the owners, or when taken in distraint until replevied, such retention being in the nature of a pledge or security to compel satisfaction for debt or damage done. Animals may be seized or impounded when *(a)* distrained for rent; (b) damage *feasant, i.e.*, doing harm on the land of the person seizing; *(c)* straying; (d) taken under legal process. The pound-keeper is obliged to receive everything offered to his custody and is not answerable if the thing offered be illegally impounded. Where cattle are impounded the impounder must supply sufficient food and water (Cruelty to Animals Acts, 1849 and 1854); any person, moreover, is authorized to enter a place where animals are impounded without food and water more than 12 hours and supply them; and the cost of such food is to be paid by the owner of the animal before it is removed. Pounds are almost obsolete. *(See* DISTRESS.)

POUND (2)—(a) a measure of weight; (b) an English money of account. (See POUND STERLING.)

(a) The English standard unit of weight is the *avoirdupois* pound of 7,000 grains. The earliest weight in the English system was the Saxon pound, subsequently known as the tower pound, from the old mint pound kept in the Tower of London. The tower pound weighed 5,400 grains and this weight of silver was coined into 240 pence or 20 shillings, hence pound in sense (b) (a pound weight of silver). The pound troy, probably introduced from France. was in use as early as 1415 and was adopted as the legal standard for gold and silver in 1527. The act which abolished the tower pound (18 Hen. VIII: the "pounde Troye which exceedeth the pounde Tower in weight iii quarters of the oz.") substituted a pound of 5,760 grains, at which the pound troy still remains. There was in use together with the pound troy, the merchant's pound, weighing 6,750 grains, which was established about 1270 for all commodities except gold, silver and medicines, but it was generally superseded by the pound avoirdupois about 1330. There was also in use for a short time another merchant's pound, introduced from France and Germany; this pound weighed 7,200 grains. The pound avoirdupois has remained in use continuously since the 14th century, although it may have varied slightiy at different periods—the Elizabethan standard was probably 7,200 grains. The standard pound troy, placed together with the standard yard in the custody of the clerk of the house of commons by a resolution of the house of June 2, 1758, was destroyed at the burning of the houses of parliament in 1834. In 1838 a commission was appointed to consider the restoration of the standards, and in consequence of their report in 1841 the pound avoirdupois of 7.000 grains was substituted for the pound troy as the standard. A new standard pound avoirdupois was made under the direction of a committee appointed in 1834 (which reported in 1854), by comparison with authenticated copies of the original standard (see *Phil. Trans.* 1856). This standard pound was legalized by an act of 1855 (18 & 19 Vict. c. 72). The standard avoirdupois pound is made of platinum, in the form of a cylinder nearly 1.35 in. high and 1.15 in. in diameter, and is marked "P.S. 1844. 1 lb.," P.S. meaning parliamentary standard. It is preserved at the standards office, in the custody of the board of trade.

Whereas the British standard pound was determined by independent legislative action, the U.S. avoirdupois pound was derived from the international kilogram. By a law of 1866 and an executive order of 1893, the U.S. pound was established on the basis of 2.204621 pounds per kilogram.

See the *Reports of the Standards Commission* (6 parts, 1868–73).

POUND STERLING. From about the year 775 silver coins known as "sterlings" or pennies were issued in the Saxon kingdoms, 240 of them being minted from the pound of silver then in use for weighing the precious metals, which was probably about equal to the later troy pound. Hence large payments came to be reckoned in "pounds of sterlings," a phrase later shortened to "pounds sterling." After the Norman conquest the pound was divided for accounting purposes into 20 shillings and in mediaeval Latin documents the words *Libra, solidus* and *denarius* were used to denote the pound, shilling and penny, which gave rise to the use of the symbols *£., s., d. (see* SHILLING; STERLING). Silver pennies were the only coins used until the 13th century, and the pound as the unit of account was based upon a silver standard until the 18th century, when the growth of trade brought large quantities of gold into the country and permitted a gradual change from the silver to the gold standard. In 1717 gold of 22 carats was rated in money at £3 17*s.* 10½*d.* per oz. troy.

The addition of paper money to the circulation added great flexibility to the quantity of money. The heavy issues of paper to finance the Napoleonic wars caused the abandonment of the gold standard in 1797 and the pound remained inconvertible until 1819 when the gold standard was restored without any change in the standard weight. During the 19th century, London was the world's leading financial centre and as such set the rules of the game associated with the classical gold standard. It was maintained without a break until 1914 when wartime dislocations and inflation brought about its suspension. The British government regulated the value of sterling at the pegged rate of 4.76 dollars to the pound.

In 1919, after World War I, there was a heavy fall in the value of sterling, but in 1925 the convertibility of sterling into gold was restored for the second time at Sir Isaac Newton's old 1717 rate.

The new gold standard, which was aptly characterized as an orchestra with three conductors—London, Paris and New York—was much more fragile than the old. Indeed, Lord Keynes argued at the time that the restoration of the prewar dollar par of exchange would subject the external and hence the internal economic position to intolerable strains. Events soon confirmed his forebodings. The great depression starting in 1929 led to an unprecedented contraction of employment and foreign trade and to an acute stringency of credit. The City, which had endeavoured to cling to its customary international financial role by borrowing short in order to continue lending long, was exposed to a huge drain of short-term capital in the summer of 1931 after the crisis of confidence set off by the failure of the Austrian Creditanstalt, which spread rapidly to the German and other banking systems. Traditional methods such as raising the bank rate and borrowing from foreign central banks having proved ineffectual, the government released the Bank of England from its gold standard obligations Sept. 19, 1931, and sterling became a fluctuating currency.

Beginning in 1932 the pound's external value was regulated by the exchange equalization account, which bought and sold sterling for gold and foreign exchange with the announced objective of limiting short-run fluctuations without necessarily preventing longer run adjustments. At the same time new issues of external loans were severely restricted. In fact, the pound-dollar relationship was quite stable within a narrow range around the old par between 1934 and 1938, when the fear of European war precipitated a heavy outflow of gold and liquid funds to New York city. Nevertheless, the account was a successful instrument of exchange policy during the chequered period in which the United States and the franc countries also abandoned the gold standard; not the least of its achievements was the approximate doubling of the official gold and dollar reserves, which enabled Britain to tide over the critical interval between the outbreak of World War II and the adoption of Lend-Lease in 1941.

When World War II began in Sept. 1939, the British government immediately imposed rigid controls over all foreign exchange transactions and pegged the dollar rate at 4.03, which was maintained for ten years. The International Monetary fund, established on the basis of the Bretton Woods agreement of 1944 envisaged the institution of a stable and orderly postwar international currency pattern. and the U.S. loan of 1945 was designed to facilitate the difficult transition to normalcy. But Britain's international economic position, and with it the value of the pound, remained precarious, as was demonstrated by the disastrous and short-lived convertibility experiment of the summer of 1947 and the devaluation of Sept. 1949, when the exchange rate was drastically cut to $2.80 U.S. The interpretation of the long-run effects of the 1949 devaluation was rendered particularly obscure and controversial because of the accompanying discrimination against dollar area imports and because of the impact of the Korean war and the sharp increase in world commodity prices.

The terms of trade, which worsened markedly in 1950–51, virtually regained their predevaluation level in 1954, but retail prices were more than 30% higher. Despite all the stresses of World Wars I and II and their aftermaths and despite its softness in relation to the dollar, the pound, the international currency of the sterling area, remained one of the two leading world currencies. *See* also EXCHANGE, FOREIGN; GOLD STANDARD; INTERNATIONAL PAYMENTS; MONEY. (S. AR.)

POUSSIN, GASPARD: *see* DUGHET, GASPARD.

POUSSIN, NICOLAS (1593/94–1665), the greatest and most characteristic French painter of the 17th century, the leading exponent of pictorial classicism of that period and one of the greatest masters of all time, was born near Les Andelys, Normandy. At about the age of 17 he moved to Paris, where he stayed for the next 12 years, working under various Mannerist artists and studying in the royal collections of painting. sculpture and engraving. At the court of the queen mother he met his first important patron, the Italian poet G. Marino, who commissioned a series of drawings illustrating Ovid's *Metamorphoses.* They are at once crude and Mannerist in style and not very promising.

In 1624 Poussin reached Rome. where Marino introduced him to Marcello Sacchetti, through whom he met Francesco Cardinal Barberini. His style during this period is not easy to define as he was experimenting in various directions at once; but one important influence was that of the Bolognese classical artist, Domenichino. The culminating work of this phase was a large altarpiece for St. Peter's representing the "Martyrdom of St. Erasmus" (1629; Vatican gallery). However, it was a comparative failure and Poussin never again tried to compete with the Italian masters of the baroque on their own ground. Thereafter he painted only for private patrons and confined his work to a format rarely more than five feet in length. From 1629 to about 1633 Poussin took his themes from classical mythology and from Torquato Tasso, and his style became romantic and poetical under the influence of the Venetians, especially Titian; examples are "The Arcadian Shepherds" (1629; Chatsworth, Derbyshire), "Rinaldo and Armida" (c. 1629; Dulwich) and "Cephalus and Aurora" (c. 1630; National gallery, London).

In the mid-1630s he began deliberately to turn toward Raphael and antiquity for his inspiration and to evolve the purely classical idiom which he retained to the end of his life. He also included religious themes once more. beginning with stories which offered a good pageant (*e.g.*, "The Worship of the Golden Calf," *c.* 1636; National gallery), but going on to choose incidents of deeper moral significance in which human reactions to a given situation constitute the main interest. The most important work which exemplifies this phase is the series of "Seven Sacraments" painted for Cassiano del Pozzo, secretary to Francesco Barberini, of which five are now in the duke of Rutland's collection; in connection with another, "The Gathering of Manna" (1639; Louvre, Paris), Poussin wrote that it should be possible to "read" the emotions of all the various figures in the composition.

In 1640 Poussin was summoned to Paris by the king and Cardinal Richelieu, and among his commissions was the decoration of the long gallery of the Louvre. However, disillusionment set in, the local artists intrigued against him and he returned to Rome in 1642. The most valuable result of his visit to his native country had been the friendships which he formed with his French patrons, notably Fréart de Chantelou, whose interest in Stoic and Epicurean philosophy appealed strongly to Poussin. Both his religious and secular paintings of the 1640s and 1650s are concerned with moments of crisis or difficult moral choice, and Poussin's heroes are always those who reject vice and the pleasures of the senses in favour of virtue and the dictates of reason; *e.g.,* Coriolanus, Scipio, Phocion. Diogenes. His style was consciously calculated to express such a mood of austere rectitude. Thus in the "Testament of Eudamidas" (1644–48; Copenhagen) there are only five figures, all painted in dull or harsh colours against the severest possible background. Even in his landscapes, a form which Poussin first took up about 1645 and which he used for the stories of Diogenes and Phocion, the disorder of nature is reduced to the order of geometry, and trees and shrubs are made to approach the condition of architecture. The second series of "Seven Sacraments," executed for Chantelou (1644–48; earl of Ellesmere's collection), has a solemnity which is relatively lacking in the more picturesque first series. In each case the composition is conceived very carefully, not only on the surface but also in depth, recalling the methods of Raphael and reflecting Poussin's own practice at this time of supplementing his preparatory drawings with a three-dimensional model made of wax figures set in a boxlike stage.

Poussin believed in reason as the guiding principle of artistic creation and he was an artist who, in Sir Joshua Reynolds' phrase, was "naturalized in antiquity," yet his figures are never merely cold or lifeless. Though in pose they may resemble figures used by Raphael or in ancient Roman sculpture, they have a strange and unmistakable vitality of their own. Even in his late period, when all movement, including gesture and facial expression, had been reduced to a minimum, his forms are instinct with life. The devotion he has inspired in so many later French artists, among them David and Ingres, Cézanne and Picasso, bears eloquent testimony to this. Poussin died in Rome on Nov. 19, 1665.

See also PAINTING: *Rise of European Schools: France and Flanders.*

BIBLIOGRAPHY.—G. P. Bellori, *Le Vite de' Pittori, scultori ed architetti moderni* (1672); W. Friedlaender, *Nicolas Poussin* (1914), *The Drawings of Nicolas Poussin* (1939–53); O. Grautoff, *Nicolas Poussin*

(1914) ; P. du Colombier (ed.), *Lettres de Poussin* (1929) ; A. Blunt. *Art and Architecture in France, 1500–1700* (1953). (M. W. L. K.)

POVERTY. Poverty may be defined as an insufficiency of the material necessities of life. This is not a very exact definition because the necessities of one society may be luxuries in another and completely unknown in a third. The idea of insufficiency is likewise difficult to fix with precision. Some writers distinguish between poverty as the normal condition of the poorest stratum of a population and indigence or misery as the economic helplessness of people who have no regular source of income.

Another way of looking at the matter is to distinguish the three types of poverty which are discussed below:

Collective poverty is a more or less permanent insufficiency of the material means of life for an entire population, because of limited economic resources. Entire regions such as India and north Africa, as well as the lower income groups in the prosperous countries of the west, fall into this category.

Cyclical poverty is the widespread but temporary deprivation which occurs because of a failure of crops in an agricultural economy or a breakdown of trade in a commercial economy or overproduction in an industrial economy. In former times, cyclical poverty implied the periodic recurrence of famine. In modern times the commonest symptom is mass unemployment.

Individual poverty is a condition of want which results from individual misfortune or incapacity. In every society the widows and orphans, the victims of accident and failure, the residents of idle villages and the workers of bankrupt enterprises, the criminals and the outcasts, the lame, the halt, the blind, the mentally abnormal and the mentally deficient, the drunks and drug addicts, the sick and the aged have special problems of support. In industrially advanced countries it has become customary for the state to provide varying degrees of relief for each of these situations, but these measures are often not sufficient to support a normal style of life. Some mention should also be made of ideal poverty, which is a condition of want, or at least of frugality. maintained as an end in itself. Thus Christianity and Buddhism both give. a large place to the conception of poverty as a virtue, and both provide for vows of poverty to be taken by those entering the religious life under certain conditions. There is also a long tradition of poverty as a secular virtue, going back at least as far as Lycurgus' constitution for ancient Sparta.

The range of possible definitions of what constitutes a condition of want is bounded by literal starvation at one end. This phenomenon was common throughout the world in earlier times. It still occurs with appalling frequency in underdeveloped regions and in the wake of war. At the other extreme. poverty may be merely a family's failure to achieve the average level of living of a particular society at a particular time. Since the level of living of technically advanced countries rises steadily, there are many inconsistencies of time and place. The 20th-century English pauper eats more and better food than the propertied yeoman of two centuries ago. An unemployed worker in the United States may enjoy more comforts than a fully employed Chinese.

Regardless of the limits set to the phenomenon of poverty. there are two important things which may be said about it.

First, the penalties of poverty are always severe. Compared with their contemporaries, the poor will always be found to have more illness! shorter lives, more physical and mental defects, more frequent personal crises, less education, less opportunity for advancement, less security and less leisure. It is debatable whether these disadvantages are offset by intangible benefits such as freedom from anxiety.

Second, it appears plainly that the economic progress of the past few centuries has tended to mitigate poverty everywhere by abolishing famine and raising the minimum level of living which society will tolerate. Indeed, poverty seems to be disappearing altogether in the most prosperous regions of the world. Although many doubts have been expressed as to the ultimate value of this economic progress, it is absurd to deny its existence. There is hardly any useful commodity whose per capita consumption has not increased in a spectacular way in the last century. In the more industrialized countries of the world, attention has shifted almost completely from the age-old problem of finding enough food for the population to the new problem of furnishing every family with automobiles and refrigerators. Even in the most backward and overcrowded agricultural regions, the increase of productivity and the improvement of transportation have made it technically possible to protect everyone from hunger.

Despite these favourable omens, the majority of the world's families in mid-20th century were still desperately poor compared with the average family of North America or western Europe. The first result of a secure food supply is a violent increase in population. Such an increase reached its peak in Europe about 1800. A similar wave of population growth was still gathering momentum in Asia and Africa in the second half of the 20th century. Consequently, there is sometimes a decline rather than an advance of living standards in the presence of increasing social wealth. This is what seems to have happened in Europe in the early part of the 19th century. It was still occurring in various parts of the world in the second half of the 20th century. Although the semi-starvation which was normal throughout past history was by then comparatively rare, it was estimated that half of the human race still subsisted predominantly on coarse grains, and that at least seven-tenths did not have a nutritionally adequate diet. The average daily ration of a Chinese could be obtained by an American automobile worker in exchange for about four minutes of work.

Collective Poverty. — There are two situations which may account for collective poverty — a scarcity of resources or an unequal distribution of resources.

The relative abundance of economic products depends upon the level of technical development in an area and the density of its population. A primitive economic system, without much use of nonhuman energy, may nevertheless be able to provide a fairly high level of living if the density of population is low and there is an abundance of arable land and other natural resources. This was still the case, for example, in the 20th century in many of the Pacific islands. With a moderately advanced technology, differences of population density become critical. Although the French controlled much the same technology as the English in the 18th century, the much greater population density of France produced living conditions which struck Arthur Young and other English observers as degraded. Similarly, despite the steady advancement of Indian agriculture and industry in the past three centuries, the acceleration of population growth over the same period—presumably due to the reduction of famine — seemed to have lowered the level of living appreciably. The existing evidence suggests that the average Hindu of 1950 did not consume as much as his forbears under the Great Mogul. Much the same might be said of China, the other great poverty area in modern Asia.

In the ancient world, where the growth of population was almost universally restricted, the level of living appears to have been distinctly higher than in medieval or early modern Europe.

In advanced economies, the relationship between density of population and level of living disappears, because the availability of land no longer sets the limits for total production. In the United States after World War II the net value added by agriculture never rose above 10% of the national income, although the value of agricultural production was more than 20 times as great as it had been before the Civil War. During the same century, the proportion of the labour force engaged in agriculture declined from two-thirds to less than one-sixth.

In 1948, North America, with about 7% of the world's population, had approximately 43% of the world's income, while Asia, with more than 55% of the world's population, had about 16% of the world's income.

Per capita income in the United States in 1950 was $1,593, while in the same year it was $50 or less in India, the colonial areas of Middle America, China and central Africa. These areas combined had about half of the world's population. There was an equally impressive gap between the industrialized countries of western Europe, with per capita incomes ranging from $400 to $1,000, and the countries industrialized more recently. The estimate for the Soviet Union in 1938 was $181. It was only $143 for Japan.

The meaning of Chinese or Indian poverty in actual experience is that the mass of population in these countries must spend most of their earnings for food. Even so, they are unable to buy a balanced diet. In order to obtain the minimum number of calories required for survival, most of their food intake must be in the form of cereals or rice. Regardless of the type of agriculture, the calorie output per man-hour of labour is greater in the production of grains than in the production of other foodstuffs.

Even in the most prosperous countries there are regions and classes which do not share in the general prosperity. In the United States, where per capita consumption far exceeded the rest of the world in 1950, there were nevertheless 1,900,000 families with incomes under $1,000 in that year and another 5,500,000 whose incomes did not exceed $2,000.

The available evidence indicates that economic progress is normally accompanied by equalization of income, so that the most unequal distributions are found in the poorest countries and the least unequal distributions are found in the richest countries regardless of their differing social and fiscal arrangements.

It is not only because of the widespread prevalence of misery that the contrast between rich and poor is more striking in undeveloped areas. The actual inequality appears to be greater. Jean Fourastié proposed a theoretical explanation in his *Machinisme et bien-être;* namely, that when a dense population is dependent upon limited agricultural resources, all of the marginal land which provides the cultivator's bare subsistence tends to be taken up, and the rent of the better land, from which a surplus can be gotten, tends to be very high. Because of the close and probably inherent relationship between economic progress and equalization of income, the remedy for collective poverty is always essentially the same. In every case, some way must be found of raising the total income of the poverty-stricken population. In other words, per capita consumption of goods and services must be raised. This in turn can only be accomplished by an increase of output per man-hour worked, since in the long run a population cannot consume more than it produces.

The consequences of collective poverty are most strikingly evident in an examination of population statistics. The life expectation at birth around 1950 was over 65 for the most prosperous group of countries, such as the United States and New Zealand. It stood between 50 and 60 for countries of intermediate prosperity, such as France and Austria; between 40 and 50 for moderately poor countries, such as Greece and Japan; and was estimated to be around 30 for India and China. Infant mortality showed an even wider range, from more than 200 deaths per 1,000 live births in the first year of life in the least favoured areas to about 25 in the richest areas.

The relationship between collective poverty and the birth rate is much more complex and cannot be fully treated here. As noted above, the first technical advances in a formerly undeveloped area are likely to be followed by sharp increases of population. The two reasons for this are the decline of infant mortality and the elimination of famine. This is what happened to the European population in the 17th century and it produced a tenfold increase in about ten generations.

Subsequently, with increasing industrial advancement, more and more of the population is drawn into nonagricultural employments and into the cities, whose habits of life tend toward smaller families. Eventually, as happened in France around 1900 and in the United States about 1930, the birth rate may fall below the level which is necessarv for the long-run maintenance of a stable population. However, with continued prosperity and the decentralization of the urban population, there is a tendency for a new cycle of population growth on a more moderate scale to appear. There is no assurance, of course, that economic progress will not be interrupted at some point in this sequence. It can be argued that the commercial development of India and Indonesia by European colonists was initially responsible for the inflation of population by improving the material conditions of life, but that as the colonial system became stabilized, the further progress which would have checked the growth of population was prevented.

The problem of productivity in overcrowded areas received a good deal of attention after World War II, in connection with the U.S. Point Four program and the efforts of the United Nations in former colonial areas. Increasing the productivity of an "underdeveloped" country is always difficult but probably never impossible. Several conditions must be met. First, capital must be provided from an outside source. Underdeveloped areas produce barely enough to keep their populations alive and are unable to provide new capital equipment out of surplus production. Second, improvements to be undertaken must be adapted to the economic circumstances of the area. In a sparsely populated region with no scarcity of land, such as the irrigable deserts of the near east, the principal need is for hydroelectric or atomic energy to stimulate manufacturing. In moderately settled areas, with primitive agricultural techniques. the most promising solution to collective poverty seems to be the improvement of agricultural productivity, since there is no other way of releasing materials and manpower for industrial production. In an area of dense agricultural population with traditions of intensive cultivation, the improvement of transportation may claim first attention.

Technical innovations cannot be successfully made without taking account of the total pattern into which the new elements must be fitted. The meanings attached to a tractor or a lathe are not the same in all cultural settings. The attitudes which contribute to industrial efficiency in Detroit cannot readily be mobilized in Rangoon. On the other hand, the fundamental motives for technological improvement exist almost everywhere—as demands for higher living standards.

In general, the penetration of western technology into the remote corners of the world did seem to be ameliorating the poverty of underdeveloped areas, although slowly and unsteadily. The 20th century especially saw a remarkable expansion in the supply of mechanical energy, which increased fourfold from 1900 to 1950. Most of the underprivileged Europeans at mid-century were far better fed, clothed and housed than the average of their preindustrial ancestors, and there was every reason to think that this improvement would be continuous if not interrupted by the atomic destruction of civilization. For most of the world's people, however, the economy of abundance could still not be assured, and could not be until the rising trend of production clearly outstripped the rising trend of reproduction.

Cyclical Poverty.—In the preindustrial world, economic crises were accompanied by high prices. Prices rose periodically because of scarcities of food, which brought widespread misery. Since the Industrial Revolution, the typical crisis has been caused by overproduction and accompanied by low prices. The sign of crisis and the characteristic type of cyclical poverty in economically advanced countries is mass unemployment.

There are some exceptions to the foregoing generalization, of course. Crises of overproduction were not entirely unknown in the commercial towns of an earlier era. Food scarcities occurred in the 20th century as a result of war or enemy occupation. The Netherlands, for example, suffered an authentic famine in the winter of 1944–45.

Famine was extremely common in the preindustrial world. Fourastié estimated that for the average peasant family in France, the minimum ration of $2\frac{1}{2}$ lb. of bread or 3,000 cal. a day was not attained in one out of four years in the 18th century. The last major famine in western Europe due entirely to natural causes was that of 1709, but hunger has been widespread at many times and places since then. Even in the United States, which has not known a general famine, there has never been a year in which some areas, such as the mountain counties of Kentucky, did not exhibit widespread hunger.

The business cycle in the modem sense, with accompanying mass unemployment, developed gradually in the 19th century. While the severity of successive crises varied, their coverage widened consistently as national economies became more dependent upon each other. There was also an irregular tendency for crises to last longer and longer. The great depression, which began about 1930, lasted for the better part of a decade in most of the countries involved.

In 1935 the number of unemployed in the United States approached 20,000,000, and about one-third of the population was receiving public relief or assistance. The impact of the crisis was equally severe in western and central Europe where it was further complicated by the political unrest which eventually led to World War II. Unemployment decreased very gradually from the high point of the early 1930s, and it was not until after the outbreak of war in 1939 that the surplus manpower was absorbed. Although the business cycle has been closely studied and the entire pattern of events is well understood, economists are not unanimous as to the causes. The remedies are of two kinds. First. through control of production or through the manipulation of market mechanisms, the state may intervene to interrupt the deflationary spiral of falling prices and decreasing employment before it acquires momentum. Second, the victims of unemployment may be protected by governmental subsidies in cash or kind or by employment on public works. As a matter of fact, all of these devices were finally adopted by the governments of all of the countries involved in the great depression, although with many variations of detail. In Britain the principal reliance was upon direct assistance, commonly known as the "dole." In the United States, after some experimentation. the federal government established the huge public enterprise known as the Works Progress administration. During the same decade, a great deal of experimentation was carried on with devices for controlling the cycle itself. In England, France, Italy and the Scandinavian countries, government participation in heavy industry was increased. In the United States, Canada, Germany and some other countries, the central supply of bank credit began to be vigilantly supervised and controlled.

Whether these devices have effectively terminated the business cycle must for some time remain uncertain. Conditions in the decade after World War II did not permit a clear-cut test. A high rate of productive activity throughout the world was associated with heavy military expenditures, the repair of war damage and a number of unusual circumstances which facilitated economic co-operation among the nations.

Even in the absence of widespread mass unemployment, unemployment continued to present serious local problems here and there in the world, being sporadically severe in some sections of every economy. The alleviation of unemployment by insurance benefits or other forms of relief had become a standard practice in civilized countries. Such aid is only sufficient to cushion the unemployed against homelessness and starvation. It cannot prevent other kinds of family hardship, including the loss of savings, the thwarting of plans and the experience of insecurity.

Individual Poverty. — The term "individual poverty" may be used to denote the inability or failure of a family to obtain the necessary income for the minimum customary level of living at a given time and place. There is, of course, a numerical correlation between the incidence of individual poverty and of collective or cyclical poverty. In a poor country or in a bad year, the risks of indigence for marginal wage earners will be very much greater than in prosperous countries and good years. Nevertheless, the phenomenon of individual poverty is quite distinct. It occurs whenever regular earnings are interrupted in such a way that the individual or family can no longer purchase food, clothing, housing and fuel, or when the earnings of a handicapped or underprivileged worker are so low in proportion to his obligations that he cannot sustain himself without outside aid.

The earliest students of this subject took some comfort to their conscience by blaming the undeserving poor for their own plight. Thus, in his *Inquiries Concerning the Poor,* the Rev. John McFarlan of Edinburgh wrote in 1782 that "in tracing the causes of poverty, I have endeavoured to show that the greatest number of those who are now objects of charity are either such as have reduced themselves to this situation by sloth and vice, or such as, by a very moderate degree of industry and frugality, might have prevented indigence." Somewhat later it became a scholarly game to estimate the exact proportions of blameless and blameworthy paupers.. Late in the 19th century, Amos G. Warner concluded that 25% of the poor in the United States owed their condition to laxness, shiftlessness and insobriety, while the remaining three-quarters were victims of misfortune. British studies of the same period estimated about half of the poor to be innocent and the other half to be responsible for their own misfortunes. The first scientifically respectable study of the causes of individual poverty was made by the tireless Charles Booth, who analyzed 4,076 cases of indigence in London. For 62%, the principal cause of poverty was ill-paid or irregular employment; 23% of his sample had been reduced to misery by large families or illness. The remaining 15% were said to be drunken, thriftless or lazy. In subsequent British investigations by B. Seebohm Rowntree and by Sir Arthur Lyon Bou-ley and A. R. Burnett-Hurst, the attempt to find a single cause of poverty was abandoned. Among low-paid factory workers, illness or temporary unemployment were likely to bring bitter hardship for those families with many children. The same contingencies threatened only moderate hardship for single wage earners or small families. The death of the principal wage earner usually meant the impoverishment of a family with small children.

Poverty could also be explained by the varying number of dependents whom the worker had to support during his lifetime taken in relation to his varying earning power from youth to old age. Rowntree, whose three social surveys of the English to n of York (in 1900, 1936 and 1950) were the most detailed empirical investigations made in this field, described a career pattern for the industrial worker. It is characterized by two periods of sufficiency above the poverty line, in youth and in middle age, when the worker enjoys full earnings but has no dependent children; and by three episodes of poverty, as a dependent child, as an overburdened young father and as a dependent old man. Something like this individual career pattern can probably be traced in every social stratum, although it is a little difficult to establish with precision in the highly dynamic economies of the 20th century where the conditions of the worker's childhood are not likely to remain stable until his old age.

A good deal is known about the style of life of families living at a level below their previous minimum. Available cash tends to be used for the purchase of food, and there is a continuous depletion of savings, family capital and credit. Carle C. Zimmerman studied the living conditions in a Cuban sugar-growing area of families who had incomes of less than one dollar per day. Practically all of their resources were devoted to food. In less favourable climates, the problem of finding housing at the level of living where all income is needed for food is likely to provoke community action before absolute indigence is achieved. The history of such measures may be very briefly summarized:

In the preindustrial era the care of paupers was everywhere a local responsibility, and everywhere reluctantly discharged. The role of the central government, as illustrated in the famous poor law of Elizabeth I (1601) and the edicts of Colbert concerning the treatment of vagabonds, was limited to seeing that local responsibilities were carried out more or less. Less extreme cases were generally handled by private action and some elements of aid to the poor fell into the traditional domain of the church. In the industrial era, with the coming of large-scale urbanization, this traditional local responsibility collapsed. For a while nothing took its place except sporadic repression by the police. As Anatole France remarked, "The law, in its majestic equality, forbade the rich and poor alike to sleep under bridges." Beginning with the social insurance program in Germany between 1878 and 1891, the next 75 years saw the enactment at uneven rates and in various fashions of a more or less complete program of welfare measures in every industrialized country, designed to provide minimum subsistence to the victims of each category of poverty. In the United States the enactment of such measures was one of the central themes of the New Deal. It included unemployment insurance, pensions for the aged, aid to widows and dependent children and special provisions for the blind and the handicapped. The main outlines of this system were embodied in the Social Security act of 1935 and its 1939 amendments. In Britain earlier legislation along these lines was supplemented by the enactment, in the National Insurance act of 1946 and the accompanying Health Service act, of most of the features of the "cradle to grave" protection proposed by the 1942 Beveridge report.

Individual poverty in the prosperous countries may be said to be well on the way to solution. The abolition of beggary, of spectacular misery and even of the traditional roles of the widow and the orphan is a cultural revolution whose exact implications are difficult to grasp.

However, many residual problems remain. Pensions and welfare payments tend to be meagre when first established and to become more so with time as they lag behind changes in the price level. In the United States especially, the high cost of medical services creates a special category of hardship. The piecemeal nature of most welfare programs and the prevailing prejudice that public welfare benefits should be kept at a low level means in practice that if starvation has been abolished, misery has been stabilized.

Bibliography.—John McFarlan, *Inquiries Concerning the Poor* (1782); Charles Booth, *Life and Labour of the People of London*, 17 vol. (1889–1903); Robert S. and Helen Merrell Lynd, *Middletown* (1929); Carle C. Zimmerman, *Consumption and Standards of Living* (1936); Anthony Bertram (comp.), *The Pleasures of Poverty* (1950); B. Seebohm Rowntree and G. R. Lavers, *Poverty and the Welfare State* (1951); Colin Clark, *The Conditions of Economic Progress*, 2nd ed. (1951); Jean Fourastié, *Machinisme et bienêtre* (1951); Warren S. Thompson, *Population Problems* (1953); W. S. and E. S. Woytinsky, *World Population and Production* (1953). (T. Cw.)

POWDER METALLURGY, the fabrication of useful items from a metal powder or a mixture of powders, thus differing from most metallurgical techniques, which initially involve the solidification of a molten metal. Fabrication by powder metallurgy techniques is usually employed for one of two reasons: W

1. Such techniques may be the only known means of producing certain metals, alloys or mixtures of two or more metals having desirable physical or mechanical properties. This is the case in producing metals having very high melting points, such as tungsten; in making alloys of two metals or materials that cannot normally be mixed together, such as copper and graphite; and, finally, in producing porous parts which can allow a liquid or gas to permeate their pores.

2. Powder metallurgy may be the cheapest method of manufacture, as is often the case where a large number of identical small parts, such as gears for calculating machines, are required. Powder-metallurgy techniques can be used to form such parts directly to shape, with little or no finishing or machining required. Also, scrap losses are minimized, and raw-material inventory for production consists of only a few grades of metal powder. These three factors contribute to the economic advantages of powder-metallurgy techniques.

BONDING OF METAL POWDER

In order to bond powder particles into a mass which is solid enough to withstand the stresses encountered in service, the powder must be heated, or sintered. This may require from a few minutes to two or three hours for completion. There are t o distinctly different types of sintering encountered in powder metallurgy. One is described as sintering with no liquid present: the sintering temperature is such that there is no molten metal present during the major portion of the sintering period. One of the constituents of the powder being sintered may melt initially when the powder is first heated, but if this molten metal alloys with the solid particles present and thus disappears during the course of sintering, the process is considered to take place with essentially no liquid present.

A second type of sintering takes place with molten metal present during the entire sintering period. In the first case, the solid particles of metal in the powder being sintered must be allowed to bond themselves together through the rather slow motion of individual atoms of the metal within the solid. In the second case, the molten metal wets the remaining solid particles and rapidly flows around them and into the spaces between them if enough of the liquid metal is present. When the powder is cooled from the sintering temperature, the molten metal solidifies and bonds the solid particles together.

Sintering with no liquid present is analogous to the coalescence of small drops of water to form a single large drop. A finely divided material, either solid or liquid, will tend to reduce its exposed surface area as much as possible. In the case of a metal, the strength of the particles resists this tendency unless the temperature is high enough to allow the atoms of the metal to move about to some extent within the particles. The lowest temperature at which this motion takes place is called the **recrystallization** temperature of the metal.

Table I gives the recrystallization temperatures and the melting points of some metals commonly used in the powder-metallurgy industry. Sintering of these metals must take place above the recrystallization temperature but below the melting point if the part being sintered is to retain its shape.

Table I.—*Recrystallization Temperatures and Melting Points*

Metal	Recrystallization Temperature, °C	Melting Point, °C
Tin	20	232
Aluminum	150	660
Silver	200	961
Copper	200	1,083
Beryllium	—	1,280
Iron	450	1,535
Zirconium	750	1,750
Titanium	600	1,820
Molybdenum	900	2,635
Tantalum	1,050	2,996
Tungsten	1,200	3,410

The time required for sintering to take place with no liquid metal present depends on the condition of the powder, the size of the particles and the sintering temperature. The closer the packing of the powder particles, the smaller the particle size and the higher the temperature, the shorter the time required for sintering. To keep the sintering time within reasonable limits, the powder is generally compacted under high pressures to bring the particles as close together as possible. The average particle size ranges from about 0.004 to 0.00001 in. in diameter, and the powder contains both large and small particles in order to have as many points of contact between particles as possible. The temperature of sintering is kept as high as possible above the recrystallization temperature as is consistent with retaining the desired shape of the part being made.

During sintering with a liquid metal present, the proportion of liquid to solid metal must not get too high, or the part will lose its shape, or distort badly. The amount of molten metal present should not exceed about 30% of the total volume of liquid and solid together. The time required for sintering in this instance generally depends on the condition and size of the solid particles and upon the temperature, just as in sintering with no liquid metal present. However, the greater the amount of liquid metal present during sintering, the shorter will be the sintering time.

One other variety of sintering is actually intermediate between the two types described above. If a metal powder is partially sintered with no liquid metal present, it will contain interconnected holes or pores between the solid metal particles. If the partially sintered metal is placed in contact with a molten metal that will wet the sintered powder but not alloy with it, then the molten metal will infiltrate the sintered powder and, if enough liquid is present, fill up the pores.

In all sintering processes the dimensions of the mass of powder being sintered changes during sintering. This change is almost invariably a shrinkage except in the case of certain copper-tin powder mixtures. The amount of the shrinkage depends on the composition of the powder, the amount of compression to which the powder has been subjected before sintering and the time and temperature of sintering. Shrinkages vary from 1% or 2% up to about 25%. This shrinkage must be allowed for in the design of parts which are to be made directly to shape.

MANUFACTURE OF METAL POWDERS

In general, metal in powdered form is a premium product, since energy must be expended to obtain a metal in a finely divided condition. Also, powders for powder metallurgy must often meet certain specifications as to particle size, shape and other properties. To meet these, careful precautions may have to be taken during manufacture of the powder. There are two classes of methods used to manufacture metal powders: mechanical and chemical.

Mechanical methods are applied to either solid or liquid metals. The most widely used method for solids is milling by power-driven hammers (hammer milling) or balls in a rotating container (ball milling). If the metal is brittle, it will easily break into many small, equiaxed particles. Milling times may run from one or two hours to 100 hours or more, with the longer times resulting in very finely divided powder. This type of particle can be used in powder-metallurgy products. If the metal is ductile, however, and can be readily deformed, it will form small, flat flakes when pounded. This type of particle is not well adapted to fabrication of items by powder-metallurgy techniques but finds use as pigment for inks and paints. Solid metals can also be cut or machined to produce fine chips. Liquid metals can be subjected to various processes that break up the metal into droplets, atomizations, which are allowed to solidify in air or water. In most of these methods a stream of liquid metal is broken up by an air blast or a stream of water and the air or water also cools, or freezes, the metal droplets. Another method consists of having a stream of molten metal fall onto a rotating wheel which is simultaneously cooled by air or water. These processes are applicable to any metal or alloy that can conveniently be melted. Metals with melting points up to and including that of iron or steel can be produced in powder form by these techniques.

One advantage of mechanical methods of powder production is that alloy powders containing two or more constituents can be produced. Such alloys as brass (copper-zinc), bronze (copper-tin) and steel (iron-carbon) can be produced in powder form in this way. This is not generally true of the chemical methods of powder production. The greatest disadvantage of milling methods is that these are restricted to brittle metals or alloys, and most useful metals, like copper and iron, as well as their alloys, are ductile. This problem can sometimes be avoided by intentionally embrittling a normally ductile material, pulverizing this while it is in the brittle condition and then treating the powder to restore its ductility if ductility of the powder is required. Certain magnetic iron-nickel alloy powders are made in this fashion.

Chemical methods of producing metal powders are adaptable to a large number of metals. In reduction. the most widely used method, a compound of the metal (generally an oxide, although sulfides and chlorides are also employed) is reduced by a chemical agent, either a gas, liquid or solid. which breaks down the compound into particles of the desired metal and some by-product which must be removed or separated from the metal itself. If the original metal compound is a solid, the size of the particles of the resultant metal depend largely on the condition of the solid compound; a finely divided compound will yield small metal particles. Most solid metal compounds, like oxides, are brittle and can be milled to a fine particle size, so with these the reduction method can produce a finely divided metal powder.

Where the by-product of the reduction of a metal compound and a chemical agent is a gas, its removal is simple and requires only some form of vacuum pump or a continuous flow of an inert or reducing gas to sweep the by-product away. An example is the reduction of copper oxide with hydrogen gas at 350° C. (662° F.) to form copper metal and steam. The steam is easily removed by continually passing fresh hydrogen over the solid copper oxide. The by-product may, however, be a solid or a liquid which solidifies on cooling from the reduction temperature, as in the case of the reduction of titanium tetrachloride with magnesium at 900° C. (1,652" F.). The by-product formed along with the titanium metal is molten magnesium chloride, which solidifies around and between the titanium particles. The magnesium chloride must be dissolved away from the titanium with dilute acid or removed by melting and distillation in a vacuum.

Another widely used chemical method is the electrolysis of a liquid solution which contains the desired metal. Many metal compounds may be dissolved in water at room temperature or in a molten metal compound at elevated temperatures. An electric current is passed through the solution, and the metal is deposited on the cathode. This process is similar to electroplating, but the conditions of current and temperature are adjusted to produce a porous, flaky or brittle deposit of metal. This coating is scraped off or broken up to obtain the powder. If the powder is required to be ductile, it is generally heated in an inert or other protective atmosphere to soften the metal. Nickel, copper and iron powders are often made by this process from aqueous solutions. Titanium and zirconium powders are made by electrolysis of fused chlorides.

A few miscellaneous chemical methods are used to produce minor amounts of metal powders. Some metals. like copper, are readily obtained as water solutions of their compounds. If clean scrap iron or steel is placed in these solutions, copper metal will be precipitated while iron dissolves in the solution. Since copper is more valuable than steel, this process is economically sound for copper production. Iron and nickel form gaseous compounds with carbon monoxide at elevated temperatures and pressure. These compounds are called carbonyls, and they may be broken down into metal particles and carbon monoxide again at low pressures. This technique allows the formation of spherical particles of iron or nickel, which are useful in certain specialized applications in the electronics industry. Stainless steel which has been slowly cooled from a high temperature is attacked rapidly at local areas throughout the material by dilute acidic copper solutions in water. This local attack causes the stainless steel to literally fall apart into individual particles, which can be quite small if the material has been properly treated. This last case is an exception to the general rule that alloy powders cannot be made by chemical methods.

TABLE 11.—Metal Powder Manufacturing Processes

Metal	Processes
Tin	Atomization
Aluminum	Atomization
Silver	Atomization, electrolysis, precipitation
Copper	Reduction, atomization, precipitation, electrolysis
Brass	Atomization
Bronze	Atomization
Beryllium	Reduction, electrolysis
Iron	Reduction, electrolysis
Steel	Atomization
Titanium	Reduction
Molybdenum	Reduction
Tantalum	Electrolysis
Tungsten	Reduction

Table II is a list of some metals used in powder metallurgy, along with the processes mhich can be used to produce each.

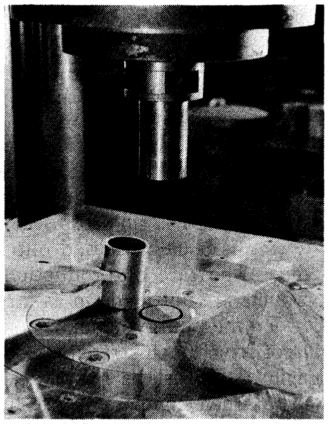
PROCESSES AND PRODUCTS

The processes used in powder metallurgy can be divided into three general classes, depending on the types of metal used in each those involving metals of relatively low melting point which are ductile. such as silver. copper and iron; those processes involving the so-called refractory metals of high melting point which are usually brittle, such as tungsten, molybdenum and titanium; and the processes for the production of materials known as cemented carbide, which contain tungsten carbide.

Ductile Metals.— Parts made from ductile metal powders generally are produced directly to the shape in which they will be utilized. Most of these parts mhich are produced by ponder metallurgy consist of an alloy of two or more metals, such as copper and tin, or a mixture of two or more metals that do not alloy and that cannot normally be mixed together, such as copper and tungsten. If an alloy part is the final product, it is often made by starting with the separate constituents and allowing alloying to take place during the sintering operation, rather than starting with alloy powder. This practice is usually carried out with parts made from copper alloys, while iron-alloy parts are more often made by starting with alloy powder.

The production starts with the mixing or blending together of the required constituent powders along with a solid lubricant, which is very similar to a soap, such as zinc stearate; this lubricant allows the powder particles to flow easily and also is necessary to reduce friction when the powder mixture is pressed to shape. The powder at this point has a density of about 50% to 60% of the density of a similar mass of solid, nonporous metal of the same composition.

A pressing, or briquetting, operation forms the metal powder to the desired Shape at room temperature. A die of strong, hard material, generally a high-quality steel, and a punch, or plunger, are used. This method of forming parts has several limitations that must be borne in mind in the design of parts to be made from ductile metals by powder metallurgy. The die must have straight sides and cannot be undercut, since metal powder, even though it is blended with a lubricant, will not flow readily into an undercut portion of the die cavity that is not directly subjected to pressure from the punch. In addition, the powder tends to adhere to the inside walls of the die cavity. This effect is called die-wall friction and acts to decrease the pressure which is available to compact the powder. Despite lubricants blended in with the powder, die-wall friction prohibits the compaction of parts whose height is more than about three times their width, so that tall, narrow shapes are not easily made by pressing. Die-wall friction also causes wear of the die; the lifetime of a die is of the order of 150,000 pressings even when the surface of the die cavity is made as hard and wear resistant as possible.



BY COURTESY OF AMPLEX DIVISION, CHRYSLER CORP

BRIQUETTING PRESS SHOWING (LEFT) PART EJECTED FROM THE DIE AND (RIGHT) METAL POWDER FROM WHICH PARTS ARE MADE

The pressures used to compact ductile metal powders range from about 10 to 50 tons per square inch, depending on the shape of the part and the type of metal used. After pressing, the part is removed from the die, and the pressure used must have been sufficient to give the compacted powder enough strength to withstand this removal and subsequent handling. If only a few parts are being made on an experimental basis, simple hand-operated hydraulic presses are used. If many thousands of parts are to be made, automatic presses, either mechanical or hydraulic, are necessary; the former have maximum capacities of about 100 tons total force and can produce parts at rates up to 100 per minute, while the hydraulic presses are capable of exerting up to 5.000 tons total force at a rate of one to five pressings per minute. The tonnage capacities of such presses limit the size of parts that can be made to about two inches square in mechanical presses or about eight inches square in hydraulic presses. One type of automatic mechanical press known as the rotary press compacts several small batches of powder simultaneously and is capable of a maximum output rate of several thousand parts per minute. Automatic presses measure the correct amount of powder into the die cavity, compact the powder, eject this compacted powder and then repeat their cycle. Either the total amount of compaction of the powder or the total force exerted on the powder may be controlled, depending on the type of press. Some presses have a double action that exerts pressure on the powder in the die from both top and bottom to obtain more uniform compaction.

During pressing, the metal powder is compacted by a ratio of almost 2 to 1, so that the compacted powder is about 60% to 80% as dense as a similar mass of solid metal. Only ductile metals can be subjected to a compaction of this magnitude. Brittle powders usually have a high strength that prevents such a considerable compression at practically attainable pressures, and even if they could be compressed by the application of a high enough pressure, the particles of a brittle material would fracture and not interlock or flow around each other as do the particles of a ductile metal powder. This last feature is particularly important, since it means that the interlocked particles of a compacted ductile metal powder will have appreciable strength after pressing. The powder after pressing is called a green compact and should have a strength of at least a few hundred pounds per square inch to allow normal handling. The exterior surface of the green compact after it has been ejected from the die will have almost exactly the same shape and size as the cavity of the die in which it was formed. To develop strength to withstand the stresses encountered in service, however, it must be sintered to bond the individual particles together.

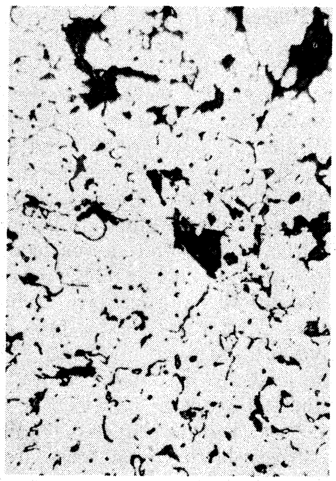
Sintering of green compacts of ductile metal powders generally takes place with no liquid phase present, since this method of sintering results in the least distortion of the shape of the green compacts. Many iron-powder parts, however, are sintered in contact with molten brass or copper, so that the liquid metal infiltrates the partially sintered iron structure. The furnaces used for sintering ductile metals show as much variation in size and type as do presses for compaction Sintering furnaces have one characteristic in common: they must protect the heated metal powder being sintered from contact with the air if a clean. oxide-free part is desired. Gaseous furnace atmospheres commonly used for this purpose are carbon monoxide-carbon dioxide mixtures with varying amounts of nitrogen, pure hydrogen, and hydrogen-nitrogen mixtures. The carbon monoxide-carbon dioxide mixtures are made from the partial combustion of coke or illuminating gas; hydrogen is made by electrolyzing water into its constituents and is readily available commercially; and hydrogen-nitrogen mixtures are obtained by the dissociation of ammonia gas. The sintering atmosphere is usually enclosed in a muffle which is heated externally by burners or electric-resistance elements. Electric heating is more generally used because it is clean and easy to control. The temperatures used to sinter ductile metal compacts range from about 900° C. (1,625° F.) to about 1,300" C. (2,372° F.).

The smaller furnaces used for sintering may be only a few feet long and of the pusher type in which an operator places green compacts in trays and pushes these slowly through the furnace from one end to the other. This type will sinter only a few hundred parts per hour. Large furnaces are employed where many parts must be sintered, and may be of the pusher type with automatic and mechanized operation. the roller-hearth type with rollers along the bottom of the muffle over which trays of parts are passed, or the belt-conveyer type which has an endless heat-resistant alloy belt passing continually through the furnace. This latter type of furnace can sinter thousands of parts per hour. (See FURNACE, METALLURGICAL.)

The strength and toughness of a sintered compact of a ductile metal powder will be somewhat less than those of a cast material of the same composition due to porosity inherent in the powder-metallurgy part. Infiltration of a partially sintered part, however, increases its strength. Also, parts made from some types of steel powder can be heat-treated after sintering to develop higher strengths than would be obtained from as-sintered material. In general the good compressive strength and the lower tensile strength and toughness of pressed and sintered parts must be considered for projected applications.

Ductile metal compacts experience a shrinkage of about 1% to 5% in their dimensions during sintering. When this is properly allowed for in the design of dies, sintered parts can be produced which will have their dimensions equal to any specified size within a tolerance of from 0.3% to 1%. Many parts produced to such tolerances can be used as is, with no further treatment necessary. This dimensional tolerance may not meet all design requirements, however, so that some postsintering operation is necessary. The most common procedure is to make parts slightly oversized as regards the exterior dimensions and then compress the part slightly in a split or sectional die to bring it to the correct size. This is known as coining, and no metal is removed from the part in this operation. Interior dimensions, some exterior contours, and such features as an internally threaded hole which cannot be pressed to shape require machining operations on the sintered part. Sintered parts may also receive treatments other than coining or machining. Parts designed for use as bearings are usually impregnated with lubricating oil or a solid antifriction material by means of a vacuum treatment. The oil in the pores of the bearing serves as a reservoir for lubrication during the lifetime of the bearing. Steel parts which require high strength may be reheated and quenched in oil or water to develop this strength. Parts may also be electroplated to provide a more corrosion-resistant or attractive surface.

A few types of powder-metallurgy products made from ductile metals do not follow the exact cycle of pressing and sintering which has been described. Metal-powder filters are one example of such parts. These filters are made from powder particles of equiaxed or spherical shape and uniform size so that the openings between the particles will all be of the same size. The powder is not pressed. since pressing would distort the particles. Instead the powder is poured into suitable forms of graphite or ceramic and heated while still confined in these forms. The sintering of the particles is allowed to take place to develop reasonable strength in the filter. but not to the extent where the pores between the particles are closed up due to shrinkage.



BY COURTESY OF PRESMET CORP.

SURFACE OF POROUS BRONZE BEARING MADE FROM METAL POWDER; POLISHED. NOT ETCHED. DARK AREAS REPRESENT VOIDS IN THE METAL BEARING. MAGNIFIED 250 TIMES

Alloy powders, such as bronze or stainless steel for corrosion-resistant purposes, are generally used in the manufacture of metal-powder filters.

The pressing operation may also be replaced by other compacting procedures. Ductile metal powder can be fed between a pair of rotating rolls which compact the powder into a wide, continuous sheet. Or metal powder can be extruded through a shaped. wear-resistant alloy nozzle called an extrusion die. This process is much like that of pressing paste through a tube, except that higher pressures are required. Extrusion is particularly successful in fabricating parts from aluminum powders. *(See* also DIE CASTING.)

TARLE 111.—Items Made From Ductile Metal Powders

Description	Composition	Uses
Small structural parts, such as gear cams, retainers .	Iron, brass, bronze, ion infiltrated with copper, aluminum	Machine parts where strength is not extremely important
Small structural parts . .	Steel	High strength machine parts
Porous bearings . . .	Bronze, copper-graphite, lead-bronze	Bearings or bushings (often impregnated with lubricating oil)
Electric conductors . .	Copper-tungsten, silver-molybdenum, copper-graphite	Switch contacts current collectors in 'rotating machinery
Friction linings . . .	Copper-graphite silica-lead	High-friction material for heavy-duty clutches and brakes
Filters	Bronze iron stainless steel,' nickel'alloys	Rigid filters, corrosion-resistant filters
Heavymetal. . . .	Tungsten-nickel	High-density material for weights and radiation shielding

Table III is a list of some of the items made from ductile metal powders. Some of these have unique compositions or physical properties that can be attained only through use of powder-metallurgy techniques. Others could also be made by more conventional processes but are sometimes more economically produced by powder metallurgy when a large number of parts, of the order of *10,000* or more, is required.

Refractory **Metals.**—The refractory metals can be considered as those with melting points above about *1,600"* C. (2,912° F.), with the exception of beryllium, which melts at 1.280° C. *(2,336"* F.). These metals, unlike metals of lower melting points, are generally obtainable from their compounds only as powders. They are usually utilized in the pure form .or with only small amounts of other elements as alloying additions. A few parts are made directly to shape by the pressing and sintering of powders of the refractory metals, just as in the case of ductile metal ponders. This is particularly true with beryllium and titanium. Chiefly. honever, powder metallurgy is used to produce a bar or ingot of the refractory metal, which is then further processed by mechanical working to make wire, rod, tubing or sheet.

Since most refractory metals form powder particles which are either too brittle or too hard to be compacted like the ductile metals, they can be compacted at room temperature only with a binder to hold the particles together. Examples are niobium, tantalum, molybdenum and tungsten. Production starts with the blending of the metal powder with from ½% to *2%* of a binder, such as paraffin wax, dissolved in a volatile solvent. The solvent is evaporated by gentle heating to leave a coating of binder on each powder particle. The powder is then compressed at pressures of up to *50* tons per square inch, in a die with a rectangular cavity about *1* in. in cross section by *12* or *18* in. in length. The pressing is usually carried out in hydraulic presses controlled by hand. The rate of production is low, but the refractory-metal products are not made in as large quantities as are parts made by ponder metallurgy from the ductile metals. The binders used do not have much strength so that the compacted powder is quite fragile and must be handled carefully to prevent breakage.

The green compact is presintered in a protective atmosphere at about *1,000"* C. (1,832° *F.)* to volatilize the binder and to give the compact enough strength to withstand further sintering. The second sintering must be carried out at high temperatures that would be difficult to obtain in conventional furnaces *(see* Table I). Heating of the ingots to accomplish sintering is carried out by passing a heavy electric current through the metal. Heat is generated directly within the ingot because of the resistance it offers to the current flow. *(See* FURNACE, ELECTRIC.) The amount of the current is carefully controlled to bring the temperature of the ingot close to its melting point in order to carry out sintering in the shortest possible time. Distortion of the ingots is pronounced under these conditions but is not important, since the ingot is mechanically worked by hot forging or other processes after sintering.

The atmosphere used for sintering of the refractory metals must not only prevent oxidation of the metal but also must not react detrimentally with the metal itself. For molybdenum and tungsten purified hydrogen gas makes a satisfactory atmosphere. Since niobium and tantalum are embrittled by heating in a hydrogen atmosphere, they are sintered in vacuum.

Molybdenum and tungsten ingots are brittle, although strong, after sintering, in contrast to niobium and tantalum. Some amount of ductility can be produced in the former by proper mechanical aorking of the ingots; this working also closes up the pores remaining in the ingot after sintering, to make a completely dense material. The sintered ingots must first be forged hot, then forged or rolled at successively lower and lower temperatures until deformation, such as cold-rolling into sheet or drawing into wire, is possible at room temperature.

To make ingots or certain shapes of refractory metals from powders, the processes of pressing and sintering can also be combined into a single operation known as hot-pressing. This is actually compaction of the metal above its recrystallization temperature. Extrusion is a more satisfactory process to achieve compaction than is pressing in a die because of the problem of finding a die material that can withstand the high temperature encountered in hot-pressing. In extrusion, on the other hand, the process is so rapid that the extrusion die does not become too hot during the process except at the surface immediately in contact with the hot metal powder. Hot extrusion has been applied chiefly to beryllium. zirconium and titanium. Since these metals would oxidize if exposed to air when hot, the powders are placed in a thin-walled steel container which is evacuated by means of vacuum pumps. The container and powder are then heated, and the hot assembly is extruded in presses of up to *1,000* tons capacity. The steel container is removed after extrusion by machining. The result of extrusion is a rod or tube with a diameter of up to two or three inches, which is almost completely dense. A rod can be further mechanically worked by rolling or other processes. while tubes are used for applications requiring piping which has to nithstand corrosive or other conditions for which these metals are suited. In this connection, it should be noted that beryllium and zirconium are both particularly useful in the production of nuclear energy, since these metals have a very low neutron absorption. and parts made from them can be used in the interior construction of nuclear reactors.

Hot-pressing with a die is most feasible with refractory metal powders if the powder is placed in the die and heated by passing a current through the powder itself. If the rate of heating of the powder is high enough, the die will not become hot throughout but only at the surface in contact with the ponder. This technique requires that the powder be insulated electrically from the die wall by some type of high-resistance lining so that the die will not short-circuit the heating current around the powder.

Ingots of the refractory metals can also be made from relatively coarse powders of these metals by the process of arc melting. In this process, the powder is fed through a vertical hollow tube into an electric arc which is struck between the powder and a water-cooled ingot mold. The heat of the arc actually sinters the powder as it approaches the end of the tube so that the arc is burning from the relatively rigid sintered powder at the bottom of the tube The heat of the arc melts the ponder. but not the water-cooled mold. so that molten metal drips into the mold to form a small pool of molten metal just beneath the arc. Arc melting is carried out in a vacuum to prevent oxidation of the metal and also to eliminate impurities in the metal nhich can be removed as gas or vapour.

TABLE IV.—*Refractory Metals*

Metal	Use
Beryllium . . .	Construction of nuclear reactors, windows for X-my tubes
Zirconium	Construction of nuclear reactors, corrosion-resistant parts
Titanium	Lightweight aircraft parts, corrosion-resistant parts
Molybdenum . . .	Vacuum-tube components, electrical resistors, electrical contacts
Tantalum	Highly corrosion-reiistant parts, vacuum-tube components, electrical capacitors
Tungsten	Vacuum-tube filaments and parts, electrical contacts, glass-to-metal seals

Completely dense ingots weighing over 100 lb. can be produced by arc melting; these are generally brittle as made and must be hot-forged and mechanically worked like a pressed and sintered ingot. Arc melting has been successfully applied to all refractory metals.

Some of the refractory metals, notably titanium, molybdenum and tungsten, are used as alloying elements in the manufacture of certain grades of steel. The metals are alloyed with molten iron in about a 50–50 proportion to form a brittle material which is then crushed to a coarse powder for addition to molten steel.

Table IV lists some of the uses of relatively pure refractory metals made by powder metallurgy.

Cemented Carbides.— The so-called cemented-carbide materials made by powder metallurgy contain, as their principal constituent, powder of the compound of tungsten and carbon known as tungsten carbide. This compound is formed by heating tungsten powder and carbon powder together to 1,500° C. (2.732" F.) in a hydrogen atmosphere for from one to two hours. The powders are held in graphite crucibles and heated in furnaces like those described below which are used for the sintering of the cemented-carbide material. Other refractory metals, notably titanium and tantalum, also form similar compounds, and these are often used along with tungsten carbide powder. The carbides have extremely high melting points and are very hard. The principal use of cemented carbides is as metal-cutting tools and as parts which must resist wear or abrasion.

The melting point of carbides is so high that pure tungsten carbide powder cannot be satisfactorily sintered. The carbide particles must be bonded or cemented together with another metal, and cobalt is generally used for this purpose in amounts ranging from 3% to 25%. The manufacture of cemented-carbide materials starts with the blending of carbide powders and cobalt powder. The blended powders are mixed with a binder, as in the case of the refractory metals. and pressed to shape in a die and punch set. A presintering treatment at about 900° C. (1,652° F.) evaporates the binder and results in a material which has about the strength and consistency of chalk. The material in this condition can now be shaped by machining or grinding to provide the shape necessary in the finished part. The machining operation must be carried out at this point in the manufacture because the final product is so hard as to defy most cutting or grinding operations except those using the hardest of abrasives.

After shaping the presintered compact to size, this is sintered at a temperature of from 1,450" C. to 1,550° C. (2,642° F. to 2.822° F.). During this sintering process the cobalt melts so that molten cobalt metal completely surrounds the carbide particles. Shrinkages of up to 25% in the dimensions of the compact take place during sintering. and this shrinkage must be carefully allowed for in the shaping of the presintered compact.

The furnaces used for sintering cemented carbides are fairly small. Many utilize a ceramic muffle tube and an electric-resistance heater made either from one of the refractory metals, such as molybdenum, or from graphite. Some furnaces consist of a graphite muffle tube surrounded by a water-cooled coil of copper tubing. with a high-frequency electric current passing through the tubing (3,000–100,000 cycles per second). This arrangement is known as an induction-heating furnace. since the high-frequency current in the coil induces an electric current in the graphite tube within the coil. The induced current. in turn, heats up the graphite to a high temperature. In both types of furnace, purified hydrogen gas is generally used as the furnace atmosphere to protect the carbide and the cobalt metals from oxidation and also to protect the heater of an electric-resistance furnace or the graphite of an induction-heating furnace. To accomplish this, the entire furnace, heater and muffle alike, is surrounded by an enclosure which contains the furnace atmosphere. Electric-resistance furnaces used for sintering cemented carbides are of the pusher type. while induction-heating furnaces are usually batch type which must be loaded with presintered compacts: heated to the sintering temperature, cooled, emptied of their charge and then reloaded. The heating and cooling rates of an induction-heating furnace are high enough so that this procedure is feasible. (See also FURNACE, ELECTRIC.)

The sintered carbide material may be utilized as is or subjected to further operations. In the manufacture of cutting tools for high-speed metal-cutting machines, such as lathes, milling machines or drill presses. the cemented carbide is needed only for the tip of the cutting tool. A steel shank. which is a rod or rectangular piece of tough steel, is used to hold a small piece of the sintered carbide material. This piece may typically be only a fraction of an inch in thickness and half an inch square. Smal! pieces of cemented carbide of this type are fastened to the steel shank by brazing or soldering with copper or silver alloys. This technique can be used to fasten cemented-carbide tips to lathe cutting tools, drills, saw blades and almost any other type of cutting tool. The advantage of cemented carbide over tool steel as a cutting tool stems from its ability to cut while red hot.

If the cemented carbide is to be used as a wear-resistant material, it may be inserted in a hole made in a heavier piece of steel. The dimensions of the carbide and the hole should be such that carbide can be pressed into the hole under pressure. Another method of getting a good fit is to cool the carbide to below room temperature, while the steel is heated to cause expansion. If the dimensions of the carbide and the hole are correct, the chilled carbide can easily be inserted in the hole in the warm steel, and when the whole assembly reaches room temperature, the steel will have contracted around the cemented carbide to grip it tightly.

A few types of small cemented-carbide parts are made by hot-pressing in dies, as in the case of refractory metals. This process offers some advantage in rapidly producing parts of somewhat lower quality than those made by pressing and sintering.

Carbide powders can also be used to provide hard, wear-resistant coatings on large areas of a softer metal without going through the pressing and sintering cycle. For this purpose, carbide powder and cobalt powder are forced into a hollow nickel or iron tube about one-quarter inch or larger in diameter. Twelve-inch lengths of this carbide-filled tubing can be used as arc-welding electrodes to provide a hard facing of carbide particles bonded with a cobalt-nickel-iron alloy on any electrically conducting surface. The process consists of striking an electric arc between the electrode and the surface to be plated, just as in arc welding. The heavy electric current in the arc (50–200 amp.) causes melting of the end of the tube, the cobalt and the surface layer of the work being plated. Tungsten carbide and molten metal drop from the end of the electrode to the surface of the work and solidify there to produce a material much like a cemented carbide,. In this fashion, a tough base metal may be coated with an extremely wear-resistant coating about one-sixteenth to one-eighth inch thick.

In another version of this process, a hot mixture of tungsten carbide and cobalt powders is projected forcibly onto a base-metal surface by a gas explosion to produce very thin wear-resistant coatings on the base metal.

Since the end of World War II, much effort has been devoted to the development of heat-resistant materials which can operate under stress at high temperatures, as, for example, in gas turbines or jet engines. These materials have been made experimentally from powdered compounds of refractory metals with carbon, boron and silicon. These elements form carbides, borides and silicides, respectively, with most of the refractory metals. Powder particles of these compounds can be bonded together with a metal, as in the manufacture of cemented carbides. The major shortcoming of such materials is their poor resistance to mechanical shock. The same may be said of metal-ceramic combinations made from ceramic powders which are bonded with a metal. But ceramic parts of silicon carbide and aluminum oxide are produced by pressing and sintering on an industrial scale for unique application.

BIBLIOGRAPHY.—C. G. Goetzel, *Treatise on Powder Metallurgy,* vol. i, *Technology of Metal Powders and Their Products,* and vol. ii, *Applied and Physical Powder Metallurgy* (1949); C. H. Samans, "Powder Metallurgy," *Metals Handbook,* American Society for Metals (1948); L. J. Hull and D. L. Schwartz, "Cemented or Sintered Carbides," *Metals Handbook,* American Society for Metals (1948). (J. WU.)

POWDER RIVER, the name of two streams in the western part of the U.S., one heading in Wyoming and the other in Oregon.

Powder river in Wyoming drains the east and south slopes of the Bighorn mountains through Crazy Woman and Clear creeks and a flat central plains area through its north, middle, and south fork tributaries. Near Kaycee, Wyo., the river flows east 18 mi. and then bends abruptly north to the Wyoming-Montana border, where it curves eastward and then northward to join the Yellowstone near Terry, Mont. Little Powder river, an east side tributary, heads in Wyoming near Gillette and flows due north to the main stem near Broadus, Mont.

Powder river in northeastern Oregon is bordered on the west by the Blue mountains, on the north by the Wallowa mountains and on the south by sagebrush-covered hills. The river flows generally southeast and empties into Snake river near Robinette, Ore. (G. V. SK.)

POWELL, CECIL FRANK (1903–), British physicist, who was awarded the 1950 Nobel prize for physics "for his development of the photographic method in the study of nuclear processes and for his discoveries concerning mesons," was born at Tonbridge, Kent, Dec. 5, 1903. After studying natural science at Sidney Sussex college, Cambridge, he worked for two years as a research student in the Cavendish laboratory. In 1928 he was appointed research assistant to A. M. Tyndall, director of the Wills Physical laboratory at the University of Bristol; there he remained as lecturer, reader and, after 1948, as Melville Wills professor of physics. His experiments led to many fundamental discoveries. The most important of these was the development of a photographic method of observing the tracks of elementary particles. The method was subsequently applied to the study of the particles occurring in the primary cosmic rays which come from outer space. This was done by exposing plates coated with a special emulsion on high mountains and in special balloons made of a thin plastic material. One consequence of this work was the discovery in 1947 of new forms of matter, the heavy mesons. Powell was elected a fellow of the Royal society in 1949. In collaboration with G. P. S. Occhialini he wrote *Nuclear Physics in Photographs* (1937) and many papers on the development of the photographic method in nuclear physics. (W. J. BP.)

POWELL, JOHN WESLEY (1834–1902), U.S. ethnologist and geologist, the founder of the United States Bureau of American Ethnology, is remembered both for his pioneer classification of American Indian languages and for his surveys of the Rocky mountain region. He was born in Mount Morris, N.Y., on March 24, 1834, and educated at Wheaton (Ill.) and Oberlin (O.) colleges. After serving in the Union army throughout the Civil War, he began his professional career in geology with his appointment, in 1865, as professor of geology and curator of the museum at Illinois Wesleyan university, Bloomington, and afterward at Illinois Normal college, Normal. In 1867 Powell began a series of expeditions to the Rocky mountains and the canyons of the Green and Colorado rivers during which, in 1869, he made a daring boat trip of three months through the Grand Canyon. For the Smithsonian institution, in which he founded and directed the Bureau of American Ethnology, he also made ethnological studies that resulted in the first definitive analysis of North American Indian languages. His able work led to the establishment of the United States geographical and geological survey of the Rocky mountain region, with which he was occupied from 1870 to 1875. This survey was incorporated with the United States geological and geographical survey in 1879, the year in which Powell became director of the Bureau of American Ethnology. In 1881 he was appointed director also of the geological survey, a post he occupied until 1894. He died in Haven, Me., on Sept. 23, 1902.

Powell's works in linguistics included *introduction to the Study of American Indian Languages* (1880); and the classic "Linguistic Families of North America," Bureau of American Ethnology, *Seventh Annual Report* for 1885–86 (1891). His main publications in geology were *Exploration of the Colorado River of the West and Its Tributaries* (1875); *Report of the Geology of the Eastern Portion of the Uinta Mountains* (1876); *Report on the Lands of the Arid Regions of the United States* (1878); and *Canyons of the Colorado* (1895).

See also LINGUISTICS: *Descriptive Linguistics;* GRAND CANYON.

See also W. C. Darrah, *Powell of the Colorado* (1951); Wallace Stegner, *Beyond the Hundredth Meridian: John Wesley Powell and the Second Opening of the West* (1954).

POWELL, VAVASOR (1617–1670), Welsh Nonconformist, was born in Radnorshire and educated at Jesus college, Oxford. About 1639 he became an itinerant preacher, and for preaching in various parts of Wales he was twice arrested in 1640. During the Civil War he preached in and around London. In 1646 he returned to Wales, and with a salary granted by parliament resumed his itinerant preaching. In 1650 parliament appointed a commission "for the better propagation and preaching of the gospel in Wales," and Powell acted as one of its principal advisers. In 1653 he returned to London and, having denounced Cromwell for accepting the office of lord protector, he was imprisoned. At the Restoration in 1660 he was arrested for preaching, and after a short period of freedom he was again seized, and remained in prison for seven years. He was set free in 1667, but in 1668 he was again a prisoner, and he died in custody on Oct. 27, 1670.

See *The Life and Death of Mr. Vavasor Powell,* ed. by E. Bagshaw the younger (1671), which contains his autobiography; D. Davies, *Vavasor Powell* (1896).

POWER. The word "power," as used by the engineer, indicates energy under human control and available for doing mechanical work. The principal sources of power are the muscular energy of men and animals; the kinetic energy of the winds and of streams; the potential energy of water at high levels, of the tides and of waves; the heat of the earth and of the sun; and heat derived from the combustion of fuels. Of these sources of power the winds. waves and solar heat suffer the disadvantage of being essentially intermittent and therefore requiring some method of storage of power if the demand for power is continuous. From the point of view of the size and cost of the power plant. when large amounts of power are required, windmills. wave motors and solar engines are not adaptable to large-scale power generation; tidal power, while it may be developed in certain'places for large power. usually entails excessive first cost; volcanic power or natural steam is used in Italy and Iceland; hydraulic turbines and heat engines alone permit the construction of compact plants of. practically unlimited capacity and of moderate first cost. The commonly accepted unit of power is the horsepower, which was defined by James Watt (1736–1819) in 1783 as the equivalent of 33.000 foot-pounds (f.p.) of work per minute. This is about ten times as much work as can be done per minute by a labourer working eight hours per day.

The use of domesticated animals was the first enlargement of the power of man and the beginning of his civilization. The use of the wind for sailing vessels was an early development, but its use in operating windmills dates from about the 12th century. Water wheels were known in Greek times and are described by Vitruvius. but their capacity was very small. To the end of the 18th century the largest water wheels for industrial use did not exceed 10 h.p. The earliest operative heat engine was the cannon, used first at the end of the 13th century. The social consequences of its invention were momentous; it had a great part in the destruction of the feudal system. It represented a greater concentration of power than had been possible previously. Its indirect influence in stimulating the development of the art of cutting metals is of prime importance in the history of the heat engine.

The special incentive which gave birth to the steam engine was the desire to remove water from mines (particularly the tin mines of Cornwall). In 1698 Capt. Thomas Savery's engine was patented and a number of his engines were built. They were found to be extravagant in their use of coal. Four years later the first steam engine using a cylinder and piston was devised by Thomas Newcomen.

It was while repairing a model of this engine that James Watt made the improvements that resulted in the modern steam engine. In 1782 Watt patented a double-acting rotative engine which, for the first time, made steam power available for driving all kinds of mechanism. The result of this invention was the factory system and the Industrial Revolution. It became possible also to apply steam power to navigation and to railroads.

The next important advance in power generation mas the invention by Benôit Fourneyron of the hydraulic (reaction) turbine in 1827, for utilizing the energy of water available under high heads. Impulse water turbines of the Pelton type! adapted to use the highest heads. were developed in California about 1860. Hydraulic turbines reached a high degree of perfection, giving efficiencies in excess of 90%.

The thermal efficiency of a heat engine is a function of the maximum and minimum temperatures of the working substance and also of the cycle of operations. The cycle of maximum efficiency for given temperature limits is the Carnot cycle. Combustion, which is the source of heat in heat engines, may occur either outside the engine (external combustioni or inside the engine (internal combustion). In external-combustion engines the working substance is distinct from the products of combustion, and heat travels to it by conduction through containing walls, such as boiler heating-surface, The maximum temperature of the working substance is then limited by the strength of the containing walls at high temperature. \\-ith internal combustion the products of combustion are used as the working substance, and there is no maximum temperature limit, since the containing walls. piston and valves can be water-cooled. The theoretical thermal efficiency of the steam turbine is about 36%, of the diesel engine about 50% The brake thermal efficiencies actually realized are considerably loner. The internal-combustion engine is compact, of light weight, instantly available for use, has low labour cost and no stand-by losses. Its principal disadvantage is that it uses a fuel more costly than coal except in diesel engines utilizing the cheapest grades of oil.

The first practical internal-combustion engine was that of E. Lenoir (1860). Two years later Beau de Rochas showed that for good efficiency it is necessary to compress the explosive mixture before igniting it. and in 1876 this idea was effectively realized in a successful explosion engine by N. 4. Otto. The Otto cycle is the standard cycle in automobile. airplane and many stationary and marine engines. The fuel used by Lenoir and Otto was coal gas, but in 1883 Gottlieb Daimler substituted volatile liquid hydrocarbon fuel (gasoline or petrol) and thereby made the engine available for automotive purposes. The use of less volatile hydrocarbon fuels (kerosene, fuel oil, etc.) was first successfully developed by Hornsby in the Hornsby-Xckroyd engine of 1893. A year later Rudolf Diesel built his first engine, in which the air is brought up to the temperature of ignition of the fuel by the work of compression alone and fuel is injected in a finely atomized state after the compression is completed. It is possible to burn in it any fuel that can be atomized by high-pressure air injection. by spraying under very high pressure through small openings, or by other means. It ofiers the combination of the cheapest fuel and the highest efficiency of utilization. The diesel engine was slow in development at first because of many practical difficulties. especially from heat stresses. It came into wide use, however, in ships, railway locomotives and motorbuses.

The principal uses for power up to about 1890 were for driving shafting, pumps. compressors and hoists, for locomotives and for marine propulsion. With the improvements that had recently been made in the use of electricity the power station appeared. Electricity is a means for transmission of power and the only means which is economical for long distances and for complicated systems. The earlier power-transmission systems by rope drives. compressed air and water under pressure were too costly and cumbersome to survive.

The history of the development of power shows a constant striving for greater economy. greater compactness of the units and greater capacity of each unit.

See ATOMIC ESERGY; AUTOMOBILE; DIESEL ENGINE: GENERATOR. ELECTKIC; ELECTRIC POWER; HORSEPOWER; INTERNAL-COMBUSTION ENGINE; MOTOR. ELECTRIC; NUCLEAR ENGINEERING; POWER TRANSMISSION; SOLAR ENERGY, UTILIZATION OF; TURBINE; WINDMILL. (L. S. MA.; X.)

POWER ALCOHOL: *see* ALCOHOL.

POWER AMPLIFIER. In radio work the ratio of the alternating-current power produced in the output circuit to the alternating-current power supplied to the input circuit is known as the power amplification. A power amplifier is an amplifier which is capable of producing relatively large power in an output circuit.

See AMPLIFICATION.

POWER OF ATTORNEY or LETTER OF ATTORNEY is a written authority, usually, though not necessarily, under hand and seal, empowering the person named therein to do some act or acts on behalf of the principal, which otherwise could only be done by the principal himself. It is either general or special. A general power of attorney authorizes the agent to act for his principal in all matters, or in all matters of a particular nature. or generally in respect of a particular business. A special power of attorney authorizes the agent to represent his principal only in regard to some particular specified act.

A power of attorney expires with death of the principal, and is revocable at his n-ill, even by a verbal notice. unless it has been given for a valuable consideration to secure some interest of the donee. The law relating to powers of attorney is a branch of the law of agency.

Powers of attorney are used freely in the United States. where their form and usage follow that of England. *See* AGENCY.

POWERS, HIRAM (1805–1873), perhaps the most famous U.S. sculptor of the middle of the 19th century. was horn in Woodstock. Vt., on June 29. 1805. He discovered his talent for modeling while working in a waxworks museum in Cincinnati, O., about

1829. In *1835* he set out for Italy to become a sculptor, stopping in Washington to model a portrait of Andrew Jackson (now in the Metropolitan Museum of Art, New York city), which is probably the best portrait he ever made.

He arrived in Italy in *1837* and settled in Florence, where he remained for the rest of his life. Powers' most famous work was the "Greek Slave" (Corcoran gallery, Washington, D.C.), a female nude, which caused a sensation when it was exhibited at the Crystal Palace exposition in London in *1851.* High prices were paid for his work. He produced many portrait busts of the prominent American visitors to his studio, where he charmed them with his lively conversation.

Powers died in Florence on June *27, 1873,* just when his sculpture and that of his contemporaries was beginning to be supplanted by the work of a later generation.

See Albert Ten ***Eyck*** Gardner, ***Yankee Stonecutters*** (1945) ; Lorado Taft, ***History*** of *American* ***Sculpture (1924).*** **(A. T. G.)**

POWER TRANSMISSION. The appliances for the utilization of natural sources of energy may be classified into three groups: (1) Prime movers, by means of which the natural form of energy is transformed into mechanical energy. To this group belong all such devices as water, gas and steam turbines, steam engines, internal-combustion engines, etc. (2) Machinery of any kind which is driven by energy made available by the prime mover. To this group belong all machine tools, textile machinery, pumping machinery, cranes—in fact every kind of machine which requires any considerable quantity of energy to drive it. *(3)* The appliances by means of which the energy made available by the prime mover is transmitted to the machine designed to utilize it.

In many cases the prime mover is combined with the machine in such a way that the transmitting mechanism is not distinctly differentiated from either the prime mover or the machine, as in the case of the locomotive. In other cases the energy made available by the prime mover is distributed to a number of separate machines at a distance from the prime mover, as in the multiple pulley-and-belt drives used in early factories. In this case the transmitting mechanism has a distinct individuality.

Finally, prime movers may be located in places where the natural source of energy is abundant (near waterfalls or in the neighbourhood of coal fields), and the energy made available is transmitted in bulk to factories, etc.. at relatively great distances. In this case the method and mechanism of distribution become of paramount importance, since the distance between the prime mover and the places where the energy is to be utilized is limited only by the efficiency of the mechanism of distribution.

This article deals with power transmission by mechanical and hydraulic means. For a discussion of the generation, transmission and distribution of electricity, *see* ELECTRIC POWER. (X.)

MECHANICAL POWER TRANSMISSION

Mechanical power transmission refers to the transfer of power through and among machines by means of mechanical devices, such as shafts, gears, belts and clutches. Other methods of power transmission, *e.g.,* electrical, are generally used to convey power over long distances. Power can also be transmitted by means of vibrating media, such as sound and electromagnetic waves—as, for instance, in the tremendous force that is effected by an explosive charge. Any moving mass possesses energy and, therefore, power. A flowing river or a blowing wind each possesses power which is available anywhere along its path of travel.

POWER AND ITS MEASUREMENT

Power.—Power is the time rate of doing work. When a body weighing 5 lb. is raised vertically a distance of *4* ft., *20* ft. lb. of work are performed. In general, work is done whenever a force is moved through a distance; work is the product of force times displacement. Either the force or the displacement must be effective; *i.e.,* either the displacement must be the component parallel to the force direction or the force must be the component parallel to the displacement path.

In fig. *1,* for example, the applied force makes an angle of 30° with the direction of motion of the box along the floor. Thus the component parallel to the floor—the effective force—is *100* × cos 30°, or *86.6* lb. The work, then. is *86.6* × 5. or *433* foot-pounds (f.p.). The downward component, *100* × sin 30°, or 50 lb.. per-

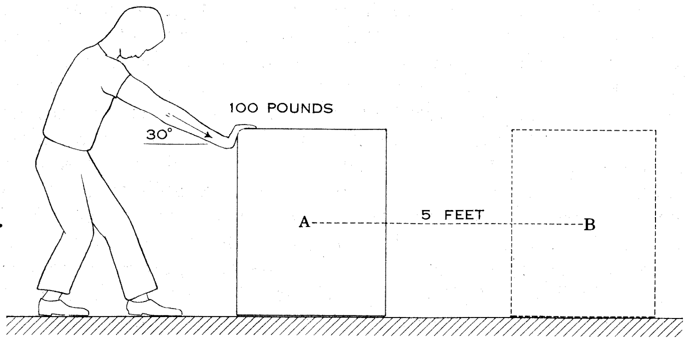


FIG. 1.—WORK SHOWN AS A RESULT OF FORCE (THRUST OF 100 LB. AT AN ANGLE OF 30°) AND DISTANCE (OBJECT MOVED 5 FT.. A TO B)

forms no work because the box does not move in the vertical direction.

The factor of time is not considered in this example. On a slick floor the box might have moved 5 ft. in *3* seconds. while on a rough floor the time might have been *30* seconds. The difference is due to the frictional force between floor and box. What the frictional force does is also work, but the energy is wasted in heating the floor or the box, or both. Less of the total work is left in the second case, and so the box moves (accelerates) slower. The point is that the same amount of work is expended in each case but over a different period of time. In the first case, work is performed at *43313* or *144.3* foot-pound-seconds (f.p.s.), and in the second case at *433130* or *14.43* f.p.s. These figures are a measure of power—the time rate of doing work *(see* POWER; HORSEPOWER).

Mathematically, the time rate of work is expressed as dW/dt—the first derivative of work, W, with respect to time, t. This is the power at any given instant; the average power during some particular time interval is the total work divided by the time consumed: $P_{avg} = W/\Delta t$.

Work performed by a force F on a body which is thereby displaced a distance ds in the direction of the force is Fds; the power P is Fds/dt. Since ds/dt, the time rate of displacement, is velocity, power equals force times velocity, or $P = Fv$. Thus, force multiplied by effective velocity is an expression of power.

A torque or moment M_t applied to a body will cause it to rotate. That is, the body will undergo an angular displacement $d\theta$ during the time dt. The power involved here is: $\mathbf{P} = dW/dt = M_t d\theta/dt = M_t \omega$, where ω is the angular velocity. Power is thus the result of force translation along a straight line, torque rotation about a plane, or some combination of the two.

These fundamental definitions can be used to derive the power involved in any particular case. When the force, or torque, and velocity are constant, power is computed, using the finite expressions. When either or both vary, the infinitesimal expressions are applied and integrated. Such cases can become quite complicated, mathematically.

Power Measurement.—Power-delivering machines must be evaluated, because the amount of power being delivered is most important. In numerous cases, power output can be measured at different places. For instance, in the case of an automobile, power can be measured at the output end of the engine or at the wheels. Thus it is possible to measure and identify power in many ways, such as indicated horsepower, brake horsepower, shaft horsepower and friction horsepower *(see* HORSEPOWER).

In steam, gasoline and diesel engines, the working substance, resulting from the fuel combustion outside or inside the cylinder, exerts a varying force on a moving piston. In a reciprocating compressor and pump, power supplied to the shaft is transmitted to the piston and, in turn, to the working substance. In either case the piston force is variable. This variation must somehow be measured if the power delivered to or by the piston is to be determined. **A** special device called an indicator is used, and indicated horsepower (i.h.p.) is thus measured.

Of the many types of indicators, probably the most common is the piston type, often called a steam-engine indicator (it was originally designed to measure the power of steam engines). In a device of this type. the piston within the body of the indicator is actuated by the varying pressure within the engine cylinder to which it is connected. Motion of the indicator piston is, in turn, resisted by a calibrated spring and thus moves in direct proportion to the pressure and the spring force. A string fastened to the drum at one end and to the engine crosshead at the other rotates the drum to correspond to the engine-piston motion, giving a record of pressure versus piston displacement on a sheet wrapped around the drum. The area within the indicator diagram, being force times displacement, represents the net work performed by or on the engine piston during each cycle. It is therefore a measure of the engine's power. Actually, power is determined by first computing the mean effective pressure (m.e p.)—the diagram area divided by the diagram length. The calculation yields the equivalent constant pressure which defines the same amount of work. When the m.e.p. is multiplied by the piston area, the total force is found. This force multiplied by the stroke L and the number of cycles per minute n, and divided by the horsepower factor, yields the indicated horsepower:

$$\text{i.h.p.} = \frac{(\text{m.e.p.})ALn}{33{,}000} \text{ per piston face}$$

The result, of course, must be multiplied by the number of cylinders (or faces when each side of each piston develops power) present in the engine. Other indicators differ in the type of pressure-sensing unit or recording device; electrical, optical and diaphragm principles have been used.

Power may also be measured at the output end of an engine. A dynamometer such as the Prony brake, is used for this purpose. The Prony brake is an energy-dissipating device in which friction generates heat. Some dynamometers use fluid friction in place of solid friction; e g., hydraulic and air dynamometers. In other types, poner is converted to electrical energy and dissipated in resistors as heat. Still another type is the torque transmission dynamometer, which measures the power actually being delivered. The power passes through the dynamometer without waste and is delivered by it to the work shaft. It is the angular twist occurring in the dynamometer shaft nhich is measured; this twist is directly proportional to the torque and so can be used to obtain the shaft horsepower (s h.p.). Another transmission dynamometer uses electric strain gauges to sense the twist in the shaft, the strain gauge output being calibrated to yield the torque. which then can be converted into shaft horsepower (see DYNAMOMETER).

Whenever one body slides or rolls over another, friction develops. Friction consumes power, and the poner thus lost is called friction horsepower. Friction horseponer is not easy to measure. It can be determined, however, by measuring the power input at zero load; the entire input must be friction power, since external mork is not being done. Friction horsepower can also be found by the method of difference: both input and output power, *e.g.*, indicated and brake horseponer, are measured; the difference between the two is loss and so represents friction horsepower.

Any power wasted in friction becomes unavailable to do the machine's work, and thus the machine becomes less efficient. Mechanical efficiency, therefore, can be stated as the ratio of input to output horsepower. It is a measure of an engine's capacity to keep the externally usable power at a maximum; alternatively, it is also a measure of the ability of a machine to use the power supplied it to do useful work.

POWER PRODUCTION

Prime Movers.—Prime movers are power-generating devices, the output of which is used to operate machines. It is immaterial how the power is developed within the prime mover. In some, the energy is created chemically, as the burning gases in the internal-combustion engine; others convert one form of energy into another by physical means. For instance, steam is expanded to yield shaft power in the reciprocating steam engine; *i.e.*, heat is transformed into mechanical power.

The terms prime mover, power source and power plant are often used interchangeably. but differences may exist. A prime mover provides the immediate energy needed to run the machine: the tiny motor powering an electric shaver is a prime mover. A power plant generates power within itself: the automobile engine is a power plant, but it also acts as a prime mover, turning the rear wheels of the car.

Fundamentally, the sun is the source of all power; the equivalent of the energy obtained from 2×10^{14} tons of coal reaches the earth as solar energy each year. If man knew how, he could produce 1 h.p. from the solar energy striking each square yard. Some of this energy is naturally consumed for man's welfare: evaporation and climatic differences, which bring about rain and winds, supply water, water power and wind power; vegetation feeds both man and animal and so generates muscular power; and the vegetation of past ages is available as coal and petroleum.

For practical purposes, discussion must be limited to power sources found on earth in sufficient quantity for man's use. These are muscle, water and wind power, wood, coal. petroleum and natural gas. The direct use of solar energy constitutes another, although as yet minor, source (see SOLAR ENERGY, UTILIZATION OF). Atomic power is a source man has learned to harness only recently, and nuclear reactors are now used as the heat source in steam-power plants and marine propulsion. The only major difference between the ordinary and the nuclear steam-power plant is the replacement of the boiler by the reactor (see ATOMIC ENERGY; NUCLEAR ENGINEERING).

A typical list of prime movers might include: (1) muscles; (2) windmills; (3) sails; (4) water wheels; (5) reciprocating steam engines; (6) spark-ignition engines; (7) diesel engines; (8) hydraulic turbines; (9) steam turbines; (10) gas turbines; (11) jet and rocket engines; (12) electric motors; and (13) springs. The first four are industrially no longer important in much of the world, although they were in the past; however, in technically undeveloped nations they still provide the major portion of the power consumed.

MECHANICAL TRANSMISSION ELEMENTS

Devices which transmit the power output of prime movers to the place of use are transmission elements. Power involves time, force or torque, and velocity. The same power can result from a large force at low velocity or from a small force at high velocity. In one place on a machine one combination may be required; at an adjoining place, the other combination. If both locations are to be supplied by the same prime mover, many transmission elements may have to be interposed. Therefore, the elements may be numerous and complex.

Mechanical transmission elements include such devices as shafts, gears, belt drives, chain drives, couplings, clutches, brakes, power screws, cams, linkages, flywheels and bearings.

Shafts.—The various designs of shafts may be classified for convenience into two groups: transmission and machine shafts. Transmission shafts are those used outside the machine to bring power to it. These may be relatively long and supported at several places. Line shafts and countershafts, so common in older manufacturing plants, were of this type, distributing the power from a single prime mover to machines throughout the plant. In modern plants the single prime mover has been replaced by individual prime movers, one in each machine. Therefore any shafting needed becomes an integral part of the machine and so falls into the second group, machine shafts.

Basically there is no difference between machine and transmission shafts. Both transmit power, and they differ only in length and the number of stations at which power is withdrawn. The diameter depends upon the torque being transmitted and may be just as large on a short shaft as on a long one. In addition to the torque, shafts are subjected to bending forces (transverse to the shaft), if only due to their weight. Thus, flexure, as well as torsion stresses, is alnays present.

Since shafts are often critical members, they must be properly designed. The amount of twist, as well as the stress, must remain within safe limits. Generally, shafts are made of plain carbon and alloy steels. When greater strength is required, particularly at higher speeds, nickel, nickel-chromium and chrome-vanadium alloy steels are used. Shafts are hot-rolled to standard sizes. and for use under severe fatigue conditions. they are turned and ground or polished to eliminate all surface defects. In addition, they often are given special heat-treatments.

Most shafts are solid and of circular cross section, although they may be hollow, *e.g.*, to carry lubricants on an inner, concentric shaft, and occasionally a power shaft may have a cross section other than circular (see SHAFT. DRIVING).

Keyways and keys are an integral part of power shafting. Sometimes a shaft alone is used betn-een the prime mover and load; more often. however, shafts have many other power-transmission elements attached to them. The elements must be fixed rigidly to the shaft. and to assure this, fasteners, such as keys, pins, cotters and splines. are used. These devices are interposed between the shaft and transmission elements to prevent relative motion between them. This often involves keyways along the shaft, as well as fasteners (*see* KEYS AND KEYWAYS).

Gears.—When teeth are placed around the surface of a cylinder, cone or hyperboloid. the member becomes a gear, another power-transmission element. Gears can transfer power from one shaft to another. and the shafts may be intersecting. as well as parallel. The transmission is positive because gears provide meshing surfaces which do not depend upon friction as the driving medium. Power must be transferred at a constant velocity ratio, quietly and with a low friction loss. Such requirements are not easily satisfied. Thus, gear teeth must be of proper profile, dimension. tolerance and finish. Gears having standard profiles but differing in other details are needed to connect the many shaft directions and satisfy other conditions arising in power transmission. The following types have been developed: spur, bevel, hypoid, helical, herringbone and norm. Detailed descriptions and applications may be found in the article GEARS.

Belt Drives.—Belts are convenient power connectors when shafts are some distance apart and when an absolutely constant velocity ratio is not essential. Belts usually are used to connect shafts that are parallel, but the flexibility of belts permit other arrangements. Belt-connected shafts can be made to turn in opposite directions by crossing the belt.

Leather is the most common flat belt material) but rubber, balata and textiles are also used. The leather is tanned. mineral tanning being preferred for applications where water, steam and oil are present. and layers of the leather then are cemented to form multiple-ply belts. Belt lengths must be fastened together to form the closed loop needed for a drive. The most efficient joint is the cemented lap joint. A simple type is the rawhide-lacing method; wire hooks and steel loops are also used.

A necessary part of the belt drive is the pulley over which the belt rides. Iron, steel, wood, compressed fibre. and plastic laminates are all used to make pulleys. Split as well as solid pulleys are common, the split type being easy to fasten to a long shaft because the halves can be placed over the shait and clamped to it. When it is required to stop and start the driven shaft while the driving shaft continues its rotation. a tight-loose pulley combination is useful; the belt is shifted from one pulley to the other by means of a lever arrangement.

The V-belt, having a reinforced trapezoidal section: can transmit more power because of the gripping action between the belt sides and the V-grooved sheave. Most V-belts have a rubber-fabric outer cover surrounding a central portion of cotton- or wire-reinforced rubber. V-belts are made endless and in a sufficient nurnber of standard sizes to meet most needs. Stretch in these drives is best taken up by means of idler pulleys or pivoted motor bases.

A more recent belting development is the toothed belt. which has teeth on its inner surface to engage corresponding spaces on axially grooved pulleys. This arrangement approximates the positive gear drive. and it can be used when a flexible drive capable of synchronizing the shafts is needed. (See also PULLEY AND BELT.)

Chain **Drive.**—When positive power transmission between shafts too far apart for gear connection is desired, chain drives become useful. The greater elasticity of chain drives also provides better shock absorption. In addition! wear is reduced because of the larger contact area.

A chain is a combination of close-tolerance links, pins and rollers. Standard chains are made in two forms: roller chain and silent chain. and they are manufactured in many sizes. Three principal dimensions define the chain: the pitch (length between rollers). the inside width of the chain and the outside diameter of the roller. A special link. easy to assemble and disassemble, is used to fasten the chain ends. Chains ride on sprockets or toothed wheels, the teeth being shaped to mesh precisely with the chain links.

A less refined but equally practical chain drive can be obtained by running a common link chain over a sprocket designed in the form of a pulley with its rim shaped to interlock with the links. This type of drive is especially useful when heavy loads must be lifted without danger of slippage, as in the anchor windlass and in the differential chain hoist used in maintenance shops. (See CHAIN.)

Couplings.—Couplings are used to join shafts. In general, a coupling is considered a permanent connector, although it can be disconnected for repairs. Both rigid and flexible couplings are made: the latter allow for slight shaft misalignments. Couplings are made in many different styles, the most important of which are discussed in the article COUPLING.

Clutches.—The clutch is a device designed to connect and disconnect a power source and a load. Mechanical-contact clutches are of the positive friction type. Positive clutches contain protruding jaws which engage when the two halves are brought together. The jaws are either square (in which case rotation in either direction may be handled) or spiral (in which case only unidirectional rotation is possible).

The positive clutch is simple, slip-free and light. It does not develop appreciable heat and so can be engaged and disengaged frequently. On the other hand, the sudden engagement and release subjects not only the clutch but also the attached machinery to much shock and wear.

The friction clutch contains two friction surfaces. one on the driving element, the other on the driven element. and some form of linkage to engage and disengage the friction surfaces. Probably the chief advantage of the friction clutch is its ability to slip slightly when first engaged, thus cushioning shocks and reducing wear and stresses. The most common types are discussed in the article CLUTCH.

Brakes.—The mechanical brake, like the clutch, contains two friction surfaces and a mechanism which brings them into contact. The brake absorbs kinetic energy by generating and dissipating heat. Block, band, disk and shoe brakes are common. (See BRAKE.)

Power Screws.—Threaded rods (screws) are often used to transmit power. Lathes, presses, jacks and materials-testing machines are typical of devices employing power-transmission screws. Screw drives are not very efficient, but for slow. powerful motion, they are convenient. The lathe tool-carriage screw (see LATHE) is illustrative of an important trait of the power screw: its ability to convert a rotational force (torque) into a powerful linear (translational) force.

Cams and Linkages.—A cam transmits power by means of a follower in direct contact with it. The contact is either sliding or rolling. The cam itself can take many forms and can impart an infinite variety of reciprocating or oscillating motions to the follower. Because it can be designed to provide nearly any complex motion. it finds much use in automation devices, computers and servomechanisms. (See CALI.)

Like cams, linkages primarily transmit motion. although in some applications they may push or pull a load and in transmitting power become machines. For instance, the power generated at the piston of an internal-combustion engine is transmitted to the crankshaft by means of the connecting rod. The combination is one of the two basic link mechanisms: the slider crank and the four-bar chain. Important linkages of one type or the other are devices like the Scotch yoke, the Whitworth quick-return mechanism, the Geneva wheel, escapements, toggle joints, Hooke's coupling and the straight-line mechanisms. (See LINKAGES.)

Flywheels, Bearings. — These two devices only assist in power transmission; they do not in themselves actually transmit power. Flywheels are attached to a shaft and. because of the large mass involved, absorb and release energy to maintain a more uniform rotation. For example, during the power stroke of a punch press the kinetic energy of the flywheel provides some of the power suddenly needed. Therefore, shaft rotation is reduced but not stopped, as it might be without the flywheel.

Bearings permit motion of one part relative to another with a minimum of friction or power loss, while simultaneously supporting the load on the moving element. Thus, again, bearings are necessary machine elements in a power-transmission system but do not themselves transmit useful power. (See BEARINGS.)

(J. P. V.)

HYDRAULIC POWER TRANSMISSION

A variety of machines use some liquid for developing a push or pull, for moving some object or for controlling some action. Oil, water or some other liquid can be used, but oil is the most common. For practical purposes, it does not change its volume when the pressure is increased. Thus, if oil fills a hydraulic system completely (leaving no air or gas pockets), the motion of a piston can be controlled conveniently and within close limits by the oil flow. Oil lubricates the sliding parts and also prevents rust.

Many complicated hydraulic systems have been developed; however, most of these are essentially combinations of certain simple hydraulic circuits. A study of these simple systems is helpful in understanding the more complicated systems.

Hydraulic Press. — The simple system in fig. 2 illustrates the action of many devices, including the hydraulic press. The two cylinders are connected by a pipe. There is a close-fitting piston in each cylinder, and liquid in the pipe and cylinders. Assuming no leakage past the piston, the pressure of the fluid is the same in all parts — a statement of Pascal's law (see MECHANICS, FLUID). Essentially the same fluid pressure acts on the face of each piston. Thus a small force F_1 on piston A (small area) can balance a large force F_2 on piston B (large area). In principle, the hydraulic press is analogous to the mechanical lever.

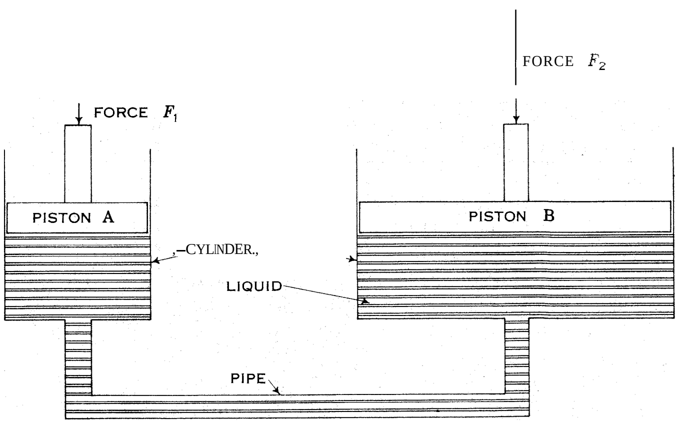


FIG. 2.— HYDRAULIC PRESS

Hydraulic System.—Fig. 3 is an example of a hydraulic system. Oil from a reservoir flows through a pipe into the pump, which increases the pressure of the oil. The oil then flows through a pipe into the control valve, which regulates the flow to the cylinder. A relief valve, pre-set at some safe maximum pressure, is provided for the protection of the system; if the oil pressure should rise above the safe maximum, the relief valve will open and relieve the pressure. Oil entering the cylinder acts on the piston, and this action develops a force on the piston rod which can be used to operate some device. Oil from the cylinder returns to the reservoir. A filter in the circuit removes dirt and foreign matter from the oil.

As an illustration, assume that the oil pressure produced by the pump is 1,000 lb. per square inch (p.s.i.) and that the piston area

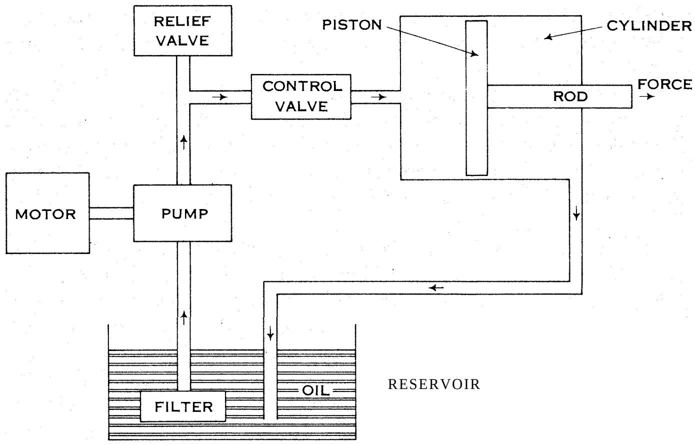


FIG 3 — COMPONENTS OF A HYDRAULIC SYSTEM

over which the oil pressure acts is 3 sq.in. The force on the piston then is $3 \times 1{,}000$, or 3,000 lb. Thus, a relatively small pressure, acting on a small cylinder, produces a relatively large force to act on some load.

Fig. 3 also illustrates the principle of the hydraulic amplifier. Assuming that the pump produces a pressure of 1.000 p.s.i in the system. as above, and that a force of 8 oz. is required to move the control valve through its entire range, from fully closed to fully opened, the 8-oz. force can be used to vary the output force on the piston through a range of 0–3,000 lb.

General Features of Hydraulic Systems. — There are three basic parts in the typical hydraulic system: (1) an oil pump; (2) a cylinder or chamber having an actuating piston driven by the liquid; and (3) valves and piping to control the flow of the liquid. The actuating piston can be given any motion desired for control and power. Straight-line reciprocating motion is common. and rotary motion of the driven unit can be accomplished with different hydraulic motors. With these basic features in mind, it is possible to develop different combinations of the simple system.

Hydraulic Pumps and Motors. — In the electric generator, mechanical energy is converted into electrical energy. In the fluid pump, mechanical energy is converted into fluid energy. Therefore, the electric generator and the pump are analogous. Likewise, both the electric motor and the hydraulic motor produce mechanical work, the former from electrical energy, the latter from mechanical energy. The fluid motor may be of either the reciprocating or the rotary type.

Hydraulic machines are of two principal kinds: the dynamic or velocity machine and the positive-displacement or static-pressure machine. In the dynamic or velocity type the action between some mechanical part and a fluid involves significant changes in fluid velocity. The electric fan and the automobile torque convertor are examples of the dynamic type.

In the positive-displacement or static-pressure machine the characteristic action is a volumetric change or a displacement action. The hand bicycle pump is an example of the displacement type of hydraulic machine. A positive-displacement machine may have either a fixed or a variable displacement. For example, the internal-combustion engine involves a crank, connecting rod, and piston; the piston displaces a certain fixed volume in the cylinder with each revolution of the crank. If the stroke could be varied, then the displacement could be varied.

The basic hydraulic machine is the common plunger pump. It consists of a cylinder fitted with a reciprocating piston, and valves for directing the liquid to and from the cylinder. When acting as a pump, the piston does work on the liquid; the pressure is increased. When functioning as a motor, the liquid does work on the piston.

In a rotary hydraulic pump, work is done by a rotating member on the fluid; the pressure at the outlet is higher than the pressure at the inlet. In a rotary hydraulic motor, fluid pressure at the inlet is higher than fluid pressure at the outlet; the difference in fluid pressure is absorbed by the rotating member to turn the out- shaft. Rotary machines are usually classified into three main types, according t the design of the rotating element: , vane or piston.

The hydraulic gear pump or motor has a pair of meshing gears in a casing. As the gears rotate, liquid passing through the inlet is trapped between their teeth and the casing and is carried around to the outlet. During each revolution of the gears a certain volume of liquid is transferred from inlet to outlet, so this is a fixed-displacement machine.

The hydraulic vane pump or motor has a rotating member fitted with sliding vanes and set off-centre in a casing. The entering liquid is trapped between the vanes (which ride on the inside of the case) and is carried to the discharge. Both the gear machine and the vane machine are described further in the article PUMP.

Fig. 4 shows the design principles of a hydraulic radial-piston pump or motor. The stationary reaction ring and the rotating cylinder block have centres which do not coincide. As the cylinder block rotates, the pistons in the cylinder block execute a reciprocating motion in a radial direction. By means of a valve arrangement, the liquid moves in and out of the machine at the centre of the cylinder block. The displacement of this machine can be varied by altering the distance between the centres of the cylinder block and the reaction ring.

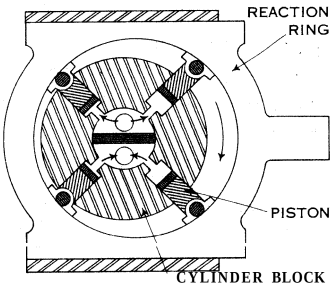


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FIG. 4.— HYDRAULIC RADIAL-PISTON PUMP OR MOTOR

Various arrangements of axial-piston machines have been devised. Fig. 5 illustrates the features of one arrangement of a hydraulic axial-piston pump or motor. The pistons move back and forth in the cylinder block in a direction parallel to the axis of rotation of the cylinder block; this explains the term "axial-piston." The liquid enters and leaves the piston chambers, or bores, at the left end of the cylinder block, which is suitably arranged with a valve plate. The axis of the rotating shaft (either driver or driven) is set at an angle with respect to the axis of rotation of the cylinder block. As the shaft rotates, the piston connector actuates the piston; in one revolutibn of the shaft, each piston has reciprocated back and forth. This machine can be arranged for a variable displacement by varying the angle.

Standard gear pumps and motors are available for pressures of 2,000 p.s.i. or more, and gear motors are rated to deliver up to 20 h.p. Vane pumps and motors are made for the same pressures, and vane motors will deliver up to 125 h.p. Rotary piston pumps and motors are built for pressures of 5,000 p.s.i. or more, and the motors have outputs of as much as 150 h.p.

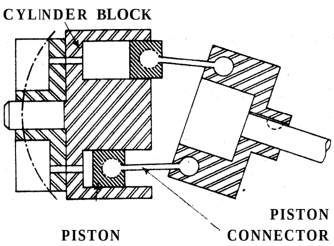

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FIG. 5.— HYDRAULICAXIAL-PISTON PUMP OR MOTOR

Valves.—In hydraulic systems one of the most common types of valve is the piston or spool valve (fig. 6). As shown in the figure, fluid enters port A, passes through the valve body and leaves at port B. By sliding the valve stem, the ports A and B could be blocked by a spool. Various arrangements of ports and spools can be used to get different types of flow control.

Accumulators.—Some hydraulic systems include an accumulator, which is a device for storing fluid energy. An air accumulator is a closed chamber, partly filled with air, into which the pump supplying hydraulic power to a machine delivers liquid while the machine is not working at full capacity. Such an air cushion is used on many reciprocating water pumps. The main purpose of the accumulator is to allow hydraulic machines, such as lifts and

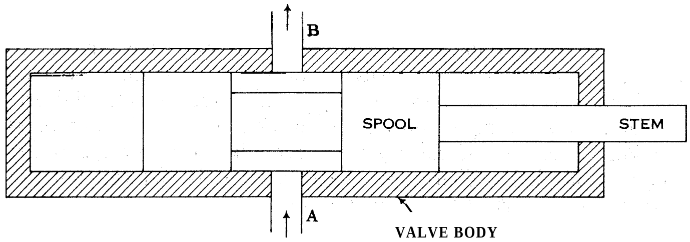


FIG. 6.— PISTON OR SPOOL VALVE

presses, to work for a short time at a greater rate than the pump can supply energy. The accumulator acts as a pressure regulator; it serves to damp out pressure surges and shocks in the system.

Hydraulic **Transmissions.**—Various methods can be used to connect two rotating shafts. In many cases purely mechanical connectors are suitable: gears, chain drives, clutches. In other applications, however, service requirements are best met with some form of hydraulic connector or transmission. In practice two types of hydraulic transmissions are commonly found: (1) the static or displacement transmission; and (2) the hydraulic, hydrodynamic or dynamic coupling.

Displacement Transmission.—The hydraulic displacement transmission is a combination of a rotary pump and a rotary motor connected by piping. The pump may be some distance from the motor, or the two may be mounted in a single housing.

This type of transmission has several advantages For example, the output shaft can be maintained at a constant speed despite a varying input-shaft speed. The direction and speed of the output shaft can be controlled remotely and accurately, and a fixed power output can be maintained over a range of speeds. Automatic overload protection can be maintained, and power consumption can be kept low.

There are four major combinations of pump and motor in a displacement-type transmission.

In the first, a variable-displacement rotary pump is connected to a fixed-displacement hydraulic motor. For a constant work load, a variation in the output-shaft speed will result in an almost constant output torque and variable power. Constant-torque hydraulic transmissions are used on machine tools and conveyors.

A second arrangement couples a fixed-displacement rotary pump with a fixed-displacement rotary motor; there is a flow-control valve in the connecting line to vary the rate of oil flow to the motor. If the load on the output shaft is constant, the output torque will be constant and the power will vary proportionally with the speed.

In a third arrangement, a fixed-displacement pump is connected to a variable-displacement motor. There are various applications, as in machine-tool spindle drives, in which it is desired to maintain constant output power as the output speed is varied. This condition can be realized by varying the hydraulic motor displacement; in this case the output torque decreases as the speed increases.

Finally a variable-displacement pump may be connected to a variable-displacement motor. This combination gives different variations in output-shaft speed, torque and power.

Hydraulic Coupling.—A hydraulic coupling is a combination of a centrifugal pump and a hydraulic turbine. It is sometimes called a hydraulic flywheel, primarily because it reduces torsional vibrations. The action of a hydraulic coupling can best be illustrated by two ordinary electric fans set facing each other. One fan is started by switching on the electric current; its blades rotate, the air flow turning the blades of the other fan. In the hydraulic coupling, the rotating input or primary shaft drives a centrifugal-pump runner or impeller. This usually has straight radial vanes or blades; in construction it resembles a grapefruit half, with the fruit removed. As the pump runner builds up speed, kinetic energy is added to the fluid, which flows outward along the vanes, crosses a gap and enters the turbine runner. Usually the turbine runner is similar in construction to the pump impeller, with straight radial blades. After sufficient energy has been developed, the liquid turns the turbine runner, which is connected to output or secondary shaft. There is no mechanical connection between the input and output shafts; the linkage between them is solely through the medium of the moving fluid.

Since there are no torque-reacting members in the hydraulic coupling other than the pump impeller and the turbine runner, the output torque always equals the input torque for steady operating conditions. The speed of the input shaft always exceeds that of the output shaft. At the start of operation, the input shaft rotates while the output shaft remains stationary; the "slippage" is 100% ; at normal speeds and loads: the slip may be low as 1%–4%. The efficiency of the coupling is defined as the ratio of the power output to the power input. At ,normal speeds and loads, the efficiency of a hydraulic coupling is high; it may be 95%–99%. Torsional vibrations or shocks on either shaft of the hydraulic coupling are damped by the fluid: The load on the output shaft may be stalled without stalling the driver or input shaft. Hydraulic couplings have been built with capacities ranging from 1 to 36,000 h.p. In some automotive transmissions, a hydraulic coupling-is added, along with the gearbox, in the power drive between the engine and the rear wheels. The hydraulic coupling is not a substitute for the gearbox: the gearbox is used to change the torque, whereas the hydraulic coupling does not change the torque. The hydraulic coupling merely serves to cushion shocks.

A variant of the hydraulic coupling is the electromagnetic clutch, which contains a fluid suspension of paramagnetic particles (*e.g.,* a compound of iron). When an external magnetic field is applied, the fluid suspension becomes almost solidified and capable of transmitting torque. (R. C. Br.)

Bibliography.—Abbott P. Usher, *A History of Mechanical Inventions,* rev. ed. (1954) ; C. W. Ham *et al., Mechanics of Machinery,* 4th ed. (19.58) ; R. E. Hampton, *Introduction to the Basic Mechanisms* (1956) ; H. H. Mabie and F. W. Ocvirk, *Mechanisnzs and Dynamics of Machinery* (1957) ; H. L. Stewart and F. D. Jefferis, *Hydraulic and Pneumatic Power jor Production* (1955) ; W. Ernst, *Oil Hydraulic Power and Its Industrial Applications* (1949) ; I. McNeil, *Hydraulic Opevation and Control of Machines* (1955) ; J. J. Pippenger and R. M. Koff, *Fluid-Power Controls* (1959) ; W. E. Wilson, *Positive-Displacement Pumps and Fluid Motors* (1950) ; H. G. Conway, *Fluid Pressure Mechanisnzs* (1949) ; R. Hadekel, *Hydraulic Systems and Equipment* (1954) ; R. C. Binder, *Advanced Fluid Mechanics,* vol. i (1958).

POWHATAN. This group of Algonkin Indian tribes in the tidewater portion of Virginia and southern Maryland had been melded into a confederacy by the conquests of an able chief known by the same name, shortly before the settlement of Jamestown in 1607. His daughter Pocahontas (*q.v.*) married John Rolfe. After Powhatan's death the Indians massacred 347 British settlers in 1622. Fourteen years of relentless warfare followed until the Indians submitted, only to rise again in 1641 and slay 500 whites. The war that followed broke them, and though in 1669, 2.100 remained of the original 8,000, they dwindled to about 700. mixed with Negroes and whites, and were known as Chickahominy, Pamunkey and by other tribal names. (A. L. K.; X.)

POWIS, EARLS AND MARQUESSES OF. Before the Norman Conquest the Welsh principality of Powis, comprising the county of Montgomery and parts of the counties of Brecknock, Radnor, Shropshire, Merioneth and Denbigh, was subject to the princes of North Wales. Early in the 12th century it was divided into upper and lower Powis. In 1283 Owen ap Griffith, prince of upper Powis, is said to have formally resigned his princely title (*nomen et circulum principatus*) and his lands to the English king Edward I at Shrewsbury, and received the lands again as an English barony. This barony of Powis passed through female inheritance to the family of Cherleton and in 1421 to that of Grey. It fell into abeyance in 1551.

In 1587 Sir Edward Herbert (d. 1595), a younger son of William Herbert, earl of Pembroke, purchased some of the lands of the barony, including Red castle, afterward Powis castle, near Welshpool, and in 1629 his son William (c. 1573–1656) was created Baron Powis. William's grandson. William, the 3rd baron (*c.* 1626–1696), was created earl of Powis in 1674 and Viscount Montgomery and marquess of Powis in 1687. As one of the leading members of the Roman Catholic aristocracy in England, Powis was accused of complicity in some of the alleged popish plots and was imprisoned in the Tower of London from 1678 to 1685. Me followed James II into exile and was created duke of Powis by the dethroned king. William. 2nd marquess, who had a somewhat chequered career as a Jacobite, died in October 1745, and when his son William, the 3rd marquess, died in 1748 the titles became extinct.

In 1748 Henry Arthur Herbert (c. 1703–72), who had been made Baron Herbert of Cherbury in 1743, was created Baron Powis and earl of Powis. The titles became extinct a second time when his son George Edward died in January 1801. George's sister and heiress, Henrietta Antonia (1758–1830), married Edward Clive (1754–1839), son and heir of the great Lord Clive. In 1804, he was created Baron Powis and earl of Powis.

P'O-YANG, a lake in northern Kiangsi province, China, is a rapidly silting up flood reservoir for the Yangtze river at the northern end of the basin, the drainage of which coincides with the area of Kiangsi province in central China. The lake covers an area of 1,073 sq mi. and is 70 ft. deep at high water. but shrinks greatly during the dry winters. Through its flood plain flows its chief river, the Kan Chiang. from the south. the Lo-an Shui and Hsin Chiang from the east, and the Hsiu Shui from the northwest. River steamboats navigate between the lower reaches of these and the narrow northern P'o-yang arm to reach the Yangtze at Hu-k'ou. (H. J. Ws.)

POYNMGS, SIR EDWARD (1459–1521), lord deputy of Ireland. was the only son of Robert Poynings. second son of the 5th Baron Poynings. His mother was a daughter of Sir William Paston. and some of her correspondence is to be found in the *Paston Letters.* Robert Poynings was implicated in Jack Cade's rebellion, and Edward was himself concerned in a Kentish rising against Richard III. which compelled him to escape to the continent. He attached himself to Henry, earl of Richmond, afterward King Henry VII, with whom he returned to England in 1485. Poynings was employed by Henry VII in the wars on the continent, and in 1493 he was made governor of Calais. In the following year he went to Ireland as lord deputy under the viceroyalty of Prince Henry, afterward King Henry VIII. Poynings immediately set about anglicizing the government of Ireland, which he thoroughly accomplished, after inflicting punishment on the powerful Irish clans who supported the imposture of Perkin Warbeck. He then summoned the celebrated parliament of Drogheda, which met in December 1494, and enacted the "Statutes of Drogheda." famous in Irish history as "Poynings's law," subordinating the Irish legislature to that of England, till its repeal in 1782. After defeating Perkin Warbeck at Waterford and driving him out of Ireland, Poynings returned to England in 1496, and was appointed warden of the Cinque Ports. He was employed both in military commands and in diplomatic missions by Henry VII. and later by Henry VIII. his achievement being the negotiation of the "Holy League" in 1513.

See Sir Francis Bacon, *The History of the Reign oj King Henry VII* (1641) ; Richard Bagwell, *Ireland Under the Tudors,* 2 vols. (1885) ; J. T. Gilbert, *History of the Viceroys of Ireland* (1865) ; J. A. Froudc, *The English in Ireland,* 3 vols. (1872–74) ; Wilhelm Busch, *England Under the Tudors,* ed. by James Gairdner (189;).

POYNTER, SIR EDWARD JOHN, 1st Bart. (1836–1919), English painter. son of Ambrose Poynter, architect, was born in Paris on March 20. 1836. He pursued his art studies in England and in Paris (under Gleyre. 1856–59), and exhibited his first picture at the Royal Academy in 1861. He became a member of the Royal Academy in 1876.

In .the decorative arts he practised freely as a designer in fresco, mosaic. stained glass. pottery, tilework and the like.

Poynter proved himself a vigorous and successful administrator, in 1894 becoming director of the National gallery. Under his rule the National Gallery of British Art. at Millbank. presented by the late Sir Henry Tate. became a department of the National gallery. He edited the great *Illustrated Catalogue* of *the National Gallery* (1889–1900). in which every picture in the collection was reproduced. On the death of Sir John Millais in 1896, Poynter was elected president of the Royal Academy and was knighted. He was made a baronet in 1902. Poynter died in London on July 26, 1919.

POYNTING, JOHN HENRY (1852–1914), British physicist and experimenter in gravitation, was born at Monton, near Manchester, on Sept. 9, 1852. He studied at Owens college, Manchester, and at Trinity college, Cambridge. He was bracketed third wrangler in 1876. Poynting went as demonstrator in physics to Owens college, but returned to Cambridge in 1878 on his election as fellow of Trinity college. In 1880 he was appointed professor of physics at the Mason college, which afterward became the University of Birmingham. He retained this post until his death at Birmingham on March 30, 1914.

Poynting carried out experiments over a period of 12 years to determine the gravitational constant and the mean density of the earth. He used a balance method and during the course of his experiments added considerable knowledge to the technique of accurate weighing. (*See* GRAVITATION: Poynting's Experiment.) Poynting's best-known work is that in the papers "On the Transfer of Energy in the Electromagnetic Field" (Phil. Trans. *A.*, 1884) and "On the connection between Electric Currents and the Electric and Magnetic Induction in the Surrounding Field" (*Phil.* Trans *A.*, 1888). In the first paper Poynting showed that the flow of energy at a point could be expressed by a simple formula in terms of the electric and magnetic forces at that point. This is known as Poynting's theorem and the vector is also called by his name. Poynting also wrote papers on radiation and the pressure of light and several books.

See his *Collected Scientific* Papers, edit. *by* G. A Shakespear and G. Rarlow (1920).

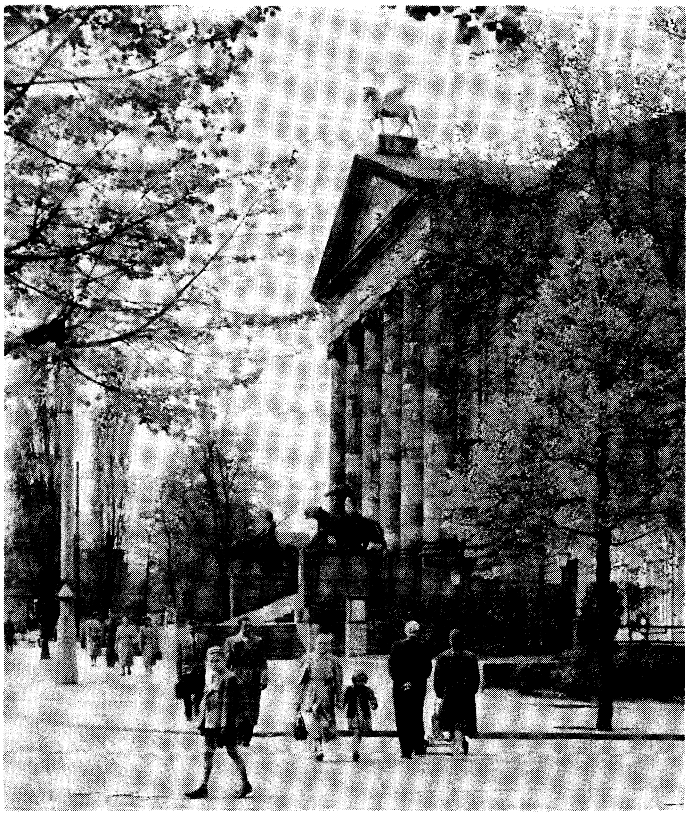
POZAREVAC or PASSAROWITZ, the capital of the Pozarevac department of Serbia, Yugoslavia. Population (1961) 24,290. It lies 8 mi. from its harbour, Dubravitsa, on the Danube. The town has no special industry, but being a road centre, is the principal market of a large and fruitful plain. At Lubichevo, 2 mi. W., is a state model farm, a stud farm, and a nursery for mulberries. Lignite is worked at Kostolats, 7 mi. N. by E., and the hills in this district show many traces of Roman mines. Roman coins, sarcophagi and inscriptions are also found. The famous Treaty of Passarowitz between Austria and Turkey was signed there in 1718. The town was taken by the Serbs under Kara George in 1804, and in 1815 Prince Milosh of Serbia again defeated the Turks there. Germans occupied it in April 1941.

POZNAN, one of the oldest cities of Poland, the chief town of Poznan province (*wojewodztwo*) and the see of a Roman Catholic archbishopric, is situated on a uide plain on the Warta, a tributary of the Oder, 174 mi. W. of Warsaw and 146 mi. E. of Berlin. Area 84.6 sq.mi. Pop. (1950) 320,670; (1960) 407,800.

The oldest part of the city lies in the fork formed by the two arms of the Warta (here flowing northward) and the Cybina, its right bank tributary. It became known as the Cathedral Island or Ostrow *Tumski.* There, in 968, the first Roman Catholic cathedral of Poland was erected in Romanesque style. It was rebuilt in Gothic style in the 14th and 15th century and again in the 18th century. Badly damaged during the 1945 fighting, it was rebuilt in Gothic style. The Golden chapel (1837), a Raczynski foundation, escaped destruction; it contains the tombs of the first two kings of Poland, Mieczyslaw or Mieszko I and Boleslau I the Brave. The smaller Gothic St. Mary's church (1434) and the baroque archbishop's palace (1732) stand nearby.

In the 13th century a new town (now known as the Old Town or *Stare Miasto*) began to grow on the left bank of the Warta Its centre was occupied by the Old Market place with a town hall built about 1300 in Gothic style; after the great fire of 1536 it was rebuilt in 1556–60 in Renaissance style; destroyed in 1945 it was restored to its former magnificence to become a museum.

Toward the end of the 18th century the city grew farther westward. New streets were constructed around a wide rectangular square (1803) named Freedom square in 1919. The most remarkable building facing the square is the neo-classic Raczynski library (1829); this, too, was destroyed in 1945 and rebuilt in 1956. In 1905–10 William II, the German emperor, built in the



PHOTOGRAPH, EASTFOTO

POZNAN OPERA HOUSE

western part of the city a neo-Romanesque castle, which after Poland's restoration housed some faculties of the university and became the new city hall after 1945. The city walls, built by the Germans in the mid-19th century, were dismantled in 1902 and replaced by a green belt, but the citadel on the north side remained. The town area was increased by including the suburbs of Srodka (east), Wilda (south), Jezyce and Lazarz (west) and Gorczyn (southwest). In 1921 the administrative area covered 25.5 sq.mi. and the population was 169.422, including 9,392 Germans and 2,088 Jens. Between World Wars I and II Poznan grew considerably in size and its population increased by more than 100.000.

Poznan has a university founded in 1919, a college of engineering, a medical academy, a higher school of agriculture and five other institutions of higher education. It is the seat of an association of sciences founded in 1857. It has an astronomic observatory, five museums, an opera house and five theatres.

Poznan is an important communications centre lying on the Berlin-Warsaw main railway line. It is also linked by rail with Danzig, Szczecin, Prague and Lodz, and by air with Warsaw.

The city's industries, originally connected with agriculture, were considerably developed after 1918, when the Hipolit Cegielski plant, founded in the mid-19th century, was enlarged to build heavy machinery. A tire and chemical factory were also established. In 1921 the Poznan fair was inaugurated and from 1925 it acquired an international importance.

History.—Poznan was founded as a fortified place with a castle in the 10th century. It became the see of the first Polish bishop (968) and the first (together with Gniezno) capital of Poland. In 1253 Poznan was granted municipal autonomy and in 1394 King Wladyslaw II Jagiello gave the city staple right (see STAPLE) for all wares passing from Poland into Germany and from Germany into Poland. The German settlers, who began to arrive about 1250, were gradually assimilated. From the mid-15th century to the beginning of the 17th century the city prospered and became a centre of the Polish Renaissance and Reformation movement. The Lubranski academy, the first humanist institution of higher education in Poland, was founded there (1519).

The Swedish wars of the mid-17th century and the Great Northern war at the beginning of the 18th century ruined the city. Its revival at the end of the 18th century was interrupted by its annexation to Prussia in 1793. From 1807 to 1815 Poznan was part of the duchy of Warsaw, afterward reverting to Prussia.

Under the German regime, especially during 1830–48, the city was a centre of Polish cultural and social progress and political conspiracy. After the unsuccessful rising of 1848, measures of repression against Polish organizations followed, but a resolutely anti-Polish and anti-Roman Catholic policy on a large scale was originated by Otto von Bismarck, and was carried out after 1871. Poznan then became the bulwark of the Poles in their successful struggle against germanization. In 1886 the Commission on Colonization was established in the city to buy up Polish land for German colonists. The Poles countered by co-operative credit organizations in which both peasants of the countryside and the middle class of the town took a prominent share. Aleksander Jackowski (1816–1905) and Father Piotr Wawrzyniak (1849–1910) were the main organizers of this economic resistance movement; soon the Poles succeeded in buying more land than they lost.

In 1894 the creation of a subsidized *Deutscher Ostnzurkenverein* (nicknamed H.K.T. by the Poles from the initials of its three founders) for the promotion of German advance in the east, the great increase of the funds at the disposal of the Commission on Colonization, the financing of a campaign against the Polish middle class—all proved insufficient: and Bernard von Bülow, the German chancellor, brought, in 1904 and 1908, new legislative means to bear. but they were largely rendered futile by the disciplined organization of the entire Polish element, as well as by its continuous growth. Poznan and its countryside shared in the material progress of Germany after 1871. Between that year and 1910 the city's population increased from 56,000 to 156,000.

On Dec. 27, 1918, the city rose against the Germans, shaking off a 103-year occupation. In Sept. 1939 the Germans returned to Poznan for more than five years. In Jan.–Feb. 1945 the city became a battlefield for the retreating Germans and the victorious Soviet forces. By the 1950s the city's rebuilding was completed. Although remaining the chief town of the province, Poznan, in 1956, became an independent administrative unit. The famous strike at the Cegielski plant on June 28, 1956, was the beginning of a national process of liberalization.

BIBLIOGRAPHY.—J. Łukaszewicz, *Obraz historyczno-statystyczny Poznania,* 2 vol. (Poznan, 1839); M. Jaffe, *Die Stadt Posen unter preussischer Herrschaft* (Leipzig, 1909); K. Malinowski, ed. *Dziesięć Wieków Poznania* (Ten Centuries of Poznan), 3 vol. (Poznan, 1956).

(Jz. A. Z.; H. J. Z.)

POZNANIA (Polish, POZNANSKIE), a Polish province (*wojewodztwo*), bounded north by the province of Koszalin, northeast by the province of Bydgoszcz, east by the province of Lodz, south by the provinces of Opole and Wroclaw. and west by the provinces of Zielona Gora and Szczecin. Area 10,596 sq.mi. Pop. (1960) 1,993,600.

The province is part of the central Polish plain and consists of a low plateau intersected by the Warta river, the right bank tributary of the Oder. The surface is dotted with small lakes and ponds, and there are many broad fens and swamps. The soil is light and sandy, but much of the land reclaimed in the marshy districts is very fertile. The greater part of the province is under tillage and only about 17% is occupied by forests. The principal crops are rye. wheat. oats. barley. potatoes, sugar beet. hops and tobacco. There are also excellent pastures supporting large numbers of cattle and sheep. Pigs are raised on a large scale. The mineral resources of the province are small, but there are important machine-building. chemical. cement. glass and textile industries at Poznan. Kalisz. Gniezno and Ostrow. as well as purely agricultural industries such as distilling. brewing, sugar and tobacco. Besides Poznan, the chief town. there are the following medium-sized towns in the province (pop. 1960): Kalisz (70,000), Gniezno (44,000), Ostrow (42,000), Pila (34,000) and Leszno (29,000).

History.—Poznania is the cradle of the Polish state. From very early times it has been known as *Wielkopolska,* or Great Poland, as opposed to *Malopolska,* or Little Poland, to the southeast. From 1138 to 1314 Wielkopolska was one of the autonomous Polish principalities within a form of a federal Polish state. After the re-uniting of the kingdom of Poland under Wladyslaw I Lokietek. Poznania shared the fate of the united country.

At the first partition of Poland, in 1772, the districts to the north of the Notec river fell to the share of Prussia. The rest of the province followed in 1793. In 1807, after the peace of Tilsit, the province was incorporated with the duchy of Warsaw, but in 1815 it reverted to Prussia as the grand duchy of Poznan. During the first decades after the Congress of Vienna, the Prussian regime was, on the whole, conciliatory and Prince Antoni Radziwill, a Polish nobleman, was appointed lieutenant governor of the province; there was a provincial assembly and local representative bodies. At the end of 1830, however, a new policy was inaugurated with the presidency of E. H. von Flotwell: the experiment of settling subsidized German colonists on Polish soil (started by Frederick the Great after the partition of Poland) was resumed, and the Polish language deprived of its position of equality with German in the government offices, the law courts and the schools.

In 1848 Poznania revolted against Prussian rule, but this armed rising was suppressed and a policy of stricter germanization was applied. In the period of *Kulturkampf,* from 1872–74, German became the language for all teaching. Polish was not allowed except for religious instruction and in the two first classes of the primary schools. In 1900 Polish was completely eliminated by the decision that even the catechism must be taught in German. This measure provoked, in 1901, the incident of Wrzesnia (the protest of Polish mothers who took the part of their children when the latter were beaten by the schoolmasters for refusing to say the Lord's Prayer in German) and, in 1903, the famous children's strike, which lasted for more than a year.

The sharpest battle that the Poles had to sustain in defense of their nationality was the struggle for the soil. It was marked by three laws: the Colonization lam (April 26, 1886); the law forbidding building (Aug. 20, 1904); and the Law of Expropriation (March 20, 1908). In enforcing these laws Germany spent 1,300,000,000 gold marks (mainly in Poznania, but also in Pomorze and Upper Silesia) between 1886 and 1914. Bismarck established the form of this policy, and Bernhard von Bülow continued it. But the Poles would not give in. The report of the Commission on Colonization (Ansiedelungskomnzission). prepared in 1906. on the 20th anniversary of its foundation, stated: "Incontestably the Poles have increased their material force. Their national consciousness has become stronger."

In 1910 the *Provinz Posen,* as it was called, covered an area of 11,193 sq.mi. and had a population of 2,099,831 of which, according to the German census, only 61% were Poles. These "61%," however, shortly after the armistice of Nov. 11, 1918, rose on Dec. 27 and shook off German domination.

The treaty of Versailles did not restore Poznania to Poland according to its historic frontiers. but left certain border districts in Germany. This newly defined Poznania had an area of 10.242 sq.mi. with a population of 1,967,865 (1921 census), including 327.846 Germans. Ten years later the total population was 2,106,500. including 173,500 Germans. A change in the administrative division of Poland took place on April 1, 1938. Certain northern districts of Poznania (for instance. Bydgoszcz) were given to Pomorze, while certain others, belonging previously to the province of Lodz (Kalisz. Kolo), were added to Poznania. As a result, its area was increased to 10,899 sq.mi. and its population (1931 census) to 2,339,600.

During World War II Germany annexed the whole of western Poland. Poznania was called *Gau Wartheland* and even Lodz (renamed Litzmannstadt) was added to it. After the war. when the formerly German lands east of the Oder-Seisse frontier were included in Poland. the province of Poznania was temporarily extended westward up to the Oder. but on July 6, 1950, when a new province of Zielona Gora was created in the west. Poznania returned. with a few exceptions. to its 1938 boundaries.

POZOBLANCO, a town of southern Spain in the province of Córdova. near the headwaters of the Guadamatillas and of other small subtributaries of the Guadiana. Pop. (1950) 14,773 (mun.). Its fairs are famed for their livestock and agricultural products. There are zinc and argentiferous lead mines nearby, and manufactures of cloth and leather in the town.

POZZO, ANDREA (1642–1709), Italian painter and architect, who was noted for his use of perspective. was born at Trento on Nov. 30, 1642. At the age of 24 he entered the Society of Jesus as a lay brother, and most of his work was done in painting frescoes and altarpieces for his order. After Pozzo won recognition by his painting in the dome of the Jesuit church in Turin, he was called to Rome to decorate the Church of St. Ignatius, where he did what many consider his most notable work. Pozzo died on Aug. 31, 1709.

POZZO DI BORGO, CARLO ANDREA, COUNT (1764–1842), Russian diplomatist, was born at Alata, near Ajaccio, of a noble Corsican family, on March 8, 1764, about four years before the cession of the island to France. He was educated at Pisa, and in early life was closely associated with Napoleon and Joseph Bonaparte, the two families being at that time closely allied in politics. Pozzo mas one of the two delegates sent to the National Assembly in Paris to demand the political incorporation of Corsica in France, and was subsequently a Corsican deputy to the Legislative Assembly, where he sat on the benches of the right until the events of Aug. 1792. On his return to Corsica he was warmly received by Paoli, but found himself in opposition to the Bonaparte brothers, who were now veering to the Jacobin party. Under the new constitution Pozzo was elected *procureur-général-syndic,* that is, chief of the civil government. while Paoli commanded the army. With Paoli he refused to obey a summons to the bar of the Convention, and the definite breach with the Bonaparte family, who actively supported the revolutionary authorities, dates from this time. Eventually Paoli and Pozzo accepted'foreign help, and from 1794 to 1796, during the English protectorate of Corsica, Pozzo was president of the council of state under Sir Gilbert Elliot. When Napoleon sent troops to occupy the island he was excepted from the general amnesty, and took refuge in Rome, but the French authorities demanded his expulsion and gave orders for his arrest in northern Italy. After a short stay in London he accompanied in 1798 Elliot (now become Lord Minto) on an embassy to Vienna, where he lived for six years.

In 1804, through the influence of Prince Adam Czartoryski, he entered the Russian diplomatic service. In 1805 he was Russian commissioner with the Anglo-Neapolitan, and in 1806 with the Prussian army. He was entrusted with an important mission to Constantinople in 1807, but the conclusion of the alliance between Alexander I and Napoleon at Tilsit in July interrupted his career. He returned to Vienna. but on the demand of Kapoleon for his extradition Metternich desired him to leave the capital. He then retired to London again and remained in England until 1812, when he was recalled by Alexander. He diligently sought to sow dissension in the Bonaparte household, and in a mission to Sweden he secured the co-operation of Bernadotte against Napoleon. On the entry of the allies into Paris he became commissary general to the provisional government.

At the Bourbon restoration Pozzo di Borgo became Russian ambassador at the Tuileries, and sought to secure a marriage between the duke of Berry and the Russian grandduchess Anna. Alexander's sister. He was present at the congress of Vienna, and during the Hundred Days he joined Louis XVIII in Belgium, where he was instructed to discuss the situation with Wellington. The tsar dreamed of allowing an appeal to the people of France on the subject of the government of France in accordance with his vague liberalizing tendencies, but Pozzo's suggestions in this direction were met by violent opposition, the duke refusing to make any concessions to what he regarded as rebellion: in St. Petersburg, on the other hand. Pozzo's attachment to the Bourbon dynasty was considered excessive. During the early years of his residence in Paris Pozzo laboured tirelessly to lessen the burdens laid on France by the allies and to shorten the period of foreign occupation. That his French sympathies were recognized in Paris is shown by the strange suggestion that he should enter the French ministry with the portfolio of foreign affairs.

Pozzo's influence at the Tuileries declined with the accession of Charles X. whose reactionary tendencies had always been distasteful to him; but at the revolution of 1830. when the tsar Nicholas was reluctant to acknowledge Louis Philippe, he did good service in preventing difficulties with Russia. In 1832 he visited St. Petersburg: the next year he was in London renewing his relations with Wellington, and early in 1835 he was suddenly transferred to the London embassy in succession to Prince Lieven. Although he did not lose in official standing, Pozzo was aware that this change was due to suspicions long harboured in various quarters in St. Petersburg that his diplomacy was too favourable to French interests. In London his health suffered, and he retired in 1839 to Paris, where he died on Feb. 15, 1842.

See Ouvaroff, *Stein et Pozzo* (St. Petersburg, 1846) ; *Correspondance diplomatique du comte Pozzo di Borgo et du comte de Nesselrode,* ed. by Charles Pozzo di Borgo, 2 vol. (Paris, 1890–97); Vicomte A. Maggiolo, *Corse, France et Russie. Pozzo di Borgo, 1764–1842* (Paris, 1890); J. B. H. R. Capefigure, *Les Diplomates européens,* 4 vol. (1843–47).

POZZUOLI (anc. PUTEOLI, *q.v.*), a seaport and episcopal see of Campania. It., in the province of Naples, $7\frac{1}{2}$ mi. W. of it by rail. Pop. (1957 est.) 46,434 (commune). It is on the base of a hill projecting into the Bay of Pozzuoli, separated from the main portion of the Gulf of Naples by the promontory of Posilipo. The volcanic pozzuolana earth (also found near Rome), used now as in Roman times for making cement and concrete, derives its name from the place. In the middle ages Pozzuoli was frequently sacked and also damaged by the natural convulsions of 1198 and 1538. It has large ironworks and melting furnaces.

PRABHU, the small writer caste of western India, corresponding to the Kayasth of Bengal. It stands high socially and professionally.

PRACHINBURI, is a sparsely settled province (changwat) of Thailand. Area 4,554 sq.mi. Pop. (1960) 325,089. It is located east of the Chao Phraya river delta between the hills of northeast and southeast Thailand and provides a historic corridor to Cambodia through which rival armies moved to attack each other. Most of the area is in pasture and forests. The cultivated land and population settlements, including the provincial capital, are concentrated in the northnestern part where there is heavier rainfall, better soils and irrigation facilities. The chief products are hardwood, charcoal, rice, sugar cane, horns and hides. Prachinburi, the provincial capital and river port, is 76 rail mi. from Bangkok on the trunk railroad which connects with Phnom Penh, the capital of Cambodia. As an old walled city, it was an outpost to guard the kingdom from approaching Cambodian armies or to serve as a supply depot for Thai armies moving eastward to attack Cambodia. (T. F. B.)

PRACTICE AND PROCEDURE. The practice and procedure in the English and United States courts stems from a common source, the common-law and equity procedures as developed in England from the 14th to the 18th centuries. While later innovations had considerable similarities, yet certain diversities developed in the two countries. The fact. plus the variations among the American states themselves, makes desirable the separate treatment of the subject for England and for the United States.

ENGLAND

The practice and procedure of the high court of justice in England is regulated by the Judicature act. 192j (which repealed and consolidated nearly all the former Judicature acts). and the various rules of court made pursuant to various acts passed in and since 1883. Lest the Judicature acts and rules as so framed should not provide for every contingency, it was expressly provided by rule in 1883 that "where no other provision is made by the Judicature Act or Rules the procedure and practice existing in 1883 should remain in force." The object of the Judicature acts and the rules made thereunder was to improve a system of practice and procedure which had grown up through the centuries. Although those concerned to defend the ancient order were wont to say that it made for precision, particularly in the matter of pleadings, there can be no doubt that its advantages were, or became. hidden under its chief defects—prolixity and technicality.

The following is an attempt to state, in outline, the practice and procedure in the high court in England. In the performance of his task the writer has kept one fact constantly in mind; namely, that if the reason for a particular rule or canon of procedure is appreciated. the rule will be better understood. The rules of procedure did not spring into being in a single day; they are the result of years of experience. And it will always be found that whether it be sound or not there is a reason for every rule, howsoever technical it may appear to be.

Various Forms of "Proceeding." — In the high court of justice, civil actions are begun by obtaining from the officers of the court a document known as a writ of summons. In this document are stated the names of the parties and the nature of the claim made (nhich in the case of liquidated sums of money must be precise and particular). It is sealed and issued to the party suing it out, and served on the opposing party, not by an officer of the court but by an agent of the plaintiff. The tenor of the writ is to require the defendant to appear and answer the claim, and to indicate the consequences.

Many proceedings in the high court are initiated by forms of summons different from the writ of summons. Of those issued in the high court three classes merit mention:

1. For determining interlocutory matters of practice and procedure arising in "a pending cause or matter." These are now limited as far as possible to a general summons for directions introduced in 1883 so as to discourage frequent and expensive applications to the masters or judges of the high court on questions of detail. These summonses are sealed and issued on application at the offices of the high court. The matters raised are dealt with by a master with an appeal to a judge in chambers summarily. In matters of practice and procedure there is no appeal from a judge at chambers without leave from him or from the court of appeal.

2. For determining certain classes of questions with more dispatch and less cost than is entailed by action or petition. This kind of summons is known as an "originating summons," because under it proceedings may be originated without nrit for certain kinds of relief specified in the rules (see *The* Annual Practice, 1956, p. 1041). The originating summons may be used in all divisions of the high court, but is chiefly employed in the chancery division, where it to a great extent supersedes actions for the administration of trusts or of the estates of deceased persons, and for the foreclosure of mortgages. A similar but not identical procedure was created with reference to questions of title, etc., to real property. In the queen's bench and probate divisions the originating summons is used for determining summarily questions as to property between husband and wife, or the right to custody of children, and many other matters (O. 54, rr. 4B–4F), but there is nothing to prevent a summons of this kind issuing in the queen's bench for the determination of some such question as the construction of a bill of lading. The proceedings on an originating summons are conducted summarily at chambers without pleadings, and the evidence is usually written. In the chancery division when the questions raised are important the summons is often adjourned into court. An appeal lies to the court of appeal from decisions on originating summonses. The forms of summonses and the procedure thereon in civil cases in the high court are regulated by the Rules of the Supreme Court.

3. Certain proceedings on the crown side of the queen's bench' division are begun by summons (*e.g.,* applications for bail); and in vacation writs of habeas corpus. mandamus, prohibition and certiorari are asked for by summons as the full court is not in session. (See Croun Office rules. 1906.)

Mandamus has always been regarded as an exceptional remedy to supplement the deficiencies of the common lam, or defects of justice. The writ is used to compel inferior courts to hear and determine according to lam cases nithin their jurisdiction; *e.g.,* where a county court or justices in petty or quarter sessions refuse to assume a jurisdiction which they possess to deal with a matter brought before them. It has been employed to compel municipal bodies to discharge their duties as to providing proper sewerage for their districts. etc. The courts do not prescribe the specific manner in nhich the duty is to be discharged, but 'do not stay their hands until substantial compliance is established.

At common law mandamus lies only for the performance of acts of a public or official character. The enforcement of merely psivate obligations. such as those arising from contracts, is not uithin its scope. But now a mandamus may be granted by an interlocutory order of the high court in all cases in which it shall appear to the court just or convenient that such an order should be made. (O. 53.) The remedy which is thus created is an attempt to engraft upon the old common-law remedy by damages a right in the nature of specific performance of the duty in question. It is not limited to cases in which the prerogative writ would be granted; but mandamus is not granted when the result desired can be obtained by some remedy equally convenient, beneficial and effective, or a particular and different remedy is provided by statute. An action for mandamus does not lie against judicial officers such as justices. The mandamus issued in the action is no longer a writ of mandamus, but a judgment or order having effect equivalent to the writ formerly used. (See INJUNCTION.)

Action at Law. — The term "action" in English law means at the high court of justice "a civil proceeding commenced by writ of summons or in such other manner as may be prescribed by rules of court" (*e.g*, by originating summons). The proceeding thus commenced ends by judgment and execution. The stages in an English action are the writ, by which the persons against whom relief is claimed are summoned before the court; the pleadings and interlocutory steps, by which the issues between the parties are adjusted; the trial, at nhich the issues of fact and law involved are brought before the tribunal; the judgment, by which the relief sought is granted or refused; and execution, by which the law gives to the successful party the fruits of the judgment.

The procedure varies according as the action is in the high court. a county court or one of the other local courts of record which still survive; but there is no substantial difference in the incidents of trial, judgment and execution in any of these courts.

Action Against the Crown. — Until 1947 the crown was not liable in tort. and for a breach by the state of a contract between the state and a subject, the remedy of the subject was not by action against the agents of the state who acted for the state in the making or breach of the contract. but against the crown itself by the petition of right, which was granted only on the fiat of the attorney general. By virtue of the Crown Proceedings act, 1947, however, any claim which might formerly have been enforced by petition of right may be enforced in accordance (broadly speaking) with the ordinary rules of procedure. The act further provided (by s. 2) that (subject to certain exceptions) the crown shall be liable (1) for tort committed by its servants or agents, (2) for breach of the duty which a master is liable, at common law, to his servant or agent and (3) for breach of any duty attaching at common law to the ownership, occupation, possession or control of property. It is important to notice. however, that the servant or agent here referred to must be in the paid service of the crown. This very general liability of the crown is cut down in two certain important respects. Thus no proceedings in tort lie against the crown for anything done or omitted by an officer of the post office in relation to a postal packet. The crown, however. may in certain circumstances be liable to some extent for the loss of a registered inland postal packet. Again. the act makes special provision as to the liability of the crown (in tort) for anything done or omitted by a member of the armed forces. Broadly speaking, neither the crown nor the soldier is liable for anything done by the soldier when on duty, or when on any land, premises or vehicle used for the purposes of the armed forces.

But notwithstanding all that is to be found in this act, the old maxim of the constitution—"the sovereign can do no wrong"——still prevails, for it was provided by s. 40 (1) that nothing in the act was to apply to proceedings brought against or to authorize proceedings to be brought against the sovereign in his private capacity.

The Writ of Summons. — This is the universal means of commencing an action in the high court. It is addressed to the defendant, and may be either generally or specially endorsed with a statement of the nature of the claim made. The latter form of endorsement is allowed in certain cases (see section Specially

Endorsed Writ and Summary Judgment below). The writ may be issued out of the central office or out of a district registry, and the plaintiff may name on his writ the division of the high court in which he proposes to have the case tried. There are special rules governing the issue of urits in probate and admiralty actions. The writ remains in force for 12 months, but may be renewed for good cause after the expiration of that time. Service must be personal, unless where substituted service is allowed. and in special cases, such as actions to recover land and admiralty actions. Service out of the jurisdiction of a writ or notice of a writ is allowed only by leave of a judge. Notice of the issue of a writ and not the writ itself is served on a defendant who is neither a British subject nor in the British commonwealth. The law is contained in the Rules of the Supreme Court, especially Orders ii–xi and xiv.

Appearance. — Every writ has upon it a memorandum pointing out to the defendant that he must, in due course, enter an appearance, otherwise judgment may be signed against him in default. Appearance is entered by the defendant delivering to the proper officer a memorandum stating the name of his solicitor or that he will defend in person (O. 12, r. 8). If a defendant is appearing in person (*i.e.,* without a solicitor) he may enter an appearance by posting the appearance to the proper officer (O. 12, r. 8a). He must give notice of appearance to the plaintiff or his solicitor. He must give his address for service which, if he has entered appearance in London, must be within three miles of the royal courts of justice, and if in a district registry, the address must be within the district. In the vast majority of cases the defendant leaves it to his solicitor to enter appearance for him. He may enter a conditional appearance if he disputes the jurisdiction of the court. or desires to allege some informality or irregularity in the service of the writ (O. 12, r. 30).

If the defendant does not enter an appearance and the writ has been specially endorsed (*see* below), the plaintiff may sign judgment in default for his debt and costs (O. 13, r. 3). But this rule does not apply where the defendant is an infant or a lunatic—the court, in the exercise of its parental jurisdiction, prohibiting such litigants from compromising without leave. Where, however, a defendant does not appear to a writ in which the plaintiff claims damages or other relief O. 13, rr. 5–7 (as amended in 1957) make special provision to enable the plaintiff to obtain speedy judgment. As to actions on bonds, *see* 0. 53G, r. 14. Judgment for the possession of land may be obtained as a result of default in appearance. These rules as to default, however, are subject to this—that any judgment by default may be set aside on such terms as to costs or otherwise as to the court shall seem just (O. 13, r. 10). As a general rule, however, if the judgment has been regularly signed, it will be set aside only on very stringent terms, and the defendant must show that he has a meritorious defense.

Specially Endorsed Writ and Summary **Judgment.**—Appearance having been entered, the next step is taken by the plaintiff. In any action in the chancery of queen's bench division other than one which includes (1) a claim for libel, slander, malicious prosecution, false imprisonment, seduction or breach of promise of marriage or (2) a claim based on fraud, the writ may be specially endorsed with or accompanied by a statement of claim (0. 6, r. 1). Failure to use the special endorsement may have effect to diminish the costs of a successful plaintiff in certain cases but not, for example, in a case involving a claim for damages for personal injuries. If the writ has been specially endorsed, the plaintiff may (unless the crown be defendant) issue a summons for summary judgment before a master (O. 14, r. 1). A summons for judgment must be supported by an affidavit; the plaintiff must depose that in his belief there is no defense save (in a proper case) as to the amount of damages. If the defendant does not appear, or if he appears and shows no cause to the contrary, judgment will be given forthwith by the master in chambers. Where, however, the defendant appears in answer to the summons and shows by affidavit or otherwise that he has a defense, going to the whole cause of action, leave to defend will be given, and the master will then give directions as to the further conduct of the suit. Sometimes it will appear that the defendant has no answer to part of the claim. In that case the master generally orders payment to the plaintiff's solicitors in a certain time, or judgment in default, and gives directions as to the balance. In rare cases the master will order money sought to be brought into court as a condition of leave to defend. But a plaintiff ought not to proceed for summary judgment unless he has substantial grounds for believing there is no defense to the action. Should it turn out that there is a defense of which he must, or ought to, have known, he runs the risk of having to pay the costs.

Having given leave to defend, or to enter judgment subject to suspension of execution pending trial of a counterclaim, the master must give directions for the further conduct of the proceedings pursuant to 0. 30, rr. 2 to 7. If the issue is clear and simple he has power to send it for trial into the short cause list. In that case it is set down for trial without pleadings, and it comes on for trial before a judge alone in a very short space of time. Where, however, service issues are raised necessitating an order for discovery and pleadings, directions are given providing for those matters and settling the place of trial—whether in London or at assizes. If the amount is below a certain figure, the case is generally remitted for trial in the county court, the costs being left to the county court judge. If it involves a technical or scientific inquiry, or the examination of accounts, the master may send it to an official referee. Finally, if the parties agree, he may order it to be tried before a master, who fixes a time and day and hears the whole case with witnesses. His decision on a reference of this kind is subject to an appeal to a divisional court.

From the decision of a master on a summons for judgment, an appeal lies to the judge in chambers, who may reverse or vary the master's order. It not infrequently happens that the party who is unsuccessful before the master carries in fresh evidence before the judge in chambers. From the judge an appeal lies (with leave) to the court of appeal. subject to this, that where the judge has given unconditional leave to defend, there is no further appeal of any kind.

Application for Trial Without Pleadings. — If (in certain cases, *see* below) the writ is specially endorsed the plaintiff may (instead of the notice, if any, to the defendant that if he enters an appearance he must also deliver a defense) including a notice to the defendant that if he enters an appearance, the plaintiff intends to apply for trial without further pleadings. This rule does not apply (broadly speaking) to actions for negligence, nuisance or for damages in respect of the death of any person. The application must be supported by an affidavit (O. 14B, r. 1).

Summons for Directions. — In all other cases commenced by writ and subject to an exception to be presently mentioned, the plaintiff in every action must take out a summons for directions (0. 30, r. 1). This he does seven days after the pleadings have been closed. This rule, however, does not apply to (among others) admiralty actions, or to an action where the writ is specially endorsed, or to an action for infringement of a patent. The powers conferred upon "the court or a judge" (which phrase includes a master) to give directions are very wide. It is impossible to set them all out in this place. They derive (in the main) from rules of court as revised in 1954, and the extent of the master's pou-ers is made known to the parties by the form of the summons (form 3A in appendix K to the R.S.C.) in which all the matters with which the master can deal are set out—the idea being that those that are not required to be inserted in the order shall be struck out by the master. Such directions may be given as to the future course of the action as appear best adapted to secure its just, expeditious and economical disposal. If any particular matter cannot be disposed of on the first hearing of the summons, it can be adjourned (0. 30, r. 2). On the hearing the master must consider, if necessary of his own motion (1) the amendment of pleadings; (2) the admission in evidence of statements in documents although the makers of those statements are not called as uitnesses; (3) the mode in which evidence may be given at the trial and the limitation of evidence in certain cases (0. 30, r. 3). The master must also endeavor to cause the parties to make reasonable admissions with a view to saving costs; (ibid., r. 4) and may record any agreement to limit the right of appeal (ibid., r. 5). He may order documents to be produced to him without being produced to the other side and cause any refusal to produce such a document to be recorded. but subject to this — that no document which is privileged from disclosure need be produced save with the consent of the party concerned (ibid., r. 6). When giving directions the master deals with discovery and inspection of documents, interrogatories, letters and the place and mode of trial. If a plaintiff fails to take out a summons for directions, the defendant may apply for the' action to be dismissed for want of prosecution (O. 30, r. 7 [8]).

Parties. —.All persons may be joined in one action as plaintiffs in whom any right to relief arising out of the same transaction is alleged to exist, whether jointly or severally, or in the alternative where, if such persons brought suit separately, a common question of law or fact would arise (O. 16, r. 1). Should it appear, however, that any such joinder may embarrass or delay the trial, separate trials may be ordered (*ibid.*). Again. if an action is by accident brought by the wrong plaintiff a new plaintiff may be substituted or added (O. 16. r. 2).

As regards defendant. all persons may be joined as such against whom the right to any relief is alleged to exist. whether jointly or severally or in the alternative (O. 16, r. 4). If numerous persons having the same interest in the cause or matter desire to assert or defend their rights, the court may authorize one or more of them to represent all (O. 16, r. 9). As a corollary to the above rules it is important to notice that the court has ample power to strike out parties improperly joined. and to add others who should be before the court in order that the matters in dispute may be effectually determined (O. 16, r. 11). As regards lunatics and infants the rules are strict to prevent anything in the nature of a settlement or compromise of an action save with the consent of the court or a judge. Money recovered by infant or lunatic may be; kept in court or otherwise protected for the benefit of the party concerned.

Third-Party Procedure. — It is obvious that where A has a claim against B, B may have a claim against C which arises, or which he desires to assert, only because A has brought an action against him. It would be unfortunate and would involve unnecessary expense to all parties if B were bound to refrain from suing C until A had sued him. A remedy for this is provided by what is known as third-party procedure (O. 16A. r. 48), under which, where a defendant claims contribution or indemnity against a person not a party to the action, he may, by leave, issue a third-party notice.

To that notice (which corresponds to a writ) the third party must appear, otherwise judgment may go against him by default (O. 16A, r. 1). If he does appear, suitable directions may be given so that all the questions between all the parties may be tried in the same action (O. 16A, rr. 4, 5). The third party may bring a fourth party from whom he seeks indemnity subject to the same rules as prevail in relation to third parties (O. 16A, r. 11).

Change of Parties. — An action does not abate because of the marriage, death or bankruptcy, etc., of any party thereto, if the cause of action survives (O. 17, r. 1). and nhere any marriage, etc., takes place, or there is any devolution of estate by operation of law, the court may order that the husband, personal representative, trustee or other successor to interest of any party shall be made a party and served with notice of the proceedings (O. 17, r. 2 Similarly, any person. who by reason of a marriage, death, bankruptcy or assignment after action brought acquires an interest in the dispute may apply to be made a party (O. 17, r. 4).

Several causes of action may be joined in the same action; but the court may order that there shall be separate trials if the various causes of action which appear upon the record cannot be conveniently tried together (O. 18, r. 1). This rule is subject to one notable exception; namely, that no other cause of action can be joined with an action for the recovery of land, except by leave of the court (O. 18, r. 2). Application for leave is made ex parte to a master before the writ is served.

The Pleadings. — Normally, in an action tried in the queen's bench division, "pleadings" are delivered. They consist of a statement of claim. the defense (and counterclaim, if any) and reply and, in rare cases, a rejoinder. No pleading subsequent to defense can, however, be delivered without leave.

A pleading is the term applied in English law to the preparation of the statement of the facts on which either party to a civil action founds his claim to a decision in his favour on the questions involved in the proceeding; and also to the document in which these statements are embodied. The term "pleadings" is used for the collected whole of the statements of both parties; the term "pleading" for each separate part of the pleadings.

The object of the pleadings is to secure that both parties shall know what are the real issues between them. A plaintiff must (in certain cases) deliver a statement of claim; a defendant must put in a defense and he may also plead a setoff or counterclaim. The plaintiff must (in certain cases) reply to the defense, and must put in a defense to the counterclaim. The rules of pleading are so framed as to restrict the length of pleadings as much as possible. So "every pleading shall contain, and contain only, a statement in a summary form of the material facts on which the party pleading relies for his claim or defence. as the case may be, but not the evidence by which they are to be proved." The pleader must confine himself to material facts — but an allegation may be material though it is not necessary. He must confine himself, too, to facts material at that stage of the action.

With a view to avoiding prolixity, the rules provide that a contract which is to be implied from a series of letters or conversations, or from various circumstances, may be referred to as a fact without setting out all the letters. etc., in detail. But reference to those letters, etc., and the substance of material conversation must be given. Matters of law need not be pleaded to. But even though it may necessitate a long and elaborate statement, all material facts must be set out in a pleading. If material, dates. names and items are not given, the pleader may be ordered to give particulars. A pleading may contain alternative and inconsistent allegations.

As indicated. particulars may be ordered if a pleading is not sufficiently explicit. With regard to the defense. it is seldom enough merely to traverse (*i.e.,* deny or refuse to admit) the matters in the statement of claim. For example, if the plaintiff sets up a contract which was in fact made, it would be idle for the defendant merely to deny the existence of a contract. He should. in a proper case. confess (*i.e.,* admit) the contract and avoid the effect of that confession by (1) setting up the statute of fraud or limitations or by setting up (2) that the contract has been duly performed or rescinded; or (3) that it was illegal; or (4) that some condition precedent to his liability has not been performed. In an action of debt a mere denial of the debt is expressly declared by the rules to be inadmissible; and in an action for liquidated sums the defense must deny the order or contract, the delivery or the amount claimed. Again, in an action for money had and received, the defense must deny the receipt of the money, or the existence of those facts which are alleged to make such receipt by the defendant a receipt to the use of the plaintiff. If the defendant desires to deny the right of a plaintiff to sue in a representative capacity, he must do so specifically (O. 21, r. j). While the defendant should make every denial which is really necessary, he should avoid denying matters which are really immaterial. If he does so, the court has power to make him pay any extra costs occasioned thereby (O. 21, r. 9).

A defendant may set off, or set up by way of counterclaim, any right or claim, against the plaintiff, and this has the same effect as a cross action (O. 19, r. 3; O. 21, r. 15). (But as to setoff or counterclaim against the crown, see **O.** 19, r. 3A.) Further as to counterclaim, it may be made not only against the plaintiff but against other parties to the action, and against a person who is not a party (O. 21, r. 11). But whereas a counterclaim against a plaintiff and a person already a party is merely delivered, a counterclaim involving a third party must be served on him like a writ. Such third party must appear as if he were a defendant to an action, and, having done so, may deliver a defense without any leave from the court (O. 21, r. 14). If there is a counterclaim on the record, and the original action is stayed, discontinued or dismissed, the counterclaim can nevertheless be proceeded with (O. 21, r. 16). As to defenses generally, a plea "in abatement" (*e.g.,* that a third person should have been added as plaintiff) is not allowed. Finally in an action for the recovery of land against a defendant who is in possession by himself or his tenant the defendant (unless he has some equitable defense) need only plead that he is in possession. This puts everything in issue and enables him to raise any defense—even the statute of limitations (O. 21, r. 21). The reason assigned for this (by Lord Justice William Brett, later Viscount Esher) is that the plaintiff in an action for recovery of land must recover on the strength of his own title and not through any defect in the defendant's title. "Possession is nine points of the law."

Payment Into Court.—There is no part of the procedure in civil actions more important to the litigant than that which enables a defendant to pay money into court. By a judicious payment into court a defendant may bring proceedings to an end, and so avoid the costs of what may be an expensive action. Further, if he pays in enough or more than enough to satisfy the plaintiff's claim, the plaintiff will have to bear all costs incurred subsequent to the date of payment-in.

The rules provide that in any action for debt or damages (not, *e.g.,* in an action for an account) or in an admiralty action, the defendant, at any time after appearance, may, upon notice to the plaintiff, pay into court a sum of money in satisfaction of the claim, or, where several causes of action are joined in one action, in satisfaction of one or more causes of action; and that if the defendant pleads tender, he must bring the amount tendered into court. In his notice (which must be in writing) the defendant must specify the cause of action to which the payment is related, and state whether he admits or denies liability (O. 22, r. 1). Within 14 days of a notice of payment-in, the plaintiff may, by notice, accept the payment in satisfaction. and then becomes entitled to receive payment out of court, which must be made to him or his solicitor. Thereupon the action is stayed as to the cause of action in respect of which the payment is made (ibid., rr. 2 [1] [2]). If the plaintiff accepts the amount paid in, or accepts a sum paid in respect of one cause of action, and gives notice that he abandons his other causes of action, he may tax his costs incurred down to the date of payment-in and sign judgment for those costs (ibid., r. 2 [3]). But this rule (O. 22, r. 2) does not apply to admiralty actions, or in cases where there is a plea of tender.

A special privilege is conferred on the plaintiff in an action for defamation. Having taken money out in satisfaction. he may apply for leave to make a statement in open court on terms approved by a judge (O. 22, r. 2 [4]).

One of two or more defendants sued in the same action may pay into court, but in that case, although the action is stayed as regards that defendant. the money cannot be paid out except in pursuance of an order of the court disposing of the whole action (O. 22, r. 4).

Except in certain actions for libel (see below), the fact of payment-in must not be mentioned in the pleadings or to the judge or jury until after the trial. The judge may then take the fact into account when deciding upon costs (ibid., r. 6).

This rule applies in an ordinary action for libel; but in an action for libel brought against a newspaper, the defendant may plead absence of malice, publication without gross negligence, apology and payment into court, by virture of the Libel acts, 1843 and 1845 (ibid., r. 6). In such a case, the payment into court is mentioned in the pleadings.

There is one case in which the defendant ought certainly, in his own interest, to pay money into court. This is where, in answer to a claim for a liquidated sum, he has made a tender before action. Tender of what is due is a complete defense to an action; but where there is a plea of tender upon the record, it will not avail the defendant unless he has brought the amount tendered into court. And this is good sense, because the defendant's attitude must be that he always was and still is ready and willing to pay his debt. But where money has been paid into court with a plea of tender, the plaintiff cannot terminate the action by taking that money out of court; for he will thereby admit the defense and the costs of the whole action will be the defendant's.

But it is not always necessary for a defendant to admit liability for the sum paid in. In any action of debt he may pay in without admitting liability (except when he pleads tender). This is a mere offer to secure peace, which may appear with any other defense; *e.g.,* a denial of the contract or a plea of performance.

To the general rule that it rests with plaintiff to say whether he will or will not accept money paid into court, there is an exception in any case where the plaintiff is an infant or a person of unsound mind. Acceptance of a sum paid in involves (or may involve) a compromise of the action. and the court, exercising a parental jurisdiction in such matters, will refuse to allow a compromise which may not be fair to the plaintiff. And so the court has power, not only to refuse to allow a compromise, but it may provide, by order. for the money being retained in court and invested or otherwise disposed of for the benefit of the infant (until he attains the age of 21) or lunatic as the case may be. (See generally O. 22, r. 14 [2].)

Reply and Subsequent Pleadings.—The defense having been delivered, the plaintiff may find it necessary to deliver a reply. But now a mere joinder of issue is unnecessary and (O. 27, r. 13) no reply or subsequent pleading (*e.g.,* rejoinder, surrejoinder, etc.) can be delivered without order except in certain admiralty cases (O. 23). But a reply must be delivered in certain actions for defamation (see O. 19, r. 22). A defendant must not suggest a new cause of action in his reply, for that would be what the old pleaders called a "departure." And the reason is plain. To a new cause of action the defendant must be enabled to put in a defense in accordance with the rules. A new cause of action must therefore appear in an amended statement of claim.

Cases may occur in which, although the plaintiff had a good cause of action when he issued his writ. something happened afterward to satisfy his claim or discharge the cause of action. For example, he may accept payment of the debt sued for, or a sum of money by way of compromise of a claim for damages. Such acceptance or compromise would constitute a defense. If it takes place before the expiration of the time limited for defense, the defendant may raise it in his defense, signifying that it arose since action brought (O. 24, r. 1). And even if it arises after that time, the defendant may raise it by leave (O. 24, r. 2). The plaintiff may thereupon "confess" such defense and tax his costs up to the time when it was delivered (O. 24, r. 3) unless the court shall otherwise order. A similar rule obtains with reference to a reply which sets up new matter in defense to a setoff or counterclaim. A counterclaim may be founded on facts which have arisen since action brought, but it must be phrased as so arising.

Discontinuance.—In certain circumstances an action may be discontinued, or a defense withdrawn. Thus at any time before receipt of defense, or after receipt thereof before taking any proceeding other than interlocutory (*e.g.,* a summons for particulars), the plaintiff may, without leave, by notice in writing discontinue the whole action, or withdraw any part of it as against all or any of the defendants, subject to the payment of costs (O. 26, r. 1).

Proceedings in Lieu of Demurrer.—In former days it was competent for a defendant to "demur" to the statement of claim on the ground that it disclosed no cause of action. The result was that many a claim was defeated and costs were often incurred merely because the plaintiff had not put his case in proper form. Demurrer was later abolished (O. 25, r. 1) but any party may raise a point of law by his pleading, and the point so raised shall be disposed of at or after the trial subject to this, that if the parties consent or the court so orders the point may be set down for hearing and disposed of before the trial (O. 25, r. 2). If the decision substantially disposes of the whole action, the action may be dismissed (O. 25, r. 3). This course may be conveniently adopted where it is obvious that a serious question arises as to whether the statement of claim as drafted discloses any cause of action, or the defense any answer in law to the claim.

Striking Out Pleadings.— The court may order a pleading to be struck out on the ground that it discloses no reasonable cause of action or answer (O. 25, r. 4). In any such case, or if the action or defense be shown by the pleadings to be frivolous or vexatious: it may be stayed or dismissed, or judgment may be entered for the defendant accordingly as may be just (ibid.). To succeed in such an application, an objecting party must be able to point to some defect in the pleading itself. The rule is acted upon only in plain and obvious cases. So if. in an action on a contract, it be clear that there is no contract between the plaintiff and the defendant; or no contract valid in law; or that the matter is already decided; or where the statement of claim on the face of it shows that there is a good defense: it will be struck out.

But the court will generally give a party leave to amend a pleading before striking it out. Apart from the rule above mentioned (and O. 19, r. 25, which enables anything scandalous or vexatious, or which tends to delay. etc.. the trial of an action, to be struck out) the court has inherent jurisdiction to stay all proceedings before it which are obviously frivolous or vexatious or an abuse of its process. An application to strike out on these grounds should be supported by an affidavit. Discontinuance by the plaintiff does not affect a counterclaim, but a counterclaim cannot be set up after discontinuance.

A defendant may by leave, and only by leave, and upon terms, withdraw the whole or part of his defense or counterclaim. If the defense is withdrawn, the plaintiff can sign judgment in default of defense. An application so to withdraw may be made at any time. A cause entered for trial may be withdrawn by either plaintiff or defendant upon producing a consent in writing to the proper officer (0. 26, r. 2). The plaintiff must pay the defendant's costs if he discontinue an action (0. 26. r. 3); and if he bring another action for the same or substantially the same cause. it may be stayed if the costs of the former action are not paid (O. 26, r. 4).

Default of Pleading.— The rules of pleading are enforced by this— that if a party does not plead as and when required. he may, if he is a plaintiff, have his action dismissed, if he is a defendant, have judgment signed against him. Thus if a plaintiff being bound to deliver a statement of claim does not do so within the time allowed, the defendant may apply to have the action dismissed for want of prosecution. and on the hearing of the application the court may either dismiss the action or make such order as shall be thought just (O. 27, r. 1). Where the plaintiff delivers his statement of claim after the application has been made, the court will generally make no order save that he pay the costs. The plaintiff need not deliver a statement of claim save under an order for directions. for which he must himself apply. If he does not so apply within 14 days of the defendant's appearance the defendant may have the action dismissed (0. 30, r. 8). A plaintiff may be in default in delivering a reply .and defense to a counterclaim. If so, the defendant's only remedy is to move for judgment under O. 27, r. 11, even when the counterclaim is for a liquidated demand and even if some other person has been made a defendant to the counterclaim.

A defendant may make default either in not entering an appearance or in not putting in his defense. If he has not appeared, and, the writ not being especially endorsed, he has had a statement of claim filed against him in default, he must appear and deliver his defense within ten days of the tiling of the statement of claim. Otherwise he may have judgment signed against him with costs (O. 21, rr. 2–9). In such a case, however, if the plaintiff could have signed judgment merely in default of appearance, he can only have such costs as he would have had in that case. In other words, he will not be allowed the costs of the statement of claim. If a defendant has appeared to the writ other considerations arise. If the writ was specially endorsed he must deliver a defense within ten days 'unless the plaintiff has proceeded for summary judgment (0. 21, r. 6), and in other cases if a separate statement of claim has been delivered he must deliver his defense within the time limited by the summons for directions (0. 21. r. 8).

The procedure to be adopted if the defendant has not put in a defense depends upon the nature of the action. (See generally O. 27, rr. 4–6, as amended by R.S.C. No. 1, 1957.)

Close of Pleadings.— There comes a time in every action when the pleadings are deemed to be closed. Where no reply or subsequent pleading is ordered then within four days of the delivery of the last pleading, or where a reply has been ordered within a certain time, at the end of that period the pleadings are to be deemed closed and all statements therein put in issue (0. 27, r. 13). This, however, does not apply to a reply to a counterclaim which is really a defense. Unless the plaintiff obtains leave to reply to a counterclaim, the statements of fact which it contains shall be deemed to be admitted after the expiration of ten days, unless a reply has been ordered, in which case, if the order is not complied with, the facts will be deemed to be admitted.

Amendment.— In former times the ends of justice were often defeated. and the litigant was put to an enormous amount of unnecessary expense, because the powers of the court to allow amendment of pleadings were greatly restricted. Now. however, the court or a judge may at any time, and on such terms as to costs or otherwise as may be thought right, amend any deficit in any proceedings, and all necessary amendments shall be made for the purpose of determining the real question or issue raised by or depending on the proceedings (0. 28, r. 12).

Amendment of Pleadings.— The court or a judge may at any stage of the proceedings allow either party to alter or amend his endorsement or pleadings in such manner and on such terms as may be just, and all such amendments shall be made as may be necessary for the purpose of determining the real question in controversy between the parties (0. 28, r. 1). Under this rule amendment will always be allowed, if it can be made without injustice to the other side. While a new cause of action may be introduced into the statement of claim by amendment, if the plaintiff at the same time seeks to stand on his original claim, leaving his writ unamended, this is practically a discontinuance, for the new claim is wholly unsupported by the writ. Such an amendment will only be allowed on the terms that the plaintiff pays all costs down to the time of the amendment, and that all proceedings are stayed until those costs are paid.

A common informer is but seldom allowed to amend his statement of claim in an action for penalties. Amendment is often allowed on an application to strike out a pleading as embarrassing or because it discloses no cause of action. Although, when a statement of claim is delivered the plaintiff may therein alter, modify or extend his claim without any amendment of the writ, he cannot add a claim on a wholly new and different cause of action except by leave; and if leave is given the writ should be amended. The writ or the statement of claim must be amended in one case; *i.e.*, where the plaintiff recovers by verdict of a jury more than the amount he has actually claimed. Otherwise he cannot recover the amount of the verdict. Amendment may be allowed at any time but it should obviously be made at the earliest possible moment. A defendant may have no answer to the claim as amended. A plaintiff may find it necessary to confess an amended defense and stop his action; or, where the amendment involves a payment of money into court, he may be content with the amount paid in.

A plaintiff may, in certain cases. and within a certain time, amend his statement of claim. whether endorsed on the writ or not, without leave (0. 28, r. 2). But he cannot, in the exercise of this privilege: add a cause of action which has accrued to him since the writ—although he can do that by leave. Nor can he add new parties. If he has delivered particulars with the statement of claim he can amend them under this rule; but particulars delivered otherwise can be amended only by leave. Under this rule a special endorsement can be amended provided the claim is one which can be specially endorsed. A similar rule (0. 28, r. 3) applies to a counterclaim. But it is important to notice that any amendment so made without leave may be disallowed—or allowed only upon terms—on the application of the other side if the justice of the case so requires (0. 28. r. 4).

It has been stated that amendment to statement of claim or counterclaim without leave can be made only within a certain time. All other amendments to claim or defense, or to any other pleading, can be made only by the leave of the court or a judge and upon such terms as to costs as may be just (0. 28, r. 6). If an order giving leave to amend is made and the amendment is not made within the time limited or within 14 days of the date of the order, the order is void, unless the time is extended by the court or a judge (0. 28, r. 7). Moreover, the amended pleading must be delivered to the opposite party within the time allowing the same (0. 28, r. 10).

Actions By or Against Firms.—If a firm desires to bring an action; or anyone desires to bring an action against a firm, in the firm name. special considerations arise. Broadly speaking, a firm consisting of more than one person carrying on a business within the jurisdiction may sue or be sued in the firm name. but subject to this—that the names of the partners must, if required, be revealed to the other side. Where, however, a man carries on business in a name other than his own, he can sue only in his own name, but he may be sued in the name of his firm. He must, however, reveal his true name if required. Service of process on a firm may be effected either upon any one of the partners, or upon the manager at the place of business of the firm. The person served must be told, at the time, whether he is served as a partner or as manager. A firm cannot enter an appearance as such, it must appear by one of the partners personally; but an alleged partner may appear with a denial that he is a partner. The property of the firm within the jurisdiction can be seized in execution of a judgment against the firm, and so can the property of individual partners. This is but a summary of 0. 48A, which provides a complete code of rules on the subject. It must be carefully studied by anyone who is concerned in an action by or against a firm.

Discovery.—The pleadings having been closed, the parties in most cases proceed to have discovery, either of facts or documents or both. The English common-law courts were originally unable to compel a litigant before a trial to disclose the facts and documents on which he relied. In equity, however. a different rule prevailed, there being an absolute right to discovery of all material facts on which a case was founded. Now the practice is regulated by the Rules of the Supreme Court. 1883, Order 31. Discovery is of two kinds; namely. by interrogatories and by affidavit of documents, provision being also made for the production and inspection of documents. Where a party to a suit can make an affidavit stating that in his belief certain specified documents are or have been in the possession of some other party, the court may make an order that such party state on affidavit whether he has or ever had any of those documents in his possession, or if he has parted with them or what has become of them. A further application may then be made by notice to the party who has admitted possession of the documents for production and inspection. Copies also may be taken of the more important documents. There is also discovery of facts obtained by means of interrogatories; *i.e.*, written questions addressed on behalf of one party. before trial. to the other party. who is bound to answer them in writing upon oath. In order to prevent needless expense the party seeking discovery used to have to secure the cost of it by paying into court a sum of money, but this rule was later abolished. Objection may be taken to discovery either of a fact or a document on the ground of privilege or that the matters sought to be discovered are criminatory.

Thus all documents and communications passing between a litigant and his legal advisers are absolutely privileged and need not be disclosed. Again, where an admission of a fact or the production of a document might involve the admission of a criminal offense, the litigant may refuse to give discovery. Where the opposite party is not satisfied with an affidavit of documents, or the answer to an interrogatory, he may in certain cases apply for a further and better affidavit or answer, and in some cases the master to whom the application is made will himself examine a document in order to see whether it shall be disclosed or not. The advantage of discovery lies in this—that it forces a litigant to reveal his case on oath. It is one thing to make a statement or deny a fact in a pleading. That merely has effect to put the matter in issue. It is a much more serious matter to have to swear to a fact in an affidavit, because, in the case of the answer to an interrogatory, it may be put in evidence by the opposite party at the trial. As to discovery against the crown, see O. 31, r. 5B; and as to discovery in action for libel and slander special attention should be paid to O. 31, r. 12, and to a note on p. 517 of the *Annual* Practice, 1956.

Evidence on Commission.—Cases often arise in which it is impossible because of illness or absence to secure the attendance of a witness at the trial. In such circumstances the court has power (conferred by O. 37, r. 5 et seq.) to direct that the evidence be taken anywhere before an officer of the court or any other person. It must be shown, however, that the witness will be unable to attend. either because of illness or because he is out of the jurisdiction, and cannot be compelled to attend by subpoena. Even a plaintiff may be allowed to give evidence on commission: but this is a privilege seldom granted. The evidence of the witness is written down and signed by him and can be put in at the trial. In certain foreign countries, where evidence cannot be taken on commission, it is secured by letters of request, which are sent through the foreign office.

Admission.—Although the pleadings show that everything is in issue in an action, it is competent for either party to give notice that he admits the truth of the whole or part of his opponent's case (0. 32, r. 1). This secures the costs of proving those facts, and, if the whole cause of action is admitted, enables the party to whom the admission is made to apply for judgment (0. 32, r. 6). Apart from this. either party may give notice to the other to admit facts and if he refuses to do so unreasonably he may have to pay the costs of the necessary proof of those facts (ibid., [4]). Similarly notice may be given to admit documents; indeed the costs of proving any document may be disallowed if the notice is not given (O. 32, r. 3).

Special Case.—The parties to any cause or matter may concur in stating the questions of law arising therein in the form of a special case for the opinion of the court (0. 34, r. 1), and the court may order a question of law to be decided either by special case or otherwise before any question of fact is tried (0. 34, r. 2).

Transfer and Consolidation of Action.—Action may be transferred from one division of the high court to another by an order of the court or a judge of the division in which the case is proccding (0. 49, r. 1). Causes pending in the same division may be consolidated with each other (O. 49. r. 8).

Application and Proceedings at *Chambers*.—All applications at chambers (*i.e.*, before a master or a judge) are made by summons unless they are made ex parte; that is to say, by one side only. Applications at chambers generally are regulated by O. 54, while 0. 55 prescribes the rules observed in chambers in the chancery division.

Proceedings in District Registries.—To meet the convenience of suitors who do not live in or near London, district registries have been established in various parts of the country. Proceedings can be taken in a district registry only in an action in which the writ has been issued out of that registry. Broadly speaking. the powers of a district registrar are similar to those of a master of the supreme court.

In certain cases. however, where an action has been commenced in a registry the defendant can as of right have it moved to London, and the court has power in all cases to move an action from a registry to London or vice versa. (See generally 0. 35.) Proceedings by poor persons under the Matrimonial Causes acts in district registries are provided for by 0. 35A.

Trial.—The places and mode of trial are fixed by the order made on a summons for directions. Where a case is to be tried in London. it is assigned to one of three lists—the jury list, the London nonjury list and the short nonjury list (0. 36, r. 1A and 29 [1]). The master, when making the order, tries to form an opinion as to the time which the hearing will last. As a rule a case sent to the short nonjurp list will not require more than two hours. The plaintiff must give notice of trial (0. 36, r. 11j, and if he fails to do so, within the time prescribed by the rules, the defendant may do so, or else apply to have the action dismissed for want of prosecution (O. 36, r. 12). Trial follows upon the completion of the steps necessary to bring the parties before the court and to adjust the issues upon which the court is to adjudicate, which may be summed up in the term pleading. In England the trial is usually in open court, and it is rare to try cases at chambers or to attempt to exclude the public from the hearing. In practice, hearing at chambers is ordered only where to try in open court would be to defeat the ends of justice. An action by or against the crown cannot be tried out of London without the consent of the crown (O. 36, r. 1B). In the high court of justice in England several modes of trial are now used:

1. Trial by judge with a jury used in the queen's bench division and in probate and matrimonial cases. There is a right to have a jury as a matter of course in actions of defamation, false imprisonment, malicious prosecution, seduction or breach of promise of marriage and in cases where a charge of fraud is made.

2. Trial by a judge without a jury is invariable in the chancery division and is common in other divisions. Cases in the chancery division are not tried with a jury unless a special order is made (O. 36, r. 3); and the high court in cases in which trial without jury could be ordered without consent still retains the power of so trying them, and has also acquired power to direct trial without a jury of any issue requiring prolonged examination of documents or accounts or scientific or local investigation.

3. Trial with assessors, usually in admiralty cases (the assessors being nautical). but rare in other divisions.

4. Trial by an official referee in certain cases involving much detail (R.S.C., O. 36). Formerly there was no appeal from the decision of an official referee, save on a question of law, but now, by virtue of O. 36A, r. 8, 1957, there may, in cases involving a charge of fraud, be an appeal on a question of fact.

5. Where the parties consent, trial may be had of any case in the queen's bench division before a master in chamhers.

The parties may be represented in the high court by counsel or may conduct their case in person. The trial is carried on by stating to the court the pleadings if any and by opening the plaintiff's case. This is followed by the evidence of the witnesses, who are sworn and examined and cross-examined. On the completion of the plaintiff's case and evidence, the defendant's case is stated and evidence adduced in support of it. The plaintiff or his counsel has, as a rule, the reply or last word unless the defendant has called no evidence. If when the trial is called the plaintiff appears and the defendant does not. the plaintiff may prove his case (O. 36, r. 31). If the plaintiff does not appear, the defendant may have judgment dismissing the action, and may prove his counterclaim if he has one (O. 36, r. 32). But any judgment by default may be set aside on terms.

At the conclusion the judge sums up the law and facts of the case to the jury and their verdict is returned, or if there is no jury the judge gives judgment stating his conclusion on the law and the facts involved. He then directs that judgment shall be entered as he thinks right (O. 36, r. 39), and a memorandum is endorsed on the judgment pointing out that if it is not obeyed, the defendant will be liable to process of execution (O. 41, r. 5).

Juries.—In England the trial jury (also called petty jury or traverse jury) consists of 12 jurors, except in the county court where the number is 8. Women are now summoned as jurors, but a husband and wife cannot be summoned on the same occasion. A woman may, however, claim exemption on the ground that by reason of pregnancy or some other feminine condition or ailment she is or will be unfit to serve. Either party to the suit may apply to the court for an order that the jury shall consist wholly of men or wholly of women. In civil but not in criminal cases the trial may by consent be by fewer than 12 jurors, and the verdict may by consent be that of the majority.

The jurors are selected from the inhabitants of the county, borough. or other area for which the court to which they are summoned is commissioned to act.

Exemptions from juries include members of the legislature and judges, ministers of various denominations, practising barristers and solicitors, registered medical practitioners and dentists and officers and soldiers of the regular army. Persons over 60 are exempt but not disqualified. Lists of the jurors are prepared by the overseers in rural parishes and by the town clerks in boroughs, and are submitted to justices for revision. When jurors are required for a civil or criminal trial they are summoned by the sheriff or, if he cannot act, by the coroner.

For the purpose of civil trials in the superior courts there is only one list of jurors, special juries having been abolished.

The jurors are the judges of fact upon the evidence laid before them. Their province is strictly limited to questions of fact, and within that province they are still further restricted to matters proved by evidence in the course of the trial and in theory must not act upon their own personal knowledge and observation except so far as it proceeds from what is called a "view" of the subject matter of the litigation.

While the jury is in legal theory absolute as to matters of fact, it is in practice largely controlled by the judges. Not only does the judge at the trial decide as to the relevancy of the evidence tendered to the issues to be proved, and as to the admissibility of questions put to a witness, but he also advises the jury as to the logical bearing of the evidence admitted upon the matters to be found by the jury. The rules as to admissibility of evidence, largely based upon scholastic logic! sometimes difficult to apply, and almost unknown in continental jurisprudence. coupled with the right of an English judge to sum up the evidence (denied to French judges) and to express his own opinion as to its value (denied to U.S. judges), fetter to some extent the independence or limit the chances of error of the jury.

The appellate court will not upset a verdict when there is substantial and conflicting evidence before the jury. In such cases it is for the jury to say which side is to be believed, and the court will not interfere with the verdict. To upset a verdict on the ground that there is no evidence to go to the jury implies that the judge at the trial ought to have withdrawn the case from the jury. Under modern procedure, in order to avoid the risk of a new trial, it is not uncommon to take the verdict of a jury on the hypothesis that there was evidence for their consideration, and to leave the unsuccessful party to apply for judgment notwithstanding the verdict. The question whether there was any evidence proper to be submitted to the jury arises oftenest in cases involving an imputation of negligence; *e.g.,* in an action of damages against a railway company for injuries sustained in a collision.

This statement indicates existing practice but scarcely determines what relation between the facts proved and the conclusion to be established is necessary to make the facts evidence from which a jury may infer the conclusion. The true explanation is to be found in the principle of relevancy. Any fact which is relevant to the issue constitutes evidence to go before the jury, and roughly speaking, if there is a connection, as cause and effect, between any fact and the fact to be proved, the former is relevant. As regards damages the court has always had wide powers, as damages are often a question of law. But when the amount of the damages awarded by a jury is challenged as excessive or inadequate, the appellate court, if it considers the amount unreasonably large or unreasonably small, must order a new trial unless both parties consent to a reduction or increase of the damages to a figure fixed by the court; see *Watt* v. *Watt* (1905), App. Cas. 11j.

Judgment and Execution.—Execution is allowed as a matter of course after judgment except where it has for some reason been stayed; *e.g.,* where an appeal is pending. (See generally R.S.C., O. 42.) A judgment for the recovery of money or costs is enforced. as a rule: by writ of *fieri facias* addressed to the sheriff. and directing him to cause to be made (*fieri facias*) of the goods and chattels of the debtor a levy of a sum sufficient to satisfy the judgment and costs, which carry interest at 4% per annum. The seizure effected by the sheriff or his officer, under this writ. of the property of the debtor. is what is popularly known as "the putting in" of an execution. The seizure should be carried out with all possible dispatch. The sheriff or his officer must not break open the debtor's house in effecting a seizure, for "a man's house is his castle"; but this principle applies only to a dwelling house, and a barn or outhouse unconnected with the dwelling house may be broken into. The sheriff on receipt of the writ endorses it on the day, hour, month and year when he received it; and the writ binds the debtor's goods as at the date of its delivery, except as regards goods sold before seizure in market overt, or purchased for value, without notice before actual seizure (Sale of Goods act, 1893, s. 26, which supersedes s. 16 of the Statute of Frauds and s. 1 of the Mercantile Law Amendment act. 1856).

This rule is limited to goods, and does not apply to the money or bank notes of the debtor which are not bound by the writ till seized under it (Johnson v. Pickering, Oct. 14, 1907, C.A.). The mere seizure of the goods, however, although, subject to such exceptions as those just stated, it binds the interest of the debtor, and gives the sheriff such an interest in the goods as will enable him to sue for the recovery of their possession, does not pass the property in the goods to the sheriff. The goods are in the custody of the law. But the property remains in the debtor who may get rid of the execution on payment of the claim and fees of the sheriff. The wearing apparel, bedding, tools, etc., of the debtor to the value of £5 are protected. Competing claims as to the ownership of the goods seized are brought before the courts by the procedure of "interpleader." In the queen's bench division, the sheriff issues a summons before a master in chambers calling upon the execution creditors and claimant to appear and state their respective cases. If the claim is not admitted by the execution creditor, an issue is directed to try the merits and either party may ask the master to try the issue himself. This he generally does at the earliest possible opportunity, for the sheriff being in possession, costs are mounting up. Otherwise the "issue" is reported for trial to the high court or county court, the claimant being directed to bring the amount of the sheriff's valuation into court. That money being in coyrt, the sheriff withdraws. After seizure the sheriff must retain possession, and, in default of payment by the execution debtor, proceed to sell. Where the judgment debt, including legal expenses, exceeds £20, the sale must be by public auction, unless the court otherwise orders, and must be publicly advertised. The proceeds of sale, after deduction of the sheriff's fees and expenses, become the property of the execution creditor to the extent of his claim.

Under the law of bankruptcy, the sheriff, in case of sale under a judgment for a sum exceeding £20, is required to hold the proceeds for 14 days in case notice of bankruptcy proceedings should be served upon him. (See BANKRUPTCY.) Imprisonment for debt in execution of civil judgment was abolished except in cases of default in the nature of contempt, unsatisfied by judgments for penalties, defaults by persons in a fiduciary character and defaults by judgment debtors.

Writ of *Elegit*.—The writ of elegit is a process enabling the creditor to satisfy his judgment debt out of the lands of the debtor. It derives its name from the election of the creditor in favour of this mode of recovery. It is founded on the Statute of Westminster (1285, 13 Ed. I. c. 18), under which the sheriff was required to deliver to the creditor all the chattels (except oxen and beasts of the plow) and *half* the lands of the debtor until the debt was satisfied. By the Judgments act, 1838, the remedy was extended to all the debtor's lands, and by the Bankruptcy act, 1883 (now replaced by the Bankruptcy act, 1914), the writ no longer extends to the debtor's goods. The writ is enforceable against legal interests whether in possession or remainder but not against equitable interests in land. When the debtor's interest is equitable recourse is had to equitable execution by the appointment of a receiver or to bankruptcy proceedings. (See R.S.C., O. 43.)

Writs of Possession and Delivery.—Judgments for the recovery or for the delivery of the possession of land are enforceable by writ of possession. The recovery of specific chattels is obtained by writ of delivery (R.S.C., O. 47, 48).

Writ of *Sequestration*.—Where a judgment directing the payment of money into court, or the performance by the defendant of any act within a limited time, has not been complied with, or where a corporation has wilfully disobeyed a judgment, a writ of sequestration is issued, to not less than four sequestrators, ordering them to enter upon the real estate of the party in default, and to "sequester" the rents and profits until the judgment has been obeyed (R.S.C., O. 43, r. 6).

Equitable Execution.—Where a judgment creditor is othenvise unable to reach the property of his debtor he may obtain equitable execution, usually by the appointment of a receiver, who collects the rents and profits of the debtor's land for the benefit of the creditor (R.S.C., O. 1, rr. 15A–22). But receivers may be appointed of interests in personal property belonging to the debtor by virtue of the Judicature act, 1873, s. 25 (8). The plaintiff may apply ex parte for leave to issue a summons for the appointment of a receiver and for an injunction to restrain the defendant from parting with his property pending the hearing of the summons. Such an application may be heard by a master.

Attachment.—A judgment creditor may "attach" debts due by third parties to his debtor by what are known as garnishee proceedings. A garnishee order nisi may be made by a master of the queen's bench on the application of the judgment creditor. It must be supported by an affidavit in which the judgment creditor or his solicitor swears positively that there is a debt owing by the garnishee to the judgment debtor. Money on current or deposit account at a hank, may be attached, but subject, in the case of money on deposit. to a new rule (0.4'5. r. 10) made in 1957. Stock and shares belonging to a judgment debtor may be charged by a charging order, so as, in the first instance, to prevent transler of the stock or payment of the dividends. and ultimately to enable the judgment creditor to realize his charge.

A writ of attachment of the person of a defaulting debtor or party may be obtained in a variety of cases akin to contempt (*e.g.*, against a person failing to comply with an order to answer interrogatories, or against a solicitor not entering an appearance in an action, in breach of his written undertaking to do so), and in the cases where imprisonment for debt is still preserved by the Debtors act, 1869 (R.S.C.O. xliv). Contempt of court in its ordinary forms is also punishable by summary committal (see CONTEMPT [LEGAL]).

Another form of execution analogous to the attachment of a debt is a charging order. This directs that any stock, funds or shares of a public company in England, standing in the name of a debtor in his own right or in the name of any person in his trust for him, shall stand charged with the payment of the judgment debt and interest. The charge cannot be enforced for six calendar months after the order (O. 46, r. 1).

Interpleader.—This in English law is the form of action by which a person, who is sued at law by two or more parties claiming adversely to each other for the recovery of money or goods wherein he has no interest, obtains relief by procuring the rival claimants to try their rights between or among themselves only. Originally the only relief available to the possessor against such adverse claims was by means of a bill of interpleader in equity. The Interpleader act, 1831, enabled the defendant in such cases, on application to the court, to have the original action stayed and converted into a trial between the two claimants. The Common Law Procedure act of 1860 further extended the power of the common-law courts in interpleader; and the Judicature act, 1875 (repealed and re-enacted by the Judicature act! 1925), provides that the practice and procedure under these two statutes should apply to all divisions of the high court of justice. The Judicature act also extended the remedy of interpleader to a debtor or other person liable in respect of a debt alleged to be assigned, when the assignment was disputed. In 1883 the acts of 1831 and 1860 were embodied in the form of rules by the Rules of the Supreme Court (1883), O. 47, by reference to which all questions of interpleader in the high court of justice are now determined. Interpleader is the equivalent of multiplepoinding in Scots law.

Costs.—When giving judgment in England, the judge usually deals with the costs of the action, as to which he has an absolute discretion, although it must, of course, be exercised judicially. The term "costs" denotes the expenses incurred (1) in employing a lawyer in his professional capacity for purposes other than litigation; (2) in instituting and carrying on litigation whether with or without the aid of a lawyer.

The retainer of a solicitor implies a contract to pay to him his proper charges and disbursements with respect. to the work done by him as a solicitor. In cases of conveyancing his remuneration is for the most part regulated by scales according to value on the value of the property dealt with (Solicitors' Remuneration order, 1882), and clients are free to make written-agreements for the conduct of any class of nonlitigious business, fixing the costs by a percentage on the value of the amount involved. So far as litigious business is concerned, the arrangement known as "no cure no pay" is objected to by the courts and the profession as leading to speculative actions, and stipulations as to a share of the proceeds of a successful action are champertous and illegal. An English solicitor's bill drawn in the old form is a voluminous itemized narrative of every act done by him in the cause or matter with a charge set against each entry and often against each letter written. Before the solicitor can recover from his client the amount of his charges. he must deliver a signed bill of costs and wait a month before suing.

The high court has a threefold jurisdiction to deal with solicitors' costs: (1) by virtue of its jurisdiction over them as its officers: (2) statutory, under the Solicitors act, 1843, and other legislation: (3) ordinary, to ascertain the reasonableness of charges made the subject of a claim.

The client can. as a matter of course, get an order for taxation within a month of the delivery of the solicitor's bill, and either client or solicitor can get such an order as of course within 12 months of delivery. After expiry of that time the court may order taxation if the special circumstances call for it, and even so late as up to 12 months after actual payment.

Costs as between solicitor and client are taxed in the same office as litigious costs, and objections to the decisions of the taxing officer, if properly made, can be taken for review to a judge of the high court and to the court of appeal.

The expenses of litigation fall in the first instance on the person who undertakes the proceedings or retains and employs the lawyer. It is in accordance with the ordinary ideas of justice that the expenses of the successful party to litigation should be defrayed by the unsuccessful party, a notion expressed in the phrase "costs follow the event." But there are many special circumstances which interfere to modify the application of this rule. The action, though successful, may be in its nature frivolous or vexatious, or it may have been brought in a higher court where a lower court would have been competent to deal with it. On the other hand the defendant, although he has escaped a judgment against him, may by his conduct have rendered the action necessary or otherwise justifiable. In such cases the rule that costs should follow the event would be felt to work an injustice, and exceptions to its operation have therefore been devised. In the law of England the provisions as to litigious costs, though now simpler than of old, are still elaborate and complicated, and the costs themselves are on a higher scale than is known in most other countries.

Except as regards appeals to the house of lords and suits in equity, the right to recover costs from the opposite party in litigation has always depended on statute law or on rules made under statutory authority. "Costs are the creature of statute." The house of lords has declared its competence to grant costs on appeals independently of statute.

In the judicial committee of the privy council the power to award. in its discretion, costs on appeals from the colonies or other matters referred to it is given by s. 1; of the Judicial Committee act, 1833; and the costs are taxed by the registrar of the council.

The general rule now in force in the supreme court of judicature is as follows: "Subject to the provisions of the Judicature Acts and the rules of the court made thereunder, . . . the costs of and incident to all proceedings in the Supreme Court, including the administration of estates and trusts, shall be in the discretion of the court or judge. . . . Provided (1) that nothing herein contained shall deprive an executor, administrator, trustee or mortgagee who has not unreasonably instituted, carried on or resisted any proceedings of any right to costs out of a particular estate or fund to which he would be entitled under the rules hitherto . . . acted upon in the chancery division . . ."

The rule above stated applies to civil proceedings on the crown side of the queen's bench division, including mandamus, prohibition quo warranto and certiorari (R. v. *Woodhouse*, 1906, 2 K.B. 502, 540); and to proceedings on the revenue side of that division (0. 68, r. 1); but it does not apply to criminal proceedings in the high court, which are regulated by the crown office rules of 1906, or by statutes dealing with particular breaches of the law, and as to procedure in taxing costs by O. 65, r. 27, of the Rules of the Supreme Court.

The rule is also subject to specific provision empowering the courts to limit the costs to be adjudged against the unsuccessful party in proceedings in the high court, which could and should have been instituted in a county court (*e.g.*, actions of contract under £100 or actions of tort in which less than £10 is recovered), unless the plaintiff, claiming a liquidated sum, has taken proceedings under O. 14 in the high court, in which case he *may* get high court costs if he recovers more than £20.

Costs of interlocutory proceedings in the course of a litigation are sometimes said to be "costs in the cause"; that is, they abide the results of the principal issue. A party succeeding in interlocutory proceedings, and paying the costs therein made "costs in the cause," would recover the amount of such costs if he had a judgment for costs on the result of the whole trial, but not otherwise. But it is usual now not to tax the costs of interlocutory proceedings till after final judgment.

When an order to pay the costs of litigation is made the costs are taxed in the central office of the high court, unless the court when making the order fixes the amount to be paid (R.S.C., O. 65, r. 23).

The taxation is effected, under an elaborate set of regulations, by reference to the prescribed scales, and on what is known as the lower scale, unless the court has specially ordered taxation on the higher scale (R.S.C.. 0. 65, rr. 8, 9, appendix N).

In the taxation of litigious costs two methods are still adopted, known as "between party and party" and "between solicitor and client." Unless a special order is made the first of the two methods is adopted. Formerly "party and party" costs were found to be a very imperfect indemnity to the successful litigant, because many items which his solicitor would be entitled to charge against him for the purposes of the litigation were not recoverable from his unsuccessful opponent. The high court can, in exercise of the equitable jurisdiction derived from the court of chancery, make orders on the losing party to pay the costs of the winner as between solicitor and client. These orders are not often made except in the chancery division. But even where party and party costs only are ordered to be paid under the present practice (dating from 1902), the taxing office allows against the unsuccessful party all costs, charges and expenses necessary or proper for the attainment of justice or defending the rights of the successful party, but not costs incurred through overcaution. negligence or by paying special fees to counsel or special fees to nitnesses or other persons. or by any other unusual expenses (R.S.C., O. 65, rr. 27, 29). This practice tends to give an approximate indemnity, while preventing oppression of the losing party by making him pay for lavish expenditure by his opponent. (As to costs in cases where one of the parties has legal aid, *see*, generally, *The Annual* Practice, 1957, pp. 1482–83 and 3747–52.)

Cost of Litigation.— Complaint is often made of the cost of litigation. It is important to notice, however, that the losing party to a suit who is condemned in costs need pay only the amount allowed on taxation Counsel may have 1,000 guineas on his brief; but the taxing master may afterward determine that "the other side" shall pay only one-tenth of that fee. What he pays his own solicitor is the litigant's onn concern, but. subject to this, a client can always ask to have his solicitor's bill taxed. An examination of a number of bills of costs which one or other of the parties to a suit has been ordered to pay (subject to taxation) shows that the larger items are counsel's fees, fees to expert witnesses, expenses of witnesses and (in some cases) the cost of copying documents. So far as the solicitor is concerned these are all out-of-pocket items. The solicitor's own charges may, of course, be considerable if the preparation of the case has involved a large number of interviews and the examination of many documents, but in the average case the principal item is preparing the brief. The actual court fees are trifling: as regards fees to counsel, it must be observed that, subject to the rule that he must never act without a minimum fee of one guinea, a member of the bar is free to demand what he pleases, and to all intents the whole bar is open to the litigant. Similarly an expert witness may name his own fee. Unless *(1)* counsel and experts be compelled to act for less than what they consider a living wage, *(2)* the rule which provides that evidence shall be given *orally* is altered and (3) litigation can be conducted without copies of all relevant documents for the use of counsel and the judge it is difficult to see how costs can be reduced. It is well to remember, too, that in many a heavy case which occupies the time of a judge for a considerable period, the costs of all parties are slight when compared with the amount at stake in the suit. *(See* ADMIRALTY, HIGH COURT OF; APPEAL; ARBITRATION; COUNTY COURT; EVIDENCE.)

See *The Annual Practice* (London, 1957). **(W. V. B.)**

UNITED STATES

The practice and procedure of the courts in the various jurisdictions of the United States was originally derived from the English common-law system of court administration. But since each state or territory, and the federal government, also, now has its own system of courts and its own procedure, a considerable diversity exists. In general, a reform of the common-law procedure has occurred in many ways similar to the English reforms of the 19th century. The extent of the reform varies in the different jurisdictions. The most far-reaching change was that of the so-called code reform of procedure inaugurated by the code of civil procedure adopted in New York in *1848* and (by the early 1950s) in force in 32 U.S. states and territories and the federal system. A later reform was that of the Federal Rules of Civil Procedure. adopted in the United States courts in *1938* and copied in many of the states. as noted below.

The Code Reform. — In *1847* the New York legislature instructed a commission "to provide for the abolition of the present forms of actions and pleadings in cases at common law; for **a** uniform course of proceeding in all cases whether of legal or equitable cognizance. and for the abandonment of all Latin and other foreign tongues, so far as the same shall by them be deemed practicable, and of any form and proceeding not necessary to ascertain or preserve the rights of the parties" (N.Y. laws, 1847, C. 59, §*8)*. During the following year the commission reported a code which was adopted on April 12, 1848. This measure. which served as the model for other codes in the United States, was largely the work of David Dudley Field, a member of the commission. It is often called the "Field code."

The chief characteristic and most fundamental part of the code is its single form of action for all cases. The distinctions of the common-law actions and of their forms were abolished; the separation in procedure of equitable from legal relief was abandoned. As a substitute, the codifiers planned a blended system of law and equity with only one form of action to be known as the *civil action*. In effect, this is the same step taken in England a generation later in the Supreme Court of Judicature act (1873). The full benefits of this reform were not attained in all the states: for many courts considered the ancient forms of action to rest upon distinctions fundamental in the law. Furthermore, some courts took a hostile attitude toward the attempted union of actions at law and suits in equity. Here the history and tradition of the separate systems of law and equity proved strong obstacles to a complete amalgamation. It has therefore often been held that the theory of the action. whether legal or equitahle. must be pointed out in the pleadings. In fact, however, the difference between law and equity actions is chiefly in the remedy to be granted and this should not be an objection to the single action or the simpler forms of pleading.

Perhaps the obstacle which has seemed greatest to the courts in preventing a complete union of law and equity is the requirement common to the state constitutions that the right of trial by jury shall remain inviolate. This is construed to mean a preservation of the jury trial right substantially as it was at the time of the original adoption of the constitutions. In view of the historical practice of jury trials in courts of law, this means in effect that in modern substitutes for action at law, jury trial is a matter of right, while in equitable claims no such right exists. Some courts in protecting the constitutional right continue to force a division of all actions into "law actions" and "equity actions." A more convenient rule and one more in keeping with the code principle is followed in many states, where the question of the form of trial is not allowed to affect the pleading in advance of the trial. If an issue arises at the trial as to the existence of a right to jury trial in either party, it is then determined by the nature of the issues developed in the pleadings in the light of the historical method of trying such issues.

Another important characteristic of the code is its emphasis upon pleading facts, not conclusions of law or evidence. *Fact pleading* was substituted for the *issue pleading* of the common law. This part of the code reform has been comparatively unsuccessful, because no clear line of demarcation exists between statements of fact and statements of law. An additional change wrought by the code was the adoption of the equity principles of greater freedom of joining parties and of rendering judgments in part for or against the various parties, as the justice of the case may require (the *split judgment* of equity). In spite of the fact that the code reform has not met with the same degree of success in all the states! it seems in general to have been in accord with the desires of the people for simpler judicial procedure. Modern plans for further reform are all in the direction of a greater simplification of practice.

Federal Rules of Civil Procedure. — These plans found realistic embodiment in the Federal Rules of Civil Procedure. adopted by the supreme court of the United States for regulation of the practice in the United States district courts. The rules represent the culmination of a long struggle for reform in the federal system carried on by leaders of the bar. Traditionally the procedure in these trial courts had been divided, although a single judge sat in both law and equity cases. In equity the practice was uniform in the many district courts under rules promulgated by the supreme court. But on the law side each district court was supposed to conform to the practice at law in the courts of the state where it was sitting, subject, however. to a considerable and constantly increasing number of congressional statutes dealing with specific procedural details. The resulting hodgepodge had led the American Bar association to press with vigour from *1912* on for the grant of complete rule-making authority to the supreme court. so that a single uniform system might be developed. Legislation was not forthcoming for several years, however, because of long opposition from senators convinced of the need of preserving their local practice. At length, upon adoption of the Rule-Making act on June *19,* 1934 (now *28* U.S.C., §*2072*, as amended!, the supreme court appointed an advisory committee of lawyers and lam teachers to consider and present a draft of rules. The committee consulted extensively with members of the bar and bench and teachers in the law schools and, after the publication and revision of preliminary drafts. made its final report, which the court accepted in 1937. After the set of rules was reported to and lay before congress for a full session, as required by the statute! they became eifective on Sept. *16, 1938*. The committee remained in office: recommending amendments from time to time. of which those effective March 19, *1948,* brought the rules extensively down to date, and that effective Aug. 1, 1951, added a complete rule governing the taking of property by eminent domain (Rule 71A, Condemnation of Property).

This system, both in the manner of its adoption — upon report of a court-appointed drafting committee — and in the substance of the procedure set forth. became a model for reform generally throughout the states. The directly imitating states arc noted below; but there is hardly a state which has not been affected by the movement in some degree or at least had its bar fired with zeal for thoroughgoing reform. The system was designed to employ all the best features of English and U.S. state practice acts or codes, and it is generally regarded as materially ensuring simple, flexible and effective court administration.

State of Pleading. — It has been customary to classify the U.S. states as "code" or "noncode," depending upon whether they have adopted the Field code or not. Since the federal rules represented in essence an advanced and refined stage of code pleading, the distinction still had validity thereafter, although the lines of demarcation became more blurred. The system inaugurated in New York in 1848 had by mid-20th century been adopted in the following jurisdictions: Alaska (1900); Arizona (1864); Arkansas (1868); California (1850); Colorado (1877); Connecticut (1879); Illinois (1934); Indiana (1852); Iowa (1851); Idaho (1864); Kansas (1859); Kentucky (1851); Minnesota (1851); Missouri (1849); Montana (1865); Nebraska (185j); Nevada (1860); New Jersey (1948); New Mexico (1897); New York (1848); North Carolina (1868); North Dakota (1862); Ohio (1853); Oklahoma (1890); Oregon (1854); Puerto Rico (1904); South Carolina (1870); South Dakota (1862); Utah (1870); Washington (1854); Wyoming (1869); Wisconsin (1856); and the United States — the vast federal system, consisting of 86 district courts having exclusive federal jurisdiction and the courts of the District of Columbia and Guam.

In Arkansas, Iowa, Kentucky and Oregon a formal distinction between actions at law and suits in equity, and in Illinois a formal labelling, is still maintained, though the same judges hear both in the same courts.

The federal rules, as applicable in the United States courts, were also fully adopted in the following jurisdictions: Alaska (1949); Arizona (1940); Colorado (1941); Minnesota (1952); New Jersey (1948); New Mexico (1942); Puerto Rico (1943); Utah (1950); and Delaware (1948) for the courts of law only. Beyond this they have been followed extensively, although not completely, in revisions of practice in Florida (1950), Iowa (1943), Rlissouri (1944) and Texas (1941); while at various intervals specific sections have been adopted in Maryland, New York, Pennsylvania, South Dakota and Washington, and individual rules in California, Connecticut and North Dakota. An occasional rule, notably Federal Rule 16, authorizing the holding of pretrial conferences by the judge, has been adopted yet more widely. In Nebraska, where the rules were adopted in 1943, they were immediately repealed by the state legislature — a unique experience matched only by the action of Florida in first adopting (1870) and then repudiating (1873) code pleading in the hectic reconstruction days following the American Civil War.

Of the above jurisdictions Delaware, Florida, Maryland, Pennsylvania and Texas have not been traditionally viewed as code states; but their approach to the federal system makes them at least "quasi code" states, a somewhat vague classification indicating considerable resemblance to the code system, in which should certainly be included Massachusetts and Michigan. States which had adopted the federal pretrial rule by mid-century included New Hampshire, Virginia and West Virginia. A partial revision of procedure in Virginia in 1950 did not follow the federal model, although an extensive motion practice, in lieu of a formal complaint and answer, tended toward modern adaptability. So, too, the Georgia practice has long had a considerable flexibility; and the Louisiana code of practice, based upon the civil law of that state, has naturally a lessened emphasis upon formal pleading. Less trace of the modern approach appears in Alabama, Maine, Mississippi, Rhode Island and Tennessee, although these can hardly be termed "common-law" jurisdictions. For the ancient practice has been ameliorated in many ways, such as the breaking down of the old distinctions between law and equity, by the pleading of "equitable defenses" in '.actions at law" and the free transfer of cases from one side to the other of the court, and by the blotting out or broadening of the former forms of action. True, the surface diversity thus shown among U.S. jurisdictions is accentuated by such barriers as the localization of the bar, so that an attorney of one state cannot appear as counsel in the courts of another state except by special permission requested of and granted by the court for the limited occasion. Underneath, however, is a substantial similarity of objective which could be more easily and fully achieved by uniform rules identically followed throughout the union. Wide state adoption of the federal rules is an obviously desirable trend toward such uniformity.

Course of Proceedings in a Civil Action. — Notice to the defendant at the institution of suit and an opportunity to present his side of the case are essential to the U.S., as to any, system of justice. In many of the states (some of which have adopted the code procedure), the traditional practice of issuing a writ in the name of the state directing the sheriff to make the summons is followed. In others, however, the writ of the sovereign is supplanted by a simple written summons to appear, signed by the plaintiff or his attorney and served upon the defendant by anyone not a party — usually by a clerk in the office of the plaintiff's attorney. Even in these jurisdictions, when the plaintiff claims some extraordinary or provisional remedy, such as attachment of the defendant's property, arrest of the defendant or an injunction, notice is given in the form of a court order served by some public officer, such as the sheriff. It is necessary that proper *service* of the summons be had, for unless the defendant is legally notified of the action, no *jurisdiction* is acquired over his person. Moreover, unless the action is brought to the proper court, *jztrisdiction over the subject matter* does not exist. Next come the pleadings, the first step being the filing by the plaintiff of his *complaint* or *petition* (the *declaration* or *count* of the common law). This contains the names of the parties and the court, a statement of the facts constituting the plaintiff's cause of action and a demand for the judgment to which he thinks himself entitled. The complaint is served upon the defendant with the summons or after the parties are in court or else is supplied to the defendant by the court clerk. If the defendant desires to defend. his first move is to enter an *appearance,* which may be done, without his presence in court, by a written notice of appearance by his attorney or by filing an *answer* to the complaint. By *demurring,* the defendant may question the legal sufficiency of the complaint. But if the demurrer is abolished. as in Illinois and New York, he moves for judgment and thus raises the same issue. In the defendant's answer he may deny the plaintiff's allegations or he may admit them and allege new matter in his defense or as a basis for a *counterclaim* against the plaintiff. To this the plaintiff under most codes may file a *reply* (corresponding to the common-law *replication*), and at this stage the pleadings are generally required by the statute to come to an end. Thereafter follows the actual trial with the production of evidence by the parties, followed by the verdict, if a jury is present, and judgment. If the defeated party so desires he may then take an appeal to some appellate tribunal. (*See* APPEAL.) When the judgment is finally effective, extensive proceedings are available to secure its enforcement.

The new federal system followed this same course in substance, but with some change of emphasis from formal pleadings of fact to short and succinct statements of claim or defense, ending usually with the answer or, in any event, with a reply to a counterclaim. The old demurrer was abolished and objections may be presented either by answer or by a motion, including a motion for summary judgment, supported by affidavits or depositions on the merits. Stress is placed on reaching the merits quickly, rather than on form. Hence, that each party may be thoroughly apprised of all elements of the case at once and may thus prepare his case completely in advance of trial, there is an extensive system of discovery by the taking of depositions, submission of interrogatories, requests for admission and the production of documents and so on. Wide adoption of the optional provision for pretrial conference, settling the issues and dispensing with formalities of proof of detail, adds to this sense of full preparation and often facilitates settlements. There is practically complete freedom of joinder of actions, both of parties and of causes, as well as of counterclaims. New parties may be summoned in or impleaded to answer claims developed in the case. Provisions governing trials, including waiver of jury trial by failure to make seasonable claim therefor, simplifying the appeals and abolishing the noting of formal exceptions and other like restrictions, round out the system. This is often supported by an accompanying movement, also supported by the American Bar association, for improved court structure and administration, of which the main feature is a unified court, sitting in various divisions as required, under a single administrative control headed by the chief justice, assisted by an administrative director.

Criminal Procedure.— Here again the English practice is the source. Indictment by a grand jury is still an essential step in a criminal prosecution in many jurisdictions for capital and many other serious crimes. This body varies in number in the different jurisdictions but usually consists of not less than 12 and not more than 23 persons, at least 12 of whom must concur in presenting an indictment. It may act upon its own knowledge, upon an information of the prosecutor or upon a complaint made under oath by a private person before a committing magistrate. The indictment, which is usually prepared beforehand by the prosecutor and given to the grand jury for its consideration, serves as the prosecution's complaint at the trial. A number of technical rules apply to the indictment, making criminal procedure very rigid. Thus, in many jurisdictions unless the indictment describes the offense with great particularity, including its time and place of occurrence and the accused's name, it may be quashed. Such technicalities are a relic of ancient common-law times when the accused was favoured because of the serious penalties imposed for minor offenses. But as the reason for these rules is now gone, authorities today advocate a procedure requiring only that reasonable notice of the ground of complaint be given the accused. In a considerable number of states an information by the prosecutor was substituted for the indictment by the grand jury. An information suffices in the federal courts except in offenses punishable by more than one year's imprisonment. Trial by jury is usually a constitutional guarantee except in minor offenses. But in Maryland and Connecticut the accused may elect a trial to the court if he so chooses. The American Law institute, an organization of judges, lawyers and law teachers with headquarters in Philadelphia, Pa., recommended an advanced and simplified Model Code of Criminal Procedure (1931), which has been adopted in some states, as substantially in Connecticut in its pleading aspects as early as 1929. More lately the supreme court, under statutory authority and following its plan of drafting first employed as to the civil rules, adopted the report of its Advisory Committee on Rules of Criminal Procedure recommending the Federal Rules of Criminal Procedure, which became effective throughout the federal system on March 21, 1946. (See ADMIRALTY JURISDICTION; APPEAL; ARBITRATION; CRIMINAL LAW; EVIDENCE; JUDICIAL REFORM; PROBATE; SUPREME COURT OF THE UNITED STATES.)

BIBLIOGRAPHY.—C. M. Hepburn, *Development of Code Pleading* (1897); Charles E. Clark and others, *Handbook of the Law of Code Pleading*, 2nd ed. (1947); Charles E. Clark, *Cases on Modern Pleading* (1952); George H. Dession, *Criminal Law Administration and Public Order* (1948); William W. Barron and Alexander Holtzoff, *Federal Practice and Procedzrre with Forms* (1950–51); James W. Moore, *Federal Practice*, 2nd ed. (1948–) *Judicial Administration Series, by* various authors on selected topics, in 7 vol., under the auspices of the National Conference of Judicial Councils (1939–49). There are many editions, official and nonofficial, of the Federal Rules of Civil and of Criminal Procedure and Advisory Committees' Notes; special case series include *Federal Rules Service* (1939 *et seq.)* and *Federal Rules Decisions* (1941 *et seq.*); while teaching casebooks, law review articles and local state practice books abound. In England the yearly *Annual Practice*, or "White Book," long edited by Sir W. Valentine Ball, and later by R. F. Burnand (and others) is standard. *See* also W. Blake Odgers, *Principles of Pleading and Practice in Civil Actions in the High Court of Justice*, 10th ed. (1930); R. M. Jackson, *The Machinery of Justice in England* (1940); Claud Mullins, *In Quest of Justice* (1931); E. S. Greenbaum and L. I. Reade, *The King's Bench Masters and English Interlocutory Practice* (1932); Lord Chorley, "Procedural Reform in England," in Alison Reppi, ed., *David Dudley Field Centenary Essays (1949).* (C. E. CL.)

PRAEMUNIRE, in English law an offence so called from the introductory words of the writ of summons issued to the defendant to answer the charge, "Praemunire facias A.B.," etc., *i.e.*, "cause A.B. to be forewarned." From this the word came to be used to denote the offences, usually ecclesiastical, prosecuted by means of such a writ, and also the penalties they incurred. From the beginning of the 14th century papal aggression had been particularly active, more especially in two forms. The one, the disposal of ecclesiastical benefices, before the same became vacant, to men of the pope's own choosing; the other, the encouragement of resort to himself and his curia rather than to the courts of the country. The Statute of Provisors (1306), passed in the reign of Edward I., was, according to Coke, the foundation of all subsequent statutes of praemunire. This statute enacted "that no tax imposed by any religious persons should be sent out of the country whether under the name of rent, tallage, tribute or any kind of imposition." A much greater check on the freedom of action of the popes was imposed by the Statute of Provisors (1350–51) and the Statute of Praemunire passed in the reign of Edward III. The former ordained the free election of all dignities and benefices elective in the manner as they were granted by the king's progenitors. The Statute of Praemunire (the first statute so called), 1353, enacts "that all the people of the king's ligeance of what condition that they be, which shall draw any out of the realm in plea" or any matter of which the cognizance properly belongs to the king's court shall be allowed two months in which to answer for their contempt of the king's rights in transferring their pleas abroad. Many other statutes followed that of 1353, but that passed in the 16th year of Richard II.'s reign is usually referred to as *the* Statute of Praemunire. The Royal Marriage Act, 1772, is the last which subjects anyone to the penalties of a praemunire. A peer charged with praemunire is not entitled to trial by his peers, but is to be tried by a jury. The most famous historical instance of a prosecution of the Statute of Praemunire was that of Cardinal Wolsey in 1529.

PRAENESTE (mod. Palestrina), **a** very ancient city of Latium, lies 23 m. E. of Rome by the Via Praenestina (see below), on a spur of the Apennines facing the Alban hills. To the natural strength of the place and its commanding situation Praeneste owed in large measure its historical importance. Objects in metal and ivory discovered in the earliest graves prove that as early as the 8th or 7th century B.C. Praeneste had reached a considerable degree of civilization and stood in commercial relations not only with Etruria but with the East. In 499 B.C., according to Livy, it formed an alliance with Rome. After Rome had been weakened by the Gallic invasion (390) Praeneste joined in a long struggle with Rome which culminated in the great Latin War (340–338), in which the Romans were victorious, and Praeneste was punished by the loss of part of its territory. It continued in the position of a city in alliance with Rome down to the Social War, when it received the Roman franchise.

As an allied city it furnished contingents to the Roman army and possessed the right of exile (*ius* exilii), *i.e.*, persons banished from Rome were allowed to reside at Praeneste. The nuts of Praeneste were famous and its roses were amongst the finest in Italy. The Latin spoken at Praeneste was somewhat peculiar, and was ridiculed by the Romans, e g., by Plautus. In the civil mars the younger Marius was blockaded in the town by the Sullans (82 B.C.); and on its capture Marius slew himself, the male inhabitants were massacred in cold blood. and a military colony was settled on part of its territory, while the city was removed from the hill-side to the lower ground at the Madonna dell' Aquila, and the temple of Fortune enlarged so as to include the space occupied by the older city. Under the empire Praeneste, from its elevated situation and cool salubrious air, became a favourite summer resort of the wealthy Romans, whose villas studded the neighbourhood. Horace ranked it with Tibur and Baiac, though as a fact it never became so fashionable a residence as Tibur or the Alban hills. Still, Augustus resorted thither; here Tiberius recovered from a dangerous illness, and here Hadrian and Marcus Aurelius had villas. Amongst private owners were Pliny the younger and Symmachus.

But Praeneste was chiefly famed for its great temple of Fortune and for its oracle, in connection with the temple, known as the "Praenestine lots" (sortes praenestinae). The oldest portion of the sanctuary was, however, that situated on the lowest terrace but one. Here is a grotto in the natural rock, containing a beautiful coloured mosaic pavement, representing a sea-scene—

a temple of Poseidon on the shore, with various fish swimming in the sea. To the east of this was a basilica in two storeys. As extended by Sulla the sanctuary of Fortune occupied a series of five vast terraces, which, resting on gigantic substructions of masonry and connected with each other by grand staircases, rose one above the other on the hill in the form of the side of a pyramid, crowned on the highest terrace by the small round temple of Fortune. This immense complex, probably by far the largest sanctuary in Italy, must have presented a most imposing aspect, visible as it was from a great part of Latium, from Rome, and even from the sea.

The modern town of Palestrina, a collection of narrow alleys, stands on the terraces once occupied by the temple of Fortune. On the summit of the hill (2,471 ft.), nearly a mile from the town, stood the ancient citadel, the site of which is now occupied by a few poor houses (Castel San Pietro) and a ruined mediaeval castle of the Colonna. Considerable portions of the southern wall of the ancient citadel, built in very massive Cyclopean masonry of blocks of limestone, are to be seen; and the two walls, also polygonal, which formerly united the citadel with the town, can be traced. The calendar set up by the grammarian M. Verrius Flaccus in the forum of Praeneste was discovered in 1771. Excavations made in the ancient necropolis, which lay on a plateau surrounded by valleys at the foot of the hill, have yielded important results for the history of the art and manufactures of Praeneste. The Ficorni casket, engraved with pictures of the arrival of the Argonauts in Bithynia and the victory of Pollux over Amycus, was found in 1738. (J.G. Fr.; R. S. Co.; T. A.)

PRAESEPE, a loose star-cluster in the constellation Cancer having a "bee-hive" shape. It is a favourite object for telescopes of low power. The cluster is located at a distance from the sun of about 600 light-years.

PRAETOR, originally a military title (a leader; Lat, *prae . . .* ire), was the designation of the highest magistrates in the Latin towns.

Under the republic the Roman consuls were at first called praetors; by the Licinian law of 367 B.C., a new magistrate was created who was to be a colleague of the consuls, though with lesser powers. This new magistrate was entrusted with the jurisdiction in civil cases; in other respects his powers resembled those of the consuls. His title was the city praetor (praetor *urbanus*), and when the number of praetors was increased, the city praetor always ranked first. To this new magistrate the title of "praetor" was thenceforward restricted. About 242 B.C. the increase of a foreign population in Rome necessitated the creation of a second praetor for the decision of suits between foreigners (peregrini) or between citizens and foreigners (praetor *peregrinus*). About 227 two more praetors were added to administer the provinces of Sicily and Sardinia. The conquest of Spain occasioned the appointment of two more in 197. The number of praetors remained stationary until Sulla's time (82 B.C.). But in the interval their duties multiplied. On the one hand, five new provinces were added to the Roman dominions; on the other new and permanent jury courts (quaestiones perpetuae) were instituted at Rome, over which the praetors were called on to preside. To meet this increase of business the tenure of office of the praetors and also of the consuls was practically prolonged from one to two years, with the distinction that in their second year of office they bore the titles of propraetor and proconsul instead of praetor and consul. The prolongation of office formed the basis of Sulla's arrangements. He increased the number of the praetors from six to eight, and ordained that henceforward all the eight should in their first year administer justice at Rome and in their second should as propraetors undertake the government of provinces. The courts over which the praetors presided, in addition to those of the city praetor and the foreign praetor, dealt with the following offences: oppression of the provincials by governors (repetundarum), bribery (ambitus), embezzlement (*peculatus*), treason (maiestatzs), murder (de sicariis *et veneficis*), and forgery (falsi). Later, more provinces were added and more courts constituted, including that of *Gallia Cisalpina.* Iulius Caesar increased the number of praetors.

The praetors were elected, like the consuls by the *comitia* centuriata (see Comitia) and with the same formalities. They held office for a year. The insignia of the praetor were those of the higher Roman magistrates—the purple-edged robe (toga praetexta) and the ivory chair (*sella curulis*); in Rome he was attended by two lictors, in the provinces by six. The praetors elect cast lots to determine the department which each of them should administer. A praetor as a civil judge at or before his entry on office published an edict setting forth the rules and law procedure by which he intended to be guided. These rules were often accepted by his successors, and corrected and amplified from year to year, became, under the title of the "perpetual" edicts, one of the most important factors in moulding Roman law. Their tendency was to smooth away the anomalies of the civil law by substituting rules of equity for the letter of the law.

Under the Empire.—Under the empire various special functions were assigned to certain praetors, such as the two treasury praetors (praetores aerarii), appointed by Augustus in 23 B.C.; the ward praetor (praetor tutelaris), appointed by Marcus Aurelius to deal with the affairs of minors; and the liberation praetor (praetor de liberalibus *causis*), who tried cases turning on the liberation of slaves. Of the praetorships with special jurisdiction (especially the ward praetorship and the liberation praetorship) some lasted into the 4th century and were copied in the constitution of Constantinople.

Besides their judicial functions, the praetors as colleagues of the consuls, possessed the consular powers, which they exercised in the absence of the consuls; but in the presence of a consul they exercised them only at the command either of the consul or the senate. (For the praetor as provincial governor see Province.)

PRAETORIANS. In the early Roman republic, praetor (*q.v.*) meant commander of the army: later praetor and propraetor were the usual titles for provincial governors with military powers. Accordingly, the general's quarters in a camp came to be called *praetorium,* one of the gates porta praetoria and the general's bodyguard *cohors* praetoria. Under the empire *cohortes* praetoriae formed the imperial bodyguard. This, as founded by Augustus, consisted of nine cohorts. each 1,000 strong. some part of which was always with the emperor, whether in Rome or elsewhere. Tiberius concentrated this force on the eastern edge of Rome in fortified barracks.

The men were recruited voluntarily, in Italy or Italianized districts, and enjoyed better pay and shorter service than the regular army; they were commanded by *praefecti praetorio*. This force was the only body of troops in Rome (save a few cohortes *urbanae* and some non-Roman personal guards of the emperor) or, indeed, anywhere near the capital. Accordingly it could make or unmake emperors in crises—at the accession of Claudius in A.D. 41, in 68–69, and again late in the 2nd century.

PRAETORIUS, MICHAEL (1571–1621), German musical historian, theorist and composer. was born at Kreuzberg, Thuringia, on Feb. 15. 1571. His father's name was Schulz or Schultze, and the name was latinized as Praetorius. He studied philosophy at Frankfurt-on-Oder, and on the death of his brother, on whose support he relied, he was given a post as organist in the town. In 1604 he became organist and later *Kapellmeister* and secretary to the duke of Brunswick-Wolfenbüttel, and was rewarded for his services with the priory of Ringelheim, near Goslar. He died at Wolfenbüttel on Feb. 15, 1621.

The most important of his compositions are: *Polyhymnia* (15 vol.), *Musae Sioniae* (16 vol.) and *Musa Aonia* (9 vol.), all written partly to Latin and partly to German words. But more precious than all these is the *Syntagma musicum* (3 vol. and an appendix of plates; Wittenberg and Wolfenbuttel, 1614–20).

PRAGMATIC SANCTION, originally a term of the later Roman law, is found in the Theodosian and Justinian codes (Lat. *pragmatica* sanctio, from the Gr. πρᾶγμα, business). It was a decision of the state dealing with some interest greater than a question in dispute between private persons, and was given for some community (*universitas hominum*) and for a public cause. In later times it was adopted by those countries which followed the Roman law, and in particular by despotically governed countries, to signify an expression of the will of the sovereign defining the limits of his own power or regulating the succession.

Justinian regulated the government of Italy by pragmatic sanctions after it had been reconquered from the Ostrogoths. In after ages the king of France, Charles VII, imposed limits on the claims of the popes to exercise jurisdiction in his dominions by the pragmatic sanction of Bourges in 1438.

The emperor Charles VI settled the law of succession for the dominions of the house of Habsburg by pragmatic sanction that was first published on April 19, 1713 (see AUSTRIA, EMPIRE OF). Philip V, the first of the Bourbon kings of Spain, introduced the Salic law by a pragmatic sanction, and Ferdinand VII revoked it by another. The term was not used in England.

PRAGMATISM, a term of philosophy (from Greek *pragmata*, "acts," "affairs," "business") chosen by the U.S. logician C. S. Peirce (*q.v.;* 1839–1914), apparently in the course of discussions with William James and others in the 1870s, to stand for a way of making our ideas clear or, more accurately, for "a method of logic, a method of determining the meanings of intellectual concepts, that is, of those upon which reasoning may hinge" (Collected Papers *of* Charles Sanders Peirce, ed. by Charles Hartshorn and Paul Weiss, vol. 5, p. 464; Cambridge, Mass.: Harvard, 1935). Pragmatism was popularized by the writings of James during the first decade of the 20th century; but the later publication of Peirce's Collected Papers showed that the two fathers of the doctrine diverged considerably in their interpretations of it.

Peirce's original formulation of the pragmatist principle was: "Consider what effects, that conceivably might have practical bearings, we conceive the object of our conception to have. Then our conception of these effects is the whole of our conception of the object" (Collected Papers, vol. 5, p. 2). A more readily intelligible and apparently equivalent formula of James is that "the whole ineaning of a conception expresses itself in practical consequences, either in the shape of conduct to be recommended or in that of experience to be expected if the conception is true, which consequences would be different if it were untrue: and must be different from the consequences by which the meaning of other conceptions is in turn expressed" (William James in James Mark Baldwin, Dictionary of Philosophy and *Psychology;* New York: Macmillan Company.,1902). Both statements make a point which is closely related to the central teaching of British empiricism; but where traditional empiricism has taught that none of our conceptions (or the verbal expression of them) has a meaning unless it has been derived from some elementary sensory impression, pragmatism teaches that no conception has meaning unless it can be applied, directly or indirectly, in the location and description of something of a kind that might be revealed to our senses.

Regarded in this way, the positive content of pragmatism is simple enough; viz., that all our conceptions, even the most abstract, derive their peculiar point or meaning from things or from differences in such things as we can actually observe and point to. But pragmatism has certain features which constitute a further important development of traditional empiricism. Two things differ practically, or differ for us, in so far as we find ourselves compelled to treat them differently or to expect different reactions from them. Similarly, according to pragmatism, two words (or conceptions) have different meanings, not because of some direct relation between word and thing in either case, but in virtue of their different uses; *i.e.,* in virtue of the different ways in which they help to express or communicate different procedures—involving expectation and adjustment — with regard to the things in queston Thus pragmatism contains, or rests upon, what might be called a procedural theory of meaning. Moreover, Peirce's principle has proved a most searching tool of criticism. We are all liable to confuse highly abstract and erudite conceptions, not only in metaphysics but also in the mathematical and natural sciences; but if one conception does not differ "practically" (in Peirce's sense) from a second, then our employment of it adds nothing to our employment of that second conception. Again, we are sometimes tempted to engage in speculations which have no assignable "practical hearings": but in that case, according to pragmatism, our thoughts and words have no assignable meaning whatsoever. Men of science. Peirce claimed. have always unconsciously applied the pragmatist method to distinguish better conceptions which common sense treats as one or to identify conceptions which common sense has traditionally regarded as several. Unfortunately philosophers have not made much use of the method.

Thus far Peirce and James were in agreement; the grounds of their divergence were more complex than either of them appreciated. In the first place, for example, James wished to use the pragmatist method to vindicate — not simply to elucidate — our basic moral and religious beliefs by reference to their beneficial practical consequences on our conduct and temper. Peirce was on the whole averse to applying the pragmatist method to moral or to religious concepts, which seemed to him of a kind that could not be made clear; and certainly he was flabbergasted by some of James's ventures in this field. Second, as the basis, to a large extent, of these ventures, there was James's "pragmatist" account of our conception of truth, his view that a belief or theory is true in so far as it "works" or "pays." To be sure, James has often been cruelly misunderstood in this connection. yet it is questionable whether his account of truth can be regarded as an inevitable —and still more questionable whether it can be regarded as the one and only possible — result of applying the pragmatist method to our normal uses of the word "true." Third, underlying most of James's applications of the pragmatist method (including the case of "truth") was his strong prejudice in favour of whatever is concrete and particular and against whatever is abstract and general. This finds expression in his statement that the meaning of any proposition "can always be brought down to some particular consequence in our future experience . . . the point lying rather in the fact that the experience must be particular, rather than in the fact that it must be active" (William James: Collected Essays and Reviews, p. 412; New York: Longmans. Green & Co., 1920). Peirce explicitly repudiated this view. Fourth, the last-named prejudice of James mas closely connected with his hankering after that form of metaphysics — "radical empiricism" he called it—according to which the fundamental reference of all discourse is "pure experience." something which is in itself neutral as between mind and matter and which is exemplified in the content of our sensations and the felt transitions between our sensations. (For example, "truth" on this view stands for certain experienceable transitions between one "bit" of experience and other bits with which it can be brought into harmonious and successful relation.) James openly confessed that he was attracted to pragmatism because he thought it would help him to vindicate his radical empiricism—of which indeed it seemed to him to be simply the logical facet. Peirce on the other hand vehemently rejected the suggestion that any doctrine of logic should be preferred for its metaphysical affinities. "Pragmatism is no doctrine of metaphysics."

Of these four grounds of divergence the last two are fundamental. In them we see the transition, from Peirce's account of the meaning of a term or statement as an attribute of certain prescribable and justifiable procedures, to James's account of it as an attribute of certain describable, because individually experienced. processes. The illegitimacy of this transition seemed plain to Peirce from the fact that his pragmatist principle was put forward, as has been said. as a method of "determining the meanings of intellectual concepts. that is, of those upon which reasoning may hinge." For all reasoning is. in Peircian phrase, subject to "logical control" (*i.e.,* to agreed logical canons); but whatever is amenable to control by rules must be in the nature of a habit or general procedure of action. Hence it can only be to concepts (or their verbal expression) which are irreducibly general (*i.e.,* such that they can be employed by any rational being in any situation of appropriate general kind) that the pragmatist principle can apply. Alternatively we can say: Pragmatism, according to Peirce, teaches thdt our descriptions of things are to be understood as mays of dealing with those things — but of dealing with them from the standpoint. in some respects highly specialized, but in other respects entirely general, of reasoning; *i.e.,* of finding out how observation. hypothesis, deduction and checking of consequences shows them to behave. But while making this protest against James's misuse of his pragmatist principle, Peirce was no less strenuous than James in emphasizing its empiricist purpose; only in so far as an intellectual concept (or its verbal expression) refers to "compulsory perceptions" of a certain sort — perceptions forced upon anyone who uses it — does it possess distinctive and genuine meaning.

Largely because of these disagreements between its originators, partly also because of their respective literary failings — James's writings at their worst are intolerably slapdash, Peirce's at their worst distressingly obscure — pragmatism was subjected during the first quarter of the 20th century to scathing criticisms from philosophers both of the realist and of the idealist schools. For later readers, the annals of this interschool battle are neither lively nor illuminating.

But the inner vitality of Peirce's pragmatist teaching is sufficiently shown by the variety of first-class minds that subsequently described themselves or allowed themselves to be described as pragmatists. Among these may be mentioned the English philosopher F. C. S. Schiller, whose very uneven writings contain some admirable expositions of the "question-and-answer" character of all purposive thinking; John Dewey (*q.v.*), whose "instrumentalist" theory of knowledge owes much to Peirce and whose naturalistic metaphysics of experience would have appealed greatly to James; G. Mead, who developed in the most suggestive manner Peirce's conception of inquiry as a socially controlled activity. C. Lewis drew on Peirce's teaching to restate the Kantian distinction between a *priori* and empirical elements in knowledge.

See also Index references under "Pragmatism" in vol. 24.

BIBLIOGRAPHY.—C. S. Peirce, *Collected Papers*, 6 vol. (1931–35), especially vol. v, and *The Philosophy of Peirce*, ed. by J. Buchler (1940); W. James, *The Will to Believe* (1897) and *Pragmatism* (1907); J. Dewey, *Essays in Experimental Logic* (1916); F. C. S. Schiller, *Humanism* (1903); G. H. Mead, *Mind, Self and Society* (1934); C. I. Lewis, *Mind and the World Order* (1929); W. B. Gallie, *Peirce and Pragmatism* (1952); Manley H. Thompson, *The Pragmatic Philosophy of Peirce* (1953); J. D. Butler, *Four Philosophies and Their Practice in Education and Religion* (1957). (W. B. GE.)

PRAGUE (CZECH PRAHA), the capital of Czechoslovakia, is situated in the Prague region along both banks of a large meander of the Vltava (Ger. Moldau), a tributary of the Elbe. The Vltava is here crossed by 13 bridges. Prague lies 650 ft. above sea level and is approximately 160 mi. N.W. of Vienna and 75 mi. S.E. of Dresden. Area 72 sq.mi. Pop. (1961) 998,493.

The modern town has spread along the winding river banks, up the steep terraced hill slopes and into the side valleys. The hilly position of the town forms a serious barrier to modern communications but adds greatly to its beauty which is enhanced by the many medieval and baroque buildings with their towers and spires and by the numerous parks, of which Stromovka and the Petrin orchards and gardens are the most extensive. A few industrial districts are situated on the left bank, but the chief factories are along the right bank. The residential quarters lie farther away from the centre of the town and form part of greater Prague which has engulfed the surrounding towns, from which daily over 100,000 people travel to work in the capital.

The historical parts of the town, which have retained their ancient appearance, are kept up by the state. The vast 16th- to 17th-century fortified palace on Hradcany hill, now the residence of the president of the republic and formerly that of the ancient kings of Bohemia, dominates the entire town. The castle has a number of halls including Vladislav hall in late Gothic style and the Spanish hall in 15th-century baroque. In the inner castle yard stands St. Vitus cathedral, begun in 1344 and finally completed in 1929. Other important buildings on the castle hill include the Romanesque basilica of St. George (912) and the Renaissance Belvedere. The Little Town below the castle is a district of picturesque streets overshadowed by the baroque dome of St. Nicholas' cathedral (1703). Overlooking the many fine squares and narrow streets stand numerous palaces, which are used today for various public purposes. The Little Town is joined to the Old Town by the famous Charles bridge (1357), now flanked by baroque statues. The Old Town abounds in monuments and quaint relics of the history of the district. Its most remarkable features include the Old Town square with the ruins of the town hall, burned down during the 1945 uprising, and the ancient clock of the seasons. On the opposite side of the square rises the 14th-century Tyn church, built in the Prague Gothic style, containing the tomb of Tycho Brahe, the Danish astronomer. The church was the religious centre of the Hussite movement and in the centre of the square is a monument (1915) to John Huss. Close by are the remnants of the old Josef's town (the Jewish ghetto) and a 13th-century Jewish cemetery and synagogue.

Passing out of the Old Town through the 15th-century gate, or Powder tower, to Prikopy, the site of the former moat round the old walls, there is a change from ancient beauty to modern, commercial life with department stores, hotels, restaurants and offices. The centre of the modern town is Wenceslas square with the statue of St. Wenceslas (1913) and the National museum (1894). Other sights worth mentioning include the Tyl theatre, where Mozart's Don *Giovanni* was first performed; the National theatre (1883); Vysehrad hill with the church of St. Peter and St. Paul and the poets' corner; the national monument at Zizkov with the mausoleum; the statue of the Hussite leader Jan (John) Zizka by Bohumil Kafka (1950); and the large Stalin monument on Letna hill.

Education and Culture. — Prague university, founded by Charles IV in 1348, was the first in central Europe. The Technical university, founded in 1707, has developed a great number of faculties. Other centres of learning include the Prague School of Economics, the arts and crafts school (1885), the Academy of Graphic Arts (1799), the Academy of Music, Dancing and Film (1948), the Conservatoire (1811) and the Institute of Physical Training. The Czechoslovak Academy of Sciences carries out its research in numerous buildings.

Besides the National museum (founded 1818) there are a technical, an ethnographical, an arts and crafts and a Jewish museum, and museums of Czechoslovak literature and of the Working Class Movement. The National gallery contains pictures and sculptures by famous Czech, Slovak and foreign artists and has a unique collection of Gothic art. In addition to the central municipal library there is the university library which on-11s a collection of precious manuscripts and old prints. Prague maintains its claim to be a centre of culture and has 26 theatres, including 3 belonging to the National Theatre, where drama, opera and ballet are performed, special theatres for children, (puppets) and a theatre of recorded music. A number of symphony orchestras, headed by the Czech Philharmonic, avail themselves of the numerous concert halls.

Industry and Communications. — As a capital, Prague is the seat of the ministries, foreign trade corporations, the chamber of commerce and the highest church dignitaries. It is also a big industrial town. Most of the industries are highly specialized, with more than half the production capacity devoted to heavy and precision engineering. All works have been greatly expanded and brought up to date since nationalization in 1945. Products include cars, motorcycles, omnibuses, airplanes, railway engines and carriages, machine tools, boilers, mining and foundry equipment, cranes, machinery for the chemical industry, etc. Other big industries include the manufacture of foodstuffs (mills, dairy produce, breweries), clothing, and chemical and pharmaceutical products. There are also printing works, phonograph and film industries, and tanneries.

The electric power for the city is brought by grid from the brown coal basin in northwestern Bohemia, which also supplies gas. There are hydroelectric power stations on the Vltava at Stechovice, at Vrane and at the Slapy dam (1955).

Prague is the meeting place of rail and air routes joining the north and south of Europe and, especially, the east and west. There are three railway stations. The airport, Ruzyne, is 7 mi. from the centre of the town. Holesovice, the inland harbour, is the terminus of Elbe-Vltava shipping.

History. — There is evidence that the site on which Prague stands has been inhabited since Paleolithic times. Its fertile soil and mild climate (average temperature 35° F. in January, 67° F. in July), its easy fords across the river and the possibilities of defense and of trade, favoured the growth of a town which later became the political centre of Bohemia (*q.v.*). The ruling dynasty of the Premyslides (until 1306) succeeded in defeating all foreign attempts at subjugation and preserved the territorial integrity of the country.

The earliest settlements. documented from about the 9th century. were found at the foot of the ancient castles built on two dominating hilltops, Yysehrad on the right bank of the river and Hradcany on the left, which were residences of the Bohemian princes and later kings. On the right bank a small settlement formed the market centre for the isolated homesteads in the neighbourhood. This developed into Stare Mesto (Old Town), and on the opposite bank King Premysl Otakar II founded Mala Strana (Little Town) in 12j;. Under Charles IV, king of Bohemia (1346–78) and Roman emperor. Nove Mesto (New Town) was built adjacent to the old town, and the ghetto was developed.

In the 14th century Prague was already one of the most important towns in central Europe. It n-as a vital crossroad of trade routes running from north to south and from east to west, and it was also a centre of culture, its university attracting scholars and students from all over Europe. Charles IV, besides founding the university, was personally responsible for extensive building activities in the town according to an elaborate plan. Outstanding examples are the Charles bridge joining the Little Town to the Old Town, the Carolinum (the central auditorium of the university) and the town hall as well as several churches and monasteries in the New Town.

Foreigners who came to settle in Prague contributed toward its growth, and the German and Italian merchants grew into a rich patriciate who ruled the town. They could usually rely on the support of the king in all measures designed to curb the guilds formed by Czech craftsmen. Many conflicts arose between the two social groups and were waged with an eye to nationality. Disputes between guild masters and their journeymen incited numerous town paupers to minor uprisings, which went on prior to and throughout the period of the Hussite wars.

Among the scholars of the university. John Huss soon assumed a leading role in the struggle that ended with the Kutna Hora decree (1409), in which Wenceslaus IV granted the Czechs a predominant position in the university. Huss, basing his criticism on the theoretical writings of Wycliffe, publicly voiced sharp criticism of the church and of the sinful life of the clergy. His sermons, delivered in the Bethlehem chapel (restored to its original appearance in 1954), gained him support among the common people. Repressive measures on the part of the church and the patriciate led to violent uprisings in 1419 during which the radical elements, led by John Zelivsky, rose to power. Prague came to the aid of the people's uprisings in the countryside, which were led by the Hussite supporters, who had established a model community at Tabor in southern Bohemia. The Taborites. led by Zizka, helped Prague and gained a decisive victory in the battle of Vitkov hill in 1420. After the defeat of the radicals the town gradually changed sides until, toward the end of the Hussite wars, Prague stood in the ranks of the opponents. (See HUSSITES.)

The town's significance grew under the rule of George of Podebrad and the Jagellon dynasty, during which Prague was enriched by the building of churches and halls (*e.g.*, Vladislav hall) in Late Gothic style. The following centuries witnessed the growing opposition to the Habsburgs who had become kings of Bohemia on the death of Louis II of Hungary and were endeavouring to reintroduce Catholicism by force. Opposition to those measures and attempts to put an end to the feudal might and Catholic influence of the monarchy and the church led to the defenestration of Prague (May 23. 1618), one of the steps leading to the Thirty Years' War (see BOHEMIA: *Habsburg Rule, 1526–1918*).

During the Hussite wars the town was a Czech stronghold, but after the defeat of the Protestants at the battle of the White mountain in 1620, and after the public execution of Czech noblemen and I'rague commoners on the Old Town square in 1621, the German predominance increased again. Prague ceased to be the chief town of the German empire and its significance began to wane. At the very end of the Thirty Pears' War the town was partially occupied by Swedish armies and shared in the general chaos and decline suffered by the whole of central Europe for many decades after the cessation of hostilities. On May 6, 17j7, Frederick the Great won his first great victory over the Austrians at the Battle of Prague during the Seven Years' War. (See SEVEN TEARS' WAR.)

In the baroque period, rich merchants and the mainly foreign nobility (German, Spanish, Italian) who had settled in Prague and its surroundings invited some outstanding architects and artists, who were later aided by Czech masters, to come and embellish the general appearance of the town. At the time when Mozart lived in Prague. the city, especially Little Town, boasted of large gardens, aristocratic palaces and baroque churches.

Prague's most rapid expansion. however, came with the advent of industrialization. mainly engineering. which took advantage of the proximity of coal mines and ironworks at neighbouring Kladno and Kraluv Dvur. In the 19th century, with the rapidly changing social and economic relations within the town population. Prague became the centre of a great cultural drive for the revival of the Czech national heritage. During the revolutionary wave of the year 1848, a Slav congress was convened at Whitsuntide, the townspeople attempted to put up resistance to the repressive measures of the Austrian generals, but the fighting on the barricades ended in surrender. Nevertheless. Czech feeling and cultural life gained in significance and in 1861 the Czechs won a majority in the town administration. At the conclusion of World War I the independent republic of Czechoslovakia was established with I'rague as its capital city. In March 1939 the country was occupied by the Germans, and Hitler established a protectorate with a puppet government. On May 5, 1945, the citizens of I'rague rose against the German occupying forces, erecting barricades and holding out against superior German forces until the entry of the Soviet army four days later. Prague once again became the capital of the Czechoslovak republic. (T. GR.)

PRAGUERIE, THE, a revolt of the French nobility against King Charles VII in 1440, so named because a similar rising had recently taken place in Prague, Bohemia. It was caused by the desire of the princes and great vassals to regain control of the king's council. The instigator was Charles I. duke of Bourbon, who three years before had attempted an unsuccessful rising. He and his bastard brother Alexander were joined by the former favourite Georges de la Trémoïlle, by John V, duke of Brittany, who allied himself with the English, by John II, duke of Alençon, by Louis, count of Vendôme, and by captains of mercenaries like Antoine de Chabannes and Jean de la Roche who were opposed to the recent military reforms.

The duke of Bourbon gained over to their side the 16-year-old dauphin Louis — afterward Louis XI — and proposed to set aside the king in his favour, making him regent. Louis was readily induced to rebel: but the country was saved from a serious civil war by the energy of the king's officers and the solid loyalty of his "good cities." The constable de Richemont marched with the king's troops into Poitou, his old battleground with Georges de la Trémoïlle, and in two months he had subdued the whole country. Charles VII then attempted to ensure the loyalty of the duke of Bourbon by the gift oi a large pension, forgave all the rebellious gentry and installed his son in Dauphiné (see LOUIS XI).

PRAIRIE, the grassland biome (formation) of North America, the main body extending from southern Alberta to Texas and from the western arid desert eastward to contact with the humid forests. Other grasslands are the desert plains, extending southward from western Texas and Arizona into Mexico, the California prairie of central California and the Palouse prairie of the northwestern states of the U.S. Grasslands ecologically equivalent to various prairies, including the steppe of Russia, the veld of south Africa and the pampas of South America, occur on all continents.

Perennial grasses gave the prairies their special character, but numerous colourful flowering plants, particularly legumes and composites, were conspicuous in spring and autumn. Bison and pronghorn antelope, grazing animals originally abundant on the prairies, disappeared in the earliest days of exploration and settlement. The coyote, jack rabbit, badger, prairie dog, prairie chicken and many kinds of grasshoppers, robber flies and other 'insects are representative of a rich variety of animal life.

Prairie climate is marked by low, irregular rainfall, high summer temperatures, strong winds, high rates of evapotranspiration and intense late summer drought, and is increasingly rigorous from east to west. Along this gradient of decreasing water supply tall grass prairie, of sod-forming grasses 8–10 ft. high, occupied the more humid eastern area to about the 100th meridian, where it graded into the mixed prairie of bunch and sod grasses reaching heights of about 4 ft. Westward, on the high plains leading to the Rocky mountains, sod grasses only a few inches high characterized the short grass plains.

Deep, fertile, organic soils and climate favourable to grain farming led to early destruction of most prairies; only vestiges remain in the highly productive corn and wheat belts. (M. E. B.)

PRAIRIE CHICKEN or PRAIRIE HEN (*Tympanuchus cupido*), a North American grouse (*q.v.*) inhabiting the prairies of the Mississippi valley north to Manitoba and south to Louisiana and Texas. The male has a neck tuft of ten or more rounded feathers, reduced in the female. The lesser prairie hen (T. *pallidicinctus*). smaller, with more buff above, is confined to southwest Kansas and western Texas. The Attwater prairie hen (T. a. *attwateri*) inhabits the coast districts of Louisiana and Texas.

PRAIRIE DOG (*Cynomys*), a heavy-bodied, short-tailed ground squirrel of the western United States and northern Mexico, named for its barking voice. The black-tailed species (C. *ludovicianus*) of the Great Plains lives in large colonies or towns. Formerly these areas covered many miles and contained many thousands of these rodents. but they have been nearly exterminated.

The burrows have raised funnel-shaped entrances, serving to keep out water. Three white-tailed species are found in mountain meadows and high plateaus in the Rockies. All species are buff-coloured, from 10 to 12 in. long, plus tail 2 to 3 in. Rattlesnakes, burrowing owls and the large black-footed ferret are also found in the burrows. but this does not indicate a happy family arrangement, since these animals prey on young "dogs." *See* RODENTIA. (J. E. HL.)

PRAIRIE DU CHIEN, the seat of Crawford county in southwestern Wisconsin, U.S.. owes its existence to the military and economic importance of its site, a point on the Mississippi river about 3 mi. above the mouth of the Wisconsin river. The French and British each maintained a trading post and fort there before the territory became part of the United States in 1783. Ft. Cran-ford. erected in 1816. was for the next four years a link in the chain of military outposts guarding the Indian frontier. After 1820. when the American Fur company erected a depot there. the settlement continued to be the area's trading centre. The development of varied industries ensured its permanence and in 1572 it received its city charter. Campion academy, located in the city. is a widely known residential high school for boys. Villa Louis. home of Hercules Dousman. a factor of the American Fur company, is maintained by the state historical society as a museum. For comparative population figures see table in WISCONSIN: *Population.* (R. F. F.)

PRAKRIT LANGUAGES, in its widest sense, denotes those languages of India which chronologically are Middle Indo-Aryan as distinguished on the one hand from Old Indo-Aryan, *i.e.,* Vedic and Sanskrit; and on the other hand from Modern Indo-Aryan; *i.e.* the present-day languages of north India and Pakistan (see INDO-.%RYAN LANGUAGES). It is thus used by modern scholars both in the west and in India. In this sense it includes the literary Prakrits and Apabhraṁśas used by Hindu. Jain, and Buddhist writers, the languages of many inscriptions and other nonliterary documents ranging from the 3rd century B.C. to the 4th century A.D., the Pali language of Southern Buddhism, and Buddhist Hybrid Sanskrit, in which the Northern Buddhist scriptures were written. The word Prakrit has been used in more restricted senses, especially by the scholars of medieval India. Some have included only the four most important literary Prakrits; others have extended the list greatly, some even to include the Dravidian literary languages, which are not Indo-Aryan at all but have borrowed many Indo-Aryan words. In general these Indian scholars have included only the literary Prakrits used by Hindu and Jain writers: excluding the Buddhist languages and the inscriptional Prakrits. They have listed and characterized briefly many varieties which are claimed to be vernaculars, but of which nothing is otherwise known. There was a tendency to exclude the Apabhramia dialects.

Several etymologies have been given of the Sanskrit word *prākṛta* which denotes these languages. One is that it is derived from *prakṛti* "nature" and means "the natural language" as opposed to Sanskrit (*saṁskṛta*), "the refined (or literary) language." Another involves *prakṛti* in its meaning "basis"; *prākṛta* is then "derived from the basis (Sanskrit)." In either case it is implied that Sanskrit is the norm and the Prakrits are departures from the norm and in a way inferior.

Two slightly differing dialects of Old Indo-Aryan became literary languages in the last two millennia B.C. One is that of the Vedas. The other is classical Sanskrit as formulated by a succession of grammarians ending with Pāṇini (probably 5th century B.C.). From a very early period. other dialects were already developing, differing from these two in the direction of Middle Indo-Aryan. The literary languages after their standardization remained practically unchanging in usage, but the vernaculars continued to diverge. As time went on, the users of the literary languages composed in the literary forms but spoke normally in dialects which were closer to Middle Indo-Aryan. There are even traces of their vernaculars, *i.e.,* Prakritisms, to be found in their literary compositions.

The Prakrits in their turn began to be written, and many of them received literary cultivation. The early chronology is very uncertain, but, it may be that the earliest 'literature is the religious texts of the Buddhists and Jains. The Buddha (6th–5th centuries B.C.) directed that each of his disciples should teach in his own vernacular dialect. It is thought that in the first few generations after the Buddha numerous Middle Indo-Aryan dialects were used in preaching and teaching. This state of affairs seems to be reflected in the multiplicity of Prakrit dialects found in the religious inscriptions of the Buddhist emperor Aśoka (3rd century B.c.). As certain Buddhist centres gained influence, the dialects of these centres came to be used as literary languages to the exclusion of the others, although it is notable that there was much dialect mixture. These teaching dialects, like Sanskrit itself, became standardized, and gradually the spoken vernaculars diverged from them. Of the Buddhist languages, Pali became the standard language of Southern Hinayrtna Buddhism and the vehicle of a great body of canonical and exegetical literature. Other Buddhist schools, including many of the Mahāyāna schools, which are known as Northern Buddhism, seem to have used another Prakrit for a voluminous literature. As controversy with Hinduism began to flourish, Sanskrit came to be used by Buddhists, especially in polemic philosophical discourses. The use of Sanskrit infected this Prakrit, and resulted in a partial Sanskritization of the prose written in it and even of verse texts. The result is that there survive no pure examples of this hypothetical Prakrit; the texts that survive are all more or less Sanskritized, and the language is generally known now as Buddhist Hybrid Sanskrit (BHS). Both chronology and locality are very uncertain. It may be that BHS originated in a more westerly Prakrit dialect and Pali in a more easterly one, which however is still to be identified as central or west central in the Ganges valley. Crystallization of both dialects was complete in the pre-Christian period. A version of one Buddhist text, the Dharmapada (Pali and Prakrit Dhammapada), was found in a central Asian excavation at the end of the 19th century, written in a Prakrit which was different from that at the base of BHS and which belonged originally to northwest India. In all probability there were in the early centuries of Buddhism literatures in other Prakrits than these three that have survived.

For the Jain religion the situation is somewhat similar. The canonical texts of the Śvētāmbara sect are in two dialects of Ardhamāgadhī. Later texts, especially commentaries on the canon, but also others such as the epic *Paümacariya* of Vimala Sūri (perhaps 4th century A.D.) are in Jain Māhārāṣṭrī. The Digambara sect used Jain Śaurasēnī.

In the literature of the Hindus also, Prakrit in several dialects came to be used probably at the end of the pre-Christian era. Later, Māhārāṣṭrī was especially used in composing lyric poetry, possibly on the basis of a popular oral lyric in the dialect; it began to flourish in the 3rd–4th centuries A.D. The most important independent work of this kind that is preserved is an anthology by Hāla, called the *Sattasaī* (Sanskrit title *Saptaśatī* "the 700 verses"); it was compiled between the 3rd and 7th centuries. Māhārāṣṭrī is the language of the lyric verses in the classical period of the Sanskrit drama beginning (in what survives to the present) with Kālidāsa. In this dialect there were also composed epics of the *kāvya* or belles-lettres type. The most important specimens are the *Rāvaṇavaha* or *Sētubandha* (attributed to Pravarasēna, possibly 6th century A.D. dealing with the subject of the Rāmāyaṇa, and the *Gaüḍavaha* of Vākpati (8th century A.D.), celebrating the conquest of Bengal by Yaśōvarman, king of Kanauj. Others exist, including the *Kumārapālacarita*, or the last eight cantos of the poem *Dvyāśraya-mahākāvya* written by Hēmacandra (12th century A.D.) to serve as a series of illustrations to his Sanskrit and Prakrit grammar, the *Siddha-hēmacandra*. These cantos in Prakrit illustrate the Prakrit section of the grammar.

The Sanskrit drama is an important source for knowledge of Prakrit. From its beginning its dialogue must have been intended as a realistic linguistic picture. In it educated men, like kings and brahmans, spoke and also sang in Sanskrit, the literary language par excellence. All others, with few exceptions, spoke the vernacular; *i.e.,* Prakrit. It must have been the case, however, that people of various classes or castes spoke differing dialects, and that people of different localities appeared in the plays speaking their own local dialects. By the time of the earliest specimens now preserved conventions had begun to harden, and by the time of the classical theatre of Kālidāsa and his successors various types of characters were always provided with dialogue in the dialects which were considered appropriate and which had taken on conventional, unchanging forms. Most women, if not of low caste. speak Śāurasēnī, but sing in Māhārāṣṭrī; some children and various other characters, including the brahman clown, speak Śāurasēnī. Various types of servants! fishermen, lowcaste men and many others speak Māgadhī. Other dialects appear in the drama. Unfortunately, after the grammarians had prescribed the forms of the dramatic Prakrists, the dramatists seem to have composed according to rule rather than from any real knowledge of the dialects as living forms of speech.

A Prakrit called Pāiśācī is known through grammarians' statements. According to literary tradition it was the language in which Guṇāḍhya's *Bṛhatkathā* was composed, before A.D. 500 and possibly in the 1st or 2nd century A.D. This work is known through much later reworkings, especially Sōmadēva's *Kathāsaritsāgara* (11th century A.D.), but unfortunately the Pāiśācī text has not yet come to light.

Of nonliterary materials in Prakrit there are early coin inscriptions and inscriptions on stone (3rd century B.C. to 4th century A.D.). Beside the inscriptions of Aśoka, which are the earliest, the most interesting are probably the materials from Niya in Chinese Turkestan. These are official documents from the Kroraina kingdom and date from the 3rd century A.D. Their Prakrit is close to that of the Dhammapada. The original home of the language was northwest India, probably the region of Peshawar; it seems to have been the administrative and literary language of the Kushan empire and its central Asiatic offshoots.

Some of the other Prakrits may be located geographically with some accuracy. Śāurasēnī was the dialect of Śūrasēna, the country around Mathurā (Muttra). It was the language of the Gangetic Doab, and probably extended westward as far as Lahore and eastward as far as the confluence of the Jumna and the Ganges. Its use extended also to Rajputana and Gujarat. Māgadhī was spoken in the eastern half of the Ganges valley, extending westward prohably as far as Banaras. Māhārāṣṭrī was the language of Mahārāṣṭra, the "great Kingdom" south of the Nerbudda river, where in modern times Marāṭhī is spoken. Not all the dialects may be located with equal exactitude. Pāiśācí, for example, may have been spoken in the northwest, although the Vindhya region south of the Ganges valley seems more probable.

Because of the literary pre-eminence of Māhārāṣṭrī, it is the Prakrit described at greatest length by the Indian grammarians, *e.g.,* by Vararuci (before A.D. 700, perhaps much earlier) and Hēmacandra (12th century A.D.). The other Prakrits used in the dramas, as well as numerous others which never appear in the literature, are described sketchily in terms usually of their deviations from Māhārāṣṭrī.

After various Prakrits had been given standard literary form, the vernaculars continued to diverge from these standards. Again at a later period various dialects received literary form; the earliest reference to a literary use of these seems to be in the 7th century A.D. They are known by the name apabhraṁśa ("departure from correct speech"). One dialect; western apabhramia, belonged to the region of Śāurasēnī Prakrit, and is represented by numerous texts. most of them by Jain authors, such as Dhanavāla's *Bhavisatta-kaha* (probably 10th century A.D.), Haribhadra's *Sanatkumāracaritam* (A.D. 1159), and Somaprabha's ***Kumārapāla**-pratibōdha* (A.D. 1195). There are also texts in a southern apabhraṁśa, corresponding to Māhārāṣṭrī, and a few in an eastern apabhraṁśa, corresponding to Māgadhī.

The apabhraṁśa dialects are the immediate predecessors of the modern Indo-Aryan vernaculars, the older stages of which seem to have been recognized by the Indian grammarians as early as the 12th century A.D. The relations. however, between the various Middle Indic dialects and the modern languages are not yet clearly known in detail.

Characterization of the Languages.—The Middle Indo-Aryan languages are marked by progressive changes from the type of the Old Indo-Aryan languages. (Skt. = Sanskrit; Ś = Śaurasēnī; M. = Māhārāṣṭrī.)

Phonetic change is conspicuous. The complex consonant clusters of Skt. are simplified. most frequently by assimilations or losses, sometimes by insertions of vowels, *e.g., putra* "son" > *putta, ratna* "jewel" > *Ś. radaṇa,* Māgadhī *ladaṇa.* Stop consonants between vowels were liable to many sorts of changes. Voiceless stops (k, *t, p*) remained in Pali, became voiced (*g,* d, v) in some dialects, *e.g.,* Ś and apabhramia. but were lost in M., *e.g.,* Skt. *śata* "100" > Pali sata, Ś. *sada,* M. saa. The cumulative effect of all changes was to produce words which are very far from their Skt. origins, *e.g.,* Vappaïrāā = Skt. *Vākpatirājā* "king Vākpati"; *prākṛta* "Prakrit" > Ś *pāüda,* M. *pāüa.*

Noun morphology tends toward simplification; *e.g.,* by loss of the dual number. The eight-case system of Skt, is reduced by loss and amalgamation of cases. Dative forms are completely lost in some dialects; syntactically the dative merges with the genitive. In feminine stems in *ā,* the instrumental. genitive, and locative singular have identical forms. In the apabhraṁśa stage case declension had gone a long way toward the Modern Indo-Aryan system of practically only two cases, absolute and oblique. The system of three genders remains intact until in apabhraṁśa masculine and neuter came near to a complete merging. The numerous declensional types of Skt. are somewhat reduced in number. Especialiy, the consonant stems tend to add vowels and merge with the vocalic declensions.

Verb conjugation shows even greater departures from the Skt. system. With some exceptions, the Skt. consonantal conjugation has been replaced in Prakrit by the conjugation type in which a vowel appears between the final consonant of the root or stem and the inflectional suffix. In Middle Indo-Aryan the vowel is often -a- as in Skt., hut there has been a great extension of use also of *-ē-*, which derives from *-aya-* of the Skt. causative and denominative conjugations. The causative stem on the other hand often has a suffix *-vē-*, in which *v* represents Skt. *p* which in Skt. appears in only a few verbs. Exceptional remnants of the Sanskrit consonantal conjugation include the highly irregular enclitic verb "to be", *e.g., mhi* "I am" (< *asmi*), si "you are" (< asi), etc.; the 3rd singular form atthi (< *asti*) is not enclitic. The past tenses are completely remade into one fairly well unified system in Pali. but in the Prakrit dialects very little remains of them, except such forms as *āsī* "was, were" (< *āsīt*). The present tense has an imperative and an optative. The future remains, usually formed with a suffix *-issa-* or *-ihi-* (< Skt. *-iṣya-*) added to the present stem. Passive stems either derive from Skt. passive stems: with Skt. *-y-* appearing in M. as *-jj-* (*e.g., dijjaï* "it is given" < Skt. diyate), or add a suffix (Ś *-ïa-*, M. *-ijja-*) to the present stem. Infinitives, gerunds, gerundives and present participles all survive from Skt., with many phonetic and other changes. Most important is the past participle, which is passive in transitive verbs and active in intransitive verbs. Syntactically, it occurs most frequently with an instrumental case of a noun, to replace the old past tense and its subject; this is the precursor of the peculiar past tense of Modern Indo-Aryan. Very frequently the past participle shows a suffix Ś. *-ida-*, M. *-ia-* (< Skt. *-ita-*) added to the present stem. This part of the verb system shows more irregularities of form than any other, because of inheritance of old forms from Skt., *e.g.,* Ś. gada-, M. *gaa-* "gone" (< Skt. gata-) beside present stem gacch-; Ś. kida-, M. kaa- "made" (< Skt. *kṛta-*) beside present stem kar-; Ś. *ṇāda-*, M. *ṇāa-* "known" (< Skt. *jñāta-*) beside present stem *jāṇ-*.

The vocabulary of Prakrit is in general derived from Old Indo-Aryan, but there are also many words not so derivable. called *dēśī* or "provincial" words. Lists of these were produced by the Indian grammarians.

See also SANSKRIT LANGUAGE AND LITERATURE ; PALI LANGUAGE; AND JAINS.

BIBLIOGRAPHY.—General grammars: R. Pischel, *Grammatik der Prākritsprachen* (1900); Madhukar Anant Mehendale, *Historical Grammar of Inscriptional Prakrits* (1948); Gajanan Vasudev Tagare, *Histovical Grammar of Apabhraṁśa* (1948). Introduction to the study of the Prakrits: H. Jacobi, *Ausgewählte Erzählungen in Mâhârâshṭrî* (1886); Alfred C. Woolner, *Introduction to Prakrit* (1928). Editions of some of the Indian grammars: E. B. Cowell's of Vararuci's *Prākṛta-prakāśa* (1868), R. Pischel's of Hēmacandra (1877–80). For *dēśī* words: Muralydhar Banerjee, *The Deśīnāmamālā of Hemacandra* (19.11). For Buddhist Hybrid Sanskrit: Franklin Edgerton. *Buddhist Hybrid Sanskrit Grammar arid Dictionary* and *Buddhist Hybrid Sanskrit Reader* (1953). For the Prakrit Dhammapada: H. W. Bailey, "The Khotan Dharmapada." *Bulletin of the School of Oriental and Ajricatz Studies,* vol. 11, pp. 488–512 (1915); the bibliography is important. For the North-western Prakrit of Central Asia: T. Burrow, *The Language of the Kharoṣṭhi Documents from Chinese Turkestan* (1937); *A Translation of the Karoṣṭhi Documents from Chinese Turkestan* (1940). For apabhraṁśa tests published in the West: H. Jacobi's editions of Dhanavāla's *Bhavisatta-kaha* (1918) and Haribhadra's *Sanatkumāra-caritam* (1921), and Ludwig Alsdorf's edition of Somaprabhn's *Kumārapālapratibōdha* (1928). For nonreligious Prakrit tests: A. Weber, *Das Saptaçatakam des Hāla* (1881); S. Goldschmidt. *Rāvaṇavaha oder Setubandha* (1880–8.3); S. P. Pandit, *The Gaüḍavaho* by *Vâkpati* (1887) and *The Kumârapdlacharita* (1900). (*M. B.* E.)

PRANDTL, LUDWIG (1875–1953), German physicist famous for his work in aeronautics, was born at Freising. Bavaria, on Feb. 4. 1875. He qualified at Munich in 1900 with a thesis on elastic stability, and was professor of applied mechanics at Göttingen from 1904 until his death there on Aug. 15, 1953. In 1925 he became director of the Kaiser Wilhelm institute for fluid mechanics. His discovery (1901) of the "boundary layer" which adjoins the surface of a body moving in air or water led to an understanding of skin friction drag and of the way in which streamlining reduces the drag of airplane wings and other moving bodies. His work on wing theory, published in 1918–19, which followed that of F. W. Lanchester (1902–07) but was carried out independently, elucidated the flow over airplane wings of finite span. This body of work is known as the Lanchester-Prandtl wing theory (*see* AERODYNAMICS).

Prandtl made decisive advances in boundary layer and wing theories, and his work became the basic material of aerodynamics. He also made important contributions to the theories of supersonic flow and of turbulence, besides contributing much to the development of wind tunnels and other aerodynamic equipment. In addition he devised the soap-film analogy for the torsion of noncircular sections and wrote on the theory of plasticity and on meteorology. (H. B. S.)

PRASEODYMIUM (symbol Pr, atomic number 59, atomic weight 140.92, stable isotope Pr^{141} [100%]) is a metallic element of the rare-earth group. It was discovered by Carl Auer von Welsbach in 1885 when he separated salts of the so-called element didymium into two fractions (praseodymium and neodymium); the name is derived from *praeseodidymium,* meaning "green didymium," reflecting the green colour of its salts. The metal occurs along with the other rare earths in the minerals monazite, cerite and allanite; it is also found among the fission products of uranium, thorium and plutonium. In the past it was usually separated by fractional crystallization employing first a double magnesium nitrate and finally the double ammonium nitrate. Many other procedures have been used but all of them involved long-continued fractional crystallization or fractional precipitation or decomposition. Since 1945 it has been rapidly separated by means of adsorption columns (see RARE EARTHS). The oxide is an almost black powder the composition of which varies according to the method of preparation. It is usually considered to be Pr_6O_{11}; it can be reduced in hydrogen to give Pr_2O_3. The higher valency state of the praseodymium is in question, some authorities claiming it to be tetravalent and others pentavalent. The evidence is slightly in favour of the pentavalent state; thus. Pr_6O_{11} would be a double oxide, $2Pr_2O_3.Pr_2O_5$. The black oxide dissolves in acids. with the liberation of oxygen. to give green solutions or green salts such as $Pr_2(SO_4)_3.8H_2O$. Only the trivalent forms are known in solution; they show a strong characteristic absorption spectrum and are paramagnetic.

The metal is prepared by the electrolysis of the fused halides or by thermoreduction oi its salts with the alkali metals or alkaline-earth metals. Two allotropic forms are known. The α form (somewhat distorted hexagonal close packed, $a = 3.662$ Å, $c = 5.908$ Å) has a calculated density = 6.776 g. per cubic centimeter. The β iorm (cubic close packed, $a = 5.151$ Å) has a calculated density = 6.803 g. per cubic centimeter. The metal melts between 940° C. and 960° C. Alloys of the metal, particularly misch metal (*see* CERIUM), have found various uses. Its salts have found application in the ceramics industry for colouring glass and glazes. *See* RARE EARTHS. (F. H. SG.)

PRATAPGARH (formerly PARTABGARH), a town and district in the Fyzabad division of Uttar Pradesh, India. The town, headquarters of the district. lies about 25 mi. N. of Allahahad, on the Varanasi-Lucknow railway.

PRATAPGARH DISTRICT (area, 1,460 sq.mi.; pop. [1961] 1,251,-402) lies in the southeast of Uttar Pradesh with the Ganges forming its southwestern boundary. The general aspect of the district is that of a richly wooded and fertile plain, relieved by gentle undulations and broken into ravines near the rivers and streams. Smallish barren tracts impregnated with saline efflorescence (reh) occur in places. The only mineral products are salt. saltpetre and *kankar* (nodular limestone). Main crops are rice. barley, pulse, millets and sugar cane; hemp and hides are also produced.

PRATAPGARH is also the name of a town in Chittorgarh district of Rajasthan, India, and of a former princely state. The walled town lies 75 mi. S.E. of Udaipur. Pop. (1951) 14.586. It was founded in 1698 by Maharamat Pratap Singh and became the capital of the princely state, which was once tributary to Indore (Holkar). It came under British protection in 1818 and was merged with Rajasthan in 1945. The people are mostly Bhils and other aborigines (*see* BHIL). Pratapgarh was once well known for its engraved gold enameled work inlaid on emerald-coloured glass. (S. M. T. R.j

PRATINAS (fl. c. 490 B.C.), Greek poet of the Dorian city of Phlius, who brought his satyr plays to Athens and was reckoned as the inventor of this kind of drama. He composed tragedies also, but of the 50 plays claimed for him by the Suda lexicon 32 were satyric, which may indicate that he began to produce before the competition was organized in tetralogies. including one satyr play. His son Aristias competed in 467 with a set of Pratinas' plays, so that he probably died shortly before that date. Unfortunately nothing of his plays survives. Athenaeus quotes a hyporcheme of his (a type of lyric sung by a chorus to the accompaniment of vigorous dancing), which gives a fine impression of his lyric powers: the chorus energetically overwhelm their overpretentious flute player and teach him his place, as their accompanist. This is often stated, against Athenaeus' explicit evidence, to be a fragment of a satyr play. (A. M. DE.)

PRATINCOLE, a shore bird belonging to the genus *Glareola* of the old world family Glareolidae, the best-known being the common pratincole, *Glareola pratincola.* The pratincoles, of which more than 20 species have been described, are small birds, slenderly built and delicately coloured, with a short stout bill, a wide gape, long pointed wings and a deeply forked tail. In some of their habits they are thoroughly ploverlike, running swiftly and breeding on the ground. but on the wing they have much the appearance of swallows and. like them. feed, at least partly, while flying G. *pratincola* breeds in many parts of Spain, north Africa and Sicily, along the valley of the Danube and in southern U.S.S.R.

The black-winged pratincole, G. *nordmanni*, which has black instead of chestnut inner wing coverts, accompanies or, farther east. replaces it; other species occur in Asia, Africa and Australia. *See* also PLOVER.

PRATO IN TOSCANA, a town and episcopal see of Toscana, Italy, in Firenze province, 11 mi. by rail N.W. of Florence, 207 ft. above sea level. Pop. (1957 est.) 93,046 (commune). It is situated on the Bisenzio, and was dominated by a castle built by Frederick II (*c.* 1250). The cathedral was begun in the 12th century; to this period belongs the narrow nave with its wide arches; the raised transepts and the chapels were added by Giovanni Pisano in 1317–20; the campanile dates from 1340, while the façade, also of alternate white sandstone and green serpentine, belongs to 1413. It has a fine doorway with a bas-relief by Andrea della Robbia over it and an open-air pulpit, erected in 1439 by Donatello and Michelozzo for displaying the Virgin's girdle, brought from the Holy Land by a knight of Prato in 1130. The pulpit itself has reliefs of dancing children; beneath it is a splendid bronze capital. The Chapel of the Girdle has a statue of the Virgin by Giovanni Pisano, and a handsome bronze openwork screen. The frescoes in the choir, with scenes from the life of St. John the Baptist and St. Stephen, are by Fra Filippo Lippi (1456–66) and are his best work. The massive old Palazzo Pretorio (13th century) contains a small but good picture gallery. A beautiful Madonna by Filippino Lippi (1498) is in a small street shrine at the corner of the Via Santa Margherita. The Madonna del Buon Consiglio has some good reliefs by Andrea della Robbia, by whom is also the beautiful frieze in the Madonna delle Carceri. This church, by Giuliano da Sangallo (1485–91), is a Greek cross, with barrel vaults over the arms and a dome; it is a fine work, and the decoration of the exterior in marble of different colours (unfinished) is of a noble simplicity.

PRATT, CHARLES (1830–1891), U.S. businessman. one of the creators of the Standard Oil combination, and. as such, ranking high among the men who gave form and substance to U.S. business in the 20th century, was-born at Watertown, Mass., on Oct. 2, 1830. After early training in a mercantile establishment, he became a partner in Raynolds, Devoe & Pratt. manufacturers of paints and oils, then in 1864 formed his own firm, Charles Pratt Manufacturing company, to refine and market petroleum products. He produced "Pratt's Astral Oil," a high-quality kerosene, which he sold widely at home and abroad. In 1874 Pratt decided to join the Standard Oil group of firms, and he immediately became a leading figure in the growth of that business institution. As a member of the executive committee that managed that giant business enterprise, Pratt was a spokesman for conservative policies contributing to the growth of the first great industrial business in the United States. The Pratt Institute Free library in Brooklyn. N.Y., is one of several living indications of his philanthropic interests.

Pratt died on May 4, 1891.

See Ralph W. Hidy and Muriel E. Hidy, *Pioneering in Big Business, 1882–1911* (1955), and references cited. (R. W. HY.)

PRATT, EDWIN JOHN (1883–), the leading Canadian poet of our time; was born at Western Bay, Nfd., on Feb. 4, 1883, the son of a Methodist clergyman. After a preparatory education in Newfoundland and some experience in teaching, he came to Victoria college in the University of Toronto, where he was graduated in 1911. He then studied theology and published *Studies in Pauline Eschatology* (1917). but his academic interests turned to psychology and finally to English literature, which he taught at Victoria college from 1919 until his retirement as professor emeritus in 1953.

His first collection of poems, *Newfoundland Verse* (1923), draws on his early impressions, especially of the hardships and courage of the fishermen in their constant. battle with the sea. Even when lyrical, the poems show an interest in and a distinctive command of the techniques of narrative. to which Pratt turned in *The Witches' Brew* (1925) and *The Titans* (1926), the second of which is made up of two long poems, "The Cachalot," and "The Great Feud." "The Cachalot," an account of a whale hunt, is one of his most brilliant and widely read poems. All three are in octosyllabic couplets, and show a lively humour and the free play of an exuberant imagination that marked Pratt out as a strikingly original poet in a quite new genre. Pratt's fascination with themes of shipwreck broadened and deepened in *The Roosevelt and the Antinoe* (1930) and *The Titanic* (1935), where a more sombre sense of the indifference of nature to human values prevails.

With *Brébeuf and His Brethren* (1940), a blank-verse chronicle of the martyrdom of Jesuit missionaries by the Iroquois, Pratt was established as Canada's most influential poetic personality. (For the importance of his influence *see* CANADIAN LITERATURE [ENGLISH]). Three volumes after *Newfoundland Verse* contain the bulk of his shorter poems: *Many Moods* (1932), *The Fable of the Goats and Other Poems* (1937), *Still Life and Other Verse* (1943). Many of these poems are still concerned with the sea and seafaring life, but there is a growing awareness of the poet's social responsibilities, reflected in the title poem of *Still Life*, in some bitter anti-Nazi satire, and in some philosophical verse, notably *The Iron Door* (1927) and the remarkable dialogue "The Truant" in *Still Life*.

After the outbreak of World War II, Pratt turned mainly to topical themes, especially in *Dunkirk* (1941). His *Collected Poems*, with a preface by William Rose Benet. appeared in 1944 (U.S. edition, 1945; 2nd ed., 1958). *Behilzd the Log* (1947) commemorates the heroism of the Canadian convoy fleet in running supplies to Murmansk through the war, and *Towards the Last Spike* (1952) tells of the building of the Canadian Pacific railway (1870–85). Many features of Pratt's work have made him not simply a respected but a genuinely popular poet in Canada: his preoccupation with the Canadian scene, both historical and geographical; his power of storytelling; his unforced use of the imagery of machinery and technology.

Pratt was awarded the highest civilian honour in Canada, the companion of the Order of St. Michael and St. George, in 1946. and has received many honorary degrees from Canadian universities.

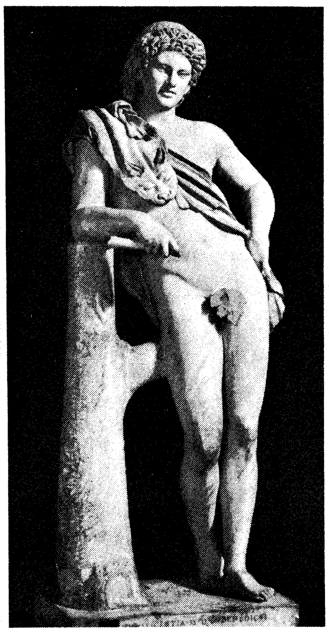
BIBLIOGRAPHY.—W. E Collin, *The White Savannahs* (1936) ; *E. K.* Brown, *On Canadian Poetry (1943); C. F.* Klinck and H. W. Wells, *Edwin J Pratt, the Man and His Poetry* (1947) ; John Sutherland, *The Poetry* of *E. J. Pratt* (1956) ; *W.* C. D. Pacey, *Ten Canadian Poets* (1958) (No. F.)

PRAXITELES, of Athens, greatest of the Attic sculptors of the 4th century B.C., was active from perhaps *c.* 370 B.C. to 330 B C. Ancient writers sing his praises. and they are borne out by what would seem to be the only major original work that has survived, *i.e.*, the marble statue of Hermes carrying the infant Dionysus. It was found at Olympia in the temple of Hera, in the very place where it was seen and described by Pausanias (v, 17, 3). The delicate modeling and exquisite finish of the surface enable one to add these qualities in one's imagination to the other works by him that exist only in Roman copies. His most celebrated work was the Aphrodite which he made for Cnidus, considered by Pliny not only the finest statue by Praxiteles but in the whole world. Numerous copies have been recognized — statues, heads and statuettes (in the Vatican and in the Terme museum in Rome; in the Louvre, Paris, at Toulouse; etc.).

Many other statues, both of marble and bronze, are mentioned by ancient writers as works by Praxiteles, but comparatively few have been identified in Roman copies. Chief among them are: the Apollo Sauroctonus, in which the god is shown as a boy leaning against a tree trunk, about to kill a lizard with an arrow; the Artemis Brauronia perhaps reproduced in the charming Artemis of Gabii in the Louvre; and several Erotes and Satyrs.

Two sculptures that can be connected with Praxiteles stand apart. One is a base decorated with Marsyas and the Muses described by Pausanias as in a temple at Mantineia and supporting the statues of Leto, Apollo and Artemis by Praxiteles. Three slabs of this base have actually come to light, and, though probably not executed by Praxiteles himself, for the execution is cursory, they presumably reproduce his design. The other nork is the bust of a youth, found at Eleusis. It seems to be an original Greek work of the 4th century and has by some been thought to be the Eubuleus known to have been made by Praxiteles. It approximates, though it does not equal, the workmanship of the Hermes.

According to Pliny, when Praxiteles was asked which of his statues he valued most highly, he replied "those to which Nicias (a famous painter) has put his hand; so much did he prize the application of colour (circumlitio) of that artist." To visualize the sculptures of Praxiteles it is well to remember how much this colour must have added to the general effect.



ALINARI

"THE CAPITOLINE FAUN," COPIED FROM AN ORIGINAL SCULPTURE ATTRIBUTED TO PRAXITELES. IN THE MUSEI CAPITOLINI ROME

Praxiteles was one of the most original of Greek sculptors. He transformed the 5th-century style of detachment and majesty into one of gentle grace and sensuous charm. His favourite material was marble. of which he was perhaps the greatest exponent. Diodorus says of him that "with consummate art he informed his marble figures with the passions of the soul." It is indeed this subtle, personal element. combined with an exquisite finish of surface, that imparts to his figures their singular appeal.

The influence of Praxiteles was widespread. Figures standing in graceful, sinuous poses and lightly leaning on some support became favourite representations and were later further developed by the sculptors of the Hellenistic age. *See* also GREEK ART.

BIBLIOGRAPHY.—J. Overbeck, *Die antiken Schriftquellen,* no. 1190–1300 (1868), for the ancient sources; G. E. Rizzo, *Prassitele* (1932); G M. A Richter, *The Sculpture and Sculptors of the Greeks,* rev, ed, pp. 259–267 (1950); G. Lippold, *Die griechische Plastik,* pp. 234–243 (1950); C. Picard, *Manuel d'Archéologie grecque, iv,* 2, pp. 236–410 (1954) (G. M. A. R.)

PRAYER, a term used generally for any humble petition, but more technically, in religion, for that mode of addressing a divine or sacred power in which there predominates the mood and intention of reverent entreaty (from Lat. *precari,* entreat; Ital. *pregaria;* Fr. *prière*).

Prayer and its Congeners.—Prayer in the latter sense is a characteristic feature of the higher religions, and we might even say that Christianity or Mohammedanism, ritually viewed. is in its inmost essence a service of prayer, At all stages of religious development, however, and more especially in the case of the more primitive types of cult, prayer as thus understood occurs together with, and shades off into, other varieties of observance that bear obvious marks of belonging to the same family.

Confining ourselves for the moment to forms of explicit address, we may group these under three categories according as the power addressed is conceived by the applicant to be on a higher, or on much the same, or on a lower plane of dignity and authority as compared with himself. (1) Only if the deity be regarded as altogether superior is there room for prayer proper, that is, reverent entreaty. Of this we may perhaps roughly distinguish a higher and a lower type, according as there is either complete confidence in the divine benevolence and justice, or a disposition to suppose a certain arbitrariness or, at any rate, conditionality to attach to the granting of requests. In the first case prayer will be accompanied with disinterested homage, praise, and thanksgiving, and tends to lose its distinctive character of entreaty or petition, passing into a mystic communing or converse with God. In the second case it will be supported by pleading, involving on the one hand self-abasement, with confession of sins and promises of repentance and reform, or on the other hand self-justification, in the shape of the expression of faith and recitation of past services, together with reminders of previous favour shown. (2) If the worshipper place his god on a level with himself, so as to make him to some extent dependent on the service man contracts to render him, then genuine prayer tends to be replaced by a mere bargaining, often conjoined with flattery and with insincere promises. This spirit of *do ut des* will be found to go closely with the gift-theory of sacrifice (*q.v.*) and to be especially characteristic of those religions of middle grade that are given over to sacrificial worship as conducted in temples and by means of organized priesthoods. So when the high gods are kind for a consideration, the lower deities will likewise be found addicted to such commerce; thus in India the hedge-priest and his familiar will bandy conditions in spirited dialogue audible to the multitude (cf. W Crooke, *Things Indian, s.v.* "Demonology," pp 132, 134) (3) Lastly, the degree of dependency on human goodwill attributed to the power addressed may be so great that. instead of diplomatic politeness, there is positive hectoring, with dictation, threats, and abuse Even the Italian peasant is said occasionally to offer both abuse and physical violence to the image of a recalcitrant saint; and antiquity wondered at the bullying manner of the Egyptians towards their gods (cf. Iamblichus, *De mysteriis,* vi. 5–7). Westermarck supplies many instances from Morocco of *'âr* the "conditional curse," applied to saints in order to make them attend, on pain of disaster if they are recalcitrant (*History and Development of the Moral Ideas,* passim). This frame of mind, however, is mainly symptomatic of the lower levels of cult. Thus the Zulu says to the ancestral ghost, "Help me or you will feed on nettles"; whilst the still more primitive Australian exclaims to the "dead hand" that he carries about with him as a kind of divining-rod, "Guide me aright, or I throw you to the dogs."

So far the forms of address are explicitly directed towards a power that, one might naturally conclude, has personality, since it is apparently expected to hear and answer. At the primitive stage, however, the degree of personificaticn is, probably, often far slighter than the words used would seem to suggest. The verbal employment of vocatives and of the second person may have little or no personifying force. serving primarily but to make the speaker's wish and idea intelligible to himself. When the rustic talks in the vernacular to his horse he is not much concerned to know whether he is heard and understood; still less when he mutters threats against an absent rival, or kicks the stool that has tripped him up with a vicious "Take that!"

These considerations may help towards the understanding of a second class of cases, namely, forms of implicit address shading off into unaddressed formulas. Wishings, blessings, cursings, oaths, vows, exorcisms, and so on, are uttered aloud, partly that they may be heard by the human parties to the rite, but in many cases that they may be heard, or at least overheard, by a consentient deity, perhaps represented visibly by an idol or other cult-object.

From Suggestion to Prayer.—To address and entreat a fellow-being is a faculty as old as that of speech, and, as soon as it occurred to man to treat sacred powers as fellow-beings, assuredly there was a beginning of prayer. We are not likely to know how religion first arose, and the probability is that many springs went to feed that immense river. Thus care for the dead may well have been one amongst such separate sources. It is natural for sorrow to cry to the newly dead "Come back!" and for bereavement to add "Come back and help!" Another source is mythologic fancy, which, in answer to child-like questions: "Who made the world?" "Who made our laws?" and so on, creates "magnified non-natural men," who presently made their appearance in ritual (for to think a thing the savage must dance it); whereupon personal intercourse becomes possible between such a being and the tribesmen, the more so because the supporters of law and order, the elders, associate themselves as closely as possible with the supreme law-giver. From Australia comes a certain amount of evidence showing that, in the two ways just mentioned. some inchoate prayer is being evolved. On the whole, the absence of prayer from the magico-religious ritual of the Australians is conspicuous. Uttered formulas abound; yet they are not forms of address, but rather seli-sufficient pronouncements charged with *mana* (*q.v.*). They involve a wonder-working recognized as such, the core of the mystery consisting in the supposed transformation of suggested idea into accomplished iact by means of that suggestion itself. To the man endowed in the opinion of his iellows (and doubtless of himself) with this wonderful power of effective suggestion, the output of such power naturally represents itseli as a kind of unconditional willing. When he cries "Rain, rain," or otherwise makes vivid to himself and his hearers the idea of rain, expecting that the rain will thereby be forced to come, it is as if he had said "Rain: now you must come," or simply "Rain, come!" and me find that suggestional formulas mostly assume the tone of an actual or virtual imperative, "As I do this, so let the like happen," "I do this in order that the like may happen," and so on. Now it is easy to "call spirits irom the vasty deep," but they do not always come. Hence such imperatives have a tendency to dwindle into optatives. "Let the demon of small-pox depart!" is replaced by the more humble "Grandfather Smallpox, go away!" where the affectionate appellative (employed, however, in all likelihood merely to cajole) signalizes an approach to the genuine spirit of prayer. Again, the user of suggestion conscious of his limitations will seek to supplement his *mana* by tapping, so to speak, whatever sources of similar power lie round about him. A notable method of borrowing power from another agency involving *mana* is simply to breathe its name in connection with the spell that stands in need of reinforcement; as the name suggests its owner, so it comes to stand ior his real presence. Even the more highly developed forms of liturgical prayer tend, in the recitation of divine titles, attributes and the like to present a survival of this formalist use of potent names.

Prayer as a Part of **Ritual.**—By an exactly converse process prayer actually generates formalism, instead of growing out of it. In advanced religion, indeed. prayer is the chosen vehicle oi the free spirit of worship. Its mechanism is not unduly rigid, and it is largely autonomous, being rid of subservience to other ritual factors. In more primitive ritual, however, set forms of prayer are the rule, and their function is mainly to accompany and support a ceremony the nerve of which consists in action rather than speech. Hence, suppose genuine prayer to have come into being, it is apt to degenerate into a mere piece of formalism; and yet, whereas its intrinsic meaning is dulled by repetition according to a well-known psychological law, its virtue is thereby hardly lessened for the undeveloped religious consciousness, mhich holds the saving grace to lie mainly in the repetition itseli. But a formula that depends ior its efficacy on being uttered rather than on being heard is virtually indistinguishable irom the purely suggestional type of utterance, though its origin is different. A good example oi a degenerated prayer-ritual comes from the Todas (*see* W. H. R. Rivers, *The Todas,* ch. x.). The prayer itseli tends to be slurred over, or even omitted. On the other hand, great stress is laid on a preliminary citation of names of power followed by the word *idith*. This at one time seems to have meant "for the sake of," carrying with it some idea oi supplication; but it has now lost this connotation, seeing that it can he used not merely after the name oi a god, but after that of any sacred object or incident held capable of imparting efficacy to the formula. Even the higher religions have to fight against the tendency to "vain repetitions" (often embodying a certain sacred number, *e.g.* three), as well as to the use of prayers as amulets, medicinal charms, and so on. Throughout we must carefully distinguish in theory, though hard in practice, between legitimate ritual understood as such, whether integral to prayer, such as its verbal iorms, or accessory, such as gestures, postures, incense, oil or what not, and the formalism of religious decay, such as generally betrays itseli by its meaninglessness, by its gibberish phrases, sing-song intonation and so iorth.

Silent Prayer. — .% small point in the history of prayer, bearing on the subject of its relation to magic, is concerned with the custom oi praying silently. Charms and words of power being supposed to possess efficacy in themselves are guarded with great secrecy by their owners, and hence, in so far as prayer verges on spell, there will be a disposition to mutter or otherwise conceal the sacred iormula. Thus the prayers of the Todas already alluded to are in all cases uttered "in the throat," although these are public prayers, each village having a iorm oi its own. At a later stage, when the distinction between magic and religion is more clearly recognized and an anti-social character definitely assigned to the former, on the ground that it subserves the sinister interests of individuals, the overt and, as it were, congregational nature of the praying comes to be insisted on as a guarantee that no magic is being employed, a notion that suffers easy translation into the view that there are more or less disreputable gods with whom private trafficking may be done on the sly. Thus, in accordance with the outlook of the classical period, Plato in his *Laws* (909–910) prohibits all possession of private shrines or periormance oi private rites; "Let a man go to a temple to pray, and let anyone who pleases join with him in the prayer." Nevertheless, instances are not wanting amongst the Greeks of private prayers of the loftiest and the most disinterested tone (*cf.* L. R. Farnell, *The Evolution of Religion,* p. 202 *et seq.*). Finally, in advanced religion, at the point at which prayer is coming to be conceived as communion, silent adoration is sometimes thought to bring man nearest to God.

The Moralization of Prayer. — As to the moral quality of the act of prayer, this contrast between the spirit of public and private religion is iundamental for all but the most advanced iorms of cult. In its public rites the community becomes conscious oi common ends and a common edification. Even a very primitive people such as the Arunta of Australia behaves with the greatest solemnity at its ceremonies, and professes to be made "glad" and "strong" thereby. Of his countrymen, whom he would not trust to pray in private, Plato testifies that in the temples during the sacrificial prayers "they show an intense earnestness and with eager interest talk to the gods and beseech them" (*Laws,* 887). In acts of public worship at any rate, therefore, prayer and its magico-religious congeners are at all stages resorted to as a "means of grace," even though such grace does not constitute the expressed object of petition. Poverty of expression is apt-to cloak the real spirit of primitive prayer, and the formula under which its aspirations may be summed up, namely, "Blessings come, evils go," covers all sorts of confused notions about a grace to be acquired and an impurity to be wiped away, which, as far back as our clues take us, invite interpretations of a decidedly spiritualistic and ethical order. To explicate, however, and purge the meaning of that "strong heart" and "clean" which the savage after his fashion can wish and ask for, remained the task of the higher and more sell-conscious types of religion. A favourite contrast for mhich there is more to be said is that drawn between the magico-religious spell-ritual, that says in effect, "My will be done," and the spirit oi "Thy will be done" that breathes through the highest forms of worship. Such resignation in the face of the divine will and providence is, however, not altogether beyond the horizon of primitive faith, as witness the following prayer of the Khonds of Orissa: "We are ignorant of what it is good to ask for. You know what is good ior us. Give it to us." (E. B. Tylor, *Primitive Culture,* 4, 369 [1903]). At this point prayer by a supreme paradox virtually extinguishes itseli, since in becoming an end in itself, a means of contemplative devotion and of mystic communing with God, it ceases to have logical need ior the petitionary form. Thus on the face of it there is something like a return to the self-sufficient utterance of antique religion; but, in reality, there is all the difference in the world between a suggestion directed outwardly in the fruitless attempt to conjure nature without first obeying her, and one directed towards the inner man so as to establish the peace of God within the heart.

BIBLIOGRAPHY.—For prayer irom the comparative standpoint: E. B. Tylor, *Primitive Culture,* ch. xviii. (1903) ; C. Tiele, *Elements of the Science of Religion* (Gifford lectures, lect. 6) (1897) ; F. Max Müller, "On Ancient Prayers," in *Semitic Studies in Memory of* **Rev.** *Dr. Alexander Kohut* (1897) ; L. R. Farnell, *The Evolution of Religion,* lect. 4 (1905). For prayer in relation to magic: R. R. Marett, "From Spell to Prayer," in *Folk-Lore* (June 1904) ; W. W. Skeat, *Malay Magic* (1900). Degeneration of prayer: W. H. R. Rivers, *The Todas,* ch. x. (1906). Use of the name of power; F. Giesebrecht, *Die alttestamentliche Schätzung des Gottestzanaens* (1901) ; W. Heitmuller. *Im Namen Jesu* (1903). Silent prayer: S. Sudhaus, "Lautes und leises Beten" in *Archiv für Religionswissenschaft,* 185 *seq.* (1906). Beginnings of prayer in Australia: A. W. Howitt, *The Native Tribes of South-East Australia,* 394, *cf. 546* (1901) ; K. Langloh Parker, *The Euahlayi Tribe,* 79 *seq.* (1905) ; the evidence discussed in *Man.* 2, 42, 72 (1907). Prayer and spell in North American religion: W. Matthews, "The Prayer of a Navajo Shaman," in *American Anthropologist,* i.; *idem,* "The Mountain Chant; a Navajo Ceremony," in *Fifth Report of Bureau of American Ethnology.* Greek prayer: C. Ausfeld, *De graecorum pvecationibus quaestiones* (1903). Christian prayer: E. von der Goltz, *Das Gebet in der ältesten Christenheit* (1901) ; *id., Tischgebete und Abendmahlsgebete* (1905) ; O. Dibelius, *Das Vaterunser: Umrisse zu einer Geschichte des Gebets in der alten und mittleren Kirche* (1903) ; T. K. Cheyne, "Prayer," in *Ency. Bib.* (1902); W. G. Procter, *The Principles and Practice of Prayer* (1927) ; W. H. Frere, *The Principles of Religious Ceremonial* (1928). (*See* also MANA; *RITUAL.*)

(R. R. M.)

PRAYING WHEEL, used by the Buddhists of Tibet as a means of offering invocations. The smallest kind consists of a cylinder of metal or other substance turning on a handle as pivot. Outside it and on strips of paper within is inscribed the invocation to Avalokiteśvara or his consort, *Om Manipadme hūm.* A weight hangs at the side, and with a slight movement of the hand the cylinder revolves. Larger wheels are made to revolve by means of wind or water.

PREACHING, the proclamation of a Divine message, and the regular instruction of the converted in the doctrines and duties of the faith. is a distinctive though not a peculiar feature oi the Christian religion. The Mohammedans exercise it freely, and it is not unknown among the Buddhists. The history of Christian preaching with mhich alone this article is concerned has its roots (1) in the activity of the Hebrew prophets and scribes, the former representing the broader appeal, the latter the edification of the iaithful, (2) in the ministry of Jesus Christ and His apostles, where again we have both the evangelical invitation and the teaching of truth and duty. Whichever element is emphasized in preaching, the preacher is one who believes himseli to be the ambassador of God, charged with a message which it is his duty to deliver.

The Patristic Age, to the Death of St. Augustine, 430.—From the Acts of the Apostles we gather something as to the methods adopted by St. Peter and St. Paul, and these we may believe were more or less general. The Apostles who had known the Lord would naturally recall the iacts of His liie, and the story oi His words and works would form a great deal oi their preaching. It is not until we come to Origen (d. 254) that we find preaching as an explanation and application of definite texts, a usage that Christianity adopted irom Greek rhetoricians. The iourth century marks the culmination of early Christian preaching. In an age of doctrinal controversy, the intellectual presentation of the Christian position was thus developed. Preaching flourished chiefly in the East; especially noteworthy are the three Cappadocians, Basil (*q.v.*) of Caesarea, cultured, devout and practical; his brother Gregory (*q.v.*) of Nyssa, more inclined to the speculative and metaphysical; and Gregory (*q.v.*) of Nazianzus, richly endowed with poetic and oratorical giits, the finest preacher oi the three. Foremost oi all stands John of hntioch, Chrysostom (*q.v.*), who in 386 began his 12 years' ministry in his native city, and in 398 the six memorable years in Constantinople, where he loved the poor, withstood tyranny and preached with amazing power. In the West the allegorical method of Alexandria had more influence than the historical exegesis cultivated at Antioch. This is seen in Ambrose of Milan and in Hilary of Poitiers. Rut the only name of first rank in preaching is that of Augustine, and even he is curiously unequal. His iondness for the allegorical and his manifest carelessness of preparation disappoint as oiten as his profundity, his devout mysticism and his practical application attract and satisiy. Augustine's *De doctrina Christiana,* bk. iv., is the first attempt to formulate the principles oi homiletics.

The Middle Ages.—After the days of Chrysostom and hugustine there was a great decline of preaching. The West did better than the East: at Rome Leo the Great and Gregory the Great could preach, and the missionaries Patrick, Columba. Columbanus, Augustine, Wilirid, Willibrord, Gall and Boniface are known by their iruits. Then came the age when the papacy was growing out oi the ruins of the old Roman empire, and the best talents were devoted to the organization of ecclesiasticism rather than to the preaching of the Word. But certain iorces were at work which were destined to bring about a great revival, *e.g.,* the rise oi the scholastic theology, the reiorms oi Pope Hildebrand and the preaching of the First Crusade by Pope Urban II. (d. 1099) and Peter the Hermit. In the 12th century the significant ieature is the growing use of the various national languages in competition with the hitherto universal Latin. The most eminent preachers of the century were Bernard of Clairvaux (1091–1153), the two mystics of St. Victor, Hugo and Richard, and Peter Waldo of Lyons, who preached a plain message to the poor and lowly. The 13th century saw the culmination of mediaeval preaching, especially in the rise of the tu-o great mendicant orders of Francis and Dominic. Representative Franciscan names are Antony of Padua (d. 1231). who travelled and preached through southern Europe; Bertold von Regensburg (d. 1272), who, with his wit and pathos, imagination and insight, drew huge crowds all over Germany; and Francis Bonaventura, the schoolman and mystic, who wrote a little book on *The But of Preaching.* Oi the Dominicans Thomas Aquinas (d. 1274), the theologian, was perhaps also the greatest preacher. With the 14th century a new note, that of reformation, is struck; but on the whole there was a drop irom the high level of the 13th. Among the popular preachers vigour was often blended with coarseness and vulgarity, Mysticism is represented by Suso, Meister Eckhart, above all Johann Tauler (*q.v.*) of Strasbourg (d. 1461), a true prophet in an age of degeneration. Towards the close of the century comes John Wycliffe (*q.v.*) and his English travelling preachers, who passed the torch to Hus and the Bohemians, and in the next age Savonarola.

The Reformation Period, 1500–1700.—The Reiormers gave the sermon a higher place in the ordinary service than it had previously held, and they laid special stress upon the interpretation and application oi scripture. The controversy with Rome, and the appeal to the reason and conscience of the individual, together with the spread oi the New Learning, gave preaching a new force and influence which reacted upon the old iaith. Most of the Reiormation preachers read their sermons, in contrast to the practice of earlier ages. The English Book of Homilies (see HOMILY) was compiled because competent preachers mere comparatively rare.

The 17th-century preaching was, generally speaking, a continuation of that of the 16th century, the pattern having been set by the Council of Trent and by the principles and practice of the Reiormers. In Spain and Germany, however, there was a decline of power, in marked contrast to the vigour manifested in France and England. In France, indeed, the, Catholic pulpit now came to its perfection, stimulated, no doubt, by the toleration accorded to the Huguenots up to 1685 and by the patronage of Louis XIV. The names of Bossuet, Fléchier, Bourdaloue, Fénelon and Massillon, all supreme preachers, despite a certain artificial pompousness, belong here, and on the reformed side are Jean Claude (d. 1687) and Jacques Saurin (d. 1730). In England, among Anglicans, are Andremes, Hall, Chillingworth, Jeremy Taylor, Barrow and South; among Puritans and Nonconiormists, Baxter, Calamy, the Goodwins, Howe, Owen and Bunyan. The sermons of these men were largely scriptural, the cardinal evangelical truths being emphasized with reality and vigour, but with a tendency to abstract theology rather than concrete religion.

The early years of the 18th century were a time of torpor as regards preaching. Generally speaking, sermons were unimpassioned, stilted and formal presentations of ethics and apologetics, seldom delivered extempore.

The Modern Period.—This dates from 1738, the year in which John Wesley began his memorable work. The example and stimulus given by him and by Whitefield were almost immeasurably productive. In their train came the great field preachers of \Vales, like John Elias and Christmas Evans, and later the Primitive Methodists, who by their camp meetings and itinerancies kept religious enthusiasm alive when Wesleyan Methodism was in peril of hardening. Meanwhile, in America the Puritan tradition, adapted to the new conditions, is represented by Cotton Mather, and later by Jonathan Edwards, the greatest preacher of his time and country. Whitefield's visits raised a band of pioneer preachers, cultured and uncultured, men who knew their Bibles but oiten interpreted them awry.

Preaching, in modern times, has been so varied, depending, as it largely does, on the personality of the preacher, that it is not possible to speak of its characteristics. Nor can one do more than enumerate a few outstanding modern names, exclusive oi living preachers. In the Roman Catholic Church are the Italians Ventura and Curci, the Germans Diepenbrock and Foerster, the French Lacordaire, Dupanloup, Loyson (Père Hyacinthe) and Henri Didon. Of Protestants, Germany produced Schleiermacher, Claus Harms, Tholuck and F. W. Krummacher: France, Vinet and the Monods. In England representative Anglican preachers were: Newman (whose best preaching preceded his obedience to Rome), T. Arnold, F. W. Robertson, Liddon, Farrar, Magee; of Free Churchmen, T. Binney, R. W. Dale. Joseph Parker and J. H. Jowett (Congregationalist); Robert Hall, C. H. Spurgeon, Alexander Maclaren and John Clifford (Baptists); W. M. Punshon, Hugh Price Hughes, Peter Mackenzie and W. L. Watkinson (Wesleyan); James Martineau (Unitarian). The Scottish churches gave Edward Irving, Thcmas Chalmers, R. S. Candlish, R. M. McCheync and John Caird. In America, honoured names are those of W. E. Channing, Henry Ward Beecher, Horace Bushnell, Phillips Brooks, to mention only a few.

See A. E. Garvie, *The Christian Preacher* (1920). (A. J. G.)

PREBLE, EDWARD (1761–1807), U.S. naval officer, whose reputation was earned in the action against Tripoli in 1803–04, was born in Portland. Me.. on Aug. 15, 1761. the son of a Revolutionary War soldier. He joined a privateer at the age of 16, and later, as a midshipman in the "Protector" of the Massachusetts state navy. fought in two severe actions. In 1781 Preble was a prisoner for a time in the notorious British prison ship "Jersey"; then he served as lieutenant in the Massachusetts ship "Winthrop" during a period in which five prizes were captured. After the Revolution he spent 15 years in the merchant service before becoming a lieutenant in the U.S. navy in 1798. Preble commanded the brig "Pickering" under Commodore John Barry during the quasi-war with France. In Aug. 1803 he set out as commodore of a squadron sent against Tripoli. Acting under Preble, Stephen Decatur with a small force destroyed the "Philadelphia," one of Preble's ships, which had been captured before Preble's arrival, in a daring action under the fortress guns of Tripoli. Preble's squadron made five attacks on the city, capturing three enemy gunboats and sinking three others. If he had remained in command a satisfactory peace probably would have been concluded with Tripoli, but a policy of rotation caused the navy department to send out a new commander in Sept. 1804. Preble died in Portland on Aug. 25, 1807. (J. B. HN.)

PRE-CAMBRLAN TIME. The Pre-Cambrian, as the name implies. includes all geologic time before the Cambrian period and all rock formations older than the basal beds of the Cambrian system (*q.v.*), the earliest period of the Paleozoic era, as indicated on the accompanying geologic time chart.

This article is divided into several sections and subsections dealing with the characteristics of Pre-Cambrian time, the economically important mineral deposits in Pre-Cambrian rocks and the more important occurrences of rocks that comprise the Pre-Cambrian record. In addition to the cross references to related material given in the several sections of this article, *see* also GEOLOGY: *Historical Geology* and geology sections of articles on continents, as AFRICA; EUROPE, etc.; and countries, as AUSTRALIA, COMMONWEALTH OF; CANADA, etc.

Following are the main divisions of this article:

Geologic Time Chart

System and Period	Series and Epoch	Distinctive Records of Life	1,000 Years
		CENOZOIC ERA	
Quaternary . .	Recent	Modern man . . .	11
	Pleistocene	Early man	1,000
Tertiary . . .	Pliocene	Large carnivores . . .	
	Miocene	Whales, apes, grazing forms	
	Oligocene	Large browsing mammals .	
	Eocene	Rise of flowering plants .	
	Paleocene	First placental mammals .	70,000
		MESOZOIC ERA	
Cretaceous		Extinction of dinosaurs .	130,000
Jurassic		Dinosaurs' zenith, primitive birds, first small mammals	160,000
Triassic		Appearance of dinosaurs .	200,000
		PALEOZOIC ERA	
Permian		Reptiles developed, conifers abundant	235,000
Carboniferous			
Upper (Pennsylvanian) . . .		First reptiles, coal forests	260,000
Lower (Mississippian) . . .		Sharks abundant . . .	285,000
Devonian		Amphibians appeared, fishes abundant	320,000
Silurian		Earliest land plants and animals	350,000
Ordovician		First primitive fishes . .	400,000
Cambrian		Marine invertebrates . .	500,000
		PRE-CAMBRIAN TIME	
		Few fossils . .	3,500,000–4,000,000

I. CHARACTERISTICS

Throughout most of the world where the contact of the Cambrian and Pre-Cambrian is exposed, a great unconformity or gap in the succession of formations separates the Camhrian from the Pre-Cambrian. In a few regions, however, there seems to be no unconformity, the Cambrian beds passing without interruption downward into strata believed to be of Pre-Cambrian age. Most of the Cambrian and later strata of the Paleozoic contain numerous fossils—evidence of varied and abundant life—while in contrast with this there are almost no fossils in the Pre-Cambrian.

Wherever erosion has removed the Paleozoic and later formations. Pre-Cambrian rocks are usually present. They are exposed over one-fifth of the land surface of the earth and, except where intruded by igneous rocks of later age, exist everywhere at a depth beneath Paleozoic and later strata. They occur in areas of two kinds: (1) the deeply denuded parts of mountain chains where they have been uplifted by mountain building; and (2) in widely extended areas of relatively low elevation, called shields because of their gentle outward slopes resembling roughly the surface of a shield. The occurrences in mountain chains are much more restricted in extent than in the shield areas.

The formations of the Pre-Cambrian are, for the most part, highly folded and intruded by masses of granite, granite gneiss and other igneous rocks, most of which came in at depth as the Pre-Cambrian mountain-building folding was in progress. On the margins of the Pre-Cambrian shield areas, Cambrian and later beds in many places lie on the upturned edges of Pre-Cambrian strata. This relationship shows that, prior to the Cambrian, the Pre-Cambrian mountains were worn down to a relatively low land area over which the Cambrian sea advanced.

Although most Pre-Cambrian rocks have been subjected to the deformation and alteration that accompanies mountain building, many of the shield areas have suffered little change through all the later eras; and original structures even of the earliest Pre-Cambrian have been remarkably well preserved. It has been found possible in many Pre-Cambrian regions, by means of detailed mapping. to determine the structural succession of formations over considerable areas. Only a relatively small part of the Pre-Cambrian has been mapped in this way; and because of the absence of fossils, much intensive geological work will be necessary before the rocks can be correlated with certainty even within most of the separate Pre-Cambrian areas.

1. Dating.—The discovery that radioactive elements slowly disintegrate into other elements affords a may in which the approximate age of Pre-Cambrian rocks can be determined. Thus from the time a uranium-bedring mineral is formed. its uranium slowly breaks up into helium and isotopes of lead.

Since the rate of disintegration of the uranium is known, it is possible to determine the age of the mineral from the amounts of lead isotopes relative either to one another or to the uranium present. Many pegmatites and other igneous rocks of the Pre-Cambrian contain uranium-bearing minerals, the oldest of which was determined in 1939 to have an age of about 2,500,000,000 years. The rocks in which these occur, however, are intrusive into older formations, and it has been estimated that the oldest Pre-Cambrian rocks on the earth's surface have an age of at least 3,500,000,000 to 4,000,000,000 years. See also GEOCHRONOLOGY.

2. The Pre-Cambrian World.—For all of Pre-Cambrian time for which there is a geological record. conditions on the surface of tht earth appear to have been similar in most respects to those of later eras. Mountain building and volcanic activity recurred as in the later periods of the earth's history; water played the same role as it does today; rocks were deeply eroded; and conglomerates, sandstones and other sediments were deposited in the same manner as at the present time. There is evidence also that ice sheets similar to the one now covering most of Greenland existed in Canada, India. South Africa. Australia and elsewhere.

II. ECONOMIC IMPORTANCE

Because most valuable mineral deposits are found in association with igneous rocks of deeply denuded mountainous or formerly mountainous regions, the Pre-Cambrian parts of the earth's surface are of special economic importance. Most of the world's largest gold mines, including those of the Transvaal and Southern Rhodesia (Africa), South Dakota (U.S.), northern Ontario and Quebec (Canada), Brazil and western Australia, are in Pre-Cambrian rocks. The important iron deposits of the Lake Superior region in the United States, the iron deposits of Labrador-Quebec, the iron ores of Brazil and northern Sweden, the great nickel-copper ore masses of Sudbury, Ont., the silver-bearing cobalt-nickel veins of Cobalt. Ont., the occurrences of uranium in South Africa and Canada, and many important copper deposits belong to the Pre-Cambrian. It also includes a great variety of useful nonmetallic minerals. Among these are garnet, talc, mica, graphite, feldspar and magnesite.

III. THE PRE-CAMBRIAN RECORD

A. North America

Pre-Cambrian rocks occur in North America mainly in the Canadian Pre-Cambrian shield that occupies most of the northeastern part of the continent. They also occur, however. in numerous scattered areas in the western or Cordilleran part and in places in the eastern belt of folded rocks that extends from Alabama to Newfoundland.

The Canadian shield is the world's largest area underlain by Pre-Cambrian rocks. It includes most of northeastern Canada and the greater part of Greenland, and extends into the United States west and south of Lake Superior and in northern New York state. It has a total area of about 2,780,000 sq.mi., of which about 800,000 sq.mi. are in Greenland; 1,905,000 in Canada; and 75,000 in the United States.

The limits of the shield are sharply defined on the east, except in eastern Greenland, by the Atlantic ocean; and on the south and west by south- and southwest-dipping sediments of later age that outcrop in a succession of alternating lowland and north- or northeast-facing scarp belts. On the north the boundary is less definite, the Pre-Cambrian surface disappearing first beneath scattered remnants, and finally beneath a most irregular border of Paleozoic or later sediments.

Only a very small part of the shield has been mapped geologically in detail but, taken as a whole, its rocks belong naturally to two major divisions—the Archean (or Archeozoic) or Early Pre-Cambrian and the Proterozoic or Late Pre-Cambrian. The major break in deposition or unconformity used as the standard of reference for the separation of the Archean from the Proterozoic was originally observed in 1845 on Lake Timiskaming on the border between Ontario and Quebec by Sir William Logan, first director of the Geological Survey of Canada; and was later found to extend with reasonable certainty from Lake Mistassini in northern Quebec to the region south of Lake Superior in the United States, a distance of more than 900 mi. Formations beneath this unconformity in the southern part of the shield are classed as Archean (Early Pre-Cambrian), those above as Proterozoic (Late Pre-Cambrian). Rocks in the northern parts of the shield are either assigned on their lithological and structural similarity to the Archean or Proterozoic; or are unclassified under the designation Archean and/or Proterozoic. In places, the Archean classification of formations is confirmed by physicochemical age determinations of minerals.

1. Canadian Shield Archean.—The Early Pre-Cambrian or Archean (from the Greek for "ancient") formations of the Canadian shield, classified according to their lithological character and mode of origin, belong to two entirely different types In the territory extending from the north end of Lake Hurcn to the Strait of Belle Isle, the Adirondack region in New York state, Baffin Island and Greenland, the Archean rocks are limestone and associated sediments of the types laid down in the sea adjacent to land of low relief; whereas elsewhere in the shield limestone is almost wholly absent and the predominant formations are lava flows and clastic sediments (that is, composed of fragments of pre-existing rocks), characterized by features that suggest either deposition on land or in the sea adjacent to mountains.

Information is far too incomplete for setting up a single tabular classification of the Archean rocks of the shield that would hold for its entire area; but in the Timiskaming region of northeastern Ontario and western Quebec, where an area of about 2.600 sq.mi. has been mapped geologically in detail, the succession in descending order (*i.e.*, from youngest to oldest strata) is as follows:

Archean Rocks in Timiskarning Region

GREAT UNCONFORMITY

Archean:

Batholithic intrusives
  Granite and related rocks
Intrusive masses, dykes and sills
  Diorite, gabbro, peridotite and related rocks
Timiskaming
  Conglomerate, graywacke and volcanic rocks

UNCONFORMITY

Pre-Timiskaming batholithic intrusives
  (represented only by pebbles in Timiskaming conglomerate)
Pontiac and Hoyle groups
  Graywacke, lava flows and fine-grained volcanic *ejectamenta* (tuff)
Keewatin
  Lavas, volcanic fragmental rocks (agglomerate) and tuff

In the region northwest of Lake Superior the Archean succession from youngest to oldest is the following:

Archean Rocks Northwest of Lake Superior

Archean:

Algoman batholithic intrusives
  Granite and related rocks
Knife lake, Steeprock lake and Seine river series
  Sediments, lava flows and pyroclastic volcanic rocks

UNCONFORMITY

Laurentian batholithic intrusives
  Granite and related rocks
Keewatin
  Lavas and Soudan iron formation member
Coutchiching*
  Mica schist and gneiss of sedimentary origin

*Relationship of Coutchiching to Keewatin uncertain

Although the above tabulations are from localities more than 600 mi. apart, there is apparently considerable similarity in the succession in the two regions and, for this reason, some correlations have been attempted between them. For example, the name Keewatin (from an Indian word for "north wind"), first proposed by A. C. Lawson in 1885 for volcanic rocks occurring in the Lake of the Woods district northwest of Lake Superior. has been used by almost all geologists for similar rocks occurring in northern Ontario and eastward in western Quebec. Some geologists have also assumed that the post-Timiskaming granites of the Timiskaming region are of the same age as the Algoman (from Algoma, Ont.) granites of the region northwest of Lake Superior. According to these assumptions two separate mountain-building uplifts extended across the whole southern part of the Canadian shield during the Archean era. It is possible that detailed geological mapping in northern Ontario might prove this hypothesis true, but much geological work would be required to establish it.

In the southeastern part of the Canadian shield, where the Grenville (Grenville township, Ont.) sediments, believed to be of marine origin, occur, the most complete succession of formations is in southeastern Ontario. A tabular statement of the sequence of formations in this region, Commencing with the youngest, is as follows:

Archean Rocks in Southeastern Ontario

Archean:

Batholithic intrusives
  Granite, granite gneiss, syenite and related rocks
Diorite, gabbro and related rocks
Hastings series
  Limestone, dolomite, graywacke, mica schist, conglomerate

UNCONFORMITY

Batholithic intrusives
  (represented only by pebbles in Hastings conglomerate)
Grenville series
  Crystalline limestone, dolomite, quartzite, garnet gneiss, mica schist, lava flows, pyroclastic volcanic rocks

Except for the presence of the Hastings (Hastings county, Ont.) series and the Grenville volcanic rocks restricted mainly to south-

BY COURTESY OF GEOLOGICAL SURVEY OF CANADA

PILLOW STRUCTURE IN VERTICALLY FOLDED LAVA FROM THE PRE-CAMBRIAN KEEWATIN FORMATION FOUND IN WESTERN QUEBEC

Pillows are rounded above and flat or V-shaped below, indicating the upper and lower sides of lava flows, and are important in determining Pre-Cambrian structure. Pillows form where lava is extruded into the sea

eastern Ontario, the above succession is similar to that throughout most of the Grenville region or subprovince that extends from the north end of Lake Huron and the Adirondack region northeast to the Strait of Belle Isle. However, at Mt. Wright and Wabush lake about 220 mi. north of the lower St. Lawrence river, recrystallized iron-bearing sediments occur that are believed to be a southern part of the Labrador-Quebec Proterozoic sedimentary belt.

2. Canadian Shield Proterozoic.—Late Pre-Cambrian or Proterozoic (from the Greek for "before" and "life," that is, before the Paleozoic, or era of "ancient life") rocks occur extensively in the southern part of the Canadian shield south and northwest of Lake Superior and in the territory extending northeast from the north shore of Lake Huron to Lake Timiskaming. In the region south of Lake Superior in 1935 they were called Algonkian type and classified by C. K. Leith, R. J. Lund and A. Leith in descending order as follows:

Proterozoic Rocks South of Lake Superior

Proterozoic	Keweenawan	Acidic intrusives Basic instrusives Sandstone, shale, conglomerate, lava flows
		Unconformity
	Upper Huronian	Sediments, iron formation, volcanic rocks
		Usconformity
	Middle Huronian	Basic intrusives, iron formation, sediments
		Unconformity
	Lower Huronian	Dolomite and quartzite
		Unconformity

In the region northwest of Lake Superior, F. F. Grout, J. W. Gruner. G. M. Schwartz and G. A. Thiel in 1951 classified the Proterozoic rocks as follows:

Proterozoic Rocks Northwest of Lake Superior

Proterozoic	Keweenawan	Upper—Sandstone, other sediments Middle—Acid, basic intrusives, lavas Lower—Conglomerate, sandstone
		Unconformity
	Animikie	Slate, iron formation and quartzite
		Unconformity

In the Lake Huron-Lake Timiskaming region in northern Ontario the Late Pre-Cambrian or Proterozoic rocks are classified as follows:

Proterozoic Rocks in Northern Ontario

Proterozoic	Acid and basic intrusive rocks Whitewater series	
		Unconformity
	Cobalt series	
		Unconformity
	Bruce series	
		Unconformity

Of the above, the Bruce series is probably the eastward continuation of the Lower Huronian of the region south of Lake Superior. The Cobalt series. although believed to be in part of glacial origin. is usually classified as Middle Huronian. The correlation of the Whitewater series is in doubt. It was formerly thought to be Keweenawan or possibly Animikie, but in 1956 J. E. Thomson suggested that .it might be oi considerably older age.

In the vast northern part of the shield, extending from the Strait of Belle Isle to Great Bear lake and the Arctic ocean. the rocks of the Proterozoic belong to three main classes: (1) in the northern part of the shield west of Hudson bay, extensive separate areas of flat-lying conglomerate, sandstone and lava flows known from place names as the Coppermine river, Et-then, Dubawnt and Athabasca groups; (2) in the eastern part of the shield, areas or belts of partly folded and partly gently dipping iron formation, dolomite and clastic sediments of the Belcher Islands. Richmond gulf. Labrador-Quebec or similar groups; and (3) in the northwestern part of the shield unconformably beneath the Coppermine river and Et-then rocks, zones of folded dolomite, limestone, quartzite and graywacke called Great Slave, Snare and Nonacho groups. The rocks of class 1 are similar to the Keweenawan of the Lake Superior region; those of class 2 to the Animikie northwest of Lake Superior; and those of class 3 to the Huronian south of Lake Superior.

3. Other North American.—In the western Cordilleran part of North America, the best known section of Pre-Cambrian rocks is that exposed in the Grand canyon of the Colorado river in Arizona. The most extensive occurrence, however, is that of the Proterozoic Beltian (Little Belt mountains. Mont.) formations. These occupy an area 300 mi. wide in northern Idaho, Montana and Washington. and extend discontinuously northwest with a maximum width of about 100 mi. through British Columbia to the Yukon in Canada.

Pre-Cambrian rocks occur in Arizona in the Grand canyon area and are widely scattered in southern, southwestern and western parts of the state. In the Grand canyon gorge the oldest rocks, known as the Vishnu schist, are classed as older Pre-Cambrian. They consist of igneous gneisses and altered sediments. They are cut by dikes of granite and pegmatite. 4 younger group of Pre-Cambrian rocks 12,000 ft. thick, the Grand canyon series, composed mainly of sediments, rests uncomformably on the Vishnu schist. In other parts of Arizona the older Pre-Cambrian rocks are known as the Yavapai or Pinal schist, and the younger as the Apache group.

The rocks of the Beltian system include argillite. impure limestone. quartzite and other sediments. They are estimated to have a thickness up to 35,000 ft. in the United States. In Canada, according to H. M. A. Rice, they have a total thickness of 67,000 ft. and occur in two series separated by an important unconformity.

In the belt of folded rocks that lies parallel with the east coast of North America. there are Pre-Cambrian rocks in eastern Newfoundland, in southeastern Nova Scotia, along the northwest shore of the Bay of Fundy in New Brunswick, and in zones within or adjacent to the eastern part of the Appalachian mountains from the Canadian border to Georgia. In southeastern Pennsylvania and adjacent parts of New York, New Jersey and Maryland. the Pre-Cambrian includes sedimentary and igneous gneisses overlain unconformably by crystalline limestone, dolomite, quartzite, sedimentary gneisses and schists. The older group of rocks is known as the Baltimore gneiss; the younger as the Glenarm series. Farther south the schists and gneisses of the Blue Ridge and the (Piedmont) plateau belts have been classed as Pre-Cambrian by most geologists who have examined them.

B. South America

Pre-Cambrian formations outcrop in South America mainly in two regions: (1) in elongated zones here and there in the western Cordilleran belt of mountains extending from Venezuela to Chile; and (2) in broad masses or scattered areas in the eastern part of the continent, but most extensively in Brazil, southeastern Venezuela. French Guiana, Surinam (Dutch Guiana) and British Guiana. The territory in northeastern South America underlain by Pre-Cambrian rocks lying south of the Amazon basin is known as the Brazilian shield or Amazonia; that north of the Amazon basin as the Guianan shield or Guiania. The zones of the Cordilleran region consist mainly of granite, schists and gneisses, which have been classed as Early Pre-Cambrian largely because of their highly altered condition. The succession of formations in central and southeastern Minas Gerais state, Brazil, is believed to be typical of the Brazilian shield. The oldest rocks of this region include gneisses and schists, presumably transformed sediments, overlain successively by two groups of late Pre-Cambrian sediments. the Minas series composed mainly of quartzite, slate, dolomite, conglomerate and iron formation called itabirite; and the Itacolumi series consisting chiefly of quartzite. All of these have been mountain built, as shown by their highly folded condition and intrusion by granite.

The oldest rocks of the Guianan shield are crystalline schists, limestone, gneisses and granite of Early Pre-Cambrian age. These are overlain in unconformable succession by two groups of Late Pre-Cambrian rocks: (1) the Balling. composed of lava flows with interbedded iron formation and other sediments; and (2) the Orapu, a sedimentary series consisting of conglomerate. quartzite and slate. Mountain building and granitic intrusion followed the deposition of both the Balling and Orapu formations.

Important mineral deposits occur in both the Brazilian and Guianan shields. These include hematite iron ore, manganese, gold, mica and diamonds in Brazil; gold in British Guiana; and hematite-magnetite iron ore in Venezuela.

C. Europe

Small areas or zones of Pre-Cambrian rocks occur widely scattered in Europe wherever deeply eroded folded rocks of mountains or former mountains are present, but by far the largest area underlain by Pre-Cambrian formations is that known as the Baltic shield (Baltica or Fennoscandia), which occupies a large part of Norway, and most of Sweden, Finland and northwestern U.S.S.R. west of the White sea. There are also considerable areas of Pre-Cambrian in the Highlands of Scotland and northeastern Ireland that may be parts of a western extension of the Baltic mass.

The most important mineral deposits in the Pre-Cambrian of Europe are in the Baltic shield. These include magnetite iron ore at Kiruna in Sweden and apatite in the Kola peninsula of U.S.S.R.

1. Fennoscandia (Baltic Shield).—The Pre-Cambrian area of Fennoscandia or the Baltic shield extends from the Arctic ocean to the island of Bornholm in the Baltic sea and from the eastern extremity of Kola peninsula in the U.S.S.R. to the westernmost tip of Norway. In the 1930s J. J. Sederholm classified the Pre-Cambrian rocks of this region into four divisions: (1) Sivonian; (2) Bothnian; (3) Jatulian-Kalevian; and (4) Jotnian, each of which he believed was separated from the underlying and overlying divisions by great unconformities. He also believed that the intervals of erosion represented by these unconformities in every case were preceded by mountain building and intrusion of granitic rocks which were laid bare by erosion before the succeeding formations were deposited. Finnish and Swedish geologists have concluded from later work. however, that mountain building did not intervene between the Sivonian and Bothnian rocks, and that these beiong to a single group. This Sivonian-Bothnian succession of formations includes abundant altered sandy sediments, conglomerate, limestone and interbedded volcanic rocks. They are intruded by basic igneous rocks and post-Bothnian granite. The Jatulian-Kalevian group is composed of conglomerate, ripple-marked quartzite, dolomite and greenstones that have been transformed by folding and intrusion of granite. Curing the Late Pre-Cambrian the peculiar Rapakivi granite was intruded, after which the Jotnian sandstone was deposited. Since the earlier work of Sederholm, considerable progress has been made in the study of the granitic rocks of Fennoscandia; and some Finnish geologists, notably P. Eskola, have concluded that these igneous intrusions are related to two mountain-building uplifts: (1) the Svecofennidic or post-Sivonian; and (2) the Karelidic or post-Kalevian. According to Eskola. the Svecofennidic mountain chain extended east-west through central Sweden and southwest Finland; the Karelidic mountain folding trended northwest from Lake Ladoga through eastern Finland and Lapland. In the folded Caledonian mountains of Norway, thick sandy sediments, known as the Sparagmite or Eocambrian formation, occur extensively at the top of the Pre-Cambrian succession.

2. Scotland.—The Pre-Cambrian of Scotland lies north of the great fault that marks the southern border of its Highlands. In this region there are four main rock groups of Pre-Cambrian or possible Pre-Cambrian age. These are: (1) The Lewisian (from Lewis-and-Harris Island in the Outer Hebrides) complex, consisting of sediments that have been transformed into gneisses and schists, and intruded by granite, igneous gneisses, pegmatite and ultrabasic racks. It occurs in the northwest Highlands and in the Hebrides Islands. (2) The Moine series, composed of metamorphosed sediments, ultrabasic or basic intrusive rocks, and banded gneisses formed by the intrusion of granite into schist. (3) The Dalradian (from region of Dalradia, Scot.) series, a metamorphic group of rocks mainly of sedimentary origin. It occurs in the southeast Highlands north of the Highland boundary fault. (4) Unaltered conglomerate, sandstone, grit and shale—the Torridonian (from Loch Torridon. Scot.) sediments. These are only gently folded. They rest unconformably on Lewisian gneiss in the northwest Highlands, in the Hebrides and other adjacent islands, and are overlain with structural unconformity by Cambrian sediments. The Lewisian presumably belongs to the Early, and the Torridonian to the Late Pre-Cambrian. The Moine sediments have been variously classified as Lewisian, post-Lewisian but pre-Torridonian, Torridonian, or early Paleozoic transformed by Caledonian mountain building. According to James Phemister, the post-Lewisian pre-Torridonian age is probably the most generally accepted hypothesis. The Dalradian rock group is of uncertain age. Some geologists think it Pre-Cambrian but others maintain that it belongs wholly or in part to the Cambrian.

D. Asia

Rocks that are positively known to be Pre-Cambrian, or are probably Pre-Cambrian. are widespread in Asia wherever eroded mountains occur. The most extensive areas, however, are in eastern Siberia, northeastern China, Korea, India and Arabia.

1. Siberia.—The Pre-Cambrian of Siberia occupies two extensive areas in the headwater parts of the Yenisei and Lena river basins. The northeasterly of these is called the Annabar shield and that to the southeast the Aldan shield. The rocks in the central parts of these ancient land masses are called Archean, and include crystalline limestone, quartzites and other metamorphosed sediments. schists, gneisses and intrusions of granite. In their border zones. notably in the Lake Baikal region, the Archean complex is overlain unconformably by a folded succession of two Proterozoic, structurally unconformable, metamorphic series. The lower of these consists of schists, conglomerate and quartzites; the upper of phyllites, sandstone and interbedded lava flows. In parts of the region Cambrian strata rest on the Early Pre-Cambrian complex, and Proterozoic strata are absent. Geologists of the U.S.S.R., noting the wide zone of unfolded Paleozoic rocks that commonly encircle the Pre-Cambrian shield areas, designate the combined shield and surrounding undeformed formations as platforms.

2. China.—In China Pre-Cambrian rocks occur widely from Mongolia southeast, east and northeast to the Siberian border. They belong to three unconformably separate groups: (1) the Tai-Shan or Archean complex of gneisses, schists and altered sediments, intruded by granite and basic igneous rocks; (2) the Wu-T'ai system composed of dolomite, conglomerate and other sediments metamorphosed to schists, interbedded greenstones—probably altered volcanic rocks—and gneisses intruded by granite; and (3) the Sinian system consisting of limestone, quartzite, shale and other sediments. The Wu-T'ai is compared by some authors with the Huronian of North America. The Sinian is similar in many respects to the Beltian sediments of western United States and Canada. In Manchuria and Korea the names Lia-ho and Keirin have been given by Shintaro Nakamura to rocks believed to be the equivalent of the Wu-T'ai and Tai-Shan systems. Geologists conclude that Pre-Cambrian granitic rocks of three ages occur in north China and Korea.

3. India.—The bedrock surface of peninsular India and the adjacent island of Ceylon is composed mainly of highly folded, crystalline schists and gneisses intruded by granite and granite-gneiss, and a widespread group of igneous rocks containing the mineral hypersthene and known as the Charnockite series. This complex was called Vedic and correlated with the Archean by Sir Thomas H. Holland. It includes an abundance of crystalline limestone, and other highly altered sediments, which, as noted by F. D. Adams in Ceylon, resemble the Grenville series in the southeastern part of the Canadian shield.

In parts of the'peninsula the sediments and schists of sedimentary origin within the complex are known as the Dharwar system. These Early Pre-Cambrian rocks are overlain unconformably by great thicknesses of little disturbed rocks called

Purana. They contain no fossils and are believed to be of Late Pre-Cambrian age. The Purana sediments have been variously named in different parts of the peninsula. In central India they are divided into two series separated by an unconformity, the Gwalier and Vindhyan. The gold-bearing veins of the Kolar gold fields in Mysore intersect schists of the Dharwar system. Deposits of white mica (muscovite) occur in pegmatite dikes cutting the Dharwar or similar rocks in several provinces of India. The graphite of Ceylon occurs in veins cutting the older gneisses.

E. Africa

Pre-Cambrian rocks occur in many places in Africa but are most widespread in an irregular zone extending longitudinally from Arabia and Egypt to Cape province of the Union of South Africa, and transversely from the Gulf of Aden almost to the western extremity of the continent. They also underlie most of the island of Madagascar and occur discontinuously in a narrow belt adjoining the west coast from the Gulf of Guinea southward. In most of these regions they are not in contact with Cambrian formations but are overlain with great unconformity by Devonian, Permo-Carboniferous or later strata. Their classification as Pre-Cambrian is, therefore, based largely on their metamorphic condition and lithological character.

In most of the Pre-Cambrian areas of Africa, a highly deformed basal group of Archean-like schists and gneisses, usually called the Basement, is overlain with great unconformity by one or more less altered rock series. A multitude of local names have been given to these various rock groups but only those occupying extended areas can be mentioned. In the Sahara region of north Africa, two major rock divisions have been observed; the lower is known as Suggarien and the upper, Pharusien. To the southwest, in French West Africa, Ivory Coast and Ghana, the names Dahomeyan or Archean, Birrimian and Tarkwaian have been used over a large area. In Kenya and Tanganyika, which are predominantly underlain by Pre-Cambrian rocks, the Pre-Cambrian formations are classified into three main groups: the Basement, Nyanzian and Kavirondian systems. Extensive areas of gneiss and granite intervening in age between the Basement and Nyanzian systems have been mapped as the Granitoid shield by G. M. Stockley.

The major Pre-Cambrian divisional names in southeast Africa are included in the following table:

Name	*Rocks*
Waterberg system	Conglomerate, quartzite, shale, volcanic rocks
Transvaal system	
Pretoria series	Conglomerate, quartzite, shale and lavas
Dolomite series	Dolomite, chert and quartzite
Black reef series	Conglomerate, quartzite and shale
Ventersdorp system	Conglomerate, quartzite, chert, shale and volcanic rocks
Witwatersrand system	
Upper division	Conglomerate, grit and quartzite
Lower division	Conglomerate, arkose, quartzite, slate, lavas

The Witwatersrand rocks are of special interest because they contain the world's largest known deposits of gold. They have a total thickness of more than 24,000 ft. The gold occurs in conglomerate beds known as bankets or reefs. In South-West Africa and western South Africa, a succession of conglomerates, quartzites, dolomite and limestone called the Nama system, because of lithological similarity, has been correlated tentatively with the Transvaal rock group. One of the outstanding features of the South African Pre-Cambrian is the widely extended assemblage of volcanic and intrusive igneous rocks known as the Bushveld complex that occurs in central Transvaal. This igneous activity occurred mainly between late Pretoria and Waterberg deposition. Considerable amounts of tin and chrome ore are found in the intrusive phases of the Bushveld complex.

F. Australia and New Zealand

The Pre-Cambrian formations of Australia and New Zealand occur in either (1) relatively small scattered areas or zones in the cores of mountains or highlands in New South Wales, South Australia, northern Queensland, western Tasmania and southwestern New Zealand; or (2) in the widely extended shield area of western and central Australia. In most of these regions an older group of schists, gneisses or volcanic rocks and intrusive granite classed as Archean is overlain unconformably by less deformed sediments or lavas called Proterozoic. At Broken Hill in New South Wales highly altered sandy, argillaceous and calcareous sediments of the Archean Willyama series are overlain unconformably by the Proterozoic Torrowwangee series composed of limestone, shale and boulder beds.

In New South Wales the older sediments of the Hutchison series and granite gneisses are overlain unconformably by folded limestone, quartzite and slate of the Adelaide series. In the Mount Isa region of northern Queensland, the Pre-Cambrian is represented by four rock groups separated by unconformities. The two older of these, the Kalkadoon-Argylla and Soldier's Cap series, are assigned to the Archean; and the two younger, the Mount Isa and Mount Quamby series, to the Proterozoic. The Mount Quamby rocks, in contrast with the underlying formations, are only gently dipping. In the shield area of western and central Australia, the Pre-Cambrian rocks are classified into two major divisions: (1) a basal, Archean group of mainly volcanic rocks but including some interbedded sediments, the Yilgarn-Kalgoorlie system; and (2) the Proterozoic Nullagine series composed of gently folded unmetamorphosed conglomerate and other sediments, lavas and fragmental volcanic rocks. Masses of granite intrude the older system and are overlain unconformably by the Nullagine series.

A considerable part of the gold of Australia has been obtained from lodes and veins occurring in the Pre-Cambrian shield of west and middle Australia. The silver-lead-zinc ores of Broken Hill in New South Wales are in intensely altered Pre-Cambrian rocks; iron ore is mined from the Archean rocks of the Middleback range in South Australia.

Bibliography.—*General:* C. O. Dunbar, *Historical Geology* (1949). *North America:* G. H. Ashley, "A Syllabus of Pennsylvania Geology and Mineral Resources," *Bull. Pa. Geol. Surv.* (1931); M. E. Wilson, "Pre-Cambrian," in *Fiftieth Anniversary Volume,* Geological Society of America, pp. 269–305 (1941); J. V. Le is and H. B. Kummel, "The Geology of New Jersey," *Bull.* N.J. *Div. Geol.,* 50 (1940); F. J. Alcock, "Problems of New Brunswick Geology," *Trans. Roy. Soc. Can.,* vol. 42, sec. 4, pp. 1–15 (1948); F. F. Grout, J. W. Gruner, G. M. Schwartz and G. A. Thiel, "Pre-Cambrian Stratigraphy of Minnesota," *Bull. Geol. Soc. Amer.,* 62:1017–78 (1951); C. A. Anderson, "Older Pre-Cambrian Structure in Arizona," *Bull. Geol. Soc. Amer.,* 62:1331–46 (1951); J. M. Harrison, "The Canadian Shield, Mainland," *Geology and Economic Minerals of Canada,* pp. 19–122, Geological Survey of Canada (1957).

South America: W. F. Jenks (ed.), *Handbook of South American Geology, Mem. Geol. Soc. Amer.,* 65 (1956).

Europe: J. J. Sederholm, "On the Geology of Fennoscandia with Special Reference to the Pre-Cambrian," *Bull. Comm. Ge'ol. Finl.,* 98 (1932); P. Eskola, "Glimpses at the Geology of Finland," *J. Manchr. Geol. Ass.,* vol. 11, pt. 1, pp. 61–79 (1950); E. B. Bailey, "The Structural History of Scotland," *Report* of International Geological Congress (18th sess., Great Britain), pt. 1, pp. 230–254 (1950); O. Holtedahl, "The Structural History of Norway and Its Relation to Great Britain," *Quart. J. Geol. Soc. Lond.,* vol. 108, pt. 1, no. 429, pp. 65–98 (1952); A. Simonen, "Stratigraphy and Sedimentation of the Svecofennidic Early Archaean Supracrustal Rocks in Southwestern Finland," *Bull. Comm. Géol. Finl.,* 160 (1953).

Asia: L. L. Fermor, "An Attempt at the Correlation of the Ancient Schistose Formations of Peninsular India," *Mem. Geol. Surv. India,* vol. 70, pt. i (1936); "Neogene of the U.S.S.R.," in *Stratigraphy of the U.S.S.R.,* ed. by A. D. Arkhangelsky, vol. 12, pp. 601–42 (1940); J. M. Weller, "Outline of Chinese Geology," *Bull. Amer. Assn. Petrol. Geol.,* 28:1417–29 (1944); L. J. D. Fernando, "The Geology and Mineral Resources of Ceylon," *Bull. Imp. Inst., Lond.,* 46:303–325 (1948); S. I. Tomkeieff, "The Rhiphaean System and the Structure of the Russian Platform," *Proc. Geol. Soc., Lond.,* no. 1501, pp. 108–112 (1953).

Africa: W. Pulfrey, "The Geology and Mineral Resources of Kenya," *Bull. Imp. Inst., Lond.,* 45:277–299 (1948); G. M. Stockley, "The Geology and Mineral Resources of Tanganyika Territory," *Bull. Geol. Surv. Tanganyika,* 20 (1948); F. Dixey and E. S. Willbourn, "The Geology of the British African Colonies," *Report,* International Geological Congress (18th sess., Great Britain, 1948), pt. 14, pp. 87–117 (1951); H. M. E. Schurmann, "The Pre-Cambrian of the Gulf of Suez Area," *Report,* International Geological Congress (19th sess., Algeria, 1952), sec. 1, f. 1, pp. 115–135 (1953); M. Lelubre, "Stratigraphy of the Pre-Cambrian of the Sahara," *Bull. Soc. Giol. Fr.,* ser. 6, 3:547–577

(1953); A. L. Du Toit, *Geology of South Africa*, 3rd ed. (1954); N. R. Junner, "Notes on the Classification of the Pre-Cambrian of West Africa," *Report*, International Geological Congress (19th sess., Algeria, 1952), pt. 1, f. 20, pp. 115–127 (1954).

Australia and New Zealand: R. T. Prider, "Igneous Activity, Metamorphism and Ore-Formation in Western Australia," *J. Roy. Soc. W. Aust.*, 31:43–84 (1948); T. W. E. David, *Geology of the Commonwealth of Australia*, ed. by W. R. Browne, vol. 1 (1950); F. G. Forman, "The Geological Structure of the Shield in South Western Australia," *Geology of Australian Ore Deposits*, publication of 5th Empire Mining and Metallurgical Congress, 1:65–78 (1953). (M. E. Wn.)

PRECEDENCE here means priority of place. or superiority of rank. Ancient in origin, it has engaged the attention of man since the first civilizations emerged and the organization of society on a hierarchical basis made some guide to the conduct of ceremonies and other social formalities indispensable. But it is only in comparatively modern times that fixed and exhaustive tables of precedence have been drawn up.

In Great Britain. as in most monarchical countries, the crown is the fountain of honour and has the undoubted prerogative to confer such rank and place as may seem 'convenient to it. Precedence is normally regulated by the crown acting through parliament (in the form of a statute), by granting royal charters. letters patent, royal warrants and ordinances, by authoritative letters of state (carrying specific instructions on precedence) and by international treaty. It is also adjusted by local enactments, by ancient usage and by established custom.

Disputes in matters of precedence are settled by the crown in England usually acting on the advice of the College of Arms, in Scotland through the Court of the Lord Lyon, in the British colonies by the governor.

In 1539 an act "for the placing of the Lords in Parliament" (31 Hen. YIII c. 10) was passed at the instance of the king; and by it the relative rank of the members of the royal family, of the great officers of state and of the royal household and of members of the hierarchy and of the peerage was definitely ascertained. Subsequent modifications were enacted in 1j63 (5 Eliz. c. 18) and in 1689 (1 Will. and Mary c. 21). The Acts of Union with Scotland (1joj) and with Ireland (1800) laid down rules of precedence for Scottish and Irish peers. At different times. too, statutes for the reform and extension of the judicial organization have affected the precedence of judges, more especially the Judicature act of 1873. But the statute of Henry VIII "for the placing of the Lords" remains the only measure dealing with any large section of the scale of general precedence; and the law, so far as it relates to the ranking of the sovereign's immediate kindred, the principal ministers of the crown and court and both the spiritual and temporal members of the house of lords, is to all practical intents what it mas made by that statute.

Precedence can be either substantive or derivative or both. Substantive precedence belongs to those whose rank or place are independent of their connection with anyone else; *e.g.*, peers, baronets, knights, etc.. and the holders of certain high offices of church and state such as the archbishop of Canterbury and the prime minister. This precedence cannot be affected by their relationship to anyone else but is inherent in the rank or position that they hold. Derivative precedence. on the other hand, belongs to those whose position is determined by their relationship (by blood or marriage) to someone else; *e.g.*, junior members of the royal family and the sons and daughters of peers. baronets. knights. etc. A peeress by marriage has both substantive and derivative precedence; she enjoys the former because she is a peeress and acquires the latter because she is the wife of a peer.

Precedence can also be either personal or official. Personal precedence (which can be either substantive or derivative) belongs to those whose rank in society entitles them to it: *e.g.*, the royal family, the peerage and certain specified classes of the commonalty. Official precedence (which must be substantive) is conferred' by the office held and not by the rank of the person holding it; *e.g.*, the speaker of the house of commons. If. however, a man's personal precedence is higher than his official rank, he is entitled to the higher place. The precedence of the sovereign is at one and the same time both personal and official.

It will be seen that precedence is thus usually acquired by one or more of the following methods: (1) birth (in the case of royal and most titled families); (2) marriage (in the case of many womenj; (3) accession to the throne or succession to a title or hereditary honour that carries precedence with it (*e.g.*, earl marshal); (4) the creation of a new title or the conferring of some honour or decoration; (5) appointment or election to certain posts or dignities. The first and the third methods must of necessity be limited to certain families. but many people are eligible for the other three. In England no man can acquire precedence by marriage but in some European countries, notably Italy, titles have often been held *jure uxoris* ("by right of the wife").

Not every hereditary honour confers precedence. The duke of Norfolk. for example. has special precedence as earl marshal, but the duke of Beaufort, as hereditary keeper of Raglan castle, has not. Nor does every decoration secure such recognition. Companions of the Distinguished Service Order (D.S.O.) have their place in the table of general precedence, but holders of the Victoria cross, although entitled to place the letters V.C. after their name (in precedence of all other designating initials): do not. The George cross and the military cross fall into the same category. Similarly, members of the Order of Merit and Companions of Honour place the letters O.M. and C.H. after their names but again receive no special precedence. Nor does rank in the Yenerable Order of the Hospital of St. John of Jerusalem (revived in England in 1888) secure recognition in matters of precedence.

Some officials, for instance the lord great chamberlain. enjoy the precedence of their office only when in the actual performance of their duties. The lord high commissioner to the general assembly of the Church of Scotland has the precedence of his office only during the sitting of the general assembly. Other officials have a different place allotted to them if their personal rank is of a sufficient degree. Thus the keepers of the great and privy seals of Scotland come above all other members of the peerage if they themselves are peers but belo the younger sons of dukes if they are commoners.

Certain members of the legal profession (*e.g.*, the lord chancellor, the lords of appeal in ordinary, the lord chief justice, judges, etc.) and of the church (*i.e.*, the archbishop of Canterburp, the archbishop of Tork and the diocesan bishops) have their place in the table of general precedence. Many professions meanwhile have a system of precedence of their own. This is a matter of custom and usage and remains unofficial. Thus military rank as such, however exalted, remains unrecognized by the table of general precedence.

Precedence Within the Peerage.—Precedence within the peerage is calculated according to the rank or degree of the peer. The Acts of Union with Scotland and with Ireland laid down the following order as between peers of equal degree: first, peers of England, next, peers of Scotland. then peers of Great Britain, then peers of Ireland and then peers of the United Kingdom (and of Ireland created since the union) according to the dates of their respective patents. No Irish peerage was created after 1898; and all new creations are now always of the United Kingdom. Baronets, on the other hand. rank among themselves solely according to the dates of their respective patents and irrespective of the country of origin of their title.

Courtesy titles, as the name suggcsts, are a matter of usage and confer no precedence as such. The children of peers enjoy such titles (see FORMS OF ADDRESS), but remain commoners; and their precedence derives from their relationship to their father and not from any courtesy title that they may enjoy.

Foreign titles of nobility conferred on British subjects carry no precedence in the United Kingdom and, strictly, should not be used unless a royal licence has been obtained. One French Canadian title is, however, recognized by the crown and so are the titles borne by the nobility of Malta. The latter enjoy precedence among themselves according to the date of the creation (and irrespective of the degree) of their title.

It is usual to accord to foreign noblemen, who of course have no legal precedence in the United Kingdom, a courtesy precedence equivalent to the rank that they bear in their own country.

The Precedence of Women.—The precedence of women is derived from the rank of their father or husband with the exception of a peeress in her own right. a maid of honour to the queen or to the queen dowager, a privy councillor (the first woman appointed was in 1929) or the holder of an order of knighthood (the British Empire Order has always been open to women and the Royal Victorian Order has since 1936) or companionage (the Imperial Service Order was opened to women in 1908). Any woman bearing a title derived from her husband loses it on remarriage. It is customary for the widow of a peer or baronet to have precedence of the wife of the incumbent of the title. Daughters of peers come immediately after the nives of their elder brothers but before the wives of their younger brothers.

The wives of high officers of state have no special precedence as such. Kor have the wives of archbishops or bishops. The anomaly in the latter case prompted Queen Elizabeth I to say to the wife of the archbishop of Canterbury. "Madam I may not call you; mistress I am ashamed to call you; so I know not what to call you; but howsoever I thank you." As most professions are now open to them women can achieve high rank by their own efforts.

Local Precedence.—There is no official order of local precedence. but in counties H.M. lieutenant (usually called lord lieutenant) has priority of place, and after him the high sheriff. In boroughs the mayor is the first citizen and naturally presides at all municipal occasions. Should, however, both the mayor and the lieutenant be present as guests at the same function (even though it be in the mayor's borough) the lieutenant takes precedence. Neither has any place allotted to him in the scale of general precedence. In the City of London precedence is decided by the terms of the royal charter. which fixes the place of the lord mayor, of the chamberlain and of the recorder, and by resolution of the corporation. There is a fixed order of precedence among the city guilds or livery companies, the 12 great London companies coming first. It is obvious that at any public function given in honour of some guest that that guest will then have precedence next to his host.

The Precedence of the Diplomatic Corps.—As many ceremonies of state involve the diplomatic corps, diplomats occupy a prominent position in social life. The practice of diplomacy. which had occasioned many unseemly disputes (notably that between the Spanish and French ambassadors in London in 1661) was regularized by the decrees of the congresses of Vienna (1815) and of Aix-la-Chapelle (1818) on an agreed basis.

Four categories of representatives mere recognized: (1) ambassadors, legates or nuncios; (2) envoys extraordinary and ministers plenipotentiary: (3) ministers resident; (4) chargés d'affaires. Precedence within the corps was established on the basis of seniority of appointment, so that the doyen (or dean) of the corps is that ambassador who has been accredited to his post the longest; *i.e.*, from the date of his official arrival and presentation of his letters of credence. In most Roman Catholic countries where the church enjoys a special position, the nuncio takes precedence over all his colleagues regardless of the date of his appointment. Even in this case! however, the senior ambassador continues to discharge most of the functions of the doyen. (It may here be mentioned that in Roman Catholic monarchies cardinals would rank with princes of the blood.)

For consular officers (consuls general, consuls, vice-consuls and consular agents) there is a comparative precedence which equates them with certain ranks of the fighting services. Thus consuls general rank with but after rear admirals, major generals and air vice-marshals, while consuls rank with but after captains of the royal navy, colonels and group captains of the royal air force.

In monarchical countries ambassadors usually have precedence after members of the reigning family or high dignitaries of church and state. In England they follow the lord privy seal, while ministers come after dukes but before marquesses. In republics practice varies: thus in France ambassadors come after the presidents of the senate and of the chamber of deputies, whereas in the Cnited States they come after the vice-president and before the chief justice. Most questions of ceremony, of precedence, etc., are settled by the *chef* de protocol (in England H.M. marshal of the diplomatic corps).

The British Commonwealth.—Soon after Canada became a dominion in 1867, the secretary of state for the colonies sent a letter (1868) to the governor general which contained instructions as to precedence. Since then various royal warrants have regulated precedence throughout the rest of the British Commonwealth. Where members of the commonwealth have become republics they have issued their own tables. Broadly speaking, these follow much the same pattern. The governor general (or president in the case of a republic) naturally takes first place. In Canada, New Zealand. South Africa, India. Pakistan and Ceylon the prime minister comes next, but in Australia the governors of states precede the prime minister. High dignitaries of the church rank after the provincial governors in Canada and before the chief justice. whereas in South Africa the chief justice comes before both cabinet ministers and ambassadors. Members of the royal family take precedence after the governor general. although on certain occasions they have been accorded precedence before him.

Considerable confusion has been caused in the commonwealth where there are both state and federal lists of precedence. which do not always accord with one another. There has also been disagreement at times as to whether precedence in England is valid elsewhere in the commonwealth.

In the United Kingdom the high commissioners for the dominions or member states of the commonwealth had all formerly ranked after secretaries of state in order of precedence. In 1948, however. those of Canada. Australia, New Zealand, South Africa. India, Pakistan. Ceylon and Eire were promoted to rank with ambassadors (the high commissioner for Eire was in fact replaced by an ambassador in 1950), their precedence among themselves being based on seniority of appointment, as among ambassadors.

Tendencies of the 20th Century.—As the prevailing policy of the 20th century favours republican forms of government, questions of precedence occupy less attention than heretofore. Even in the few remaining monarchies rank and title possess less significance than before. Thus in Denmark and in Norway all titles have long been abolished. In Japan all titles of nobility were abolished and the house of peers was replaced by a house of councillors in 1945; and the imperial house law of 1947 restricted the emperor's family to his children, his brothers and sisters and their issue, with the result that 51 princes of 11 princely houses became commoners. Most modern orders (for example the Légion d'Honneur in France and the 16 orders created in the U.S.S.R.) do not entitle the recipients to any privileges but are simply marks of recognition of merit and service.

The 17th and 18th centuries were the golden age of court ceremonial; *cf.* the *Mémoires* of the duc de Saint-Simon. Since that time the importance of questions of precedence has grown less and less pronounced. The emphasis has altered from rank and title to office and position. It is in fact a person's office rather than his personal rank or his relationship to someone else that now tends to be the governing factor in determining his precedence.

See the full tables of general precedence for men and women in England, Scotland, Northern Ireland and the commonwealth as set out in *Burke's Peerage* (London, biennial) and *Debrett's Peerage* (London, annual). (S. B.-R. P.)

THE UNITED STATES

Precedence at official functions and ceremonies in the United States is based upon official position and custom. The latter, outside of Washington, D.C.. reflects the social and economic variables found in state and local communities on official occasions. and these affect strictly official considerations in the order of precedence in terms of religion, wealth and other factors determining civic status. Political expediency rather than statutes prevails in the determination of the hierarchical order in public ceremonies. The tendency toward informality at state and municipal functions is in sharp contrast with the more ostentatious public affairs of the 19th century.

Washington, **D.C.**—Precedence in the capital of the U.S is subject to a combined governmental and diplomatic ranking which makes the department of state the arbiter. The division of protocol not only rules on official ranking, but informally provides essential guidance for social functions where official status at the national or international level is involved. Precedence has been established by custom as: the president; vice-president; speaker of the house of representatives; chief justice of the supreme court; ambassadors of foreign powers, ranked according to diplomatic rule of seniority by the date of presentation of credentials; secretary of state; ministers of foreign powers in order of diplomatic seniority; associate justices, according to date of commission; retired associate justices; the president's cabinet (the secretary of state excepted), in the order of the establishment of their offices: secretary of the treasury, secretary of defense, attorney general, postmaster general, secretaries of the interior, agriculture, commerce, labour, and health, education and welfare.

Chairman, the Atomic Energy commission; the director of the budget; the director of civil and defense mobilization; senators; governors of states; representatives; undersecretaries of state: deputy secretaries of defense; chairman, council of economic advisers; chargés d'affaires of foreign powers; secretaries of the army. navy and air force; chairman of the federal reserve system; undersecretaries, or their equivalent, of the cabinet; chairman of the joint chiefs of staff; chief of staff of the army; chief of naval operations; chief of staff of the air force; director of central intelligence.

General Services administrator; special assistants to the president; chairman, civil service commission; five-star generals and admirals; secretaries to the president; the secretary-general of the United Nations; the secretary-general of the Organization of American States; deputy undersecretaries of state; assistant secretaries of government departments; chief of protocol; governors of territories; undersecretaries of the army, navy and air force; four-star generals and admirals; lieutenant generals and vice-admirals; counsellors of foreign powers; major generals and rear admirals; brigadier generals and commodores; subordinate government officials.

States. — Generally speaking. the states of the union follow a rule-of-thumb order of precedence on official occasions. Reception and seating depend upon the obvious political ranking and the expedient religious, economic and social considerations in a given situation involving status. This situation has been facilitated by a departure from large, formal state affairs with a trend toward informality in official entertainment.

Municipalities. — U.S. cities set up their own protocol for the reception of distinguished visitors. This follows a general political pattern of officials, headed by the mayor or his equivalent in other types of urban government or his representative for the occasion. Precedence again is weighed in terms of religious and civic status; it is flexible in its application in order to permit adjustments suitable for each function.

After World War II the increasing number of foreign visitors to the U.S. with official or quasi-official sponsorship made strategically located cities important points of reception. Chief of these is New York city, where the mayor's office has special machinery for extending such hospitality to visitors. The commissioner of commerce and public events is charged with all arrangements; an officer under him works out the problems of reception and precedence. This official is in contact with the state department and the visitor's diplomatic mission in Washington or local consular representation; where the visitor's status warrants extensive ceremonies—a chief of state. head of government, etc.—these are planned by close consultation as to details of time, place and guest list.

U.S. Reception Centres. — Due to the expanding program of special visitors to the U.S. under the state department program of cultural exchanges, reception centres have been established at key points of entry to handle problems of official greeting and orientation. These are New York city. Miami. Fla., New Orleans. La., San Francisco: Calif., Seattle, Wash., and Honolulu. Hawaii. They are maintained by the department of state and operated under the joint sponsorship of the International Educational Exchange service and the International Cooperation administration. Each centre utilizes the community opportunities of the area and provides an official welcome to such visitors. During 1955 these centres served a total of more than 10,000 foreign nationals of various categories entering or leaving the U.S., including a number of diplomatic visitors.

THE UNITED NATIONS

The seat of the United Kations. though geographically located in New York city, enjoys a special international status under the headquarters agreement with the United States. U.S. jurisdiction. national. state or local. operates around the territorial centre of UN activities though there has been no alienation of U.S. territory. The U S organs with their personnel located at the headquarters are guaranteed inviolability in their functioning and the diplomatic status of the representation of all member states is recognized by the U.S. subject to suitable security arrangements.

Precedence is a matter wholly determined by the UN itself in governing its procedures, ceremonies and social functions. Directly under the secretary-general there is a unit at the headquarters to handle problems of precedence similar to that in any foreign office, the chief and assistant chief of protocol. Here all UN precedence. whether procedural. ceremonial or social. is determined. There are no hard-and-fast rules nor any official list. Precedence is a developing process which combines regulations for the functioning of UN bodies. their officials and representatives of member states with appropriate diplomatic conventions currently prevalent in international intercourse.

Basically. UN precedence rests on function and not upori the personal rank of the person discharging the duty. Hence the president of the assembly, irrespective of the delegate's personal rank, is the ranking official of the UN when the assembly is in session. The president of the Security council, the second most important organ in terms of the charter, becomes the chief functionary in terms of protocol if the assembly is not in session. However. since the headship of the Security council rotates each month among the members. the person enjoying this prerogative changes accordingly.

The third post is that of the secretary-general. the executive-administrative officer of the UN who heads the secretariat. Then follow the presiding officers of the specialized organs of the UN, the Economic and Social council, the Trusteeship council. etc., when in session; the heads of the permanent delegations accredited by the member states to the UN of ambassadorial rank; the assistant secretary-general and the undersecretaries: heads of delegations of ministerial rank; the operating heads of the departments into which the secretariat is subdivided.

The diplomatic practice that ambassadors and ministers rank according to the date of their appointment is not followed at the UN; strict observance of the alphabetical order of the countries they represent is the rule in sessions and elsewhere. In sessions of the UN organs. the actual seating facilities of the chambers used at headquarters, at Geneva, Switz., and elsewhere affect the working out of precedence for those occupying places on the rostrum; the alphabetical order in general seating of delegates on the floor rotates from front to rear so that the position of a member state's spokesman moves progressively. meeting by meeting, and no country enjoys a preferred position by reason of its name.

(Cs. H.)

ROMAN CATHOLIC CHURCH

In the canon law of the Roman Catholic Church precedence in the narrow sense means the right to a place of higher dignity in public conventions or manifestations — in synods. processions, elections. etc. More broadly, it means the higher rank or order itself, whence flows the right to walk. or be seated, in the place of greater honour. The general norms that govern precedence are given in canon 106; special norms regarding special personages are given elsewhere in the code. Within the universal church. precedence according to rank and order is the following: cardinals (in this order: cardinal legate a *latere* [papal legate]. cardinal deacon and subdcacon, cardinals of the episcopal, preshyterial and diaconal orders); legates of the Roman pontiff; patriarchs; primates; metropolitans and archbishops in their own provinces; the bishop in his own diocese: archbishops and bishops outside their own provinces: abbots and prelates *nullius* (of no diocese); vicars and prefects apostolic: administrator apostolic and capitulary vicar; vicar-general: canons (dignitaries, titular canons, honorary canons. canons with benefices); vicars forane; pastors; substitute and assistant vicars; curates. Clerics and religious generally precede the laity, except where contrary custom prevails in the case of lay personages of dignity. In determining individual precedence no distinction is made between the secular and the religious clergy. When both orders of the clergy are present as groups, the secular clergy precedes the religious clergy, and within the latter order certain customary rules obtain; *e.g.*, canons regular precede monks, monks precede clerics regular, etc. Within his own diocese the bishop determines the order of precedence, under regard for canon law. and judges controverted cases. From his judgment appeal may be made to various Roman congregations according to the case.

See G. Michiels, *Principia generalia* de *personis* in *Ecclesia*, 681–697 (1955). (X.)

PRECESSION OF THE EQUINOXES, in astronomy, an effect connected mainly with a gradual change of the direction of the earth's axis of rotation. There is a general resemblance between the motion of the earth and that of a spinning top. It is well known that when a top is slightly disturbed its axis precesses round the vertical so that it traces out a cone; the earth's axis similarly describes a cone at the rate of one revolution in about 26,000 years. In applying this analogy we must take the ecliptic (*i.e.*, the plane of the orbit of the earth round the sun) to correspond to the horizontal: the axis about which the earth spins is inclined at $23\frac{1}{2}°$ to the "vertical." and keeping this inclination it turns slowly round the "vertical." It must be emphasized, however, that this correspondence between the earth and a top is superficial, the cause of the precessional motion being upon different principles.

In this nay the north pole of the celestial sphere describes among the constellations a circle of $23\frac{1}{2}°$ radius, making a revolution in 26,000 years. At present it is near the star α Ursae Minoris, which is therefore called the polestar; but it has traveled a considerable distance within historic times. About 3000 B.C. the star a Draconis would have served as polestar; in 13000 B.C., also in A.D. 13000 Vega would he near enough to the pole to mark roughly its position. By this displacement the part of the sky visible from a particular terrestrial station gradually changes; certain constellations cease to rise above the horizon and others appear for the first time. In the time of the early Chaldean astronomers it was not necessary to travel so far south to see the Southern Cross as it is now.

Cause of Precession. — This was first explained by Isaac Newton. It is due to the attraction of the sun and moon on the equatorial protuberance of the earth. the moon being responsible for about two-thirds and the sun for one-third of the motion — the same proportion as the lunar and solar tides. Treating the equatorial bulge as an extra ring of matter surrounding a spherical earth, the attraction of the sun and moon on this ring gives a couple tending to turn the ring into the plane of the ecliptic, since both disturbing agents are in or near the ecliptic. If the earth were not spinning this would turn the earth over until the equator coincided with the ecliptic, but the spinning earth behaves like a gyrostat, so that its axis moves at right angles to the plane of the couple — just as the couple which would upset a top at rest gives the axis of the spinning top a conical motion.

The moon's orbit is inclined at about j° to the ecliptic, but it does not remain still; its nodes travel round the ecliptic in 18.6 years. Averaged over a long period of time the deviations of the moon from the ecliptic cancel out; but at any moment the precession caused by the moon may be greater or less than the average, according to the position at the time of the lunar orbit. In fact the path of the pole among the stars is a slightly sinuous curve. Astronomers distinguish the average secular motion as precession and the periodic fluctuations or sinuosities as nutation.

As the pole (corresponding to the equator) moves round the pole of the ecliptic, so the equinox or intersection of the equator and ecliptic moves round the ecliptic once in 26,000 years. Both right ascensions and longitudes are reckoned from the equinox as zero point; stellar longitudes on this account increase steadily by nearly a minute of arc every year; the effect on the right ascensions is more complicated: but these also continually increase. The vernal equinox is commonly called the first point of Aries, but it has already moved away from that constellation and is now in Pisces. It should be understood that the precession of the equinoxes has no effect on the seasons, and, for example, has no connection with the gradual departure of the spring equinox from March 21 which occurred in the old Julian calendar.

Planetary Precession. — Besides the foregoing lunisolar precession, a phenomenon of much smaller magnitude. known as planetary precession. is recognized. It is due to perturbations by the planets which cause slow changes in the plane of the earth's orbit. Planetary precession changes the position of the ecliptic, whereas lunisolar precession changes the position of the equator; either change affects the equinox. which is the intersection of the two planes. Corrections for precession and nutation are of great importance in most branches of positional astronomy.

PRECIPITATION, in meteorology, denotes all forms of water falling upon the earth's surface. It includes rain and snow and their various modifications such as drizzle. freezing rain, sleet, snow pellets and hail. Precipitation is considered to he one of the most important of all meteorological elements since it is the only important source of fresh water.

The essential difference between a precipitation particle and a cloud particle is one of size. An average raindrop has a mass equivalent to several million cloud droplets. Because of their large size, precipitation particles have significant falling speeds and are able to survive the fall from the cloud to the ground. (See CLOUD.)

Precipitation Formation. — The transition from a cloud containing only cloud droplets to one containing a mixture of cloud droplets and precipitation particles involves two basically different steps: formation of incipient precipitation elements directly from the vapour state: and subsequent growth of these elements through aggregation and collision with cloud droplets. The initial precipitation elements may be either ice crystals or chemical solution droplets.

Development of precipitation through the growth of ice crystals depends upon the fact that cloud droplets usually do not freeze at temperatures warmer than about $-40°$ F. (The reduction of cloud droplets to temperatures below the normal freezing point is termed supercooling.) Within supercooled clouds. ice crystals may form through sublimation of water vapour upon certain atmospheric dust particles known as sublimation nuclei. In natural clouds. ice crystals form at temperatures colder than about $+5°$ F. The exact temperature of ice-crystal formation depends largely upon the physical-chemical nature of the sublimation nucleus.

Once they are formed within a supercooled cloud, ice crystals will coritinue to grow as long as their temperature is colder than freezing. The rates of growth depend primarily upon the temperature and degree of vapour saturation of the environmental air. The crystals grow at the expense of the water droplets. As the crystals grow. the droplets evaporate by virtue of the fact that the saturation vapour pressure over an ice crystal is less than over a supercooled water surface at the same temperature. In favourable conditions, *e.g.*, in a large. rapidly growing cumulus cloud, an ice crystal will grow to a size of about 0.005 in. in three to five minutes after formation. At this size, the rate of growth through sublimation slows down and further growth is largely through aggregation and collision with cloud droplets.

Small solution drops are also important as incipient precipitation particles. The atmosphere contains many small particles of soluble chemical substances. The two most common are sodium chloride. swept up from the oceans by spray and bubbles, and sullate-hearing compounds formed through gaseous reactions in the atmosphere. Such particles, known as giant condensation nuclei, collect water because of their hygroscopic nature and, at relative humidities above about 80%, exist as solution droplets. In tropical maritime air masses the number of giant condensation nuclei frequently is very large. Clouds forming in such air may develop a number of large solution droplets long before the tops of the clouds reach temperatures favourable for the formation of ice crystals.

Regardless of whether the initial precipitation particle is an ice crystal or a droplet formed on a giant condensation nucleus, the bulk of the gromth of the precipitation particle is through the mechanisms of collision and coalescence. Because of their larger size, the incipient precipitation elements fall faster than cloud droplets. As a result they collide with the droplets lying in their fall path. The rate of growth of a precipitation particle through collision and coalescence is governed by the relative sizes of the particle and the cloud droplets, the size and number of cloud droplets, the fraction of the droplets in the fall path which are actually hit by the precipitation particle and the fraction of these droplets which actually coalesce with the particle after collision. Under ordinary cloud conditions it takes between 10 and 20 minutes for an incipient precipitation element to grow into a large raindrop or a large snoaflake.

The efficiencies of the natural precipitation processes are known to be rather low. Although vast amounts of vapour are condensed into cloud droplets to form clouds, most of this water re-evaporates without becoming involved in the precipitation processes. Precipitation particles also suffer considerable loss from evaporation in falling from the cloud bases to the ground. Studies carried out on thunderstorms in the humid eastern part of the United States show that only about 20% of the condensed water reaches the ground as rain. In the arid regions, the bases of clouds may be so far above the ground that most of the rain is evaporated between the clouds and the ground. (See CLIMATE AND CLIMATOLOGY.)

Measurement of Precipitation.—Rain gauges and snow gauges are used for measuring precipitation. The amount of precipitation is expressed in terms of the total equivalent amount of liquid water. Thus snow, caught in a gauge, is melted before measurement. In regions where snow forms an important fraction of the precipitation, it is customary to measure the amount of snow by means of a snow survey. (See SNOW.) In snow surveys it is necessary to determine the density as well as the depth of the snow in order to determine the water content.

The data from rain gauges and snow surveys are subject to large sampling errors, particularly during periods of sho er and thunderstorm activity. The spacing between gauges usually is several times the size of the shower rain area. Over a period of several weeks or months errors due to rain-gauge spacing tend to be averaged out.

Precipitation measurements, when collected from many places, form the basis for estimating the amount of rain falling in a region. Such data are available for regions all over the globe. Because of the problems of sampling rainfall and because of variations in rainfall from one year to the next, climatologists desire at least 40 years of record for computing average annual precipitation amounts.

The development of centimetre wave-length radar during World War II gave the first means of accurately identifying and locating precipitation areas. (See RADAR METEOROLOGY.) When combined with a few scattered rain gauges, radar enables meteorologists and hydrologists to determine the amount of precipitation falling on a given area more accurately than with the rain gauges alone.

Artificial Control of Precipitation.—Throughout recorded history, there have been attempts to control precipitation. Early societies employed various forms of magic in their efforts to increase rainfall. During the latter part of the 19th century, experiments using cannon shots. explosions and large fires were carried out for the same purpose. During World War I it was not infrequently observed that rain occurred during or immediately following major battles. and it was believed by many that the sounds of the cannons were responsible for causing the clouds to release the rain. Subsequent findings disproved this idea.

The first series of systematic experiments designed to discover the physics of precipitation and thereby find a means of producing precipitation were carried out by Vincent J. Schaefer in 1946. These experiments, ultimately involving seeding clouds with silver iodide smokes. were successful in causing light snow to fall from supercooled stratified clouds.

Experiments to increase precipitation rest upon the hypothesis that natural precipitation is limited by a shortage of natural precipitation nuclei. Silver iodide smokes, produced by burning a silver iodide-acetone solution. will supply sublimation nuclei effective at temperatures colder than about 23" F. A different approach to the problem of increasing rain involves the release of giant condensation nuclei, or small waterdrops, into suitable clouds in order to initiate rain through the collision-coalescence mechanism.,

Whether or not the amount of precipitation at the ground can be increased through any of these techniques depends largely upon large-scale meteorological factors governing the formation, growth, duration and dissipation of the clouds.

Because of the fact that natural rain is highly variable in time and space, very carefully designed experiments are necessary in order to determine the efficacy of any given rain-making technique. When rain falls from a seeded cloud, one naturally asks whether or not it would have fallen had the cloud not been seeded When rain fails to fall, one asks whether seeding prevented it. Because of this uncertainty it is impossible to estimate the effect of cloud seeding from a few isolated experiments or from experiments which do not include a group of randomly selected, nonseeded control cases, as statistical methods would require.

From the extensive experiments carried out between 1946 and 1956, it was learned that it is possible to modify some clouds and in some very favourable conditions to cause more precipitation to fall than would have fallen through natural processes. The magnitudes of these increases are not known, although they are usually thought to be less than 10%.

Chemistry.—Precipitation, in chemistry, is the process in which a substance separates from a solution as a solid. Precipitation is an important step in many chemical processes.

It may be accomplished by the concentration of the solution to the point where it is supersaturated, when. upon cooling, a part of the solid separates out, though this process is usually described as crystallization (*q.v.*). It may also be accomplished by the addition of reagents which may combine with the material to form an insoluble compound, or which may displace the material from the original solution.

The application of heat may cause coagulation, as with certain proteins, and the removal of gas may also alter conditions sufficiently to cause precipitation. A change of temperature is another method.

The salting out process as employed in the soap industry is a familiar example of precipitation. The formation of the fibre from a solution of cellulose by causing it to pass into a setting bath is a case of precipitation used in the artificial-silk industry.

See Horace R. Byers, *General Meteorology* (1944); John C. Johnson, *Physical Meteorology* (1954). (R. R. BM.; X.)

PRECISION GAUGES AND COMPARATORS. Interchangeable manufacture, pioneered about 1800 by Eli Whitney, made it essential to maintain close dimensional control of products from widely separated factories. Precision gauges and comparators are the means by which industry achieves the necessary dimensional control.

Limit Gauges.—The reproduction of dimensions of mechanical parts within specified dimensional limits of variation, or tolerances, is facilitated by checking with gauges. such as a "go" gauge representing the maximum-metal limit and a "not go" gauge representing the minimum-metal limit. Limit gauges used on products are also known as inspection or working gauges. Gauges used as standards of comparison for measuring the dimensions of inspection gauges are known as master or reference gauges.

Gauges are manufactured by highly skilled gauge makers in a large variety of forms, corresponding to the forms and dimensions of parts to be gauged and to principles of gauge design.

Master Gauges.—Precision gauges and comparators have been extensively developed since about 1850, when Sir Joseph Whitworth produced the original measuring machine and the system of accurate dimensional standards or master gauges (both end gauges and cylindrical gauges) for use with it.

On the market in the mid-1950s were these forms: (1) Precision gauge blocks or slip gauges, which are end standards of rectangular, square or circular section having accurately flat, parallel ends, available in sets of numerous selected lengths of blocks so that all dimensions, within the range of the set, can be produced in small increments such as 0.00005 in. by combining or wringing the blocks. *(See* METROLOGY.) These were invented in 1896 by C. E. Johansson of Eskilstuna, Swed., who used a hand-lapping method for their production, and are often called Johansson blocks. In 1918 a machine-lapping method was developed by Maj. W. E. Hoke at the national bureau of standards in Washington. D.C. Gauge blocks have since been produced by more than a dozen manufacturers in four standard qualities which are accurate to 0.000002, 0.000004, 0.000008 or 0.000010 in. (2) End measuring rods in the form of steel bars having flat or spherical ends. (3) Master disks which are accurately lapped steel cylinders, frequently preferred to gauge blocks when pieces to be checked by comparators are round. (4) Gauges having composite surfaces. such as screw thread, profile or spline gauges. (5) Angle gauge blocks in sets of 13 or 16 selected angles, combinations of which are wrung together to produce any angle to 90°, or with an additional square block to 360°, to the nearest second by addition or subtraction according to the relative directions in which blocks are assembled.

Measuring Machines. — Horizontal comparators commonly are designated measuring machines. These have means provided for measuring the difference between the test object and the standard, usually a micrometer screw having a divided head. Such comparators also often embody line standards of length, which may be used instead of contact length standards. A massive cast-iron bed is provided with straight ways, on which are mounted the headstock carrying the micrometer screw and one measuring anvil and the tailstock carrying the other anvil. Devices are provided, usually in the tailstock, for ensuring a constant contact pressure, which is necessary to obtain accurate comparisons. However, such devices were absent in the early models, such as the Whitworth and the Rogers-Bond universal comparator patented in 1885. There have been several different measuring machines of the modern type.

A further elaboration of measuring machines is a means for providing high amplification of the displacement of one of the anvils, such as an optical lever in the millionth comparator of J. E. Sears, providing an amplification of 30.000 times, and the Pratt & Whitney electrolimit tailstock, of 5,000 or more.

Vertical Cornparators. — In comparators of the vertical type, the master gauge and work are in turn supported on a substantial and level surface plate or anvil. The measuring contact and the amplifying mechanism which it actuates are adjustably mounted on a vertical column. These widely used instruments are available with various amplifications up to 20,000 (sometimes higher), obtained by means of a mechanical amplifying system as in the mikrokator and various dial comparators or by a combination of mechanical and optical levers as in the Zeiss optimeter and the Sheffield visual gauge or by an inductance bridge circuit as in the Pratt & Whitney electrolimit comparator, Sheffield electrichek or DoAll electric comparator.

The Brooks tilting level comparator compares two gauge blocks directly by a highly sensitive spirit level resting by ball feet on both gauges. The Watts microoptic comparator reads plunger displacement directly on an attached scale by micrometer microscope.

Interferometers. — Gauge blocks of the same nominal length can be compared, using interference of light waves. with the help of two test flats and a source of monochromatic light. The two gauge blocks are wrung edge to edge on one flat, and the second flat is placed so as to make line contact at the common edge of the thicker gauge and the other edge of the thinner. (For a discussion of the "wringing" effect, *see* METROLOGY: ***Calibration.)*** Both gauges are then seen crossed by dark bands parallel to the common edge; these represent contour lines of the air wedge between gauge and flat corresponding to integral numbers of half wave lengths of the light employed Specifically, the number of lines crossing the thinner gauge is equal to the difference in length of the gauges in units of one-half wave length.

Another method, not relying on line contact, uses polychromatic light, such as helium, which produces fringes of various identifiable colours. Here the systems of fringes crossing the two gauges are merely displaced relative to each other, and a given fringe is displaced along the common edge by a number of fringes (not necessarily integral) equal to the difference in height in one-half wave lengths.

Using collimated light and suitably filtered wave lengths, fringes can be seen between the two flats themselves if the separation is not too great. The method of coincidence of excess fractions *(see* LIGHT) can be employed to make direct determination of the length of gauge.

In 1926 a form of Michelson interferometer was devised with one vertical arm, incorporating a monochromator for isolating the various wave lengths. This instrument doubled the measurable length of gauge by working on either side of the central white light fringe system. It still required wringing the gauge to one flat. A later form of Michelson interferometer, in which the wringing is dispensed with, operates by reflecting from both sides of the gauge; it also permits the intercomparison of angle blocks of the same nominal value.

Internal Comparators. — The precise determination of an internal dimension presents special difficulties, which have been largely overcome by the development of internal comparators of different designs. Prior to the availability of such comparators, or in their absence, the sizes of such objects as ring gauges either plain or threaded, were usually estimated by the nature of their fit upon corresponding plug gauges.

When a cylindrical plug and ring are perfectly clean and dry, they will assemble if the largest diameter of the plug is the same or smaller than the smallest diameter of the ring. If well finished and liberally covered with a lubricant having high oiliness properties, a cylindrical plug gauge will enter and pass through a ring gauge which is as much as 0.0002 in. smaller than the plug without damage to either, provided that distribution of the lubricant is maintained by constant relative motion of the gauges.

The following instruments were available for the measurement of internal dimensions: the chord contact machine by G. A. Tomlinson, in which the displacement of a ball-ended piece is measured in a direction perpendicular to its length; the displacement type of internal measuring machine, having a micrometer and a double-ended stylus attached to a sensitive indicating mechanism. by J. E. Sears; the Sheffield internal-external measuring machine having gauging fingers which are positioned by means of precision gauge blocks and which move relatively to each other and actuate an amplifying mechanism; the Pratt & Whitney electrolimit universal internal comparator having one fixed and one adjustable gauging finger; the Swedish internal indicator gauge; and the Leitz Perflectometer, a special microscope.

A precision pneumatic micrometer was invented by Marcel Mennesson of France in 1928. This and other types of air gauges are uidely used to compare internal dimensions. A cylindrical spindle, somewhat smaller than the hole to be measured, has diametrically opposed orifices through which regulated compressed air is forced. The spindle is first inserted in a ring gauge of known size and then in the piece to be measured. The difference in pressure or in rate of flow of the air from the spindle in the two cases is indicated in different makes by a manometer, a pressure gauge or a float in a tapered glass tube which are suitably calibrated to yield measurements of differences in size as small as 0.00001 in. or less.

Automatic Gauging. — By the mid-1950s, rapid advances were being made in controlling machine tools by gauging their products; the products were gauged either while still on the machine or just after leaving it. For these applications, micrometers of the pneumatic or electromagnetic type were the most successful.

Projection Comparators. — The measurement of the dimensions of profile gauges and the thread angles and profiles of screw thread gauges is facilitated by optical projection methods, developed largely during and after World War I by the Kational Physical laboratory in London and the national bureau of standards in Washington, D.C. Further commercial developments of these methods are embodied in projection comparators of the Wilson, Hartness or Jones and Lamson. Bausch and Lomb, Eastman and other types; and in the tool makers' microscopes of Gaertner, Taylor-Hopson and others.

(*See* also DIMENSIONAL ANALYSIS; PHYSICAL UNITS.)

BIBLIOGRAPHY.—*Annual Reports* of *the National Physical Laboratory* (London); *R*. T. Glazebrook, "Design of Scientific Instruments," "Gauges," "Meters" and "Metrology" in vol. 3, *Dictionary of Applied Physics;* C. *G*. Peters and H. S. Boyd, "Interference Methods for Standardizing and Testing Precision Gauge Blocks," U.S. National Bureau of Standards *Scientific Papers No. 436;* J. *E*. Sears, "Precise Length Measurements," Cantor Lectures, *Royal Society of Arts* (1923); F. H. Rolt, *Gauges and Fine Measurements*, 2 vol. (New York, London, 1929); I. H. Fullmer, "Fundamentals of Mechanical Dimensional Control," *Mech. Engr.*, 57 (1935); International Business Machines Corporation, *Precision Measurement in the Metal-Working Industry*, 2 vol. (Syracuse, N.Y., 1942–44); C. W. Kennedy, *Inspection and Gaging* (New York, 1951; Brighton, 1952); National Physical Laboratory, *Engineering Dimensional Metrology*, 2 vol. (London. 1955); K. J. Habell and A. Cox, *Engineering Optics* (London, 1948; New York, 1949); C. Candler, *Modern Interferometers* (Boston, 1950; London, 1951); W. Kliever, "Automatic Machining Control," *Control Engineering*, pp. 77–81 (Nov. 1955).

(I. H. F.; S. JN.)

PREDESTINATION, as actually employed in theological literature, is a term of many meanings. In its widest sense predestination is the divine act of foreordaining by which God eternally decrees all that He intends to bring to pass in time. In a narrower sense predestination refers only to those divine decrees by which God foreordains men to their supernatural end, whether to happiness in heaven for those who depart this life in the state of grace, or to eternal punishment for those who die in mortal sin.

Modern usage, horn-ever, restricts predestination to the divine decree foreordaining the happiness of the elect. The decree by which God rejects the wicked is called reprobation.

Theological controversy has further limited the meaning of predestination. Predestination may refer to the whole series of effects by which man is saved, embracing vocation to the Christian faith, election to grace, justification. final perseverance and eternal happiness. In this sense it is called complete or adequate predestination, or "predestination to grace and glory." On the other hand the term may be restricted to any one of these elements, particularly grace or eternal happiness. It is then known as incomplete or inadequate predestination, or "predestination to grace," "predestination to glory" alone.

The counterpart of predestination is reprobation. Here again, if the historical progress of the doctrine is to be rendered intelligible, the various meanings of the term must be distinguished. Positive reprobation is God's eternal decree to inflict everlasting punishment on those who, as He foresees, will die in the state of grave sin. Such reprobation is called antecedent if damnation is foreordained irrespective of the condemned person's sins; it is consequent if it follows upon God's prevision of final impenitence. Negative reprobation is a simple exclusion from heaven rather than a positive destination to hell.

Why God from eternity has chosen definite individuals to whom He gives efficacious graces that guarantee their salvation, whereas He gives other definite persons graces with which He foresees they will not co-operate, is the heart of the mystery of predestination. Theology cannot touch this mystery, as it has no revealed data upon which it may speculate. The principal problem which engages the attention of theological science is the reconciliation between God's will to save all men and the fact that not all are predestined. A further problem is the reconciliation between God's eternal foreknowledge of all events and human freedom of action. Still another difficulty is the relation between human freedom and the efficacious graces by which a person is conducted to eternal happiness.

God truly and sincerely desires the salvation of all men (I Timothy ii, 1–4), and therefore confers on all graces which are at least sufficient to enable them to attain to eternal life. But some men fail to reach this goal (Matthew xxv, 41). Not only does God eternally foreknow that a certain portion of the human race will be saved and who these individuals are, but He has foreordained their salvation (Matthew xxv, 34; Romans viii, 28–30; Ephesians i, 4–14). Thus on the one hand God wills all men to be saved, and on the other predestines only a definite number, known to Himself alone. If God is all-powerful, how can it be that His salvific will remains ineffective with regard to many persons? Those who are predestined will infallibly be saved. the rest will not. Hence the difficulty: how can predestination, which is altogether effective, be reconciled with God's universal salvific will, which remains ineffective with regard to many?

Three solutions to the problem have been proposed, as a historical survey of the doctrine of predestination reveals. Pelagianism simply denies predestination. Predestinarianism denies that God's salvific will is universal. Catholic theology, with which several Protestant systems agree, harmonizes the two by distinguishing between God's antecedent and consequent salvific will. God wills the salvation of all men conditionally, and antecedently to His prevision of their final state; but consequent upon this prevision He wills absolutely the salvation of all who die in the state of grace and the condemnation of those who die in the state of sin. This consequent will is called predestination insofar as it decrees the eternal happiness of the just, and reprobation insofar as it decrees the eternal punishment of the wicked.

The Patristic Period. — During the first four centuries of the Christian era the question of predestination was treated chiefly by the Greek fathers. In the west only a few of the Latin fathers who had come under the influence of oriental theological thought went into the subject. The Greeks taught unanimously that all events, including human actions, were governed by divine providence. God, they held, wishes all men to be saved, and therefore offers to all the grace which is necessary for salvation. Man, however, must freely co-operate with grace if he wishes to attain eternal life.

Greek thought concerning predestination culminates in the teaching of St. John of Damascus, who perfected the earlier doctrine especially by his insistence on the distinction between God's antecedent and consequent salvific will. If God is infinitely good, he asks. how is it that some men are lost? He replies by pointing out that many sin and persevere in their malice. God punishes them only in consequence of their sin. Prior to His prevision of sin He wills the salvation of all, because He is supremely good; if He punishes subsequently to sin, it is only because He is also supremely just. Hence God's antecedent will to save is not absolute, but conditional; His absolute will to reward or punish is consequent upon His foreknowledge of the good or evil will of man. Thus predestination, as an act of God, is in accordance with the divine prevision of man's co-operation with grace. This distinction was to prove of paramount importance in all later speculations on predestination.

However, of all theologians who have grappled with the problem of predestination the most influential teacher was undoubtedly St. Augustine. Against Manichaeism he had ably defended human freedom. He was called upon to put forth much more strenuous efforts to uphold the necessity of grace for good works against the Pelagians and the totality and initiative of the workings of divine grace against the compromise theory of the Semi-Pelagians. Augustine's position with regard to predestination can be appreciated only in relation to his insistence on the sovereign independence of divine grace against these naturalistic systems.

The Pelagians held that grace is not necessary for the observation of the precepts of Christianity; grace merely renders the observance of the law easier. Hence man can work out his salvation entirely of his own free will. In this view God foreknows who will be saved. but does not predestine anyone, except in the sense that He allots heaven as a reward for natural merit.

The Semi-Pelagians, while admitting the necessity of grace for growth in holiness, ascribed the beginnings of salvation and final perseverance until death to man's natural exertions, not to the initiative of God's prevenient grace. God's universal will to save is purely conditional; if men wish to attain heaven, they can do so by their own natural efforts. The sole difference among men proceeds from their natural merits. Predestination and reprobation are wholly dependent on man's free choice.

Confronted with these conceptions, Augustine felt impelled to uphold the gratuity of predestination. Without any merit on our part. he contended. God calls some men to the grace of faith and justification, inspires them to good works and confers on them the grace of final perseverance as a wholly special gift. He summed up the substance of his teachings in his celebrated definition: "Predestination is nothing else than the foreknowledge and foreordaining of those gratuitous gifts by which God makes certain the salvation of all who are saved." Accordingly predestination is free, unmerited and unfailing. The mystery of predestination does not lie in the co-operation between God and man in the working out of salvation, but in the unfathomable secret of the divine decree.

St. Xugustine did not deny the freedom of the will. as his adversaries alleged. nor did he deny the function of supernatural merit as a factor in predestination to glory as such. His whole intent was to propound the necessity and gratuity of grace and the gratuity of predestination completely considered, extending from the beginnings of faith to consummation in glory. By his insistence on the gratuity of predestination he denied the value of natural merit as a reason for predestination.

The difference between St. Augustine and St. John of Damascus is mainly a matter of emphasis. The latter stresses the universality of the divine salvific will; Augustine, because of the controversies in which he played so vital a part. stresses the doctrine of predestination. Although he, too. explicitly taught the universality of God's antecedent will to save, he came more and more toward the end of his life to insist on God's absolute, consequent will, which coincides with predestination. His teaching requires complementing by the wealth of the Greek tradition.

The Predestinarian Controversies. — The concept of predestination commonly known as predestinarianism is a tendency diametrically opposed to Pelagian naturalism. According to the doctrine of predestinarianism some men are predestined. by an absolute divine decree, to good works and to eternal life; others are foreordained to sin and to eternal punishment. The liberty of the will has been completely extinguished by original sin, and so avails nothing toward the attainment of salvation. Grace. which constrains the will in the direction of good, is bestowed only on the predestined. Thus, while Pelagianism and Semi-Pelagianism make salvation depend exclusively on man. predestinarianism makes God alone responsible for man's eternal destiny.

The predestinarian view goes back to a 5th-century interpretation of Xugustine's doctrine on eternal election and reprobation; indeed, throughout the history of the doctrine of predestination, all the adherents of predestinarianism claim Xugustine as their champion. Lucidus. a priest of Gaul, taught that God positively and absolutely predestines some men to eternal life, and others to eternal perdition. The elect have no part in working out their salvation; grace alone impels them toward their happy end. Christ did not die for the nonelect, as they were created expressly for hell. Faustus, bishop of Riez, demanded a retraction of Lucidus, who thereupon submitted. The second Council of Orange, held in 529, put an end to controversies on predestination for three centuries.

The dispute flared up again in the 9th century, and grievously agitated the whole Frankish empire for several decades. The monk Gottschalk of Orbais, claiming that his teaching was derived from Augustine, preached that there was a twofold predestination, of the elect to eternal life and of the reprobate to eternal death. Hence, he stated, Christ died exclusively for those who were from eternity destined for heaven; God's salvific will extends to these alone. Gottschalk's former abbot. Hrabanus Magnentius Maurus, wrote a refutation of his doctrine. At the instance of Hincmar, archbishop of Reims, Gottschalk was degraded at the synod of Quierzy in 849, was forced to burn his writings and was imprisoned in the monastery of Hautvilliers.

A number of scholars, such as Ratramnus of Corbie and Prudentius, bishop of Troyes, took sides with Gottschalk against Hincmar. Soon the whole empire was in turmoil; bishops, theologians and even several provincial and national synods engaged in the controversy. Finally in 860 a synod of the bishops of 14 provinces met at Toucy. A set of propositions on which all could agree was approved. God wishes the salvation of all men, and Christ died for all; the will remains free after original sin, and is aided by grace; the world is saved by grace. and the condemnation of the lost is the result of the abuse of their free will; the predestination of the elect proceeds from divine mercy.

Although this particular dispute came to an end. the fundamental question remained unsettled. The point at issue mas the everlasting conflict between two schools of thought. Some were wholly intent on asserting above all the primacy of the divine will; others stressed the free play of human activity in the process of salvation. The debates of the 9th century contain in germ all subsequent controversies concerning predestination.

The Middle Ages. — Predestination for the great doctors of the middle ages meant primarily "predestination to grace and glory," that is, predestination adequately considered, embracing the entire course from the first call to faith to the actual conferring of the beatific vision of God in heaven. Since man cannot merit the first grace, predestination itself is gratuitous and cannot be merited.

The chief task of the medieval theologians was the harmonization of the diverging points of view emphasized by St John of Damascus and St Xugustine. How could both doctrines be formulated in such a way that neither would exclude the other?

St. Thomas Aquinas, greatest of medieval doctors. succeeded in fusing the best elements of Latin and Greek thought. With Xugustine he taught that predestination completely considered is an entirely gratuitous gift of God With John of Damascus he held that God antecedently and conditionally wills the salvation of all men. But in consequence of His prevision of man's co-operation with grace. God wills absolutely the salvation of the predestined alone, and. as justice demands, decrees the damnation of the reprobate. This distinction restores to prominence the universality of the divine salvific will. which had been somewhat overshadowed since the days of Xugustine.

According to St. Bonaventura, who developed ideas previously sketched by Alexander of Hales, the eternal design with regard to man's ultimate destiny is wholly divine. As to the temporal gift of grace man can at most dispose himself negatively for its reception; on the other hand. man can freely reject the invitations of grace. The glorification of the just and the reprobation of the unjust are in accord with man's deserts: God rewards supernatural merit by the gift of eternal happiness and punishes sin by damnation. For these two doctors God's foreknowledge of supernatural merit or of sin precedes the formal sentence of eternal reward or reprobation.

In the theory of John Duns Scotus, God with sovereign independence predestines some men to eternal life and passes over the rest. Thereupon He determines the means which will effectively lead the elect to beatitude. Duns Scotus is the first to distinguish God's will respecting the end from His will respecting the means, and focuses attention upon incomplete predestination to glory as such, this, he held, is in no nay connected with God's foreknowledge of man's merits. His objective was to stress the completely gratuitous character of both means and end.

The Reformation. — Among the precursors of Protestantism, John Wycliffe held as probable the opinion that God determines creatures in all their acts. Hence some men are predestined to glory after a life of exertion. while others, called the foreknown, are destined to perpetual punishment folloning a life of misery.

Similar viens are developed by the reformers of the 16th century. According to Martin Luther, God is the cause of all that occurs; nhatever God wills necessarily takes place. Human freedom. he taught. has been completely vitiated as a result of original sin; therefore, nhatever man does, even though he attributes his actions to his free will. he does of necessity. Man's destiny is therefore totally in the hands of God, who absolutely predestines the elect to eternal life without regard to merit, and likewise foreordains the means which lead the elect to salvation.

Huldreich Zwingli, proceeding still further, contended that God destines certain men to salvation and others to perdition in order to show forth His justice. In pursuance of this choice God effects faith in the elect.

Philipp Melanchthon, who had originally agreed with Luther, later moderated his views. He advocated a doctrine of predestination which concedes that the promises of the Gospels have been made for the benefit of all. God from eternity elects those who He foresees will believe; those who are not among the elect have only themselves to blame.

But the great doctor of predestination among the reformers is John Calvin, who formed into a system various elements taken from St. Paul. St. Augustine. Wycliffe, Luther and Martin Bucer. Whatever happens, he taught, has been eternally decreed by God. The objective of all divine willing and doing is the glory of God. The first man fell into sin because God judged it expedient; why He so judged is impervious to us; certainly He would not hare thus judged unless He thereby saw that His name would be glorified. God has foreordained a part of the human race to salvation, a part to perdition. This twofold decree of the divine will is predestination. Calvin defines predestination as the eternal decree by which God has determined His will with regard to every man. Not all have been created in equal condition; some have been foreordained to eternal life, others to eternal damnation. In accordance with the end for which each man has been created, he is said to be predestined to life or to death.

This severe doctrine underwent many modifications in the course of the centuries. From the very beginning Calvin's supralapsarian teaching was often abandoned in favour of infralapsarianism. The supralapsarians maintained that God has unconditionally reprobated a part of the human race irrespective of the fall of Adam. The infralapsarians contended that God has decreed such reprobation only subsequent to His prevision of Adam's sin. In the beginning of the 17th century Jacobus Arminius and several other leaders of the Dutch Reformed Church taught that election by God to salvation is conditional, dependent on man's utilization of grace. At the Calvinist synod of Dordrecht (1618–19) the opinions of Arminius and his followers were condemned; his adherents were later expelled from Holland. Even among the stricter Calvinists supralapsarianism was not universally favoured; many preferred infralapsarianism. The decrees of the synod left the question open.

The Jansenistic theory of grace and redemption has many points in common with the infralapsarian form of Calvinism. Cornelius Jansen taught that God has predestined a part of mankind to eternal glory without any consideration of their merits. God does not will the salvation of all who have sinned in Adam. Those who are not predestined fall under the decree of negative reprobation; indeed, they may be said to be positively reprobated, for the divine will to exclude them from eternal life is equivalent to a decree of damnation. Christ did not die for the reprobate, but solely for the predestined.

In England the stricter tenets of Calvinism were never very popular, except among the Puritans. In the United States the Presbyterian Church mitigated some of the sterner features of Calvinism and stressed the universal character of God's love for man.

Roman Catholic Controversies Since the Council of Trent.—By the end of the Council of Trent the certain teaching of the Roman Catholic Church concerning predestination had been clearly formulated. Catholic theologians unanimously agree that predestination to the first grace is utterly incapable of being merited. and hence that complete predestination to grace and glory is in no may connected with God's prevision of merit. They likewise agree that formal condemnation to eternal punishment, or positive reprobation, is decreed by God only in consequence of the divine foreknowledge of death in the state of sin.

But with regard to two perplexing problems Catholic opinion is sharply divided. Is incomplete predestination to glory as such associated with God's foreknowledge of merit? According to revelation eternal glory is a reward for supernatural merit. Does God predestine men to glory in consequence of His prevision of their merits, or is predestination to glory rather to be considered as the reason for merit, and hence for God's prevision of merit? In the former case predestination to everlasting happiness would be conditional, in the latter case unconditional. With this problem another is introduced: is the assumption of an unconditional negative reprobation theologically sound or not?

Dominican theologians, following the lead of Francisco de Vitoria. Melchior Cano. Domingo Báñez and other former professors at the University of Salamanca, hold that predestination to glory is antecedent to God's prevision of man's merits. According to this theory. God in the order of intention predestines certain persons to eternal happiness by an absolute decree, and in consequence of this decree determines to grant them all the graces necessary for salvation. But in the order of execution God follows the reverse order; that is. He first allots the predetermined graces and then grants the happiness of heaven as a reward for the merits acquired by the aid of those graces. This doctrine necessarily involves negative reprobation antecedent to the prevision of sin. Those whom God has not numbered among the elect are simply excluded from heaven or. as Charles René Billuart and others prefer to put it. are left to their own weakness and so inevitably perish. Several of the greater Jesuit theologians. among them Francisco Suarez and St. Roberto Bellarmine, likewise support this view.

Most theologians of the Society of Jesus. however, vehemently disagree and give their allegiance to the doctrine developed by Luis Molina. According to Molinism God knows what every man in every situation in every possible norld order would freely do if granted such and such graces. and with sovereign liberty decrees a definite world order. This choice, in conjunction with God's foreknowledge of every person's co-operation with the graces offered, or rejection of them. is predestination for some, reprobation for others. Therefore predestination to glory as such is consequent upon God's prevision of supernatural merit. The gratuity of predestination is guaranteed by God's free choice of a definite world order. and by His generous bestowal of unmerited grace. This doctrine eliminates the difficulties raised by any theory of antecedent reprobation. Eternal punishment is inflicted only in consequence of God's prevision of the sinner's final impenitence. Such is the theory advocated by eminent Jesuit theologians, as Franciscus Toletus and Leonardus Lessius. and outside the Society of Jesus by St. Francis of Sales. It is held by the large majority of Catholic theologians who do not adhere to the Dominican school of Thomism.

According to Protestant liberals and in the public teaching of the churches the doctrine of predestination is less emphasized. The problem is the reconciliation of human freedom with divine foreknowledge. It has been argued that, if God allows His activity to be limited by human freedom, He may also so limit His foreknowledge as to know free acts as possible and not as actual.

The Number of the Predestined.—This problem has challenged theologians from the days of the Greek fathers to modern times. That the absolute number is very large, all concede; for Apocalypse vii, 4–9 affirms that the multitude of the elect. drawn from all races, nations, tribes and languages. is so huge that no one can count them. As to the proportion of the predestined relative to the reprobate, opinions vary; modern authors incline to greater optimism than their predecessors. In any case, certitude cannot be achieved, as no clear revelation has been granted by God. Thomas Aquinas, after reporting views current in his day that the number of the elect would equal the number of fallen angels. or the number of loyal angels or the number of fallen angels plus that of all the angels created by God, concludes: "It is better to say that the number for whom eternal happiness is reserved is known to God alone" (*Summa theologica*, i, q. 23, a. 7). The best answer of all is that given by Christ who, in response to an anxious query whether only a few would be saved, told the people that they should strive to enter by the narrow gate (Luke xiii, 24).

Bibliography.—The theological literature dealing with predestination is enormous, but there are no satisfactory general accounts or monographs written originally in English. The following are basic works St. Augustine. *De Praedestinatione sanctorum, De Dono perseverantiae;* St. Thomas Aquinas, *Summa Theologicn,* part i; John Calvin, *Institutes;* Luis Molina, *Concordia liberi arbitrii* (1588). *See* also manuals of systematic theology and histories of dogma. (C. V.; X.)

PREDICABLES, in scholastic logic, a term referring to certain relationships which may obtain between the predicate of a simple statement and its subject. The traditional list of these relationships is derived from Boethius' Latin version of Porphyry's *Eisagoge* and consists of five items: genus, species! differentia, property and accident. It is based upon a similar classification set forth by Aristotle in the *Topics* (a, iv–viii), differing only by having species where the Aristotelian list has definition.

Aristotle's treatment of the matter is concerned only with statements of the form "*A* is *B*," where the subject and predicate terms are both universal. He notes that in every true statement of this type the predicate will either be convertible with the subject (*i.e.*, "*B* is *A*" will follow from "*A* is B") or it will not. If the predicate is convertible with the subject and states its essence, then it is the definition of the subject; while if it is convertible but does not state the essence, it is a property of the subject. On the other hand, if the predicate is not convertible with the subject but is part of the definition, it is the genus or differentia of the subject. for a definition always consists of genus and differentia. Finally. if the predicate is not convertible and is not part of the definition, it is an accident of the subject.

In attempting to understand these distinctions one is handicapped by Aristotle's failure to indicate clearly whether he is speaking of relations between linguistic expressions or between the meanings of such expressions. Thus, although definition is explicitly described as a phrase which means the essence. the remaining four predicables seem all to be treated primarily as nonlinguistic.

Some Aristotelian examples may be briefly mentioned. In the true statement "Man is a rational animal," the predicate is convertible with the subject and states its essence. Therefore. "rational animal!' is the definition of man. The statements "Man is an animal" and "Man is rational," while true, are not convertible. Their predicate terms, however, are parts of the definition and hence are the genus and differentia of man. On the other hand, the statement "Man is capable of learning grammar" is true and convertible. since all men are capable of learning grammar and whatever is capable of learning grammar is a man. But "capable of learning grammar" does not state the essence of man. It is therefore a property of man. For an example of an accident, take the predicate of the true statement "Man is featherless." This predicate is not convertible mith its subject, nor is it part of the definition. Accordingly, it expresses only an accidental characteristic of man.

Porphyry gives the following examples: of genus, animal; of species, man; of differentia, rational; of property, risible; of accident, white. (B. Ms.)

PRE-ELEMENTARY EDUCATION. For the purpose of this discussion pre-elementary education is defined as education and training of very young children, *i.e.*, children under compulsory school age or under kindergarten age. Kindergartens, which enroll children between the ages of five and six or seven years, have been rather generally accepted as an integral part of the primary school (*see* KINDERGARTEN; *see* also ELEMENTARY EDUCATION). Thus in this article pre-elementary education means schools for children from two to four-and-a-half or five years or, more usually, for children between three and five. In western Europe and elsewhere there is some variation in the age of compulsory school entrance, the range being from five to seven years.

Historically, the training of children before they entered primary school was considered to be the sole province of the family. An occasional philosopher or educational reformer contemplated the possibilities of improved education of toddlers and young children but the early schools appear to have been philanthropic in purpose, established primarily as substitutes for home care rather than as supplements to the educational functions of the home. In general these early institutions were set up to provide custodial care, safety and health services to destitute and homeless children and those whose mothers could not care for them in the home. These institutions were frequently in the hands of religious orders. To some extent these generalizations still hold. However, as developments in medical science, psychology and education led to better understanding of the nature and needs of the young child (*see* CHILD PSYCHOLOGY AND DEVELOPMENT), there mas increasing concern for making provision for the optimum development of young children in all aspects of their growth—physical health, emotional security, social development and educative experience.

The writings and life work of Friedrich Froebel (*q.v.*) focused attention on the possibilities of educating children before the age of seven. In 1837 he opened the first kindergarten and demonstrated that children could learn through play and without formal instruction. Since Froebel's day other educators (e g., Maria Montessori in Italy, Ovide Decroly in Belgium, Margaret McMillan in Great Britain, Harriet Johnson in the Cnited States) have viewed the preschool years as a period of great educational possibilities. In the 20th century the preschool program came to be viewed increasingly as a desirable supplement to the home—as an agency that can give effective support to parents in the rearing of children as well as offer to the children themselves appropriate experiences that will contribute to harmonious growth and to a healthy, joyous and intellectually stimulating existence.

Wide and at times confusing variation is found in the terms used to describe the institutional arrangements for pre-elementary education. Such terms as infant school (Great Britain), nursery school and day nursery (Great Britain, U.S.) crèche and *école maternelle* (France), *casa dei bambini* (Italy), kindergarten (Germany, U S.) are used. sometimes interchangeably, sometimes with quite precise meanings. These institutions are described in historical perspective in the sections which follow.

HISTORY

Great Britain.— In 1816 Robert Owen, a cotton mill owner in Scotland. founded a "preparatory school for infants" (age range of the pupils was from one to six years) where children were not to be given formal lessons but were to be permitted to play. His aim was "to prevent children from acquiring bad habits, to give them good ones, and to form their dispositions to mutual kindness." The idealism of Robert Owen and the enthusiasm of others in the years following resulted in the founding of many of these infant schools throughout the country and had an influence on the movement toaard infant schools and day nurseries on the continent and in the Cnited States. In time (1870) the infant schools became an integral part of the state system of education in Great Britain, the age of five being adopted as the age of entry to infant school and the age of three fixed as the minimum age at which children in attendance could count for a government grant. As the years passed the infant schools lost their "nursery" character and developed more and more a scholastic tradition in which little provision was made for physical activity, sleep and play. Children of three, four and five years mere required to sit still in rows in large galleries—nith arms folded and without conversing with one another—reciting lessons in which pictures and museum specimens took the place of living plants and animals and spending hours on the "three R's" and on needlenork. Outside the official system, experiments in childhood education were being tried, notably the introduction of the views and methods of Froebel in the setting up of kindergartens for fee-paying pupils and the institution of schemes for the training of kindergarten teachers. The realization came gradually that enlightened and psychologically sound methods of early childhood education ought to be used mith all children irrespective of parents' ability to pay fees, and out of this realization developed the British nursery schools. After 1918 such schools were a recognized part of the national school system with standards for nursery schools defined by law. Margaret McMillan and Grace Owen were pioneers in the movement to improve the health of young children and to provide a suitable environment for their growing minds. Both these leaders saw the nursery school as an extension of home life and as an institution which could improve through education the standard of home care of children. They further maintained that a nursery school is not a place for formal education but rather a community nursery where children up to the ages of five or six years may have appropriate opportunities for physical, mental and social growth through playing in small groups under the supervision of qualified teachers.

Miss McMillan outlined a plan for a three-year course for training teachers for these schools, maintaining that only trained personnel should work with children of these ages. Training centres at hianchester (under Grace Owen), at London (under Lillian DeLissa) and at Deptford (under Margaret McMillan) supplied nursery teachers for the entire Commonwealth as well as for the early nursery schools in the United States. The older infant-school system was modified in the light of principles underlying the nursery school experiments, for the nursery school movement in England was from the first both vigorous and articulate.

Continental Countries. — Jean Frédéric Oberlin, an Alsatian Lutheran pastor, opened what was probably the first pre-elementary school in the western world. Beginning in 1779 he founded a number of schools for young children, which he called *écoles à tricoter* (knitting schools). These were philanthropic in purpose, with religious and moral training constituting their chief objectives. Crèches and *salles d'asile* were also being established about this time in the cities, more with the aim of protecting children from the dangers of the streets than of educating them. The *salles d'asile* changed from private- to state-supported institutions in 1833 when they were made part of the national educational system. These establishments henceforth carried the designation of *écoles ntaternelles*. The objective of these schools is to work toward well-rounded development of the young child, without fatigue, restraint or force.

In Italy around 1835 a Catholic priest Abate Ferrante Aporti, working to establish elementary schools, became dissatisfied with the progress made by children and was led to investigate the conditions under which their preschool years had been passed. As a result he drew up a plan for the establishment of an infant school in which moral habits, intellectual cultivation and physical faculties were all to be emphasized. Early in the 20th century Maria Montessori (*q.v.*) began her experiments with children three to six years of age. She was a physician, who first became interested in the educational problems of mentally defective children but she soon became impressed with the learning potentialities of the normal preschool age child. Her first *casa dei bambini* was established in connection with a tenement-improvement project in Rome. In this school the children were given a special educational apparatus (*see* MONTESSORI SYSTEM). Self-education was the keynote of the plan; a large measure of individual initiative and self-direction characterizing the Montessori philosophy, the teacher would withdraw to the background and merely supervise the use of the apparatus, or "didactic material." This material was not designed to encourage children to play together. What opportunity there was for group activity occurred in connection with the housekeeping activities which the children shared: *i.e.*, keeping the rooms in order, serving the meals, etc. In 1928 Montessori mas invited by the Italian government to institute a six-month training course in the use of her method for religious and lay teachers. In the latter years of her life she traveled extensively in Europe and Asia, and her ideas regarding the education of children under six had an important influence on the development of pre-elementary education in many parts of the world.

The United States. — Beginning around 1920 in the United States, nursery schools developed as the outcome of interest that may be traced to a variety of sources: (1) a scientific interest in early childhood, resulting from new applications in the fields of psychology and medicine; (2) a rapidly expanding background of educational theory; (3) experimental efforts in the fields of psychiatry, child guidance and parent education; and (4) the efforts of individuals and agencies to improve the educational programs of day nurseries already established for the care of children of working mothers. Two national emergencies (the economic depression of the 1930s and World War II) were also responsible for the further development and acceptance of nursery schools in the United States. Because the nursery-school movement sprang from such a variety of social forces, no one type of school may be singled out and described as representative of the movement.

Interest in systematic research into the abilities and development of young children increased rapidly after 1920 and a number of nursery schools were organized in universities to provide laboratories for the study of normal young children. Children two to six years of age were enrolled to furnish subjects for research. but soon it was recognized that such laboratories had an obligation to provide an educational program for the children enrolled and to demonstrate what good educational programs for preschool children entailed Nursery schools were also established at this time as laboratories in which college girl students could study child care and development in preparation for their future roles as mothers. As more nursery schools were founded, colleges also instituted programs for the training of teachers. Prior to 1935 some nursery schools were also set up in conjunction with guidance clinics (as a parent-education effort) and in hospitals as an effort to encourage the recovery of the convalescent child.

The national emergency created by nidespread unemployment and economic distress in the early 1930s resulted in the authorization of emergency nursery schools by the federal emergency relief administration. These schools were set up to provide jobs for unemployed teachers, nurses and affiliated workers and to promote better morale among parents through fostering the physical and social well-being of their children. These nursery schools were under the control of the public school system. were for the most part housed in public school buildings and served to draw the attention of the general public to the desirability of school services for children below school age.

During World War II the number of employed women in the United States increased by more than 6,500.000 and many of these were mothers of young children. Federal legislation in 1942 made funds available to provide facilities for the day care of children whose parents were employed in industries neceiiary for nar production. Supervision of these child-care projects was under local or state departments of education or welfare. When the war was over federal funds began to be withdrawn from these projects and by mid-1946 all federal support had been nithdrann. After that date there nas no direct financial assistance from the federal government in support of schools for children under six.

Married women, honever, continued to work in increasing numbers Day nurseries (*q.v.*) for the care of children whose mothers work have long been provided under philanthropic auspices. Such centres try to meet the needs of children through group care, offering not only substitute mothering and dependable daytime care but also appropriate educational experiences.

Parent co-operative nursery schools (*i.e.*, schools operated by groups of parents who join together to make provision for their children to play together, sometimes hiring a professionally trained teacher and sometimes sharing among themselves the supervision of the children and other duties in connection mith the school) were established in large numbers after World War II. There was a trend also toward church-sponsored nurseries and kindergartens, *i e.*, weekday preschool programs operated in church buildings. some offering religious instruction to the children enrolled, others without emphasis on religious training and enrolling children from different religious backgrounds There were also efforts to offer group experience to preschool children with handicaps of one type or another. for exampie, to children who are mentally retarded, who have cerebral palsy or are otherwise physically crippled, who are blind or deaf or nho are emotionally disturbed. Sometimes this preschool experience is provided by forming small groups of children with similar handicaps and hiring teachers trained to give appropriate therapy to the children in addition to giving them a satisfying experience with peers and adults beyond the family circle. In many instances such schools are also centres for research in the educational problems of the handicapped.

MODERN THEORY AND PRACTICE

Preschool education may be viewed most correctly as an extension upward or outward of the home and family rather than an extension downward of the elementary school. The legitimate activities of the nursery school, as of the kindergarten. are those which supplement the mother's care and the home play of the child in fostering healthy physical and psychological development;

they do not include borrowing from the elementary school or attempting to prepare the child for formal school before he is ready in terms of chronological age and physical and social maturity.

The nursery exists not to replace the home and primary school but to complement them. There comes a time in the young child's life when the resources of his home cannot provide all that is needed to stimulate the development of his potentialities—potentialities for learning new things through firsthand experience. for developing self-confidence and skill in making friends outside the family, for achieving a sense of himself as a person. It is believed that such learnings are useful in preparing a child for entrance into formal school and for the tasks he faces there in learning to read, write, cipher, etc.

The preschool years are said to be of supreme importance in molding the individual's personality, behaviour patterns and attitudes toward himself and others. This is an age of partial weaning from the emotional ties to the family, of the discovery of individuality and of the appearance of new interests, abilities and attachments. It is crucial, however, that ties to the family be strengthened, not broken, and therefore one of the prime requisites of a preschool program is that it maintain a close relationship with each child's home and family. A school for the nursery ages must encourage individual development in relation to each child's personality, capacities and home environment.

The fulfillment of this task requires trained teachers with sound theoretical backgrounds and with practical experience under expert supervision in the guidance of young children. The teacher's task is to maintain. strengthen and enrich each child's personal relationship with his family and at the same time to introduce a wider world of people and opportunities. She must understand that entry into preschool creates a psychological problem for the young child as well as an opportunity for herself to make a contribution to his development. She must know hon to provide a setting appropriate to the physical skills of the children and must understand normal phases of growth throughout the preschool years in order to be prepared for changes in the behaviour of her pupils, for fluctuations in dependence and independence, for confusion between right and wrong and fantasy and fact. so characteristic of these ages. She must have skill in helping children acquire gradually the capacity for harmonious relationships with other children. She must make the proper provision of satisfying activities in play and know how play of different types (dramatic, social, free, organized! artistic and creative) contributes to the flowering of the potentialities of the child and to the solving of his emotional problems. She needs an intuitive sensitivity to the learning problems of young children, for they are ordinarily unaware of their need for help and understanding.

A preschool program may be characterized by a threefold concern for optimum development: (1) physical health, (2) mental hygiene and (3) intellectual stimulation. Children under school age should not be brought together in a group unless the sponsoring agency can demonstrate its concern for good physical care which will result in healthy growth. This includes provision for adequate food, rest, cleanliness, the learning of health habits and some active outdoor play; it also entails concern for safety, watchfulness against accidents and protection against communicable diseases.

Of equal importance is an awareness of good mental hygiene. This involves an atmosphere characterized by affection, friendliness and noncoerciveness; simple rules benevolently enforced; success and praise for effort, which give a sense of achievement; respect from adults, so that children develop self-esteem and respect for others; support from the teacher in developing the capacity for co-operative relationships with others; steadiness and consistency in adults' expectations; and outlets in play for the strong feelings of the child.

Since one of the preschool's prime reasons for being is to offer children an educative experience, such a school must provide good teaching which results in the enjoyment of new experiences and of intellectual stimulation. This means planning a rich environment in the school, including stories and picture books; painting and clay modeling; observation of nature and pets; gardening and science; singing, dancing and rhythms; block building; playhouse activities; games; and simple excursions outside the school. It is important that children engage in these experiences under the tutelage of an adult who understands their level of growth and their ability to comprehend, so that the activities are meaningful and enjoyable. It is believed that young children learn more readily from an active kind of *doing* through the medium of play than through formal lessons.

Common problems relating to pre-elementary education exist throughout the world. There is a shortage of trained teachers along with a lack of agreement as to what constitutes adequate training for teachers. In some quarters a gentle, affectionate disposition is considered sufficient for teaching little children, while in others a qualified teacher is expected to have completed several years of college and even to have postgraduate training. In general it may be said that educational standards are rather low for teachers of children under five or six years of age. Uniformly high standards for the operation of preschools are lacking and suitable housing and equipment are threatened by lack of financial resources. There remains some reluctance on the part of citizens and government authorities to accept preschools as educational rather than welfare agencies.

On the other hand some responsible citizens in every country are concerned with providing children under school age with better health care, greater emotional security and richer educational opportunities. Although this concern does not by any means extend to the entire child population, a beginning has been made everywhere.

See also EDUCATION, HISTORY OF; SCHOOL AND CURRICULUM.

BIBLIOGRAPHY.—D. C. Fisher, *A Montessori Mother* (1912); I. Forest, *Preschool Education: a Historical and Critical Study* (1927); S. S. Isaacs. *The Nursery Years,* enlarged ed. (1932); H. M. Johnson, *Children in the Nursery School* (1928); J. E. Leavitt (ed.) *Nursery-Kindergarten Education* (1958); K. H. Read, *The Nursery School: a Human Relationships Laboratory,* 3rd ed. (1960); United Nations Educational, Scientific and Cultural Organization, *Mental Hygiene in the Nursery School* (19.53).

See also other publications of UNESCO, *e.g., International Yearbook of Education* (annual); World Organization for Early Childhood Education, Reports of Conferences. (M. E. K.)

PRE-ESTABLISHED HARMONY, in the philosophy of Leibniz constitutes the explanation of the co-ordination of change in substances which are not causally related.

Leibniz asserts for logical reasons that the universe consists of monads, indivisible substances which develop in time. Every characteristic of a monad (the events which happen to it being included among characteristics) is deducible from its own nature. There is thus no causal link between different monads. They are "windowless." Nevertheless everything happens as if by mutual influence, and Leibniz accounts for this by postulating that God created the monads in such a way that each represents the universe from its own point of view. The changes in them are thus necessarily co-ordinated.

The pre-established harmony was most highly valued by Leibniz as affording a solution to the mind-body problem posed by Cartesianism. Descartes's insistence on the complete qualitative difference between mind and body, together with his account of causation, made interaction impossible, although Descartes himself did not appreciate this. His followers, who were acutely aware of the difficulty, introduced the theory of occasionalism, by which the appearance of interaction is explained by the intervention of God on appropriate occasions. For Leibniz the mind is one monad and the body, a group of monads, so that the two are not completely disparate; but his theory of substance precluded him from allowing causal connection, and he substituted for the recurrent miracle of the occasionalists the single creative act of God by which harmony between monads is once and for all established. The term *harmonie préétablie* is first used in the *Explication du nouveau système* (1695), but the essentials of the theory are already present in the *Discours de métaphysique (1686). See* LEIBNITZ, GOTTFRIED WILHELM. (M. KE.)

PREFECT (FRENCH). The prefect *(préfet)* in France is the office of a high official. 4 similar post *(psaefectus)* existed under the Roman empire, from which the title was borrowed, and in France a comparable office *(intendant)* existed under the *ancien régime*. The French office of prefect was created in *1800* by Napoleon, who raised the prefectoral corps to a position of great prestige and influence. The prefects were the administrators of the *départements,* responsible for public order and good government and for ensuring that the central government's policy was effectively carried out throughout the country. Napoleon called them *empereurs à petit pied.*

Under succeeding regimes the power of the corps increased but its prestige declined. Dependent for office on the whim of the government. the prefects became primarily concerned with police and elections, and one of their principal functions was to ensure the government a safe parliamentary majority. They reached the height of their power under the second empire. During the first decades of the third republic the prefects' position was weakened by the frequent nomination of new men by successive governments. However, prefects then became increasingly concerned with social and economic problems, and after World War II, while retaining responsibility for public order and good government, they became the dynamic element in the provinces for promoting and co-ordinating social policies.

Under *1958* conditions, as under those of *1946,* the prefectoral corps consisted of prefects, each responsible for a *département;* secretaries-general, or second in command; subprefects, responsible for the *arrondissements;* and *chefs de cabinet,* who nere the prefects' personal assistants. The prefects are appointed by the president of the republic with the approval of the council of ministers and on the recommendation of the minister of the interior, to whom they are responsible *(1958* constitution, art. *13).* They can be dismissed at any time without cause or notice. but in the second half of the 20th century they enjoyed in fact considerable security of tenure. Sweeping changes were likely only when there was a major change of political direction or regime.

Conditions of service in the corps were laid down in a special statute of June *19,* 1950. A prefect has a wide variety of poners accrued haphazardly over the years; according to one estimate there are as many as *4.000* separate sources of his legal authority. The prefect is constitutionally responsible for "co-ordinating the activities of state officials, the representation of national interests and the administrative supervision of local authorities." He is the sole legal representative of the government and the state in the department; uhen a minister delegates his powers, he is required by law to delegate them to the prefect and not directly to his own officials in the field. The prefect, therefore, acts as the agent through which all powers are transmitted from the centre to the periphery.

The prefect is the general administrator of the *département,* the chief executive officer of the elected departmental authority (the *conseil général*), the principal police authority and the supervisor of the communes in the *département*. His approval is required for many administrative acts of local authorities.

In Paris the prefect of the *département* of the Seine also exercises the municipal powers normally possessed by the mayor of a commune, there being no popularly elected mayor of Paris. There is, in addition, a special prefect of police whose jurisdiction covers the nhole Paris conurbation.

In the eight regional capitals and in Algiers, the prefects have additional emergency powers and authority to co-ordinate the work of the other prefects in the region. They have the additional title of *inspecteur général de l'administration en mission extraordinaire.* (*B.* CN.)

PREFECT (ROMAN), the title *(praefecfzu)* of various Roman officials, civil and military. A prefect nas not a magistrate proper; he was the deputy of a superior magistrate.

City Prefect. — The city prefect (*praefectus urbis*) acted at Rome as the deputy of the chief magistrate or magistrates during his or their absence from the city. He represented the consul or consuls when he or they were absent on a campaign or on other public duties, such as the celebration of the annual Latin festival on the Alban hills. The absence of all the chief magistrates for more than a single day rendered the appointment of a prefect obligatory; after the institution of the praetorship (367 B.C.) the necessity only arose exceptionally, as it rarely happened that both the consuls and the praetor were absent simultaneously. But a prefect was appointed during the enforced absence of all the higher magistrates at the Latin festival. The right of appointing a prefect belonged to the magistrate whose deputy he nas. No formalities in the appointment and no legal qualifications on the part of the prefect were required. The prefect had all the powers of the magistrate nhose deputy he was, but his office expired on the return of his superior.

Under the empire a new city prefecture was introduced. Augustus occasionally appointed a city prefect to represent him in his absence from Italy, although the praetors, or even consuls, remained in the capital. In the absence of Tiberius at Capreae during the last 11 years of his reign *(AD. 26–37),* the city prefecture, hitherto temporary, became a permanent magistracy; henceforth the prefect held office even during the presence of the emperor in Rome. He was chosen by the emperor; his office might be held for years or for life.' The prefect was not alloned to quit the city for more than a day at a time. His duty mas the preservation of peace in the capital; he was, in fact, the chief of the police, with the superintendence of the streets. markets and public buildings. He was entrusted by Augustus nith a summary criminal jurisdiction over slaves and rioters, nhich was gradually extended until it embraced all offenses by whomsoever committed. In the 3rd century A.D. appeals to the emperor in civil cases nere handed over to the prefect. An appeal lay from the prefect to the emperor. The prefect commanded the city cohorts (*cohortes urbanae*), which formed part of the garrison of Rome and ranked above the line regiments, though below the guards *(see* PRAETORIANS*)*. The military power thus placed in the hands of the chief of the police was one of the most sorely felt innovations of the empire. The changes of Diocletian and Constantine extended the power of the prefect, in whom, after the removal from Rome of the highest officials. the whole military, administrative and judicial powers were centred.

Judicial Prefects. — Under the republic judicial prefects (*praefecti iuri dicendo*) nere sent annually from Rome as deputies of the praetors to administer justice in certain tonns of the Italian allies. These towns nere called prefectures (*praefecturae*). After the social mar *(90–89* B.C.), when all Italy had received the Roman franchise, such prefectures ceased to exist.

Praetorian **Prefects.**—Under the empire the praetorian or imperial. guards were commanded by prefects *(praefecti praetorio)*, who were chosen by the emperor and held office at his pleasure. In course of time the command seems to have been enlarged so as to include all the troops in Italy except the corps commanded by the city prefect *(cohorfes urbanae*). Further, the praetorian prefect acquired a criminal jurisdiction which he exercised as the representative of the emperor. A similar jurisdiction in civil cases nas acquired by him not later than the time of Lucius Septimius Severus. Hence a knowledge of law became a qualification for the post, which was held by the first jurists of the age (*e.g.,* Papinian), while the military qualification fell into the background Under Constantine the institution of the *magistri militum* deprived the praetorian prefecture of its military character, but left it the highest civil office of the empire.

Various Other Prefects. — The title of prefect was borne by various other Roman officials, notably the folloning:

1. Praefectus Aegypti (later *Praefectus augustalis*).—The government of Egypt was entrusted to a viceroy with the title of prefect and was surrounded by royal pomp instead of the usual insignia of a Roman magistrate. He was under the immediate orders of the emperor. The exceptional position thus accorded to Egypt was due to its peculiar character and status as an imperial domain and to its high importance as the granary of Rome.

2. Praefectus vigilum.—The title of prefect nas also given to the commander of the *cohortes vigilum,* a night police force instituted by Augustus (*A.D.* 6). One of the principal duties of this force was that of serving as a fire brigade. The *praefectus vigilum,* besides commanding the *cohortes vigilum,* exercised criminal jurisdiction in cases of incendiarism and offenses committed during the night.

PREFERENCE, IMPERIAL: see IMPERIAL PREFERENCE.

PREGL, FRITZ (1869–1930), Austrian chemist who received the 1923 Nobel prize in chemistry for his work on the microanalysis of organic substances, was born in Laibach on Sept. 3. 1569, and was graduated from the *Gymnasium* in that city He received his M.D. degree from the University of Graz in 1894. After teaching in the Physiological institute at Graz for several years, he went to Leipzig in 1904. where he studied methods of physical chemistry with Wilhelm Ostwald and then nent to Berlin where he worked with E. Abderhalden. He returned to Graz in 1904 as professor of physiological chemistry at the Medico-Chemical institute. During the year that followed he investigated the components of albuminous bodies and the analysis of bile acids. From 1910 to 1913 he was professor at the University of Innshruck, returning to Graz in 1913 as director of the hledico-Chemical institute.

Lack of material in Pregl's work with bile acids had impelled him to look for methods requiring smaller amounts nhen making quantitative analyses of elements in compounds. By 1912 he was able to make measurements of carbon, hydrogen, nitrogen. sulfur and halogen, using only 5 mg.–13 mg. of starting material with results as accurate as those obtained by existing methods. Later he perfected his techniques so that as little as 3 mg.–5 mg. were adequate for measurements at least as exact as the results of microanalysis. The development of chemical microanalysis (see CHEMISTRY: *Microanalysis*) marked a great advance in organic elementary analysis. In addition to the general factor of economy, it became indispensable in many research problems of pure science, physiology, medicine and industry. Pregl also contributed a number of micromethods for measuring atomic groups and a sensitive microbalance. In 1917 he published Die *quantitative organische Mikroanalyse* (6th ed., 1949), a monograph. Pregl also perfected the Abderhalden dialysis test for the presence of ferment, so that less serum was needed for a reaction; invented a simple method for determining the functional capacities of the kidneys; and added to medicine an iodine solution, named for him, which is a mild but effective antiseptic. He died at Graz on Dec. 13, 1930.

PREGNANCY. Life has its beginning in the egg cell or ovum. These minute cells, which measure about $\frac{1}{120}$ in. (0 2 mm.) in diameter, are contained in the two ovaries, which lie in the abdomen one on either side of the uterus (womb). During healthy reproductive life one ovum is shed each month from one or the other ovary (ovulation) about the middle (12th–14th day) of a menstrual cycle. Average cycles — measured from the first day of one period to the first day of the next — occupy 28 days and in health are regular within a day or tno. For each day that the period is prolonged beyond the average 28 days, ovulation is delayed for one day, so that if the cycle is 32 days, the ovulation will be betneen the 16th and 18th days. Expressed in other words, ovulation tends to occur about 14 days before the next period regardless of the interval between the periods. After being shed the ovum enters the Fallopian tube, along which it passes to the uterus. If it is not fertilized it succumbs quickly, and it is known that the sperm cells also have a short maximum life span (two–four days), though somewhat longer than that of the ovum. It thus follows that there is only a short critical interval in the cycle during which fertilization is possible, and on either side of this critical period an interval when intercourse is unlikely to be fertile (the so-called "safe period"). If the ovum is not fertilized it escapes in the next monthly loss of blood. If, on the other hand, it is fertilized by a sperm cell (spermatozoon), pregnancy has begun.

Reproductive Physiology. — A brief summary of some matters of reproductive physiology is essential for an understanding of the complex changes which occur during pregnancy. The first factor is the pituitary gland—a small gland at the base of the brain. The front part of this gland (the anterior pituitary) plays a dominant part in the initiation and maintenance of the rhythmic functions of the sexual glands and breasts in the female, and of the sex glands in the male. It is also concerned with the functioning of the thyroid and adrenal glands. The consideration of these questions leads to the science of endocrinology, the science of the internal secretory glands, which is one of the greatest achievements in physiology of the 20th century. The internal secretory glands differ from ordinary glands, such as the salivary glands, in that they pour their secretions or hormones into the blood stream. In this way the hormones are carried to the organs on which they exert their specific actions. Specific hormones of the anterior pituitary are responsible for the periodic functioning of the ovary and the rhythmic shedding of ova. The pituitary energizes the ovary to produce hormones (estrogen and progesterone) which prepare the uterine bed for the reception of the ovum should fertilization occur, preparations which in the nature of things are only relatively rarely required. During reproductive life the ovaries shed between them from 300 to 400 ova (see ENDOCRINE GLANDS; HORMONES).

The ovary through its hormones controls the imbedding of the fertilized ovum in the uterine wall, and this control continues for about 12 weeks, after which it is taken over by the placenta (afterbirth). The placenta is the organ through which the embryo draws its nourishment from the maternal blood. Its vessels ramify freely round the uterine vessels in the placenta, where there is a constant diffusion of nutritive elements from maternal to fetal blood and of uaste products in the opposite direction. The fetal blood passes to the placenta along the tao arteries in the umbilical cord and, after it has been replenished and purified, it passes to the fetus via the umbilical vein. In addition to these combined nutritional and excretory functions the placenta takes over the hormonal functions which are in large part abdicated by the pituitary and ovaries (see PLACENTA).

A special anterior pituitary hormone (prolactin) acts on the breasts and stimulates the production of milk. It is produced in large amounts after labour, and its production by the pituitary gland continues as long as the infant is suckled. The hormonal mechanism by which the active secretion of milk from the breast is delayed till after labour is not well understood. There is some reason for the view that so long as the hormones of the placenta (estrogen and progesterone) are circulating in the blood the lactogenic influence of prolactin is inhibited and that this inhibition is not removed until the placental hormones are excreted in the days following labour (see MAMMARY GLAND).

Among the other physiological changes that are evoked by pregnancy one of the most important is an increase in weight On the average a pregnant woman gains 24 to 28 lb (10.9 to 12.5 kg.) but there are wide differences; some women enjoying apparent health may gain much less, while others may gain much more. The organs of reproduction — the uterus and its contents and the breasts — contribute an average of 11 lb. (5 kg.) to the total increase in weight. Under normal conditions the weight increase in pregnancy is quickly lost after labour, but in some instances this does not occur, and many women retain their weight gain and may even acquire active obesity dating from childbirth.

A considerable part of the normal weight gain of pregnancy is due to the retention in the body of water which is required for the increase in the total volume of the circulating blood; by the 36th week of pregnancy the total amount of blood in the heart and the blood vessels is increased by about 30% over that present in the nonpregnant state. The greater part of this increase is used up in filling the greatly expanded arteries and veins of the womb. The solid elements of the blood—the red blood corpuscles carrying the hemoglobin — are also increased. but not to the same degree. While the fluid part of the blood (the plasma) is increased by 40%, the red blood cells are increased by only about 15%, with the result that there is produced the so-called physiological anemia of pregnancy. Instead of being 100% the hemoglobin is reduced to 87%.

Duration of Pregnancy. — There is a small but appreciable elevation of the body temperature at the time of ovulation. and this. by pinpointing the date of ovulation, has provided a method of determining the interval between ovulation and childbirth. Usually this lies between 266 and 270 days. with extremes of 250 and 285 days The usual method for determining the date of childbirth is to add seven days to the first day of the last menstrual period and count forward nine calendar months. Thus, if the last period began on March 10, the estimated date of childbirth is Dec. 17. This gives a figure of roughly 280 days or ten lunar months. As ovulation occurs about the 14th day of the cycle, it follows that this estimate is in reality about 14 days longer than the true average duration of pregnancy as estimated by the temperature method.

Not infrequently the lam courts are required to pronounce on the legitimacy of a child born after an interval that is greatly in excess of the average figure or, on the other hand. that is much shorter than this figure. Some countries recognize upper and lower limits.

Diagnosis of Pregnancy. — A woman normally recognizes that she is pregnant by the cessation of menstruation (amenorrhea). and within a short time this is confirmed by the increasing swelling of the abdomen. But menstruation may cease and the abdomen increase in size apart from pregnancy, and the doctor often has to adopt other criteria for his diagnosis.

There are, indeed. only three positive signs of pregnancy. The first is the hearing of the fetal heartbeat. which is audible beginning about the 16th to 18th week of pregnancy. It is heard by placing a stethoscope on the lower abdomen, and the sound resembles closely that of a watch beating under a pillow. At the sixth month its rate is 150–160 per minute, while at the end of pregnancy it is 120–140. The second positive sign, the demonstration of the fetal skeleton by X-ray examination, is possible by the 16th week, when the fetal bones are visible. The third positive sign is the recognition of the kicking movements of the fetus, usually noticeable by the 18th to the 20th week. By this time the woman often feels the movements herself; this is the so-called "quickening" that reveals to the mother that her pregnancy has reached its halfway stage.

There are several probable signs and symptoms of pregnancy. Amenorrhea, however, can occur apart from pregnancy, commonly in anemia and other conditions leading to reduced health. Pyschological factors are also often responsible for the cessation of menstruation; *e.g.,* the mental shock associated with the death of a relative, or the anxiety of a woman who has exposed herself to the risk of pregnancy. There is a reverse of this latter condition in pseudopregnancy (pseudocyesis). when a childless woman with a fervent desire for motherhood develops, though she is not pregnant, the signs and symptoms of pregnancy, such as amenorrhea and increasing size of the abdomen and, at the end, may actually go into "labour."

A sense of fullness in the abdomen is often felt from the early weeks, and by the end of the third month the uterus can be felt where it rises from the pelvis. It reaches the level of the navel about the fifth lunar month. In the last weeks there is commonly a sinking down of the womb when the woman may feel more comfortable from relief of pressure ("lightening").

Enlargement and tenderness of the breasts are especially evident in women pregnant for the first time (primigravidae). In women who have had a previous pregnancy these changes are often less evident, though in the second half of pregnancy there is in most women a marked dilatation of the superficial veins and there is fluid in the breast which can be easily expressed from the nipple. In many women, especially brunettes, there is a dark pigmentation of the area round the nipple, which deepens with the advance of pregnancy.

Nausea, usually more evident in the morning ("morning sickness"), is a common symptom. In some women it is such a constant feature in pregnancy that they regard it, when it appears about two or three weeks after the last period missed. as a sure sign of their state. The sickness is sometimes associated with the development of an acute dislike of some ordinary article of food. Morning sickness generally passes off at the end of the third month, but in some cases it may be severe enough to require hospital treatment.

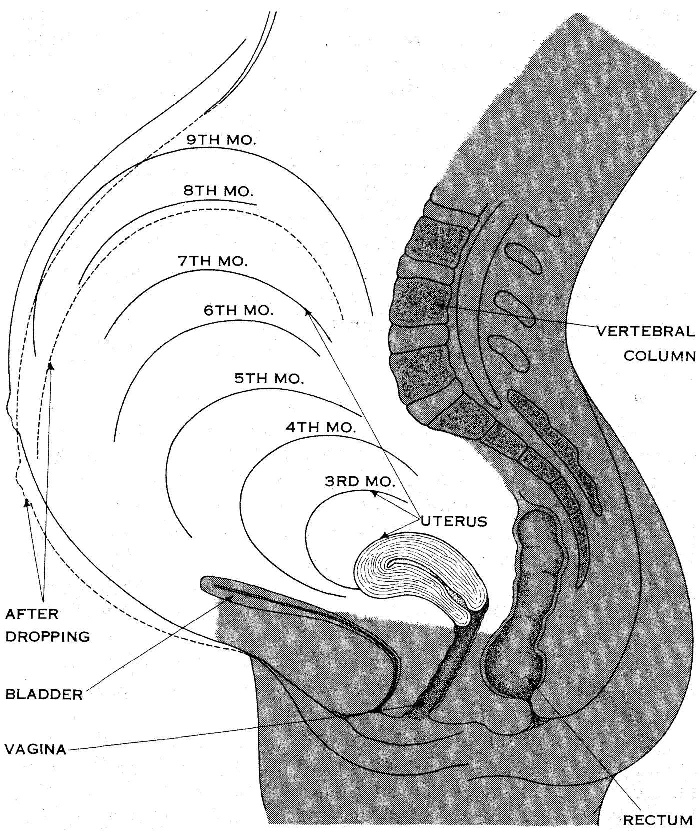
Pigmentation of the breast has already been referred to. In many women pigmentary changes in other parts of the skin are found; *e.g.,* the abdomen, where there is often a dark streak extending from the pubic hair upward as far as and, sometimes, beyond the umbilicus (linea nigra), while some women develop areas of pigmentation on the face, especially the forehead. These pigmentary deposits are believed to be due to excessive activity of the adrenal glands.

As the result of the stretching of the abdominal walls there are often formed the striae gravidarum; *i.e.,* pinkish or purple streaks where the superficial and less active layer of the skin has failed to keep pace with the generalized stretching of the abdominal wall. The pink or purplish streaks mark where the deeper and more vascular areas are thus exposed.

The doctor has access to further evidence for the diagnosis of pregnancy through internal examination, on which he can find enlargement of the uterus as early as the eighth or tenth week.

Finally. in cases of doubt, there are the biological tests for pregnancy. These depend upon the fact that one of the hormones. which is produced by the placenta and which resembles in some ways the hormone of the anterior pituitary, is excreted in the urine of the pregnant woman. When a small quantity of the urine of a pregnant woman is injected under the skin of female mice it produces characteristic changes in the ovaries of the animals. Young virgin mice so treated are killed at the end of 100 hours and the test is positive if characteristic "blood points" are present in the ovaries. The method, called after its inventors the Aschheim-Zondek test, is accurate in 98% of cases and may reveal a pregnancy that has advanced only four days beyond the first period missed. At such an early stage, however. the output of hormone may be small and it is better to wait for a further two or three weeks before having recourse to the test. Where a quick decision is required, a variation of the test that uses a virgin rabbit is generally employed. when the result is available by the end of 24 hours. In a still further animal test the female toad (*Xenopus laevis*) is used. Here a positive result is provided by the external and free escape of ova from the oviduct and is obtained as early as 18 hours.

Antenatal Care. — This includes the continuing supervision of the general health of the woman. the detection of any condition that may necessitate special attention at the time of birth (*e.g.,* contraction of the pelvis) and the detection and treatment of any



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UTERINE LEVELS DURING PREGNANCY

abnormal state that may develop during pregnancy. In addition it provides the opportunity for the establishment of that confidence between the woman and attendant that is peculiarly important in obstetrics. Finally the occasion is taken to discuss the preference of the woman in regard to the place of confinement, whether home or hospital. During the 1930s there was a great increase in hospital beds both to meet the marked rise in the demand by women for hospital care and to meet the increasing awareness of the health authorities of the importance of hospital care in obstetrical abnormalities. At the same time there were not sufficient beds to allow the admission of all women whose sole reason was personal preference. There were, however, several groups of pregnant women with a primary claim on the hospital services for their delivery: most primigravidae, those whose previous labours had been abnormal, women whose homes were unsuitable and women who had had many previous births. It is estimated that the risk of death is doubled when a woman has had six previous children and quadrupled when she has had ten or more. These groups do not include the women who, during the course of pregnancy, develop an unexpected abnormality that requires special attention. The extent of this need alone may be gauged by the records of the hospitals. Thus in one London hospital during one year 43% of the women who had booked for their lying-in (and excluding those who were specially referred by an outside doctor because of abnormalities) required special treatment in hospital during their pregnancy.

The principle underlying antenatal, or prenatal, care is the medical examination of the pregnant woman at periodic intervals throughout her pregnancy. At the first examination. which is made at an early stage of the pregnancy, a full medical history is obtained with special reference to previous illnesses, such as tuberculosis and Bright's disease. The details of any previous pregnancies (*e.g.,* difficulty at the birth and toxemia), the date of the last menstrual period and the expected date of the confinement are noted. A physical examination is made, including the recording of the weight and blood pressure. The urine is examined for abnormal constituents, especially albumin and sugar. The weight, the blood pressure and the state of the urine are recorded at each subsequent examination. The heart and lungs are examined and a sample of blood is removed from a vein to be tested for anemia, for syphilis (Wassermann test) and for the Rhesus and ABO grouping. The next examinations are made at four-weekly intervals up to the 30th week, at three-weekly intervals to the 36th week and weekly from then onward. At each of the later examinations the abdomen is palpated to determine that the position of the fetus in the womb is correct. for at this stage a faulty position often can be rectified. Excessive enlargement of the abdomen may indicate twins, which will demand special care at the delivery. Or there may be excessive fluid in the womb (hydramnios). At the 34th week an estimate of the pelvic shape and size is made with special reference to the discovery of any contraction that may require special care at birth and, in a severe abnormality, Caesarean section.

Nutrition in Pregnancy.—Scientific study indicates that the diet of a pregnant woman should contain 2,400–2,500 calories (*i.e.,* 400–500 more calories than are in the diet of the nonpregnant state) and that when she is suckling it should contain 3,000 calories. In general a woman who is ordinarily accustomed to a well-balanced diet will not require adding more to this regimen than her appetite dictates. There is in health a steady increase in the appetite that is especially marked from the third month onward. The diet thus augmented may be safely trusted to supply the protein, carbohydrates, fat, calcium, iron. vitamins and other elements that are required. Such a diet will contain red meat, eggs and sea food two or three times weekly; green vegetables, fresh fruit and at least one pint of milk daily.

From the 1920s, and especially after the discovery of the dominating influence of vitamins, abnormal nutritional states that have an adverse effect on childbearing and childbirth mere increasingly brought under control. Rickets, for example, resulting from a deficiency of vitamin D or sunshine or both, was responsible for a stunting of the skeleton and a narrowing of the pelvis in the growing child. Later in life this was a common source of difficulty and danger at childbirth, but improvements in the social field and the application of medical knowledge have rapidly reduced this menace.

While in western communities the nutritional standards of women in pregnancy are in general high, there are many less developed countries, especially in the east, where gross malnutrition may exist. There the shortage of vitamin D may result in severe rickets and osteomalacia, and the shortage of vitamins and iron may result in aggravated and dangerous anemia. (See also DIET AND DIETETICS ; NUTRITION.)

Toxemias of *Pregnancy.*—Among the most prominent of the abnormal conditions that make the periodic examination essential are the toxemias. They are of two kinds. The commoner is pre-eclampsia, which, unless recognized early and vigorously treated, may pass into a grave, convulsive form. The other kind is characterized by severe vomiting. Because of their superficial resemblance to a toxic state, these diseased conditions have been classified as toxemias, despite the fact that in neither case has intensive research revealed the existence of a causative toxic agent.

Pre-eclampsia usually develops insidiously in the latter half of pregnancy. The first sign may be the swelling of the ankles and legs and sudden increase in weight, but. while they should always arouse suspicion, these signs are often present without toxemia. Commonly the first significant sign is an elevation of the blood pressure which is first detected at a routine antenatal visit. The presence of albumin in the urine is the second most important sign. In the milder forms of toxemia ambulant home treatment, consisting of rest, is often permissible on the understanding that the patient visits the clinic or is seen by a doctor or midwife at short intervals. Where the initial signs are marked or where there is a progressive worsening of the state. the patient is admitted to a hospital or nursing home. In the 1940s, thanks to the early recognition and treatment of pre-eclampsia the risk of its passage into the grave convulsive form (eclampsia) was greatly reduced. In the graver manifestations termination of the pregnancy is called for in the interest of both mother and child. Even in the cases which become convulsive the mortality has been greatly diminished. Nevertheless this type of toxemia is the cause of nearly one-third of all maternal deaths, and until more is known about its cause it will remain the greatest challenge with which the obstetrician is faced.

Nausea, with or without vomiting ("morning sickness"), occurs in 50%–60% of women, commencing about the 6th week and subsiding about the 12th. Rarely it persists in an aggravated form (hyperemesis gravidarum), calling for the termination of pregnancy.

Rhesus Factor.--One of the reasons for an examination of the pregnant woman's blood at the first antenatal visit is to determine her blood group. Eighty-five per cent of Europeans contain in their blood an antigen similar to that present in the Rhesus monkey and are therefore classed as Rhesus positive (Rh+). The remainder of the population (*i.e.,* 15%) have no such antigen and are classed as Rhesus negative (Rh—). If the father is positive, the baby may be Rh+ ; if, in such a case, the mother belongs to the Rh— group, the bloods of mother and baby are "incompatible." In the placenta the Rhesus antigen passes into the maternal blood and stimulates the formation in the mother of antibodies which enter the fetal circulation and destroy the red blood cells (agglutination and hemolysis), uith the production of anemia or jaundice or both (erythroblastosis fetalis). The risk is small during a first pregnancy, unless the mother has by mischance previously received an incompatible transfusion; *i.e.,* of Rhesus positive or Rh+ blood.

With each succeeding pregnancy in which the fetus is Rh+ the antibodies in the mother's blood increase, and with them the risk to the fetus. In cases where the woman's blood is Rh— the husband's blood is grouped, and where it is positive the woman's blood is tested for antibodies monthly from the sixth month onward. Where the child is erythroblastotic the sole effective treatment is the replacement of the child's blood by compatible blood from a donor. Mother-fetus incompatibility similar to that found in the

Rhesus blood group occurs with other types of antigen; *e.g.,* the ABO group. See BLOOD GROUPS.

Exercise.—Walking exercise in the open air should be a daily routine for the pregnant woman, but too long walks or exhausting exercise of any kind should be avoided. Women vary greatly in these respects, and any advice given is weighed against the woman's natural habits. The prescription of special exercises became fashionable in the 1940s, and much can be said in favour of the so-called relaxation classes organized in relation to antenatal clinics. These classes are a valuable addition to the educational functions of the clinic. There the care of the body can be discussed and the facts of labour explained, so that, as Grantly Dick Read correctly stated, the young expectant mother is encouraged to forsake her fear and to adopt a more confident attitude to pregnancy and labour. These are advantages of great value, but there is no reliable evidence that by physical exercises or by psychological measures directed to the relief of anxiety the stages and duration of labour can be influenced. How far such preparation for labour can lessen the pain or make it more tolerable is not an easy matter to assess.

Vital Statistics.—The marked fall in the birth rate that occurred in western countries after the latter part of the 19th century due to voluntary restriction brought with it important consequences to public health, including maternity. The dwindling replacement at one end of the population scale and the marked lowering of the death rate at the other end of this scale greatly increased the proportion of old people. The fall in the average size of the family meant an increase in the ratio of first births, which carry greater risks to mother and child. The postponement of the date of marriage, which is especially marked in the more prosperous social orders, added to these risks by increasing the average age of motherhood. Against this there was a sharp fall in the number of women with many children (the "grand multiparae"), for whom additional births involve greater risks from such conditions as toxemia of pregnancy and difficult labour.

Maternal Mortality.—Maternal mortality declined sharply during the 1940s and 1950s. From a figure in 1938 of 3.10 deaths per 1,000 live births in England and Wales, and 4.30 in the United States maternal mortality fell steadily till, by 1955, it stood at under 1 per 1,000. This decline began in 1936 and is explained chiefly by the introduction of the sulfonamides and, later, of penicillin, which caused a sharp drop in the deaths from puerperal sepsis; this once caused approximately 40% of the maternal deaths but by 1959 caused only 2%. However, while this is the dominant cause of the decline in maternal mortality, it is not the sole cause; deaths from toxemia, hemorrhage and the accidents of childbirth have also fallen, and this must be ascribed to the improvement in the standard of medical and nursing practice and the more adequate provision and use of obstetric services—antenatal care, hospital and blood transfusion.

This decline in the maternal death rate is found in all social classes, in nearly all socially advanced countries in the world and in many backward countries as well, though there are still groups of mothers who have failed to profit fully by the improved services. Illegitimate births, for example, are associated with a maternal mortality more than twice greater than the average rate, and deaths from sepsis in association with abortion (*q.v.*) are more than three times than those from sepsis at childbirth.

Infant Mortality.—As in the case of the mother, there was during the 1940s and 1950s a steady decline in infant mortality, which is seen in the stillbirth and in the neonatal death rates. Between, 1928 and 1936, the stillbirth rate in England and Wales was about 40 per 1.000 live and stillbirths; thereafter there was a steady decline to 23.7 in 1948, after which it remained more or less stationary. In the United States the figure in 1948 stood at 16.7 per 1,000 births and declined to 13 by 1956. Unlike the maternal death rate, the stillbirth rate exhibits a sharp social gradient, and it also rises steeply with the age of the mothers after 25 and is markedly higher in first births; it is at its lowest in women who have had only one previous child. The neonatal death rate—the number of deaths under 28 days per 1.000 live births—declined steadily during the 1940s and 1950s, the rate in 1955 for England and Wales being 17.2 and that of the United States. 19.1. More than two-thirds of infant deaths occur during the first month of life. Like the stillbirth rate, the neonatal death rate has a marked social gradient; an important cause of this is the higher frequency of premature births in the more poorly nourished, lower social classes.

Premature Birth.—Five to eight per cent of babies are born prematurely, and these constitute a considerable proportion of infants that die at birth or soon after. As the maturity of a child is sometimes difficult to assess and as, in any case, from the medical standpoint the size of the child is more important than the age. "premature" babies are by international agreement defined as those weighing under 5½ lb. (2,500 g.), regardless of the maturity. In this way the study of the causes and the care of this class of infant can be standardized. Poor social conditions and poor health of the mother are important factors; *e.g.,* the incidence of prematurity is about six times greater in women of stunted stature and poor physique than in tall, healthy women. The spacing of births in a family has an important influence on the risk of prematurity; when the interval between two births is less than two pears the risk of prematurity is greater than if the interval were two to four years. The closer spacing of the births in the larger families of the less prosperous social classes contributes to their higher prematurity rate, and these considerations are a strong argument in favour of family planning (see PREMATURE BIRTH.)

See also CHILDBIRTH; GYNECOLOGY; MATERNAL AND CHILD HEALTH; OBSTETRICS; REPRODUCTIVE SYSTEM.

See Grantlv Dick *Read. Introduction to Motherhood* (1950).

(J. Y.)

PRE-HELLENIC ARCHITECTURE. This article deals nith the architecture that developed around the Aegean sea and in the near east from earliest times through the Archaic period of Greece (6th century B C.). The architecture of the subsequent period is discussed in GREEK ARCHITECTURE. Though belonging within the greater context of this discussion, the architectural history of Egypt will be found in EGYPTIAN ARCHITECTURE.

The maritime kingdom of Crete, by virtue of its central position betneen Europe, Asia and Africa, had early contacts with Egypt and the ancient near east and seems to have played an important intermediary role in the transmission of architectural influences to Greece. It is for this reason that near eastern architectural development is included here. The architecture of Achaemenid Persia, contemporary to early Greek architecture and therefore not strictly speaking pre-Hellenic, is included here also for the sake of geographic unity.

Since the chronology of pre-Hellenic times in the regions discussed in this article is subject to controversy, the dates given here are not necessarily identical with those given in other articles. In each case the author's dates are used. For further historical information see the articles about the specific places involved (*e.g.,* BABYLONIA AND ASSYRIA; CRETE; etc.).

MESOPOTAMIA

Mesopotamian civilization was theocratic; consequently it is in religious buildings that the architecture of this region finds its earliest and fullest expression. (See BABYLONIA AND ASSYRIA.) The beginnings of mud-brick architecture in the Ubaid period (4th millennium B.C.) may be seen in the earliest temples at Abu Shahrain in the south of Mesopotamia and Tepe Gawra in the north. Platforms, buttresses and recessed portals. perennial traits of Mesopotamian architecture down to the Hellenistic period, were already established at both sites. A recessed portal is part of the entrance façade of the earliest temple at Tepe Gawra, and at Abu Shahrain a similar building was placed on a platform and approached by a flight of steps.

These characteristics were repeated at Uruk (Erech, mod. Warka), with the added development that the platforin of Abu Shahrain mas replaced by the ziggurat (q *v.*), a tall staged tower nith outside staircases and a shrine at the top.

Walls and columns of early Mesopotamian temples were covered with a patterned facing of coloured clay cones that were inserted into the mud plaster: this primitive decorative technique gave rise to the later Assyrian practice of covering entire walls with richly polychrome glazed and molded brickwork. The arch was used in Mesopotamia, and false. or corbeled, vaults (*i* e., vaults constructed of successive series of projecting courses) were occasionally employed for tombs

The transition to the Early Dynastic period (*c.* 3000–2340 B.C.) brought with it certain innovations. The plano-convex brick. flat on one side and curved on the other, was invented. Both religious and secular buildings were built around a central court; the entrances to temples were generally flanked by towers and approached by a stairway.

The oval temple precinct at Khafajah is a typical example of Early Dynastic architecture. There, as at Abu Shahrain, the whole layout was elevated on a low platform. A flight of steps led up to an outer gateway flanked by two high towers. A small forecourt led to another gate which opened upon a spacious inner court. containing a well, several shallow ablution basins and the sacrificial altar. The temple proper, which probably had buttresses and recessed walls, was placed on a second platform approached by another flight of steps. Basically, this is also the type of complex at Tell Asmar and Tell Agrab. Later the square or oblong plan became more common.

Little is known about the architecture of the Akkadians, a Semitic dynasty which assumed power over Mesopotamia in the middle of the 3rd millennium B.C. This dynasty was ousted by the Guti. who were. in turn, driven out of Mesopotamia by the Sumerians at the end of the 3rd millennium, which began a time of great architectural activity.

The city of Lagash (mod. Telloh) flourished under King Gudea, but few remains of his architecture have come to light. Ur-Nammu. the first king of the 3rd dynasty of Ur (c. 2250 B.C.), erected a great ziggurat at Ur, his capital. It stands within an oblong court and is oriented to the points of the compass. Buttresses on its outer face give it added strength. Three monumental stairways with bastions in their angles converge at the first stage from which a single stairway ascends to the top of the second stage. A temple no doubt crowned the summit of the structure, but this has disappeared without a trace.

The 3rd dynasty of Ur is also represented by buildings at Uruk, Nippur, Mari (mod. Tell el Hariri). Xshur and Tell Asmar. The temple-palace of Gimil-Sin at Tell Xsmar deviates little from the development already described. The temple portion of the complex consists of a square central court, with the cella at the far end, surrounded by massive buttressed walls and entered by a towered gateway. The palace of the local ruler joins this temple at an angle and consists of antecella, cella, central court. throne room and great hall. Surrounding these large ceremonial spaces were small administrative offices; the living quarters seem to have been situated on a second floor.

Ur fell early in the and millennium B.C., and the succeeding phase is known as the Isin-Larsa period (2025–1763 B.c.). The temple of Ishtar-Kititium at Ishchali belongs to this period. Although related to, and developed from, the Early Dynastic complex at Khafajah, the original single-chambered shrine at Khafajah was there elaborated into an architectural complex with forecourt, court and cella.

A palace at Mari has been tentatively identified with the reign of Hammurabi (1792–1759 B.c.). the ruler and lawgiver of the 1st dynasty of Babylon which flourished contemporaneously with Isin and Larsa to the south.

A foreign dynasty, the Kassites, invaded southern Mesopotamia in about 1600 B.C. Their accession to power inaugurated a new era of building activity at Ur, Uruk and Dur-Kurigalzu, the new capital 20 mi. to the nest of modern Baghdad.

While the Assyrians in general adhered closely to established architectural schemes, they also brought about several important deviations from the early Mesopotamian norm. The latest Ishtar temple at Xshur and the Xshur temple at nearby Tukulti-Ninurta, built during the reign of Tukulti-Ninurta I (c. 1250–1210 B.c.), established the type that became characteristic for Assyrian temples. The latter was built against a ziggurat. as at Mari, and incorporates a dual entrance system: one entrance faces the cella as in earlier buildings; the other enters at a right angle. The cella is on a podium that lies in front of a recess cut out of the body of the ziggurat, and the ziggurat itself no longer incorporates a staircase. In fact, it may have been entirely inaccessible. The practice of setting a series of stone slabs, called orthostates, at the bottom of a wall below the mud-brick upper parts becomes common in the Assyrian period and will be seen again in Hittite architecture.

During the Late Assyrian age (c. 1000–612 B.C.), Ashur, Babylon. Nineveh, Nimrud, and Dur-Sharrukin (mod. Khorsabad) flourished as royal residences, but since only Ashur and Dur-Sharrukin have been at all fully excavated. we shall confine our remarks to the palace of Sargon II (722–705 B.c.) in Dur-Sharrukin.

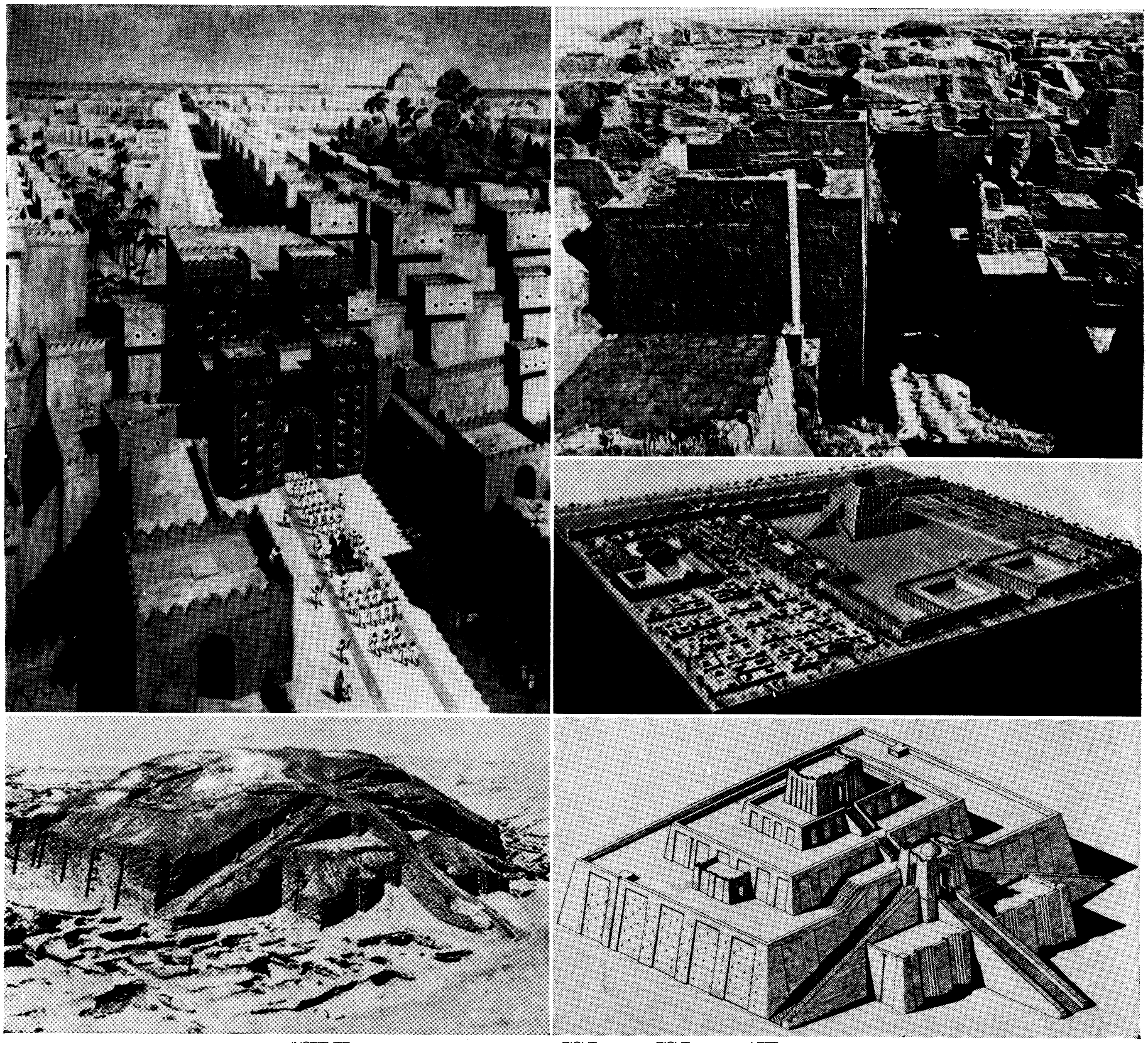
The palace area occupies about $7\frac{3}{4}$ ac., of which two-thirds are given over to the palace proper and the temple. the remainder being occupied by a large ziggurat probably composed of seven stages with an external spiral ramp. Basically, this plan is an elaboration of the traditional units that occur at Tell Asmar: square court, throne room. great hall. Each side of the court measures 300 ft., and its walls were revetted with monumental reliefs. In addition. great stone sculptures of monsters and genii, such as those that flanked the doorways, must also be considered as part of the architecture.

The final rebuilding of Babylon by Nebuchadnezzar II (605–j62 B.C.) marks one of the greatest building achievements ever attempted by man. Excavations during the first decades of this century by R. Koldeway and the German Orient society revealed no less than four gigantic castles on this site. It was during the reign of Nebuchadnezzar II that the fabled "hanging gardens" were built. The Ishtar gate of Nebuchadnezzar's palace, decorated with lively bulls and dragons executed in molded and glazed brick, has survived well and ranks as the finest monument of this great period. Of the ziggurat of Babylon. the biblical Tower of Babel, little remains today other than the ground plan and a description of the Greek traveler and historian. Herodotus.

MINOAN CRETE

The great maritime civilization of Crete (*q.v.*) crystallized around the palaces such as exist at Knossos, Phaistos. Hagia Triada. Mallia and Tylissos. The immensely important "Palace of Minos" at Knossos, excavated and reconstructed early in the 20th century by Sir Arthur Evans, offers evidence of unbroken architectural and artistic development from Neolithic beginnings, culminating in a brilliant display of building activity during Middle Minoan III (1700–1580 B.C.), and continuing until the invasion of the Achaeans in the 12th century. However, the palace is essentially a structure of the last two Middle Minoan periods (1800–1580 B.C). It no doubt rivaled near eastern and Egyptian palaces in monumentality. As in these. a quadrangular complex of rooms and corridors is grouped around a great central court, at Knossos roughly 17j ft. × 100 ft. At the northern end. toward the sea. a grand portico of 12 pilasters gave access to the central court. At this end, also, is situated the grand theatrical area, a rectangular open-air theatre perhaps used for ritual performances. The east wing of the palace is divided into two parts by a long east-west corridor and rose four or five stories above the slope of the valley. The southeast portion of the palace contains domestic apartments elaborately supplied with plumbing and flushing facilities as well as a sanctuary. A wide stairway led to an upper story which no longer exists. The northeast portion of the palace is occupied by offices and storerooms. The west portion is again divided by a long corridor, over 200 ft. long, running north and south. Behind this corridor was discovered a series of long narrow storerooms containing great numbers of pithoi, or man-size storage vessels for oil. On the other side of the corridor, toward the central court, are the rooms of state, including the throne room with its unique gypsum throne and world-famous griffin frescoes.

Light was supplied from above by an ingenious system of "light wells," and several colonnaded porticoes provided ventilation during the hot Cretan summers. Brilliantly hued frescoes played an



BY COURTESY OF (TOP LEFT) THE ORIENTAL INSTITUTE, THE UNIVERSITY OF CHICAGO, (TOP RIGHT, CENTRE RIGHT, BOTTOM LEFT, BOTTOM RIGHT) INSTITUTE OF ARCHAEOLOGY, LONDON

ANCIENT ARCHITECTURE: MESOPOTAMIA

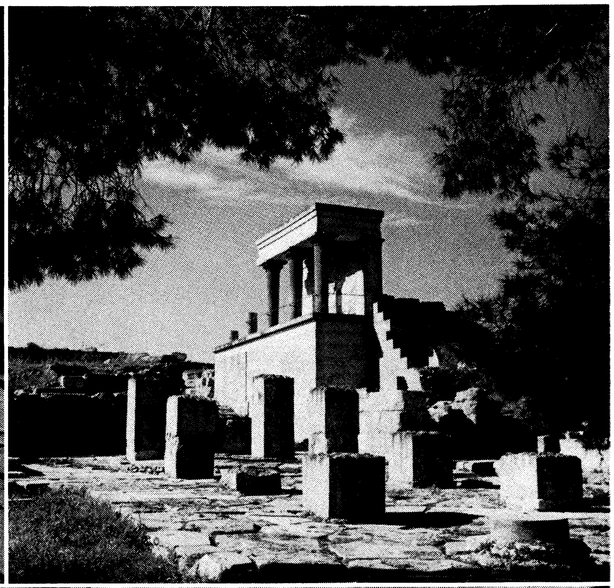
Top left: Painting of a reconstruction of the Ishtar gate, entrance to Nebuchadnezzar's palace, Babylon

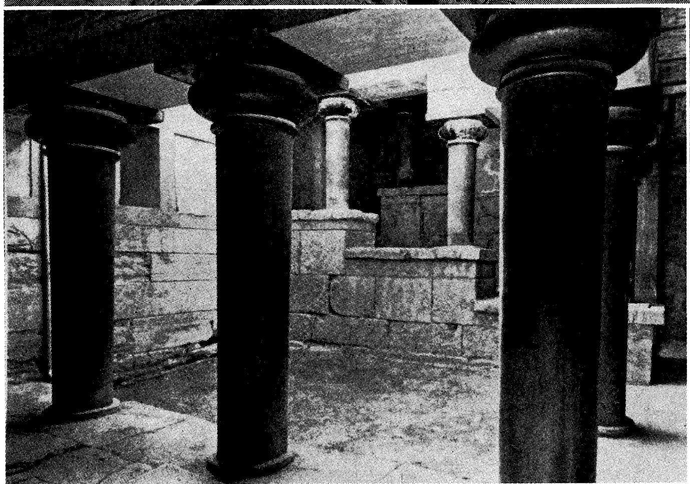
Top right: General view of the ruins of Babylon, with the foundations of the Ishtar gate in the foreground

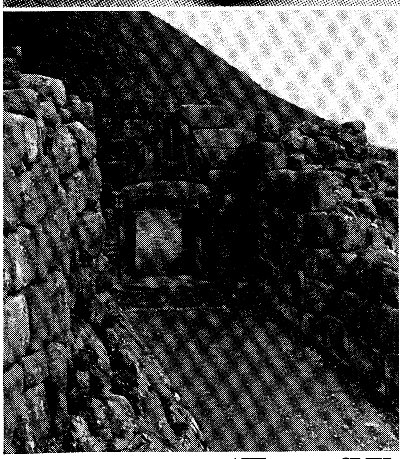
Centre right: Reconstructed model of the city of Babylon showing the biblical Tower of Babel

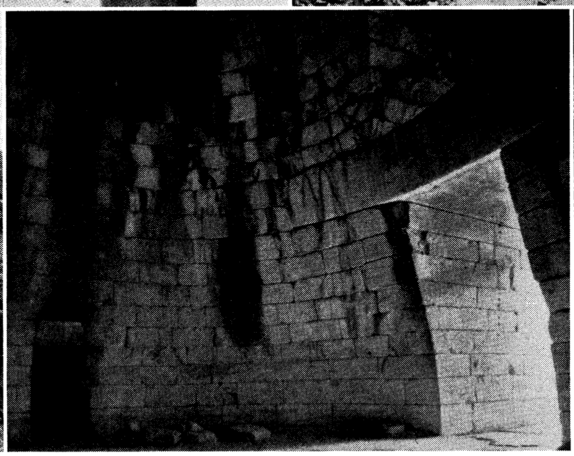
Bottom left: Ruins of the ziggurat at Ur, erected by King Ur-Nammu around 2100 B.C.

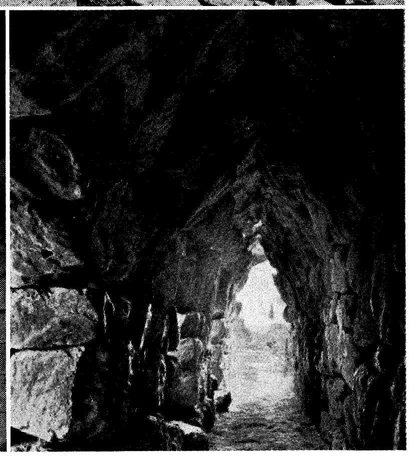
Bottom right: Reconstruction of the ziggurat at Ur











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ANCIENT ARCHITECTURE: KNOSSOS, MYCENAE AND TROY

Top left: Throne room in the Palace of Minos at Knossos showing the gypsum throne and griffin frescoes
Top right: Rebuilt portion of the north entrance to the palace at Knossos
Centre left: Grand staircase in the domestic quarter of the Palace of Minos
Centre right: Part of the wall and a tower of Troy VI erected c. 1900–1300 B.C.
Bottom left: Lion gate at Mycenae constructed during the 14th century B.C.
Bottom centre: Interior of the domed "treasury of Atreus" at Mycenae, a family sepulchre dating from c. 1250 B.C.
Bottom right: Gallery and casemates in the east bastion of the palace at Tiryns

important part in both the interior and the exterior decoration of the palace.

The development of the other Minoan palaces (Phaistos, Mallia, Hagia Triada, Tylissos) roughly parallels that of Knossos. Each has its special interest, and Phaistos is particularly fascinating. due to extensive Italian excavations. Maritime hegemony enabled the Cretan sea kings to build these palaces in low and unprotected places; consequently there is a conspicuous absence of fortification walls, as contrasted to the great walls of Mesopotamian palaces Since Cretan worship seems to have been largely in the open air, there are no real temples as in the near east. Yet, the disposition of the various parts of the palace around the central court and the avoidance of outside windows as much as possible are characteristics that seem to indicate an early contact with the near east A taste for long, straight palace corridors, as well as a highly developed hydraulic system, may also have been inherited from older civilizations to the east. The column made its first European appearance in the Cretan palace, where it is often employed individually to divide an entrance way.

The development of funerary architecture in Crete proceeds from the old chamber ossuaries of the Early Minoan period (2 750–2000 B.C.) to the developed tholoi or beehive tombs of the Mesara plain and the elaborate temple-tombs of Knossos at the end of the Middle Minoan period.

On the crest of Minoan prosperity came the great crash. An invasion from the mainland c. 1400 B C. destroyed the palaces and resulted in the removal of power to Mycenaean Greece. Architectural remains in Crete which are pre-Greek and yet subsequent to this catastrophe are very rare. Several country shrines belong in this postdestruction period, and at Prinias a unique temple building may be as late as 700 B C. The doorway of this temple is now in the Candia museum and has low reliefs on its architectural members. The opening above the lintel is flanked by seated figures, while the lintel itself is carved on its underside with figures of a goddess and of animals. That the Minoan tradition was not entirely extinct is indicated by the column which seems to have stood in the middle of this doorway. as at the "palace of Minos." (For a further discussion of Minoan palatial architecture. towns, sanctuaries and tombs, see CRETE. Archaeology.)

MYCENAEAN GREECE

The sudden architectural awakening of the Mycenaean Greek mainland is intimately connected with the zenith and decline of Minoan Crete and can only be understood against the background of a long Cretan development. Unlike Minoan Knossos, the archaeological remains on the mainland are fragmentary. In order to obtain an idea of Mycenaean architecture, we must draw on our knowledge of at least three sites: Mycenae. Tiryns and Pylos. Since the important architectural monuments visible today date largely from Late Helladic times (1580–*c.* 1100 B.C.) and since little earlier architecture is preserved, our brief survey shall be confined to this period. (See also AEGEAN CIVILIZATION.)

Fortification. — The tremendous building activity of the 14th century B.C. reflects an age of warfare, when powerful Greek-speaking kings built fortresses in key defensive positions on the mainland. The cyclopean walls of Mycenae and Tiryns (*i.e.,* the walls in which great blocks of untrimmed stone were employed) and the strategically placed Lion gate at Mycenae were constructed in this period. The latter consists of two colossal door jambs that support a monolithic lintel. The wall above the gate is so constructed as to form a relieving triangle over the lintel, and this empty space is blocked with the famous relief panel of two heraldic lions. which has given the gate its name. This method of construction provides an ingenious substitute for the arch which was unknown to the Mycenaeans.

Also justly famed are the concealed galleries of Tiryns, where the primitive corbeled vault makes its first appearance in mainland Europe.

Palaces. — Mycenaean palaces have been unearthed at Mycenae, Tiryns. Pylos, Gla and Phylakopi (Cyclades). The palace at Pylos is a typical mainland palace of the Heroic Age as described in the poetry of Homer. The characteristic plan comprises four elements: (1) a narrow court on which the structure fronts; (2) a double-columned entrance portico; (3) a vestibule (*prodomos*); and (4) the richly frescoed domos, or hall proper. The latter had a fixed throne at one end and a central fixed hearth between four wooden columns that supported an open towerlike structure rising above the roof for light and ventilation. Archives, comparable to those of the Hittite kings at Bogazkoy, were associated with this palace. Private houses, such as have been discovered at Mycenae, exhibit similar features as well as the basement storage magazines mentioned by Homer.

Tombs. — The earliest royal burials known from Mycenae are those of the two grave circles, the first discovered by H. Schliemann in 1878 and the second by A J. B. Wace in 1951. These grave circles have no architectural character, consisting essentially of vertical shafts cut into the bedrock.

More important architecturally are the tholoi or beehive tombs. The evolution of these family sepulchres began in Minoan Crete, but culminated in the so-called "treasury of Atreus" at Mycenae, now believed to have been constructed as late as *c.* 1250 B.C. This most impressive monument of the Mycenaean world is a pointed dome built up of overhanging (*i.e.,* corbeled) blocks of conglomerate masonry cut and polished to give the impression of a true vault. The diameter of this tomb is almost 50 ft ; its height is slightly less. The enormous monolithic lintel of the doorway weighs 120 tons and is 29½ ft. long, 16½ ft deep and 3 ft. high. It is surmounted by a relieving triangle similar to that over the Lion gate and decorated uith relief plaques in a manner not yet established with certainty. A small side chamber hewn out of the living rock contained the burials, whereas the main chamber was probably reserved for ritual use. Two engaged half-columns of Cretan type (now in the British museum) were secured to the façade which was approached by a dromos, or ceremonial passageway, revetted with cyclopean blocks of masonry and open to the sky. Other tholoi, though not as excellently preserved, exist at Mycenae and Orchomenos.

TROY

Excavations at Troy (mod. Hissarlik, on the eastern shore of the Dardanelles) have distinguished no less than nine stratified levels extending from prehistoric into Roman times.

Houses at Troy I (c. 3200–2600 B.C.) and Troy II (c. 2600–2300 B.C.) were formed of long narrow groups of rooms that already seem to bear a relationship to the rectangular megaron, or large hall, of the Mycenaean dwelling, sharing, as they do, the fixed hearth. deep vestibule and most of the other architectural features of megara on the Mycenaean mainland. Defensive gates flanked by towers at Troy II recall the military architecture of Hittite Anatolia to the east.

Troy VI (c. 1900–1300 B.C.), the immediate predecessor of Homer's Troy, was largely demolished by leveling operations in Roman times and at the end of the 19th century by Schliemann. This city possessed a symmetrical layout, impressive walls and, like Troy II, gate towers of splendid masonry that could be the prototype of Mycenaean as well as classical Greek propylaea. A large megaron of Troy VI incorporates a row of three columns along a central axis in its plan, again anticipating a development of Greek architecture (*e.g.,* the first temple of Hera at Samos).

Another feature of interest at Troy is the un-Mycenaean use of sun-baked brick for walling, probably a link with the construction techniques of Mesopotamia.

As more becomes known about the peculiar un-Minoan Bronze-Age civilization of Troy, other parallels with the architectural evolution of pre-Hellenic and Hellenic Greece will no doubt emerge. It is not unlikely that Troy will eventually take its place as an important intermediary for the transmission of ideas from the ancient near east to the younger cultures of the west. (See also TROY AND TROAD.)

HITTITE ANATOLIA

Because of recent excavations at Bogazkoy, Alaca Huyuk and Kultepe in Turkey, it is now possible to talk with a good deal of certainty about Hittite architecture. These three cities possess the earliest remnants of Hittite civilization. Their architecture is of a rude and primitive kind, yet not uninfluenced by the more developed architecture of older civilizations in Syria and Mesopotamia. Stones of colossal dimensions were employed in corbeled vaults for the construction of tunnels. gates and tombs. Monolithic orthostates, often decorated with reliefs: are common. At Bogazkoy (anc. Hattusas or Khattushash), the capital and most important city of the Hittites, as well as at other Hittite sites, such carved orthostates form the lowest masonry courses of palaces and temples. The absence of the column, employed by all neighbouring cultures. is conspicuous in Hittite architecture. square pillars serving in their stead. Also noticeable in the architecture of the Hittites is an apparent lack of axial planning. Hittite temples and palaces are built on an agglomerate principle, with rooms of varying dimensions grouped in tiers around a rectangular court. Internal communication must have been difficult.

Few buildings of architectural distinction remain from the Early Hittite period (1650–1460 B.C.), although from this period are the beginnings of monumental architecture on the Anatolian plateau. The flowering of Hittite architecture takes place during the three centuries of imperial expansion (1460–1190 B.C.), when the might of the Hittite kings was felt as far abroad as Egypt.

From this period date the great Hittite temples. Five such temples have been uncovered at Bogazkoy. In each of these. many small rooms are disposed about a large central courtyard. It was in this courtyard that the worshipers assembled. The cult statue was hidden in a remote holy of holies and seems to have been accessible only to the priesthood. In Temple I at Bogazkoy. this holy of holies projects from the core of the temple building. apparently in order that the cult statue could be illuminated by side windows. Numerous subsidiary rooms seem to have served administrative and storage purposes.

Architecturally, the palaces are closely related to the temples. As in the temples. the rooms of the palaces were grouped around a central courtyard. In contrast to the tightly organized palace-complexes of Crete and Mesopotamia, the palace of the Hittite kings at Bogazkoy consists of a number of isolated structures loosely disposed in a semicircular formation. Most of these buildings were multistoried. and. in addition to the royal habitation, an archive and a palace shrine have been identified. Two other excavated Hittite palaces of this period, at Kultepe and Huyuk. do not seem to differ substantially from that at Bogazkoy. The collapse of the Hittite empire at about 1200 B.C. is marked by destruction levels at these three sites. Subsequently. a short afterblossoming of Hittite culture took place in northern Syria at several centres where displaced Hittites, Aramaeans and nomads reassembled: and considerable architectural remains of this period have been uncovered at Carchemish, Tell Halaf and Zincirli in the foothills of the Taurus.

The employment of carved orthostates to adorn the lower part of a wall is a characteristic feature that unifies the architecture of these scattered sub-Hittite principalities and relates it to that of the Hittite empire at the height of its expansion. Another feature of the conglomerate architectural style that distinguishes these petty autocracies seems to be of Syrian, rather than Hittite, origin. This is the bit *hilani*, or pillared porch, the supports of which often rested on animal bases. (See also HITTITES. THE.)

ACHAEMENID PERSIA

The origins of the monumental architectural style that appeared in Persia with the foundation of the Achaemenid empire in j39 B.C. are disputed. *(See* PERSIA: History: The *Achaemenid* Em*pire.')* It has been suggested that the Persians learned the art of cyclopean building from the Urartaeans of Lake Van to the north; other elements of Persian architecture are often traced to Mesopotamia and even Egypt. It is known for certain that Greeks were among the foreign craftsmen employed in the construction of the great Achaemenid residences. The presence of horizontally fluted column bases in the Achaemenid palace at Pasargadae, similar to those of the Archaic Greek temples at Samos. Ephesus and Naukratis. is only one of several examples of their influence.

Yet. notwithstanding the presence of such foreign elements, it cannot be denied that the architecture of Achaemenid Persia is remarkably original. Veritable forests of columns and square halls of vast proportions radically differentiate Achaemenid buildings from the contemporary architecture in Greece and are more reminiscent of the native Persian development in Islamic times.

A great columned hall exists already in the palace of Cyrus at Pasargadae, the earliest of the three Achaemenid dynastic residences (other two: Persepolis and Susa). This palace was elevated on a series of man-made platforms and approached by a system of impressive stairways. A colonnaded gatehouse fronted by Assyrianizing bull-monsters gave access to the parklike enclosure in which stood the numerous pavilions and subsidiary buildings that comprised the palace. Among these there was the audience hall surrounded by four porticoes, each with a double row of pillars. Another building, believed to be the palace proper. has double porticoes flanking an almost square hall containing 30 columns arranged in j rows of 6 columns each distributed over the entire space.

The best-known. best-preserved and most spectacular of the Persian palaces is that at Persepolis (c. 521–388 B.C.). This enormous complex of buildings, terraces and stair ramps consisted, among other elements, of the palace of Darius I (522–486 B C.), Xerxes I (486–465 B C) and Artaxerxes III (359–338 B C.), a harem, a treasury, the Gate of Xerxes, the Hall of the Hundred Columns and a number of other buildings.

The Hall of the Hundred Columns at Persepolis is 22j ft. square, though its columns are only 37 ft. high as compared to 67 ft. in the smaller Hall of Xerxes at the same site. The gateways of the Hall of Xerxes are flanked by colossal winged genii similar to those associated uith Assyrian palaces; flanking the stairway leading to the Audience Hall of Darius were discovered the famous reliefs of tribute bearers that have since found their way into museums throughout the norld. Everywhere, sculpture was combined with architecture to produce a total effect of grandeur hardly surpassed by the great architectural complexes of Egypt.

At Susa, the palace is in part similar to that at Persepolis, in part related to the palace of Nebuchadnezzar at Babylon. The widespread use of glazed coloured bricks in the architecture of Susa also associates this palace with the earlier architecture of nearby Mesopotamia.

The aniconic religion of the Persians required only simple open-air fire altars for the perpetration of its rites. Consequently, there is no temple architecture, and only tombs remain to be mentioned. At Pasargadae, an early Achaemenid tomb, probably correctly identified as that of King Cyrus, consists of a rectangular single-roomed sarcophagus chamber with a gable roof recalling the tombs of Caria and Lycia in southwestern Turkey. The entire structure and the pedestal of six steps on which it stands are built of great blocks of well-dressed masonry and were formerly surrounded by a colonnade. Later Persian monarchs were interred in the cliff-hewn tombs at Naksh-i-Rustam near Persepolis. See also TEMPLE ARCHITECTURE; RELIGIOUS ARCHITECTURE; ETRUSCANS.

BIBLIOGRAPHY. — *Mesopotamia:* H. Frankiort, *The Art and Architecture of the Ancient Orient* (Pelican History of Art, 1954).

Minoan Crete: F. Matz, *Die Agais (Handbuch der Archaeologie,* vol. ii, 1954; bibliography); J. D. S. Pendlebury, *The Archaeology* of *Crete* (1939); *E.* Bell, *Prehellenic Architecture in the Aegean* (1926; good general account, though no longer up to date); Sir A. J. Evans, *The Palace of Minos, 4* vol. (1921–35; index 1936).

Mycenaean Greece: F. Matz, *Die Agais (Handbuch der Archaeologie,* 1954); E. Bell, *Prehellenic Architecture in the Aegean* (1926); *A.* W. Lawrence, *Greek Architecture* (Pelican History of Art, 1957); *G.* E. Mylonas, *Ancient Mycenae* (1957; bibliography); A. J. B. Wace, *Mycenae* (1949; excellent account, but already outdated by new discoveries); C. W. Rlegen, "The Palace of Nestor at Pylos," in *American Journal of Archaeology,* vol. 57 (1953) and *Illustrated London News,* pp. *86* ff. (Jan. 16, 1954); R. Rodenwaldt, *Tiryns* (1912, *et seq.*).

Troy and Hittite Anatolia: *R.* Naumann, *Die Architektur Kleinasiens* (1955; bibliography); O. R. Gurney, *The Hittites* (1952; on Hittite civilization in general); E. Bell, *Early Architecture in Western Asia* (1924; good general account, but outdated by subsequent excavation).

Achaemenid Persia: A. U. Pope, *A Survey of Persian Art,* vol. i (1938); R. Girschman, *Iran* (English version in Pelican series, 1954); E. F. Schmidt, *Persepolis,* 2 vol. (1953–57). (H. HN.)

PREHNITE, a relatively uncommon calcium and aluminum hydrous silicate mineral, is generally light green in colour and occurs in rounded masses of crystals. The individual crystals are not usually distinct to the unaided eye. Prehnite resembles certain varieties of the hydrous zinc silicate hemimorphite (*q.v.*). It can be distinguished from that mineral most readily by its lower specific gravity and by its type of geologic occurrence and associated minerals.

Prehnite occurs most commonly as crystal masses lining cavities in mafic (basic) igneous rocks such as basalt and diabase. Characteristically associated with it are calcite, quartz. zeolites, datolite and pectolite. Some notable localities of this type of occurrence in the United States are Paterson and Bergen Hill, N.J., Farmington, Conn., Westfield, Mass.; and the Lake Superior copper district. It has been found at Cradock, Cape Province, U. of S. Af., in the south of Scotland, the French and Tirolean Alps, the Hartz mountains and other localities. Prehnite also occurs less commonly and less strikingly in other types of rocks, such as schists, amphibolites and metamorphosed sedimentary carbonate rocks. The composition of prehnite is expressed by $Ca_2Al_2Si_3O_{10}(OH)_2$. Small amounts of ferric iron (Fe^{3+}) may be present in place of some of the aluminum. (D. M. H.)

PRELATE, an ecclesiastical dignitary of high rank. In the early middle ages the title prelate was applied to secular persons in high positions and thence it passed to persons having ecclesiastical authority. The De prelatis of Valerian is concerned with secular princes, and even as late as the 14th century the title was occasionally applied to secular magistrates. In medieval ecclesiastical usage the term might be applied to almost any person having ecclesiastical authority. The term occurs very frequently in the rule of St. Benedict and other early monastic rules.

In more modern usage in the Roman Catholic Church, prelates, properly so-called, are those who have jurisdiction in *foro* externo, but a liberal interpretation has given the title a more general significance. Prelacy is defined by the canonists as "pre-eminence with jurisdiction." and the idea supposes an episcopal or quasi-episcopal jurisdiction. But gradually the title was extended to ecclesiastical persons having a prominent office even without jurisdiction, and later still it has come to be applied to ecclesiastical persons marked by some special honour though without any definite office or jurisdiction.

We may therefore distinguish true from titular prelates. The true prelacy is composed of the persons who constitute the ecclesiastical hierarchy; jurisdiction is inherent in their office and gives pre-eminence, as with patriarchs, archbishops and bishops. The true, no less than the titular, prelates have their various ranks. differing as regards title, precedence, clothing and other insignia. The distinguishing colour of a prelate's clothing is violet; the form, like the greater or less use of violet. depends on the rank of the prelate, Four classes may be distinguished: (1) great prelates, *e.g.*, cardinals, archbishops and bishops; (2) exempt prelates, *i.e.*, abbots and religious superiors. who are withdrawn from the ordinary diocesan jurisdiction and themselves possess episcopal jurisdiction; (3) Roman prelates, (a) active and (*b*) honorary. The title is applied to numerous ecclesiastics attached by some dignity, active or honorary, to the Roman court (see CURIA ROMANA).

In the Reformed churches the title was retained in England, Sweden, Denmark and Germany. The cathedral chapter of Brandenburg consists of two prelates, the dean and the senior, besides eight other members. The chapter of Merseburg contains five prelates, viz., the dean, senior, provost, *custos* and *scholasticus*. In Baden the general synod is presided over by the prelate (*prelat*); *i.e.*, the principal "superintendent." In the Church of England the term prelate has been since the Reformation applied only to archbishops and bishops.

PREMATURE BIRTH is defined by the World Health organization as the birth of an infant weighing $5\frac{1}{2}$ lb. (2,500 g.) or less. Another and preferable standard, birth at less than 37 weeks after conception, requires facts often unobtainable. Prematurity (by the standard of weight) occurs in about 7%–9% of pregnancies in white women in the United States, and in 10%–12% of those in Negro women; the rate in the latter is higher probably because of poorer socioeconomic conditions. In the U.S. prematurity is directly or indirectly responsible for at least 50% of all deaths of newborn infants.

A presumptive reason (usually multiple pregnancy, maternal toxemia or hypertension, abnormal attachment of the placenta or congenital malformation of the infant) can be found for 40%–60% of premature births, but fully half those of single infants are of unknown cause. Poor maternal health, hygiene and nutrition increase the likelihood of prematurity; maternal accidents and acute illnesses are insignificant as causes. The chief specific causes of death among premature infants are respiratory disturbances (hyaline membrane disease, atelectasis), infections (usually pneumonia) and hemorrhages, especially into the brain or lungs and often not caused by injury. With good care about 85% of all premature infants born alive should survive. In the large group born at 4-5-54 lb. (2,000–2,500 g.) 95% or more should survive; among the few born at less than $2\frac{1}{4}$ lb. (1,000 g.) the survival rate may be less than 10%. An infant of $1\frac{3}{4}$ lb. (800 g.) rarely survives. In other words, chances of survival increase in direct proportion to weight.

Prevention of premature birth is not yet possible. Treatment of the infant begins with skillful obstetric management under minimal anesthesia during premature delivery, followed by specialized nursing and pediatric care in an environment approved as a premature infant nursery by public health authorities. This must provide the space, equipment and trained personnel for isolation against infection, regulation of temperature and humidity, feeding of human milk or special mixtures by tube or dropper and prompt relief of respiratory crises. Subsequently, instruction of the mother, supervision of home care and special attention to the nutritional requirements of rapid growth are needed.

Prematures weighing over four pounds (1.800 g.) at birth are usually born after 32 weeks, and they have much the same outlook for later growth and development as do term infants. Those of three pounds (1,350 g.) or less, especially if born before 28 weeks, are more liable to reduced stature and disturbed neuromuscular development. Research must therefore not only find means of preventing prematurity, or of increasing survival if prevention is impossible; it must also lead to normal growth and development after premature birth. See also FETAL DISORDERS; INCUBATORS; CHILDBIRTH.

See Herman N. Bundesen *et al.*, *Progress in the Prevention of Needless Neonatal Deaths (1951)*; Ethel C. Dunham, *Premature Infants: a Manual for Physicians*, 2nd ed. *(193'5)*. (C. A. SM.)

PREMIER: see PRIME MINISTER.

PREMONSTRATENSIANS, also called Norbertines, and in England White canons. from the colour of the habit; an order of Augustinian canons founded in 1120 by St. Norbert, afterward archbishop of Magdeburg. He had made various efforts to introduce a strict form of canonical life in various communities of canons in Germany: in 1120 he was working in the diocese of Laon, and there in a desert place, called Prémontré, in Aisne, he and 13 companions established a monastery to be the cradle of a new order. They were canons regular and followed the so-called rule of St. Augustine (see AUGUSTINIAN CANONS), but with supplementary statutes that made the life one of great austerity. St. Norbert was a friend of St. Bernard of Clairvaux, and he was largely influenced by the Cistercian ideals as to both the manner of life and the government of his order. But as the Premonstratensians were not monks but canons regular, their work was preaching and the exercise of the pastoral office, and they served a large number of parishes incorporated in their monasteries. The strength of the order is in Belgium.

PREMYSL, the reputed ancestor of the Premyslide line of dukes and kings which ruled in Bohemia from 873 or earlier until the murder of Wenceslaus III in 1306. According to legend Premysl was a peasant of Stadice who attracted the notice of Libusa, daughter of a certain Krok, who ruled over a large part of Bohemia, and is said to have been descended from the 7th-century hero Samo. Premysl married Libusa, the traditional foundress of Prague, and during the 8th century became prince of the Bohemian Czechs. His family became extinct when Wenceslaus III died. but through females the title to Bohemia passed from the Premyslides to the house of Luxembourg and later to the house of Habsburg.

PRENATAL HEALTH: *see* MATERNAL AND CHILD HEALTH: PREGNANCY.

PRENDERGAST, MAURICE BRAZIL (1861–1924), U.S. painter, one of the first Americans to make intelligent use of the technical advances in Post-impressionism. was born in Roxbury, Mass , on Oct. 27, 1861. He began drawing in childhood and reached a painting career through executing show cards and carving picture frames. The latter craft maintained him and his brother Charles all their lives. During the 1880s Maurice spent two years studying art in Paris; on a second trip in 1898–99 he discovered the work of Paul Cézanne and painted water colours in Venice. In his water colours he developed a mosaiclike pattern of transparent touches which successfully conveyed the gaiety appropriate to their subjects of crowded parks and beaches. In his later oils calligraphic drawing and opalescent colour in rich impasto drew a veil of wistfulness over similar scenes. His audience was never large, but with them his reputation was made secure by the works shonn in the controversial Armory show in New York (1913). The only important official honour he received was the third W. A. Clark prize from the Corcoran gallery, Washington, D.C., in Dec. 1923. He died in New York city on Feb. 1, 1924.

See Margaret Breuning, *Maurice Prendergast* (1931). (VL. B.)

PREPARATORY SCHOOLS in Great Britain form part of the public-school system. (In the United States the term is used for those schools which prepare for higher education, and they are discussed in the articles SECONDARY EDUCATION: *United* States, and EDUCATION, HISTORY OF: *United* States)

In Great Britain before Thomas Arnold in the 1830s excluded boys of under 12 years of age from Rugby there were few of these schools, but they later became very numerous. They are privately owned and are free of government control; however, they have usually invited inspection by her majesty's inspectors of schools and indeed are now compelled by law to undergo such inspection periodically. The majority of preparatory schools are linked together by membership in an incorporated association. They cater, for the most part, for boys between the ages of 7 and 14 years, and outside the large tonns and cities most of the pupils are boarders.

BIBLIOGRAPHY.—Board of Education, *Report on Preparatory Schools,* ed. by Michael Sadler (1900) ; *Preparatory Schools' Review,* issued by the Incorporated Association of Preparatory Schools (thrice yearly) ; I.A.P.S., *The Preparatory Schoolboy aad His Education,* ed. by E. H. Allen and L. P. Dealtry (1951).

PREROGATIVE, in English law, means the residue of discretionary powers and legal immunities which, by common law, are at any given time legally left in the hands of the king.

A distinction has to be made at the outset between prerogatives peculiar to the king in his "natural" capacity and confined to him—such as the rule that he is personally exempt from all jurisdiction, criminal or civil, and cannot be sued for debt—and prerogatives which belong to his "politic" capacity and as such extend to the whole government—such as the immunity of "the crown" at common law from being sued by ordinary civil process (see PETITION OF RIGHT). English law has, however, never clearly distinguished between the two capacities. The whole history of "constructive treason" is a witness to this dualism, as when the judge held that "every rebellion intendeth as its natural consequence the death of the king." The king was completely identified with the state, and even modern British constitutional law knows no such term as "the state." The state is the king.

All statutory powers conferred upon the government are declared to be conferred on "his majesty in council." All money voted by parliament is voted to "the king," even though appropriated by statute to public services from which the king cannot divert it.

The Crown.—The distinction between the king's government and his person, is used intermittently but, strictly speaking, the crown is only "a chattel in the Tower which has been entailed upon the Hanoverian dynasty." The common law, apart from statute, makes no distinction between debts due to the king's household and debts due to the crown, so that, at common law, debts due to the king personally and taxes due to his government enjoy the prerogative of priority over all other claims against the estate of a debtor, a bankrupt or a deceased person.

Similarly a royal palace and a post office are equally exempt from the payment of rates, one of the prerogatives being that "the king" is not bound, in the absence of express words, by a taxing statute. The same identification of the "natural" king and the "politic" king is in the rule that the king's government could never, in any circumstances, be used for wrongful, *i.e.*, tortious, acts. The immunity of the latter was based historically on the rule that the "king can do no wrong," which did not mean originally the perfectibility of the king, but the simple feudal fact that the king could not be tried or sued in his own courts.

As the king was, and is, the "government," the rule found a new application in the principle that no governmental acts or defaults could be the subject of legal proceedings. Had this application been carried to its logical conclusion, it would have resulted in the immunity of all the king's officers from being sued for their wrongful acts. But English lam was, and is, too practical to be logical, and a consequence so disastrous to the rights of the subject was avoided by the evolution of the principle, laid down by the judges, that no servant of the crown could be allowed to plead the command of the king, even where such a command had actually been issued, as a defense for an unlawful act, for to admit such a plea would, they held. be to impute wrong to the king, and the king could not only "do" no wrong but could not even "think a wrong."

The failure of the law to make any distinction between the natural and political capacity of the king led to some desperate fictions. of mhich the supreme example is the legal maxim that "the king never dies." Otherwise the death of the king would have dissolved the state in the interregnum between the decease of one king and the coronation of his successor. Indeed. this was actually the situation before the invention of the fiction. In spite of the fiction that "the king never dies," until 1867 the death of the king operated to dissolve parliament; the king was, and is, a constitutional element in parliament and the summons of a parliament was regarded as an act so personal to him that nhen he died his parliament died with him. The Demise of the Crown act of 1867 provided that the death of the king should not involve a dissolution. On the other hand the death of the king still operates to dissolve the whole privy council from the date of his death until his successor reappoints the members.

Exercise of the Prerogative.—The prerogative pon ers of the king, as distinct from powers conferred on him by statute, have all one feature in common: they can no longer be exercised by the king in person but only on the advice of ministers or in particular forms and by the use of particular instruments. Long before "responsible government" made its appearance in England and at a time when the commons even repudiated responsibility for the government of the country, parliament insisted that the royal prerogative in certain matters could only be exercised by the use of certain seals, notably the great seal and the privy seal. which were in the custody of certain great officers of state. For the use or misuse of these seals their custodians could be brought to book by impeachment (*q.v.*) in parliament. In the same nay the common-law courts laid down the rule at the beginning of the 17th century, that even in the court of king's bench, held before the king and in mhich medieval kings had presided in person, the king could no longer administer justice in person. There still remained the residuary jurisdiction of the king in council which could be, and was, exercised by him in person. With the abolition of the star chamber in 1641 this jurisdiction disappeared.

Pre-Cabinet Government.—So long, however, as it was in the power of the king to remove judges for decisions adverse to the exercise of his personal will or to dismiss ministers who refused to carry out his wishes, he retained *de facto* control over his prerogatives even when their exercise was subject to the formal rules described above. The efforts of parliament were therefore directed to limiting the scope of the prerogative. The chief examples are afforded by statutes such as the Petition of Right, the Bill of Rights and the Act for the Abolition of the Star Chamber, statutes abolishing respectively the prerogative of the king in taxation to supply his needs, in raising and keeping a standing army to enforce his will and in exercising a jurisdiction to punish his opponents. Parliament thus went further than the courts were prepared to go. Parliament eventually refused to accept the king's command as a defense to the impeachment of one of his ministers, as in Danby's Case (1679), while by the Act of Settlement (section 3) it enacted that the king's prerogative of pardon under the great seal should not be pleadable to an impeachment. So long, however, as the king was not dependent on supplies for the ordinary expenses of the government he could neglect to summon a parliament for as many years as he pleased and impeachment was thereby made impossible. What mas really decisive in securing the exercise of the king's prerogative by ministers in accordance with popular will was the transfer, principally as the result of Edmund Burke's reforms, of all governmental expenses from being a charge on the hereditary revenues of the crown, or the civil list, to the annual estimates. In strict law the king can still appoint and dismiss ministers as he pleases, and he is under no statutory obligation to summon parliament. But if he did the one and omitted the other. he and his ministers would be without money to carry on the government.

As with the king's ministers, so with "his" judges. By virtue of the Act of Settlement (1701) the king can no longer dismiss judges at his pleasure; they are removable only on an address by both houses of parliament. Even appointment, though technically the act of the king, is the act of a minister, the lord chancellor. Thus the prerogatives are no longer an instrument of arbitrary government. They have, constitutionally speaking, passed into the hands of the cabinet.

Modern Scope of the Prerogative.—The chief prerogative powers may be summarized as follows:

1. Foreign *Relations*.—In foreign relations the king has the exclusive power of making war and of declaring peace. The power is usually exercised by a proclamation and an order in council, and as such it is binding on the courts who must accord it the same "judicial notice" as an act of parliament. In practice the power is never exercised except with the approval of parliament.

The treaty-making power may be regarded as an exercise of the same prerogative. Whether the king can, by the negotiation of treaty, cede British territory has been much disputed; no king—in other words, no English ministry—has ventured to exercise such a prerogative since 1894 without seeking the consent of parliament in the form of a statute, and it may be regarded as settled usage that the crown will always, in the case of a treaty of peace involving cession or annexation, seek statutory powers to carry such a treaty into effect. However. the crown has often, as in the case of certain African protectorates, annexed "foreign" territories by mere prerogative in the form of an order in council. Furthermore it rests with the crown and the crown alone to "recognize" the foreign governments as de *jure* governments. Such recognition is binding on the courts and so is a declaration by the crown that a particular person is entitled to the status of a foreign sovereign, and as such is immune from the jurisdiction of the courts. So, too, with the status of an ambassador and the diplomatic immunity of himself and his suite. The king's prerogative in relation to foreign affairs is generally understood to cover also his powers over persons owing no allegiance to him. The exercise of such a prerogative, or "act of state." is a defense to an action brought against a servant of the crown.

2. Defense.—The king is head of the naval and military forces of the country and can alone recruit them. It is a statutory ofiense for any other person to "recruit." The Bill of Rights limited the exercise of this prerogative by making the raising and maintaining of a standing army in time of peace illegal. It does not prohibit the exercise of the power in time of war, and the prerogative is unaffected as regards the navy. With certain limitations, the king can requisition the subject's property and enter on his land in time of war, though this prerogative is entirely regulated by statute. The need of an annual statute to put in force the code known as the Army act has made of the army "a statutory not a prerogative force."

All army expenditure is subject to the annual vote of the army estimates. It is, in fact, impossible for the king to "make war," as distinct from declaring it, without the consent of parliament. (See also MARTIAL LAW and MILITARY LAW.)

3. *Legislation*.—The requirement of the king's assent to a bill passed by both houses of parliament before it can be "enacted" is an aspect of the royal prerogative in that the king may, in law. withhold his assent. This prerogative is not dead but it was not exercised after the reign of Queen Anne. The crown cannot of itself legislate either by proclamation or by order in council. Nor can the king dispense individuals from or suspend the operation of the laws made by parliament.

In the case of colonies acquired by conquest or cession. however, the prerogative is absolute. And the king can disallow an act to which his local representative, the governor, has assented.

4. Parliament.—It is the sole prerogative of the king to summon. prorogue and dissolve parliament. This is an executive. not a legislative, act and is of course performed on the advice of ministers. After 1924 the king could not under any circumstances refuse to dissolve parliament when a request to that effect was preferred by a prime minister. But he might still dissolve parliament himself, and against the wishes of his prime minister, when a prime minister having been defeated on a direct vote of confidence in the commons refused either to resign or to ask for a dissolution.

5. Executive.—The theory of the law is that the government of the country is still entirely a matter of prerogative, although, of course, many if not most of the powers now exercised by the crown have been conferred upon it by statute. (See STATUTE LAW: Delegated Legislation.) All ministers are appointed by the king—on the nomination of the prime minister.

In the choice of a prime minister the king has a discretion; he sends for whom he will when the outgoing prime minister has resigned, but his choice is usually limited to the leader of the opposition. All military and naval officers are appointed by a "commission" from the king, as are governors of the colonies. As he appoints, so he dismisses. Every officeunder the crown, except that of the judges and the comptroller and auditor general, is held "during pleasure," a doctrine with important legal consequences in that the king's ministers can terminate any commission or contract of service nhenever they please, and the servant of the cronn, civil or military, has no remedy.

Moreover, the crown cannot fetter its future executive action by special agreement. Thus the prerogative may operate to invest ministers with legally uncontrolled power. No servant of the crown has, apart from statute, any legally enforceable right to pay, pension or security of tenure.

6. General.—The king is the supreme landowner, a relic of feudal doctrines, which in the case of a man dying intestate and without heirs used to mean that his land "escheated" to the crown (see ESCHEAT). The king also is the depositary of the prerogative of mercy: he can pardon those who offend against his "peace"; the prerogative is now exercised exclusively on the advice of the home secretary. He is the "fountain of honour": the sole grantor of titles such as peerages, baronetcies and knighthoods; his power in this respect is subject to no limitations except those contained in peerage law, but "honours" are rarely conferred by him except on the advice of ministers. He is the "supreme governor" of the church in virtue of the Acts of Supremacy and Uniformity. The prerogatives of the crown in the courts are dealt with in the article PETITION OF RIGHT.

Effect of Statutes on the Prerogative.—Parliament has frequently intervened to abolish some particular prerogative, deemed to be oppressive, and after the Revolution of 1689 it has never been doubted that such a statute will bind not only the king who actually assented to it but all his successors. It was for long a matter of considerable doubt and speculation whether a statute could curtail a prerogative in the absence of express words to that effect. Thus it has been successfully contended that the crown is not bound by the Statute of Limitations and it has obtained judgment in proceedings against a subject, by Information of Debt, on a claim *30* years old. But the presumption in favour of the crown in the interpretation of a statute is no longer as strong as it was. In this respect the great case of *Attorney-General* v. *De Keyser's Hotel (1920)* A.C. (Appeal Cases) is decisive to the extent that when parliament has by statute regulated "the whole field of the prerogative," that particular prerogative can be exercised in no other way than that prescribed by the statute. *See* also ATTORNEY GENERAL; COMMON LAW; CONSTITUTION AND CONSTITUTIONAL LAW.

BIBLIOGRAPHY. — *A. V.* Dicey, *Introduction to the Study of the Law of the Constitution,* ed. by *E.* C. S. Wade, 9th ed. (1939); W. R. Anson, *The Law and Custom of the Constitution,* vol. ii, *The Crown,* ed. by A. *B.* Keith, 4th ed. (1935); D. L. Keir and F. H. Lawson, *Cases* in *Constitutional Law,* 4th ed. (1954). (J. H. Mo.; N. S. M.; X.)

PREROGATIVE COURTS, the name given to the English provincial courts of Canterbury and York, as far as regarded their jurisdiction over the estates of deceased persons. They had jurisdiction to grant probate or administration where the diocesan courts mould not entertain the case owing to the deceased having died possessed of goods above the value of £5 (*bona notabilia)* in each of two or more dioceses. The jurisdiction of the prerogative courts was transferred to the court of probate in 1857 by the Probate Court act, and was vested in the probate, divorce and admiralty division of the high court of justice by the Judicature act of 187j. In the U.S. state of New Jersey the court having jurisdiction over probate matters came to be known as the prerogative court.

PRESBYTER, the title borne from very early times by certain officers or ministers of the Christian church intermediate between bishops and deacons. The word is the original form of priest. See MINISTRY, THE CHRISTIAN; EPISCOPACY; PRIEST; PRESBYTERIAN.

PRESBYTERIAN, the distinguishing name of a group of Christian churches which took form during the British Reformation and subsequently gave rise to other churches bearing the same name in the Americas, Asia and Africa. Also, the specific name of a form of church constitution or polity which claims for itself origin in the Christian church during apostolic times and reformulation during the Swiss Reformation. Subsequently, this system was adopted with variations by many churches in other countries, some using the original name "Reformed Church," others the name "Presbyterian Church," or other names.

THE PRESBYTERIAN CHURCHES

England. — During the Reformation in England several groups arose, each with a different religious and political outlook according to which it sought to shape English life. In time, one of these groups assumed the name Presbyterian. Its name came from its form of church government, but its total program was an all-embracing right-wing Puritan system which took into account theology, ethics, politics and economics. The basis of the whole system was a conception of covenant or contract. William Tyndale had introduced this conception into England in his Bibles and other religious and political writings. The idea had been used in various religious and political systems of the middle ages. Tyndale seems to have gotten it from the reformers of the Rhineland cities, Zurich, Basel and Strasbourg, where it was being made the basis of a Protestant theology and a democratic-republican political theory. Other early English reformers such as John Bale and John Hooper, also used this system in their writings.

Under Edward VI (1547–53) the English Reformation went forward with royal aid. Numerous scholars from the Rhineland, Martin Bucer, Peter Martyr and others, went to England. A strong movement was created based on an Augustinian piety and theology, deeply influenced by humanism, devoted to the Bible, to ethical reform and to democratic political ideas. The covenant-contract notion underlay all of these views, as it did in the Rhineland. Queen Mary (1553–58) restored Roman Catholicism and the leading reformers fled to the continent. During this "Marian exile" the English reforming movement developed three wings. One regarded the moderate reform set up under Edward VI as typically English and final. Another group demanded further reforms, especially doctrinal, along lines laid out by John Calvin in Geneva. A third group, mostly underground in England, was working for reformation by small groups, each free in every way.

Queen Elizabeth (1558–1603) re-established Protestantism, but did so on the basis of a series of compromises framed in the interests of her royal power. After some adjustments most of the Edwardean group of reformers. led by their bishops, accepted Elizabeth's plan. The Genevan group was shunted to one side, since in both theology and politics their ideas were considered too radical. The third group of reformers remained underground and were considered as dangerous and subversive sects.

As the meaning of Elizabeth's policy became clear, open opposition to it arose. Yet, so ably did Elizabeth pursue her course that her opponents were effectively turned against each other. The "vestiarian" controversy of 1567–68 was an attempt to break the Elizabethan compromise settlement by demanding the elimination of all ministerial vestments and church furnishings formerly associated with Catholicism. The name "Puritans" was coined during this struggle. The bishops defeated this attempt by making it to appear as a quarrel over wholly peripheral matters. Then came a frontal attack by a party which came to be known as "Presbyterian."

Thomas Cartwright led a powerful movement, 1570–73, aimed at eliminating the entire episcopal system through which Elizabeth worked. He advocated a presbyterian system, modelled on the system of Calvin, in which the people chose their own pastors and then elected lay elders to share with the pastor in governing the local church. Central authority was vested in representative bodies of ministers and laymen which were chosen by the churches themselves, or by the lower judicatures. Such a system, Cartwright declared, could and would reform the church in England.

This first Presbyterian attempt at reforming the church was defeated. However, it did set in motion endeavours which shortly resulted in the working out by Cartwright and others, of a coherent and comprehensive understanding of Christianity which formed the basis for all subsequent forms of Presbyterianism. its underlying structure was that of covenant-contract, but now in a much more fully worked out form. The backbone of the system had its nearest likeness in the covenant system of the Rhineland-Netherlands reformers. Its church government theory had its nearest parallel in Calvin's theory. Its austerity, its blue laws and its theocratic outlook have often been traced to Calvin. Yet, mediaeval England and mediaeval Geneva had known blue laws, and Calvin's own attitudes on them had come to him from Zurich via Strasbourg. The Presbyterians were sabbatarian and anti-liturgical, as were the Rhineland-Netherlands reformers. Calvin was the obverse. The Puritan and Presbyterian "prophesyings" were borrowed from Zurich. On decisive doctrines such as faith, repentance, law and gospel, the church, the ministry and the two sacraments the Presbyterians stood nearest to the Rhineland-Netherlands reformers, not to Calvin or Luther. Politically their closest foreign counterparts were the Huguenots.

As early as 1572 (at Wandsworthj Presbyterians began to organize small local bodies in secret. Rather open organization was effected on the Channel Islands by *1576,* and among English merchant settlements in Holland by 1585. Secret bodies were in existence in London, Oxford, Cambridge, Warwick, Northamptonshire and elsewhere by *1585.* Because of the need for secrecy these bodies came into being as exclusively ministerial: with no lay representation and little or no real participation by the churches. This fact became decisive for the subsequent history of English Presbyterianism. It became a ministerial movement, contending for control of the English Church through the aid of the parliamentary party. with no great popular appeal or support,. As the Great Rebellion began (1641) the coalition of parliamentary-presbyterian forces took the lead in the opposition to the royal-episcopal absolutism. In the early phases of the struggle they maintained their leadership through the co-operation of the centre and left-wing Puritans and, particularly, through the aid of the ultra-Presbyterian Scots whom the two Bishops' Wars had brought to their aid. As events moved steadily toward control of England by the parliamentary-presbyterian party, episcopacy was abolished in the church by act of parliament. Then, an Assembly of Divines was summoned by parliament to act as its advisers on religious affairs. The assembly, later known as the Westminster Assembly of Divines, was chosen to be representative of each of the English counties. It included some mild episcopalians and five Independents. The rest were Presbyterians.

The excesses of the king in 1642–43 drove the Scots once more into an alliance with his enemies. The parliamentary party now signed (1643) the Solemn League and Covenant with the Scots. This agreement pledged the civil and religious unity of England, Scotland and Ireland under a presbyterian-parliamentary system. The parliament now ordered the Assembly of Divines to proceed, with the aid of six Scottish advisers, to the drafting of a complete religious constitution for the three kingdoms. The English Church thus gave up its Thirty-Nine Articles and other constitutional documents, while the Scots gave up their Confession of 1560, and other documents. The assembly then elaborated (1643–49) a *Confession of Faith*, a *Larger* and a *Shorter Catechism*, a *Form of Government* and *Directory for* Public *Worship*. These documents, the results of years of keen debate by many able scholars, put in classic form a consistent federalism (*i.e.* covenant-contract theory). Since this Assembly of Divines was but an advisory committee of the English parliament its constitutional documents met an odd fate. The Scottish Church and the Scottish parliament accepted them speedily. The English parliament delayed accepting them because of the growing power of the Independents. The English Church never had an opportunity to consider them.

Even with the aid of the Scots the military fortunes of the parliamentary party were unfortunate. It became necessary, at length, to allow Oliver Cromwell to create the New Model army which, although it proved invincible against the king, also proved invincible as the left-wing Puritans' (Independents) force against the right-wing (presbyterian-episcopal) Puritans. The army, not parliament, became supreme in England. Their political-religious program alienated the Scots, and the right-wing Puritan-parliamentary group sought vainly to dissolve the army, without due pay, in order to avoid a military state. The army several times invested London and forced parliament to do its bidding. Some right-wing leaders began to have intelligence with the king, believing that a government of law and order, though despotic, was better than army rule by sectaries. Eventually, in 1648, Col. Thomas Pride's soldiers purged parliament of all Presbyterians (140), leaving about 50 left-wing Puritans in the commons. This Rump parliament tried and executed Charles I, set up a military dictatorship under Cromwell, terminated the Presbyterian establishment and granted freedom to all religious groups while giving special privileges to Congregationalism under a modified form of establishment.

Hopeless chaos reigned after Cromwell's death. Gen. George Monk reassembled the Long parliament, thus putting great powers in the hands of the presbyterian-parliamentary group formerly purged by Colonel Pride. They re-established Presbyterianism, although granting tolerance to other Protestant bodies. Something better than army rule, however, was needed. Hence, all the right-wing groups, parliamentary and Presbyterian, royalist and episcopal, joined in restoring Charles II unconditionally. Charles quibbled briefly with the Presbyterians, who were now in full control of the church with about 8,000 beneficed ministers and professors. These ministers offered to accept a modified form of episcopacy first elaborated by Archbishop James Usher. Charles, realizing that his real supporters were the royalist-episcopal group, rejected this offer and demanded capitulation. About 6,000 ministers accepted reordination, unqualified oaths of obedience to bishops and king, abjuration of the Solemn League and Covenant. Two thousand were ejected, of whom approximately 1,500 were Presbyterian and 500 Independent. Later, many of these (about 500) conformed to the episcopal terms.

The Revolution of 1689 brought to the throne a king genuinely friendly to Presbyterianism. In view of the total situation, however, no more was gained by his accession than a measure of toleration for all Protestants. Under this toleration and its subsequent enlargements, a number (often given as high as 500) of Presbyterian congregations existed. In almost no recorded instances did any of these churches have elders or any lay leadership. Ministerial thought continued to develop along extremely autocratic and high-church lines. Such presbyteries as existed were almost exclusively ministerial. Since many of the stronger churches became endowed, actual control of them passed into the hands of the minister and a few trustees. Laymen lost all part in them. In the early part of the 18th century many of these ministers became Unitarians and numerous others conformed lo the Anglican establishment. The greater number of those who cherished the older Puritan ideals became Independent-Congregationalist under the impact of the movement known as the United Brethren, organized under the Heads of Agreement of 1691. By the close of the 18th century English Presbyterianism had become virtually extinct.

The most complete, and even the classic formulation of Presbyterianism had indeed been made by the English Puritan Presbyterians. Lack of popular support, reliance upon parliamentary forces and consequent fear of the Independents, had led to a form of strategy which destroyed English Presbyterianism by making it an exclusively ministerial movement. This unfortunate clericalism had not been the deepest aspect of the movement nor of its ideals. Its basic intent had been to reform the church on genuinely Protestant lines and to give to the people their rightful place. This Presbyterian ideal was first to be achieved in Scotland, whence also Presbyterianism was to be replanted on English soil.

Scots began coming into England in increasing numbers after the union of 1707. Many of these were Seceders, hence rigorous Presbyterians. Soon they had several congregations. In 1847 these, together with certain of the surviving English Presbyterian congregations and other Scottish groups, merged as the United Presbyterian Church. This body joined with the remaining English Presbyterians and most of the other various Scots churches in England to form in 1876 the Presbyterian Church of England. It then had 259 congregations with about 50,000 members. A theological college was founded at London in 1844, which later was moved to Cambridge under the name of Westminster college. By mid-20th century the church had about 71,000 members, 385 ministers, 360 churches; missionary work was being carried on by 30 missionaries at ten stations in China, India, Singapore and Malaya.

Scotland.—Though Presbyterianism as such took form in England, and there received its definitive theoretical delineation by the Westminster Assembly of Divines, it was in Scotland that Presbyterianism was to take its deepest roots. Moreover, although the Scottish Reformation was begun under essentially Genevan Calvinistic patterns, it adopted in time, and became the very incarnation of, the patterns of English Presbyterianism. It was able, however, to give to laymen a real place in the life of the church. Consequently in no country did Presbyterianism so deeply affect the national life. In many ways, therefore, Scottish history provides the best available illustration of Presbyterianism at work.

Scotland's first reforming martyr was Patrick Hamilton (1504–28). He had been influenced by personal contact with Martin Luther, Tyndale and other reformers. George Wishart, burned 1546, had travelled in England and Switzerland. His ideas were essentially Zwinglian. His assistant, John Knox, was to become the real leader of the Reformation in Scotland. Before long Knox had to flee and found refuge in England. During the reign of Edward VI he was an active leader in the English Reformation. When Queen Mary restored Roman Catholicism, Knox fled to the continent with numerous English reformers. Eventually he became pastor of an English refugee church at Geneva. In 1555–56 he visited Scotland and preached vigorously in the interests of the Reformation. The next year, certain nobles, the "Lords of the Congregation," led the Scottish reforming group in signing the first great covenant binding themselves to support the Reformation. Knox returned permanently to Scotland in 1559. A year later the reforming group, through English pressure on the Scottish regent, gained its first great victory. The Scots Confession (of 1560) was drawn up and accepted by parliament. A *Book of*

Common Order (Knox's Liturgy), a *Metrical Psalter* and a *Book of Discipline (The First Book of Discipline*, 1561) were also drawn up by the reformers. Parliament did not ratify these, but the church was deeply influenced by a rather general acceptance of them. These documents were all decisively Genevan in character. Knox, who had been deeply influenced by Calvin, was the leader in their framing. The *Book of Discipline* was an advance on Calvin's system in that it applied Genevan ideals on a national scale, following a lead given by the Huguenots. A general assembly was instituted as the national meeting of representatives of the church. Here, in free debate, issues were to be determined by a body of ministers and laymen met under their own chairman and at their own call. This gave the church genuine control of its own affairs. Also a governing body, the church session, was instituted for each local church. This body consisted of elders elected by the people, and had as its chairman the pastor of the church. The people themselves were given the right to elect their pastor and this election, rather than ordination by other ministers, made a man a minister. Episcopacy was abolished, but several superintendents were named to itinerate in areas without ministers and to have some limited administrative duties. The religious prerogatives and authority of bishops were not given to them, however. and they did not preside over the church courts.

The last four decades of the 16th century witnessed the defeat of the reformed, or Presbyterian, Scottish Church in spite of several notable temporary victories. In 1581 the Presbyterians gained parliamentary sanction for their *Second Book of Discipline*, and for the so-called Negative Confession of Faith. Moreover, regional church governing bodies, the presbyteries, began to be set up. Yet, the Black acts of 1584 placed bishops in control of most of the church and the more prominent Presbyterian leaders were forced to flee to England. In 1592 the Presbyterians were able to extort from the king sanction for a parliamentary law which has ever since been regarded as the Magna Carta of Scottish Presbyterianism. Five years later the king, working through bishops forced upon the church, gained almost complete control of the entire church, a control which was to last until the first of the Bishops' Wars in 1639. James became king of England also in 1603 and then set out to make the Scottish Church the principal instrument of his absolutism in Scotland. From 1603 to 1612 he brought the church wholly under the power of his bishops. From 1612 until his death he was occupied in shaping the life and work of the church to serve his general policies. So well did he succeed that at his death Scotland was under an unqualified absolutism.

Charles I continued the Tudor-Stuart policy of using the episcopacy as an instrument in the furtherance of royal absolutism. In Scotland Archbishop John Spottiswoode was his chief agent. When, however, Charles, Archbishop William Laud, and Spottiswoode attempted to force the last degree of submission upon the Scottish Church, namely "Laud's liturgy," popular resentment came to the aid of the church. In a wave of public feeling expressing opposition to the whole of Stuart absolutism, the covenant of 1557 was "renewed" by signatures of all classes all over Scotland. Spottiswoode and all but 4 of his 50 fellow bishops fled to England. In the two Bishops' Wars which followed the Scots demanded, basically, free parliaments and free general assemblies. Charles lost the wars and granted the demands. Parliament and the general assembly abolished the entire episcopal regime in church and state and restored Presbyterianism as of its "Magna Carta" of 1592.

In 1643 the two parliaments signed the Solemn League and Covenant between England and Scotland. Upon this basis of a union of England, Scotland and Ireland in state and church, the two presbyterian-parliamentary groups worked together in opposing the episcopal-royalist absolutism. One aspect of this cooperation was the adoption by the Scottish Church of the religious constitution framed by the Westminster assembly. Scottish Presbyterianism thus passed from a Genevan-Calvinistic pattern to a Puritan-lederalist pattern. When the Independents gained control in England, purged the Presbyterians and executed Charles I, many of the Scots objected and proclaimed Charles II. Cromwell defeated the Scots' armies and held the country under military occupation. During this occupation the church was not persecuted. It had. moreover, a great series of religious awakenings under Covenanter leadership.

The English restored Charles II in 1660. He brought back the episcopacy as an instrument of royal absolutism into Scotland as well as into England. Under Archbishop James Sharp a veritable Inquisition reigned in Scotland, "the killing times," as the Covenanter movement was wiped out. When William and Mary came to the throne in 1689 Presbyterianism was restored finally by constitutional act. However, despite some opposition, most of the former episcopal clergy retained their pastorates.

After 1689 Scotland was unquestionably Presbyterian, but new problems arose. Within the established state church were now two parties—one a group of convinced Presbyterians who had only recently been terribly persecuted by king and bishop; and the other, a group who had served the persecutors and now served the current regime with no great concern for it or against it. The next generation saw the rise of a large group of essentially professional clergymen known as the Moderates, whose deepest interests were in social life, in culture and in their prerogatives within a state establishment. An Evangelical group sought to promote the older reformation ideals. In 1707 the Scottish and the English parliaments were united. Five years later the parliament restored patronage in Scotland. This meant that the local landowner, or patron, had the right of nominating the minister for the congregation, and the people lost the right of electing their pastors. This system of patronage quickly brought the Church of Scotland under the control of the Moderate ministers and the wealthy landowners. As many protests were made against patronage, the Moderates claimed supreme powers for the general assembly which they controlled, and did not hesitate to resort to the use of military escorts and to the imprisonment of dissenting ministers to enforce their dictates.

By 1733 resistance to the Moderates and to patronage led to the deposition of four ministers. Led by Ebenezer Erskine they formed a secession church, the Associate Presbytery. This body "renewed" the Solemn League and Covenant in 1742 and 1744. Even so some members desired greater attachment to the old Covenanting ideals and withdrew to form the Reformed Presbytery (1743). In 1811 this group became the Reformed Presbyterian Church. Within the Seceder group also the covenanting principle raised the problem of their relation to the state. which supported the church from which they had seceded. In 1747 they divided into two groups, known after 1788 as the General Associate synod (Antiburgher; *i.e.*, against taking the burgher's oath in various cities); and the Associate synod (Burgher; *i.e.*, willing to take the oaths). By 1799 and 1805, the problem of the civil government's authority in religious matters broke both of these bodies into Auld Licht and New Licht sections.

Meanwhile patronage and the Moderate party caused further discontent. In 1761 Thomas Gillespie (deposed in 1752 for resistance to the general assembly), founded the Presbytery of Relief, a tolerant, evangelical, non-Covenanter body designed to provide relief for ministers and congregations who wished to withdraw peacefully from the establishment. In 1773 it assumed the name the Relief Church of Scotland.

These new groups grew rapidly. and were greatly strengthened by the evangelical revivals, the Sunday-school movement and the new missionary spirit. In 1820 a United Secession Church was formed by certain segments of secession bodies, and in 1827 others formed the Associate Synod of Original Seceders. These unions involved Burghers, Antiburghers. Auld Lichts and New.

From 1833 to 1843 a severe struggle took place within the Church of Scotland between the Moderates and the Evangelical group, now greatly strengthened by the revivals and the Sunday schools. Finally uhen the government in London supported on legal grounds the entire Moderate structuie, the Disruption led by Thomas Chalmers took place. A Free Church of Scotland was formed by 474 ministers and thousands of lay people, free of state control, free of patronage and zealously evangelical. All but one of the Church of Scotland's missionaries, and most of its best scholars, joined the Free Church. Henceforth the Free Church led all Christian causes in Scotland.

The United Presbyterian Church was founded in 1847 by the union of the Relief Church with the United Secession Church. In 1852 about one-half of the Associate Synod of Original Seceders joined the Free Church of Scotland. The year 1876 witnessed the union of the majority of the Reformed Presbyterians with the Free Church. Union negotiations between the United Presbyterians and the Free Church raised many problems. A small group left the Free Church in protest against the union and formed the Free Presbyterian Church. Eventually, in 1900 the United Free Church was formed by a merger of the Free Church and the United Presbyterians. A small group remained outside as the Free Church of Scotland. In many ways this new United Free Church was the most vigorous and popular religious body in Scotland.

Before long attempts were made to unite the United Free Church and the old Church of Scotland. Patronage had been abolished in 1874, and the old Moderate party had given way to a better leadership in the Church of Scotland. The issue of an established state church proved insoluble, however, until after World War I. Both churches had drawn closer together in the meanwhile. In 1921 the state by law severed its old relation with the Church of Scotland, leaving it "the national church" but not the established state church. This allowed union negotiations to make progress, and in 1929 the two churches united under the original name of the Church of Scotland. A small group remained outside and continued the name United Free Church.

Vast changes, meanwhile, had greatly altered the total religious situation in Scotland. The Lowlands had become industrialized, and had brought in large numbers of Irish workmen, most of whom were Roman Catholics. The Highlands were being depopulated by changing economic conditions. Presbyterianism as a whole enrolled only a fourth of the population of Scotland, and three-fifths of the Scots were nominally in no church. The Church of Scotland had lost heavily among the labouring classes and in the rural areas. Various movements were under way, each seeking in some measure to improve conditions: a high-church liturgical movement; a movement to bring together in the church the labouring classes and student groups (Iona group) ; and a movement for the recovery of a more adequate theology. The Church of Scotland continued to be active in missionary work, and to take a leading part in the ecumenical movement among the Protestant churches throughout the world.

Six Presbyterian bodies remained in Scotland at mid-20th century. The Church of Scotland had (in 1955) 1,307,573 members. 2,289 congregations, about 3.300 ministers. 42.289 elders; 310 missionaries in stations in Pakistan. India. Africa, Arabia. New Hebrides, West Indies. The United Free Church (continuing) had (1948) 23.863 members. 123 congregations, 81 ministers, 1,154 elders; 8 missionaries in Bechuanaland, Africa. The Free Church of Scotland had (1948) 5,500 members, 160 congregations. 111 ministers; with missionaries in South Africa. Peru and India. The Reformed Presbyterian Church had (1948) 800 members. 7 congregations, 4 ministers. 30 elders; 6 missionaries at 3 stations in North Syria. The Free Presbyterian Church of Scotland had (1948) approximately 800 members. The Original Secession Church which, in 1948. had 1,953 members, 18 congregations, 14 ministers, 94 elders, and 10 missionaries in India, rejoined the Church of Scotland in 1956.

Ireland. — Except for scattered Puritan groups. Irish Presbyterianism began with the Irish plantation of 1610. These Presbyterians were first in the established Church under the tolerant Archbishop Usher. Charles I and Archbishop Laud drove them out. During the Great Rebellion they had ups and downs almost the same as those of the Scottish Presbyterians. William III gained for them only partial toleration. Until 1869 their unduly harsh lot led hundreds of thousands to migrate to North America,

Scottish controversies usually had their counterparts in Ulster. Seceders appeared in 1741, and organized in 1750; Reformed Presbyterians came in 1752 and organized in 1792. The Synod of Ulster was the Main Presbyterian body. but did not include the Presbyterians in Dublin, and south and west Ireland. These formed the Synod of Munster. Severe doctrinal controversies occurred in both the 18th and the 19th centuries. Each time a Unitarian group left the church. Consequently Irish Presbyterianism became very conservative in theology. In 1840 the Secession Church and the Synod of Ulster merged as the Presbyterian Church in Ireland. The Synod of Munster joined them in 1854. This body in 1956 had 133.422 members, about jj6 congregations. 75 other preaching points. j62 ministers. 4,228 elders; 39 missionaries at 10 stations in north China and west India. The Reformed Presbyterian Church had (1948) about 3,400 members; missionary work was being carried on in North Syria.

Wales.—The Presbyterian Church in Wales, known also as the Calvinistic Methodist Church, grew out of the evangelical revival of the 19th century. Howell Harris and other friends of George Whitefield led the movement and gave to it the general society character of the Wesleyan societies, but the doctrinal convictions of Calvinistic Puritanism. Its earliest organization outside the Church of England in Wales took place in 1811 on a Presbyterian form of polity. Two synods, or associations, were formed, one for South Wales and one for North Wales. Twelve years later a Calvinistic, Presbyterian creed was officially adopted. In 1864 a general assembly was formed to unite, but not to control, the two associations.

The church is distinctly Welsh in all ways. About one-fourth of the congregations use the English language in some measure. The church in 1948 had a membership of 172,754 in 1,467 congregations, with 674 ministers and 7,256 elders; 54 missionaries were at work at 15 stations in India and in Brittany, Fr.

Canada. — Presbyterianism first took real root in Canadian territory after the treaty of Paris in 1763. Settlement of Scots in Nova Scotia brought many Presbyterians there. In 1817 the various elements united as the Synod of Nova Scotia in Connection with the Church of Scotland. Then, 1835, the Synod of New Brunswick in Connection with the Church of Scotland was formed. These bodies were all at work in eastern Canada.

Farther to the west the Church of Scotland was also sending ministers and aid. Secession groups had already organized, in 1826, the United Presbytery of Canada. In 1831 the Synod of the Presbyterian Church of Canada in Connection with the Church of Scotland was organized. These two bodies united in 1840.

The Disruption of 1843 in the Church of Scotland caused parallel ruptures in all the Canadian Presbyterian churches. In 1845 there were seven separate bodies. Thirty years later, in 1875, all had reunited in the Presbyterian Church in Canada, with several colleges and a strong body of congregations and ministers. Their next task was set by Canada's westward expansion.

The 20th century brought new problems to Canada, theological, social and economic. Roman Catholicism was growing. The sparse population of the Canadian prairies put a severe drain on all Protestant home mission efforts. The changing scene in Canada had made Protestantism too greatly urban. As early as 1890 projects for uniting Canadian Protestants had been broached rather widely. The Church of England in Canada quickly dropped out of these negotiations, but the two largest Protestant bodies, the Presbyterians and the Methodists, together with the much smaller Congregational Church, united as the United Church of Canada in 1925. A sizable minority of Presbyterians refused to enter the union and continued as the Presbyterian Church in Canada.

The United Church of Canada continued to maintain official connections with other Presbyterian and Reformed Churches throughout the world. In government the church is essentially Presbyterian, although in doctrine and other matters it allows great latitude to points of view traditionally non-Presbyterian, because of its Methodist and Congregational constituencies. In 1955 it had 894.556 members, 2.691 congregations, 6.222 additional preaching points. 3,178 ministers. 38,066 elders; missionaries were at work in stations in Trinidad. Africa and Asia.

The Presbyterian Church in Canada in 1953 had 179.248 members. about 900 congregations. 1,149 additional preaching points. 721 ministers, 7,957 elders: 40 missionaries at 7 stations in Asia, Trinidad, British Guiana and Poland.

Australia. — Australian Presbyterianism was essentially Scottish in origin and character. The first organized body was founded in 1826 by Church of Scotland ministers. During the stormy years following, the divisions of the homeland had their counterparts in the South Pacific. Reunions of fragments formed the Presbyterian Church of New South Wales in 1865; the Presbyterian Church of Victoria in 1870; and smaller bodies in Queensland, West Australia, South Australia and Tasmania. A federal union of most of these bodies was formed in 1886, and in 1901 all united in the Presbyterian Church of Australia. Considerable local autonomy was granted each of the regional bodies. From 1918 to 1923 strenuous efforts were made to achieve a union among Presbyterians, Methodists and Congregationalists similar to that achieved in Canada, but without success.

This church in 1948 had 104,944 members, 584 congregations, 174 additional preaching points, 704 ministers, 5,018 elders; plus missionary work in Asia and the New Hebrides.

New Zealand. — Presbyterianism in New Zealand arose in two distinct migrations. To the northern regions came Church of Scotland ministers as early as 1840. The first presbytery was founded at Auckland in 1856. Later it grew into the Presbyterian Church of New Zealand. In the southern area Scottish Free Churchmen founded a model religious colony at Dunedin in 1848. Their church grew first into the Presbytery of Otago (1854), then into the Presbyterian Church of Otago and Southland. In 1901 these bodies united as the Presbyterian Church of New Zealand.

The church in 1948 had 61,799 members, 354 congregations, 1,027 additional preaching points, 364 ministers, 2,877 elders; missionary work was being conducted in Asia and the New Hebrides.

Africa. — Scottish Presbyterians first organized in South Africa in 1892. The Presbyterian Church of South Africa was formed in 1897. This body did not include the native congregations, and the problem continued to agitate the church. Eventually, in 1923, it was solved by creating a Bantu Presbyterian Church wholly separate from the white church but with fraternal relations. This arrangement, however, resulted in little more than qualified segregation. As race tensions mounted after World War II the Presbyterians made great efforts to frustrate the all-out movement for total segregation known as *apartheid.* The entire status of missionary educational and medical work was also challenged, and the Presbyterians made strenuous efforts to improve native-white relations.

The Presbyterian Church of South Africa in 1948 had 20,996 members, 83 congregations, 53 additional preaching points, 95 ministers, 621 elders; also missionary work in South Africa. The Bantu Presbyterian Church of South Africa had 30,308 members, 61 congregations, 750 additional preaching points, 49 ministers, 1,061 elders.

Other African Presbyterian bodies, with 1948 statistics, are: the Presbyterian Church in Basutoland, about 25,000 members; the Presbyterian Church of Central Africa, 105,558 members, 116 congregations, 57 ministers, 2,192 elders; the Presbyterian Church of Gold Coast, 30,132 members, 51 congregations, 70 ministers, 895 elders; the Ewe Presbyterian Church, 15,742 members, 210 congregations, 23 ministers, 235 elders; the Synod of the Nile, 24,200 members, 168 congregations, 162 ministers and 235 elders.

United States. — The 11 Presbyterian bodies in the U.S. at mid-20th century made up the largest group in the Presbyterian family. Two of these bodies accounted for nearly 3,200,000 members, and more than 98% of all U.S. Presbyterians were in the four largest bodies. Repeated attempts at union had failed, largely because of nonreligious; *i.e.,* political, social and regional causes.

The Presbyterian Church in the U.S.A.—The earliest Presbyterian churches in the American colonies were planted on Long Island by New England Puritans who preferred the Presbyterian way to the Congregationalist. Very soon after Scotch-Irish, English and other settlers formed Presbyterian churches in Maryland, Delaware and Pennsylvania. In 1706, some of these joined in a loosely organized presbytery which in 1716 was expanded to a synod of three presbyteries. The church continued to be a blend of New England Puritan Presbyterians and Ulster Presbyterians, plus Welsh and other elements.

Shortly, repercussions of British struggles against Arianism brought trouble to the new colonial church. A Scotch-Irish group, led by John Thomson, asked for unqualified subscription by all to the Westminster Confession and a powerful centralized church government as bulwarks against heresy. The New England group, led by Jonathan Dickinson, resisted, asserting that no human creed could be absolutized, that ecclesiastical authority could not prevent heresy and that only a deeper piety would suffice. In 1729 the synod compromised by adopting the confession, but allowing men to distinguish between its essential and its nonessential points. The church government issue was avoided. The compromise did not satisfy all.

In 1733, a new group, led by William Tennent and his son Gilbert, began in Presbyterianism the revival later termed the Great Awakening. The Thomson group fought the revival bitterly, and would have driven it out of the church but for the chance appearance of George Whitefield, whom the Tennents persuaded to aid them. Whitefield won mass popular support for the Tennents, and drew the New England group closer to them. In a typical frontier controversy both the Thomson and the Tennent groups went to extremes. Serious moral failures weakened the hold of the Thomson group on the people. The climax came in 1741 when the Thomson group gained momentary control of the synod and illegally expelled the Tennents.

The Dickinson group, the more stable and best-based section of the church, sought first to mediate. Rebuffed by the Thomson group, they joined the Tennents in forming a new church, the Synod of New York, popularly called the New Side. They stood for an American, democratic, evangelistic church of all nationalities, with a deep concern for ethics, led by a ministry trained in the colonies. In 17 years they trebled their membership, established the College of New Jersey (later Princeton university) and expanded as far as western Pennsylvania and the Carolinas. The Thomson group took the name the Synod of Philadelphia, (popularly the Old Side). They stood for an autocratic ministry, a church committed to being Scottish-Scotch-Irish in all things and opposed to revivals. From 1741 to 1758 this group lost ground steadily.

The schism was at length healed in 1758, by mutual concessions, and the name of the Synod of New York and Philadelphia was adopted. In the synod there was now a preponderance of directly or indirectly New England-trained ministers, and the strongest presbyteries were those composed of churches with New England backgrounds. Beginning in 1760, however, several hundred thousand Scotch-Irish immigrants arrived in the colonies. Many of these joined the Presbyterian Church, and the character of the church gradually changed to a Scotch-Irish pattern.

In the struggles leading up to the Revolutionary War the Presbyterians took a vigorous part. They formed an alliance with the Congregationalists of New England in order to prevent the settling of Anglican bishops on the colonies, because they feared an intolerant establishment was contemplated. The struggle for colonial independence was, in time, called a Christian cause. In personnel and property the church suffered heavily in the war. The near triumph of deism among Americans after the war came as a staggering blow to the church. During the years 1785–88 a general assembly was founded with an explicit constitution. Some resistance was offered by those who feared extreme centralization. In the constitution all reserve powers were, therefore, left with the presbyteries, and the higher, central, courts were given limited and fixed powers only. Doctrinal subscriptions continued to be flexible.

The church took up frontier missions, benevolent work, the founding of schools, etc. with vigour. A series of revivals greatly increased the church's strength, despite some concurrent problems. Charles G. Finney and Lyman Beecher were active evangelistic leaders of the second quarter of the 19th century.

In 1801 the church entered into a Plan of Union with the New

England Congregationalists. These churches themselves did not merge. but they federated their home missionary work on the frontier. This did, however, draw the two denominations closer together everywhere, and reraised the old Scotch-Irish *v.* New England antipathies of 1741–58. Moreover. New England theology was restless and inquiring. The Scotch-Irish considered theology a finished structure which must now be protected against innovation. In the south the church was almost wholly Scotch-Irish, and proslavery sentiment there kept most northern Scotch-Irish Presbyterians either proslavery or neutral. The New England background Presbyterians were generally antislavery.

After years of turmoil a majority in the asembly of 1837 abrogated the Plan of Union, expelled illegally all the federated churches and demanded total subjection by all to the assembly. During the ensuing year about four-ninths of the church refused to recognize these acts and joined the expelled group in declaring themselves to be the genuine Presbyterian Church and the group who had ousted them to be a schism. The civil lower courts declared them to be the continuing church, but the appellate court reversed the decision. They continued the name the Presbyterian Church, U.S.A., and added "New School." The other group took the same name but added "Old School."

The New School denomination continued, as before 1837, to work in close co-operation with the Congregationalists in home and foreign missions, in antislavery, temperance and other work. They had a few congregations in the south (these withdrew in 1856–57), but were largely a northern church. The Congregationalists abrogated the Plan of Union in 1852, though the two churches continued some joint work. Even so, the abrogation was a setback for the Presbyterians. In frontier missions, education and benevolent work they made great contributions. Union Theological seminary, New York City, became their great centre. During the Civil War the church was active on the northern side.

The Old School Presbyterians built a well-organized church on the basis of their doctrinal, racial and social homogeneity. Though spread over all the nation, their great strength was among the Scotch-Irish and the Scottish groups. Princeton seminary became their focal point. A solid denominational structure enabled them to make great strides in missions, colleges and Sunday-school work. The Civil War brought new issues. The O.S. assembly of 1861 passed the Gardiner Spring resolutions which so wholly committed the church to the northern view that the entire southern section of the church seceded to form the Presbyterian Church in the Confederate States of America.

After the war the north-south groups of the two churches could not agree to reunite. Unions took place instead of New School and Old School, in the south to form the Presbyterian Church, US. (see below), and in the north, the Presbyterian Church, U.S.A.

The northern reunited church took up frontier mission work anew, built new colleges and institutions, expanded Sunday-school, youth and benevolent work, as the nation moved westward. A quarter of a century of achievement was interrupted by a major controversy which arose as a result of the influence of the new scientific views upon Christian thought. There came first (about 1892) a long struggle over biblical criticism, followed (about 1910) by the organization, on an international scale, of an interdenominational group, strongly Presbyterian, to defend the "fundamentals" of the faith. By World War I the Fundamentalist-Modernist controversy was intense. Moderate groups pleaded for comprehension within the church of all essentially Christian views, but without success. The struggle now assumed a new form. The Fundamentalist group attacked various boards and institutions of the church as unorthodox and founded within the church rival institutions of their own to compete with the church's institutions. This brought judicial process in the church courts against J. Gresham Machen and other Fundamentalist leaders. Most Fundamentalists then drew back from the controversy. A few, however, joined with Machen in founding the Presbyterian Church in America.

Between World Wars I and II the Presbyterian Church, U.S.A., came to have one of the largest foreign missionary enterprises in the world. In the U.S. the church had more than 50 colleges and 9 theological schools. As national and international co-operative ventures among churches were launched the Presbyterians took an active part. Negotiations for union were had also with other Reformed and Presbyterian bodies and with the Methodists and the Episcopalians. In only two instances did success come. The Cumberland Presbyterian Church (see below) re-united with the U.S.A. Presbyterians in 1906. The Welsh Calvinistic Methodists merged with the Presbyterians in 1920. On the foreign field Presbyterians moved to turn their missionary work over to independent native churches. In China and India Presbyterians united with other denominations to form new "younger churches." A Presbyterian Church of Brazil and a Presbyterian Church of Mexico, each self-controlled, were founded. In other countries local leaders took charge.

World War II brought havoc to many regions. As peace came the Presbyterians raised nearly $27,000,000 to aid in reconstruction, principally in Europe and on mission fields in former war areas. Wholly new approaches also were worked out by the church to Sunday-school studies. to youth work, etc.

In 1957 union negotiations with the United Presbyterian Church of Xorth America (see below) were completed. The Church in 1957 had 2,809,603 members, 8,658 congregations, 9.841 ministers, 70,391 elders, 1,368 missionaries at 151 stations in Africa, India, Japan. Korea. Mexico, Iran; the Philippines, Thailand, South America, Central America, Syria and Mesopotamia.

The Presbyterian *Church* in the United States.—This body, commonly called the Southern Presbyterian Church, came into being during the Civil War. Prior to the war, furious controversy had split the Presbyterian Church, U.S.A., in two bodies—New School and Old School. These divisions were not geographical; N.S. and O.S. congregations existed in both north and south. The south was predominantly O.S. The N.S. was unofficially the antislavery force in the central states, while the O.S. was officially neutral on the issue and actually proslavery in most regions. The coming of the war brought a wave of nationalism over the north, one aspect of which was the adoption in 1861 by the O.S. general assembly of the so-called Gardiner Spring resolutions which put the church so unequivocally behind the federal government that the O.S. churches in the Confederate states seceded to form the Presbyterian Church in the Confederate States of America.

The war cut off other southern Presbyterian bodies also from their northern brethren. Older lines of cleavage lost their meaning. In 1864 the United Synod of the South (largely N.S.) merged with the Confederate Presbyterians, so also did certain small units of Seceders and Covenanters. Border state Presbyterian bodies, at first neutral, joined also: Synod of Kentucky, 1869; Synod of Missouri, 1874. After the war, the name Presbyterian Church in the United States was adopted.

The church continued to devote its energies to the so-called southern states, Texas, Arkansas and hfissouri marking in general its western boundaries. The church is essentially Scottish, Scotch-Irish in membership and traditions. Its homogeneity racially, geographically and socially make it a very close-knit body. Traditionally the church divides between a spiritual and a political approach to problems. The latter approach has always been rejected. As a result the church has been very conservative on all religious, political and social issues. Yet in educational and benevolent enterprises the church has long been a leader in the south. Its educational and missionary ventures have been especially significant. In its polity great care has been taken to promote local initiative and to restrict the powers of all central agencies.

The church in 1954 had 756.884 members, 3,776 congregations, 3,068 ministers; in 1949 it had 19,270 elders; 346 missionaries in Africa, Brazil, Mexico and Asia.

Southern Presbyterians and northern Presbyterians continued to talk of reunion from the 1870s. The two churches adhered to almost identical constitutions, but continued to be separated by essentially nonreligious differences; *i.e.*, the continuing problem of the Civil War Reconstruction. While the northern church is less conservative all ways than is the southern, north-south relations remain the serious obstacle to reunion. Fraternal relations between the two bodies have long been excellent, and ministers, members and students freely transfer from one church and its institutions to the other. There is little overlapping of territory, less of competition and a growing area of co-operative endeavour (*i.e.,* joint schools, common missionary projects. etc.).

The United Presbyterian Church of North America.—Covenanter, or Reformed Presbyterian, people began coming to North America, principally from Ireland, before 1750. In 1774 their first presbytery was founded. Seceder Presbyterians organized a presbytery in 1758. Both groups were located principally in Pennsylvania. In 1782 the Reformed Presbyterians and some of the Associate (Seceder) Presbyterians united, and these together with other Secession groups merged to form in 1858 the United Presbyterian Church of North America. Covenanter and Secession backgrounds made this church very conservative in doctrine and worship. At first the church practised closed communion, sang only psalms in public worship and adhered to the Solemn League and Covenant. Gradually, however, changes came as the memory of Scottish issues faded away. The church was early engaged in the antislavery cause and other significant reform movements. Because of its solid Scottish, Scotch-Irish background its main strength lies in the regions of Pennsylvania, Ohio, New York. Illinois and Iowa. The church in 1956 had 244,-973 members. 833 congregations, 967 ministers. 6.93; elders; approximately 117 missionaries were at work in Egypt, India, the Sudan and Abyssinia.

The Cumberland Presbyterian Church.—The Cumberland Church grew out of a purely American situation; *i.e.,* frontier conditions. Differences of opinion regarding the great Kentucky revival of 1799–1802, impatience with high educational requirements for a frontier ministry, excessive use of ecclesiastical authority and differences on the subject of predestination brought about a separation in 1810 from the Presbyterian Church, U.S.A., of a group on the Kentucky-Tennessee frontier. They founded the Cumberland Presbyterian Church, stressed evangelism, repudiated predestination and avoided highly centralized church authority. Their membership was almost wholly second and third generation Scotch-Irish from the southern Atlantic states. During the 19th century the church spread through Ohio, Pennsylvania, Missouri and Texas. Until the Civil War Negroes, lay and ministerial, had a significant place in the church. In 1869, however, they formed a church of their own.

Early in the 20th century negotiations for reunion with the Presbyterian Church. U.S.A.. began. A majority of the Cumberland Presbyterians rejoined the older church in 1906. Others. however, continued as a distinct group under the Cumberland name. The church in 1954 had 84,393 members. 1,104 congregations and in 1949 more than 750 ministers. Missionary work was being done in China and South America.

The Cumberland Presbyterian *Church, Coloured.*—This church, set off from the above in 1869. reported in 1949 approximately 30,-000 members in 121 churches.

Churches Continuing the Covenanter-Secession Tradition.—These include: (1) The Associate Reformed Presbyterian Church (General Synod), which in 1954 had 27.481 members in 151 congregations; (2) the Associate Reformed Presbyterian Church of North America, which in 1954 had 400 members in j congregations; (3) the Reformed Presbyterian Church (Old School), with 6.442 members in 74 congregations (1954); and (4) the Reformed Presbyterian Church (General Synod), with 1,335 members in 11 congregations in 1954.

Later Bodies.—The Fundamentalist-Modernist controversy of the 20th century was particularly severe within the Presbyterian Church, U.S.A. From that church a Fundamentalist group led by J. Gresham Machen formed in 1936 the Presbyterian Church in America. Further doctrinal controversy broke this group into two distinct bodies in 1938: (1) the Orthodox Presbyterian Church, a body stressing classical Presbyterian orthodoxy and very conservative in worship, organization and practice, with 8.611 members. 72 congregations (1954) and 98 ministers (1949); and (2) the Bible Presbyterian Church. a body stressing revival evangelism, Bible institute work and much more loosely organized than the above, had 8,428 members and 88 congregations in 1954.

THE PRESBYTERIAN SYSTEM

The Presbyterian way of ordering the life of the church intends to be no more than a systematic and consistent attempt to follow the general principles laid out in the New Testament. It is confessed that the New Testament presents no single, definite, complete pattern. However, the very nature of what is there said of the Gospel, the church, the ministry, etc., is taken by those who hold this system as an adequate indication of the basic elements essential to the ordering of the church's life.

The name "Presbyterian" when used of this system is one of late origin. John Calvin and his associates, who rediscovered and reformulated the system during the 16th century, did not name their system as such. The name came into general use only during the controversies of the following century. The name is derived from a Greek word meaning "elder," and therefore the name designates specifically that aspect of the system which has to do with the ministry of the church. As Calvin and his colleagues elaborated the system, however, its distinctive and basic feature was the doctrine of the church, which in turn was based on their understanding of the Gospel.

Calvin learned much from the earlier reformers, and his work was not wholly original. His greatest contribution lay in his bringing into one clear, systematic statement the general Reformed view. Not all who have called themselves Reformed have ever followed him in all things, but the system is best described by reference to his presentation of it.

The Church.—Calvin's view of the church was shaped by his understanding of the Gospel. The Gospel was the "good news" of God's forgiveness of man, and the call to man to return and be reconciled to God; *i.e.,* to repent. Forgiveness and reconciliation were inseparably bound together, as Calvin saw it. This he took to mean that men were to be reconciled to God by receiving His forgiveness, and to be reconciled to their fellow men by their mutual forgivenesses. To be reconciled to God was to come into His fellowship, and to be reconciled to one's fellows was to come once again into their fellowship. On that basis, Calvin believed, there could be no private, or individualistic salvation. He declared that salvation was intensely personal, because the Christian became a responsible actor, but never a matter involving only the individual soul and God. He mas, therefore, much opposed to mysticism and its view that each individual sought God alone and directly. In this connection he quoted the old saying, "Outside the Church there is no salvation." No one could invent his own way to heaven. This view became of great importance in Calvin's doctrine of the sacraments also.

This sense of community, or fellowship, in Calvin's opinion, was to be seen also in God's method of redeeming men. It was God who sought men, rather than men who sought God. Yet, God did not work directly, but through agents, through means. This idea was basic to all of Calvin's thinking about the church. God redeemed men through the agency of their fellow men. Consequently God's love which brought men to Himself was given to men through other men, thereby forming a bond of unity among them greater than any other conceivable bond. Calvin applied this same idea also to all aspects of life. God, he declared, was the source of all good, spiritual and temporal. But because He dispensed this good to men by the labours of others, each owed to the other that which he had received. Therefore, mutual sharing was necessary. This was part of reconciliation and love.

The church, then, according to Calvin, had as its sole function the task of telling men of God's forgiveness and of leading them to reconciliation with God and their fellows. This involved several other things. Men could not accept forgiveness and agree to be reconciled to God and man without confessing that they were in need of so doing. Moreover, to be reconciled. Calvin interpreted as meaning to be reconciled to the service of God among one's fellow men. This meant that the Christian life was to be lived among God's people for their good and God's glory, not for any selfish desire for temporal or eternal gains. Ethics, therefore, were always part of theology in Calvin's thinking. Political and moral problems dominated his activities. Though the economic application was stated in principle, it was never as fully worked out.

Following St. Paul, Calvin made great use of the idea of the church as the Body of Christ. Here again the community, or corporate, aspect of the church was to the foreground. The members, he pointed out, are held together, directed and governed by the Head in one common life which fulfils the will and purpose of the Head. It is the Head, not the members, to whom all things about the church are to be referred.

Since there is only one Christ, or Head, Calvin declared, there can be only one church or Body. Wherever Christ is present redeeming men in a manner essentially agreeable to the pattern He Himself laid down, there men are to know is the church. Wherever a religion contrary to Christ's own pattern was being offered to men, there, Calvin believed, men were to know that there was no church of Christ. This, he said, was the one basic difference between the papacy and the reformers. The unity, continuity and universality of the church were all to be found in the redeeming presence of Christ, not in any particular form of government, doctrine, leadership or lineal descent of ministers.

The church was the Body of Christ on earth among men, and therefore plainly visible to all, Calvin said. Yet, he continued, because it is all too human there are senses in which it is impossible for men to mark out its exact boundaries. In that sense the church is invisible, and we are "to believe the Church," he said; *i.e.*, we are to believe that this very imperfect community is truly the Body of Christ.

The **Ministry.**—Two aspects of the nature of the Church, Calvin said, provide the occasion or reason for the ministry, namely that the church is a community and that its own life and felicity are not the reasons for its existence. It exists for the service of God. Consequently direction and leadership are needed, and this the government or ministry of the church is instituted to provide.

The one Head of the church is Christ, Calvin declared, and no one is ever His substitute or yicar. However, Christ moves His people to elect from their membership various persons to discharge the various aspects of the church's function. Some are to preach, some to teach, some to care for the poor and sick, some to exercise discipline. As Calvin believed, God Himself called His ministers, but He did it through the church. The ministry does not exist parallel to, or prior to the church. God, working through the people's election, calls the ministry. The ministry is not a sacred or spiritual order of men. It is a group of officeholders within the Body of Christ.

The church ordered its life in the service of God, then, in Calvin's thinking, by means of a ministry exercised by a variety of officeholders: pastors, teachers, elders and two types of deacons. The pastors were to preach the Gospel, to administer the sacraments and to serve as president of the other officers. Because they had the most responsible office within the total ministry, they might be called "the ministers." The teachers were to devote their whole time to teaching. Elders were to share with the pastors the spiritual oversight of the church. Deacons, men and women, were to care for the poor and the sick. No one was to exercise any function to which he had not been elected, and election to an office by the people was the sole necessary qualification. No matter to what office a man had been elected he remained merely one of the brethren. Calvin rejected the distinction between clergy and laity. All were priests on behalf of all.

God's call, made known through election by the people, was for Calvin all that was needed to make anyone the holder of any office in the ministry. Ordination by other ministers, he asserted, could not make anyone eligible to serve any office. When the ceremony of ordination was used, it meant, he declared, no more than that the ministers ied the people in a solemn prayer that God would recognize as His act that which they had done in electing the man in accord with what they believed was His will.

Those who hold offices in the ministry do so only within the church. They have no personal authority or virtue, Calvin said. Consequently, they may act only on the authority and prerogatives given them. (This view determined certain aspects of Calvin's doctrine of the sacraments.)

The Sacraments.—Because, Calvin asserted, it is God who seeks His prodigal children rather than they who seek Him, and because it is God who directs His church in the life which it lives in His service, public worship is primarily the assembling of the people of God to hear what He has to say to them. They do not assemble to seek Him, but to meet Him and to hear His word. When this takes place, they respond by receiving His love, His grace, His fellowship; and then they present their prayers and petitions.

The action of public worship was for Calvin the hearing of the Gospel, and the joyful communion with God to which that Gospel summoned men. By preaching and teaching the Gospel was to be made known and understood in the church. In the sacraments there were provided ways whereby men could actually appropriate and receive the grace offered in the Gospel.

The sacraments in themselves possessed no particular powers. Whatever man received he received by faith. The sacraments, therefore, Calvin said, are not independent of faith. They are rather a "lively preaching" intended to call forth faith. By this very fact they could not be considered necessary to salvation. Yet, since Christ commanded the church to carry out its mission in this manner, and since He did by means of the sacraments truly call forth faith, it was the duty of the church faithfully to use these "means of grace." Preaching and the sacraments could never be separated.

Baptism.—The promise of God in the Gospel, Calvin said, is that God will forgive and receive into His fellowship those who have forsaken Him. That promise was fulfilled, or sealed, when Jesus Christ came, and was crucified and raised from the dead for man's redemption. What remains to be done, Calvin believed, is that man must actually return to the fellowship of God and become a member of the community of believers who make up the church, the Body of Christ. This must be done as an act of faith, and under normal circumstances; it is to be done through receiving baptism.

Baptism symbolizes the death, burial and resurrection of Christ, according to Calvin. By accepting baptism, in an act of faith, men confess that they hope for salvation only in Christ, and that they do in fact return to God. This is their part in the sacrament. God, then and there, "incorporates" the believer into the Body of His Son, the church. This is the all-important aspect, for Calvin.

Calvin elaborated, not a doctrine of "infant baptism," but a doctrine of "Christian baptism," and then urged that children as well as adults might receive it. Children were to be given the promise held out in baptism and then brought up to exercise such faith as their growing years and perception might enable them to do. Until they exercised faith their baptism would be incomplete. Yet, Calvin thought, since their salvation depended upon God's love, and not upon baptism itself, they were safe in God's care while unable to exercise faith. Baptism was intended by God as an aid to faith, not as an indispensable rite necessary for salvation. God could, therefore, dispense with it if He chose. Men, however, were never to omit it, unless unable to use it.

Baptism could be administered by any method, Calvin believed (immersion, sprinkling, etc.), provided only that the method used clearly symbolized and proclaimed the death and resurrection of Christ. Baptism ought to take place only in the midst of the public worship of the church because it symbolized entrance into the Christian communion. Also, only those who led in public worship should baptize. There could be no private baptism because there was no private salvation. There could be no "emergency baptism" because baptism had no such character about it as to create any emergency.

The Lord's Supper.—The Lord's Supper, Calvin believed, was instituted by God to support, nourish and increase the faith of the Christian church. It was rooted in the event of Christ's death on the cross and symbolized that death. It proclaimed, therefore, the fact that God had fulfilled His promise, and that men had been forgiven. Moreover, it invited men to "take," to receive, the offered mercy of God. Receiving the sacrament in an act of faith meant, Calvin said, that one believed that God truly held out something to man in it, and that man truly received in it just what God offered, namely forgiveness, reconciliation, continued fellowship and communion with God.

The elements (bread and wine) themselves, Calvin thought, had no particular merit or significance beyond their historical connection with Christ's last supper with the disciples. Nothing in the ritual changed the elements in any way. Christ was indeed present during the sacrament as He was present in preaching or in baptism. But His presence was not associated with the bread and wine. He was present to meet with, and commune with His followers.

The sacrament should follow each occasion on which the Gospel was preached, Calvin urged. In the sermon the Gospel was proclaimed; in the sacrament it was set before men symbolically. In faith they were to receive it.

The setting for the sacrament demanded a table, Calvin said. Thus Christ instituted the sacrament, and thus it should be continued. The table symbolized the fact that God is offering to man, and that man is to come, to receive. The altar, Calvin declared, symbolized that man is offering something to God. Also, the sacrament belongs to the whole church, not to the ministers. It is to be administered only in the public worship of the congregation. All were to be invited to come. Any who feared they were "unworthy" were to know that only the confession of need could constitute worthiness. Those who came inwardly ungodly and unrepentant rejected God's mercy in the sacrament just as they rejected it when they heard it preached. Calvin believed that private communion, even for the sick, obscured the true nature of the church as a community and fostered superstitious ideas about the sacrament.

Church Government. — Though Calvin believed that the system of church government which was used by himself and his associates in Strasbourg and Ziirich was based upon the Bible and the experience of the church, he did not claim for it exclusive divine right. He acknowledged the English Church under Archbishop Thomas Cranmer, and the Lutheran Churches of Germany under their consistorial system as true and complete churches. Cranmer and the Lutherans also acknowledged the Reformed Churches.

The primary elements of Calvin's theory of church government may be summed up as three. The church is a community, or body in which Christ only is Head, and all other members are equal under Him. The ministry is given to the whole church, and is there distributed among many officers according as God has gifted and called them. All who hold office do so by election of the people whose representatives they are. The church is to be governed and directed by assemblies of officeholders, pastors and elders, so chosen as to provide just representation for the church as a whole.

Since the Reformation the various Reformed Churches, Presbyterian Churches and others, have made many adaptations of this basic structure, generally without departing from it in essentials.

BIBLIOGRAPHY.—T. M. Lindsay, *History of the Reformation*, 2 vol., rev. ed. (1922) ; A. H. Drysdale, *History of the Presbyterians in England* (London, 1889); W. T. Latimer, *History of the Irish Presbyterians* (Belfast, 1902) ; L. J. Trinterud, *Forming of an American Tradition* (1949) ; W. W. Sweet, *Story of Religion in America,* rev. ed. (1950); J. N. Ogilvie, *The Presbyterian Churches of Christendom,* rev. ed. (London, 1925); John Calvin, *Institutes of the Christian Religion,* Eng. trans. *by* H. Beveridge, 2 vol. (various dates); J. L. Ainslie, *Doctrines of Ministerial Order in the Reformed Churches of the 16th and 17th Centuries* (1940) ; A. Barclay, *Protestant Doctrine of the Lord's Supper* (Glasgow, 1927). (L. J. T.)

PRESBYTERY, in architecture. that portion of the chancel (*q.v.*) of a church in which the high altar is placed, and which is generally raised a few steps above the rest of the church. It is reserved for the priests and differs from the choir, the stalls in which are occasionally occupied by the laity. In Westminster abbey the space east of the transept is the presbytery, and the same arrangement is found in Canterbury cathedral. In S. Clemente at Rome the presbytery is enclosed with a marble balustrade or screen. For the use of the word in church government *see* PRESBYTERIAN.

PRESCOT, an urban district in the Huyton parliamentary division of Lancashire. Eng.. 8 mi. E. of Liverpool by road and 4 mi. S.W. of St. Helens. Pop. (1951) 12,474. Area 1.4 sq.mi. It is of considerable antiquity and received a grant for a market and fair from Edward III. A church existed in the 13th century. The present church of St. Mary is in various styles, with a lofty tower and spire and carved timber roof After John Miller brought the industry from Yorkshire (1730) the town has been noted for watches and watch tools. Electric cables are manufactured. To the north is Knowsley park, seat of the earls of Derby.

PRESCOTT (SPOFFORD), HARRIET ELIZABETH (1835–1921), U.S. author, was born on April 3, 1835, at Calais, Me. Her family later moved to Newburyport, Mass., where she attended the Putnam free school. For a short time, she was also a student at the Pinkerton academy at Derry, N.H.

Her father, Joseph Newmarch Prescott, a merchant, was stricken with a chronic illness about 1850, and she turned to writing in an attempt to help support the large family. Encouraged earlier by Thomas W. Higginson (*q.v.*), Harriet Prescott first gained recognition in 1859 when the *Atlantic Monthly* published "In a Cellar," an adventure story distinguished by rich description. Her reputation grew rapidly and she became a popular contributor to leading periodicals.

She published *Sir Rohan's Ghost* (1860), a novel dealing with the plight of a man who falls in love with the daughter of a mistress he tried to kill; *The Amber Gods, and Other Stories* (1863), a collection of stories in the romantic tradition; and *Azarian: An Episode* (1864), the story of egocentric, artistic Azarian who could not understand another's idealism.

Her magazine contributions of romantic tales, poems and articles were later collected in a number of books, which include *New-England Legends* (1871); *A Scarlet Poppy and Other Stories* (1894); *In Titian's Garden and Other Poems* (1897); *Hester Stanley's Friends* (1898); *Old Madame and Other Tragedies* (1900); and *The Elder's People* (1920).

After her marriage in 1865 to Richard Smith Spofford, Jr., a lawyer, she spent a great deal of time in Washington, D.C. Interested in the local colour of Washington, she later wrote *Old Washington* (1906), a novel.

She died on Aug. 14, 1921, at her home on Deer Island, in the Merrimack river, near Newburyport, Mass.

PRESCOTT, WILLIAM (1726–1795), U.S. soldier, was born in Groton, Mass., on Feb. 20, 1726. A descendant of John Prescott, one of the early settlers of Lancaster, Mass., Prescott lived as a farmer on his estate at Pepperell, Mass. He returned there after having served as an officer with the provincial army during King George's War and the French and Indian War. He had refused the offer of Gen. John Winslow, his commanding officer during the Nova Scotia expedition, to become an officer in the regular army.

Prescott helped supply food to Boston in 1774, when it was closed by the British parliament, and in the same year he was appointed a colonel in command of a regiment of minutemen. Prescott and his troops attempted to intercept the detachment of British regulars which had been sent by Gen. Thomas Gage, royal governor of Massachusetts, to Concord, where colonists had begun to store military supplies. Prescott and his force did not arrive in time to join the engagement at Lexington April 19, 1775, and he continued to Cambridge, where he joined the council of war. The majority of his troops volunteered to continue serving with him.

With about 1,000 men, he left Cambridge on June 16, 1775, to defend Charlestown, Mass. While historians have disagreed whether Prescott or Israel Putnam (*q.v.*) was in general command of the American forces at the battle on June 17, 1775, at Bunker hill, Charlestown, Prescott played a vital part in that action. *(See* BUNKER HILL.)

The alleged famous order which tradition gives as "Don't fire till you see the white of their eyes" may have been given at

Bunker hill by Prescott. Israel Putnam, it is said, relayed it as "Men, you are all marksmen—don't one of you fire until you see the white of their eyes."

Although Prescott participated in military actions in 1776 and 1777, he had sustained an injury in farm work and had to retire from military life. Returning to his estate at Pepperell, he served for a number of years as a representative in the Massachusetts legislature. He died at Pepperell on Oct. 13, 1795. In 1881 a statue of Prescott by William Wetmore Story was erected on Bunker hill.

PRESCOTT, WILLIAM HICKLING (1796–1859), U.S. historian, was born in Salem, Mass., on May 4, 1796, his grandfather being Col. William Prescott (1726–95), a commander at the battle of Bunker hill, and his father, a well-known lawyer. Although he was blinded in one eye by a crust of bread flung in the Harvard Commons, he graduated with honour in 1814 and entered his father's office as a student of the law.

The verdict of physicians abroad was that the injured eye was hopelessly paralyzed and that the preservation of the sight of the other depended upon the maintenance of his general health. His further pursuit of the legal profession seemed to be out of the question, and on his return to Boston he remained quietly at home. On May 4, 1820, he was married to Susan Amory.

Prior to his marriage he had made a few experiments in composition, but he now finally decided to devote his life to literature. A review of Lord Byron's *Letters on Pope* in 1821 constituted his first contribution to the *North American Review*, to which he continued for many years to send the results of his slighter researches. He next turned to French literature and to the early English drama and ballad literature. Of the direction and quality of his thought at this time he left indications in his papers on *Essay-Writing* (1822) and on *French and English Tragedy* (1823). In pursuance of his method of successive studies he began in 1823 the study of Italian literature, passing over German as demanding more labour than he could afford. In the following year he made his first acquaintance with the Iiterature of Spain under the influence of his friend and biographer. George Ticknor; and, while its attractiveness proved greater than he had at the outset anticipated, the comparative novelty of the subject as a field for research served as an additional stimulus.

In the meantime his aims had been gradually concentrating. History had always been a favourite study, and G. Bonnot de Mably's *Observations sur l'histoire de France* appears to have influenced him. After prolonged hesitation he recorded in Jan. 1826 his decision "to embrace the gift of the Spanish subject." The choice was certainly a bold one. He could only use the eye which remained to him for brief and intermittent periods, and as travelling affected his sight prejudicially he could not anticipate any personal research among unpublished records and historic scenes. He was happy, however, in the possession of ample means and admirable friends. His method of work is an excellent illustration of his resourcefulness and perseverance. Seated in a darkened study, he kept his writing apparatus (a noctograph) before him, and his ivory stylus in his hand to jot down notes as his assistant read aloud. These notes mere in turn read over to him until he had completely mastered them, when they were worked up in his memory to their final shape. So proficient did he become that he was able to retain the equivalent of 60 pages of printed matter in his memory, turning and returning them as he walked or drove. The rate of progress was necessarily slow, apart from any liability to interruption by other undertakings and illness. He still continued his yearly experimental contributions to the *North American Review*, elaborating them with a view as much to ultimate historical proficiency as to immediate literary effect, the essays on *Scottish Song* (1826), *Novel-Writing* (1827), *Molière* (1828) and Washington Irving's *Granada* (1829) belonging to this preparatory period. On Oct. 6, 1829, he began the actual work of composition of his *History of the Reign of Ferdinand and Isabella*, the concluding note being written June 25, 1836. Another year, during which his essay on *Cervantes* appeared, was spent in the final revision of the *History* for the press. Its success was immediate. From the position of an obscure reviewer Prescott suddenly found himself elevated to the first rank of contemporary historians.

After considering for a short time the project of a life of Molière, he decided to follow in the track of his first work with a history of the conquest of Mexico. Irving, who had already made preparations to occupy the same field, generously withdrew in his favour. Prescott's five years of labour on this second book were broken by the composition of various reviews and by the preparation of an abridgment of his *Ferdinand and Zsabella.* In Dec. 1843 the *Conquest of Mexico* was published with a success proportionate to the wide reputation he had won. The careful methods of work which he had adopted from the outset had borne admirable fruit. While the consultation of authorities had been no less thorough, his style had become more free and less self-conscious; and the epic qualities of the theme were such as to call forth in the highest degree his powers of picturesque narration. It was only a step from his great work on Mexico to that on Peru, and scarcely three months elapsed before he began to break ground on the latter subject. In Feb. 1845 he received the announcement of his election as corresponding member of the French Institute in place of the Spanish historian M. Fernbndez Navarrete, and also of the Royal Society of Berlin. The winter found him arranging for the publication in England of his *Critical and Historical Essays* (New York ed., *Biographical and Critical Miscellanies).* The *Conquest of Peru* was completed in Nov. 1846 and published in the following March.

Prescott was now over 50 and his sight sho ed serious symptoms of enfeeblement. Although during the composition of the *Ferdinand and Zsabella* it had been of very intermittent service to him, it had so far improved that he could read with a certain amount of regularity during the writing of the *Conquest of Mexico*, and also, though in a less degree, during the years devoted to the *Conquest of Peru.* Now, however, the use of his remaining eye had been reduced to an hour a day, divided into portions at wide intervals, and he was driven to the conclusion that whatever plans he made must be formed on the same calculations as those of a blind man. He had been for many years collecting materials for a history of Philip II, but he hesitated to attempt a work of such magnitude, occupying himself in the meantime with the slighter labours of a memoir of John Pickering for the Massachusetts Historical society and the revision of George Ticknor's *History of Spanish Literature.* But in March 1848 he set himself with characteristic courage to the accomplishment of the large project. Through the aid of Don Pascual de Gayangos, then professor of Arabic literature at Madrid, he was enabled to obtain material not only from the public archives of Spain but from the muniment rooms of the great Spanish families. With an exceptional range of information thus afforded him. he wrote the opening of his history in July 1849; but, finding himself still unsettled in his work, he decided in the spring of the following year to carry out a long projected visit to England, where he was received with great honour. In Nov. 1855 the first two volumes of his uncompleted *History of Philip II*, were issued from the press, their sale eclipsing that of any of his earlier books. This was his last great undertaking; but a year later he published in revised form William Robertson's *Charles V*. A slight attack of apoplexy on Feb. 4, 1858, foretold the end, though he persevered with the preparation of the third volume of *Philip II* for the press, and with the emendation and annotation of his *Conquest of Mexico.* On the morning of Jan. 28, 1859, a second attack occurred, and he died in the afternoon of the same day.

Prescott's power lies chiefly in the clear grasp of fact, in selection and synthesis, in the vivid narration of incident. For extended analysis he had small liking and faculty; his critical insight was limited in range and he confined himself almost wholly to the concrete elements of history. When he does venture upon more abstract criticism, his standards are often commonplace and superficial, and the world scheme to which he relates events is less profound than the thought of his time altogether warranted. Moreover, the authorities on whom he relied had to be corrected later in many points of detail in the light of later archaeological research. Few historians have had in higher degree that artistic feeling in the broad arrangement of materials which ensures popular interest.

BIBLIOGRAPHY.—The definitive or Montezuma ed. of Prescott's works was edited by W. H. Munro (1904). His *Life* was written by George Ticknor (1864; rev. 1875). There are later lives by R. Ogden (1904) and H. T. Peck (1905). *See* also the chapters on Prescott and J. L. Motley in J. S. Bassett, *The* Middle *Group of American Historians* (1917) and *The Cambridge History of American Literature* (vol. 2, 1918); and sketch by M. A. D. Howe in *American Booknzen* (1898).

PRESCOTT, seat of Yavapai county in west central Arizona, U.S., about 100 mi. N.W. of Phoenix, is located in a mile-high basin among pine-dotted mountains rich in minerals. Gold mining brought the first settlers; farmers and cattlemen followed. To protect them from Indian raids an army post, Ft. Whipple, was built in the 1860s about 17 mi. N. of the present city, and in 1864 the first government of Arizona territory was set up near it. Later that year the fort and the government were moved to the area of the present city and the first legislature met in the "governor's mansion," a log-walled house preserved as a historic site.

The location of the capital alternated between Prescott and Tucson until 1889, when Phoenix was made the state capital. A railroad reached Prescott in 1893 and was extended to Phoenix in 1895.

Prescott is a trade centre for cattle ranches and farms in the valleys; mining also continues to be important and small industries are increasing. The city was named for the historian William Hickling Prescott; founded in 1864, it was incorporated as a city in 1881 and in 1955 adopted a council-manager form of government. The inhabitants of Prescott boast that the rodeo staged by competing cowboys on July 4, 1888. was the first public rodeo to be given anywhere; over the years the celebration developed into a lively three-day event — Prescott Frontier Days. For comparative population figures *see* table in ARIZONA: *Population*. (A. *M*. PE.)

PRESCRIPTION, in the broadest sense, the acquisition or extinction of rights by lapse of time. The prescription of Roman law (and of modern systems based upon it) is both acquisitive and extinctive. It looks either to the length of time during which the defendant has been in possession, or to the length of time during which the plaintiff has been out of possession.

In English law prescription is used in a comparatively narrow sense. It is acquisitive only, and is very limited in its application. A title by prescription can be made only to incorporeal hereditaments and to certain exemptions and privileges. The rights claimable by prescription for the most part consist of rights *in alieno solo*. The most important are advowsons, tithes, commons, ways, watercourses, lights, offices, dignities. franchises. pensions, annuities and rents. Land or movables cannot be claimed by prescription. The foundation of prescription is the presumption that a person in undisturbed enjoyment of a right did not come into possession by an unlawful act. In England this was based upon the fiction of a lost grant. After one or two previous enactments the date was finally fixed by the Statute of Westminster the First (3 Edw. I. c. 39) at the reign of Richard I., which was interpreted to mean the first year of the reign of Richard I. (1189). This is still the law with respect to claims not falling within the Prescription Act, 1832. By that act (extended to Ireland in 1858, but not to Scotland) claims to rights of common and other profits *à prendre* are not to be defeated after 30 years' enjoyment by any person claiming right thereto without interruption for 30 years by showing only the commencement of the right, and after 60 years' enjoyment the right is absolute and indefeasible unless had by consent or agreement by deed or writing (s. 1). In claims of rights of way or other easements the periods are 20 years and 40 years respectively (s. 2). The beforementioned periods are to be deemed those next before suits, and nothing is to be deemed to be an interruption unless acquiesced in for one year (s. 4). The time during which a person otherwise capable of resisting a claim is an infant, idiot, *non compos mentis, feme covert* or tenant for life, or during which an action or suit has been pending until abated by the death of a party, is to be excluded in the computation of the periods unless where the right or claim is declared to be absolute and indefeasible (s. 7). An act to define the period of prescription for a *modus decimandi*, or an exemption from tithes by composition, was passed the same year. The claim under the statute must be one which may be lawfully made at common law. The principal rules upon the subject are these: (1) The title is founded upon actual usage. The amount of actual usage and the evidence necessary to prove it vary according to the kind of claim. (2) The enjoyment must (except in the case of light) be as of right — that is to say, peaceable, openly used, and not by licence. (3) The prescription must be certain and reasonable. Inhabitants cannot, however, claim by prescription, as they are an uncertain and fluctuating body, unless under a grant from the Crown, which constitutes them *a* corporation for the purposes of the grant. (4) The prescription must be alleged in a que *estate* or in *a* man and his ancestors. Prescription in a que estate lies at common law by reason of continuous and immemorial enjoyment by the claimant, a person seised in fee, and all those whose estate he had. Prescription in a man and his ancestors is not of ordinary occurrence in practice. Corporations, however, occasionally claim by a prescription analogous to this, viz. in the corporation and its predecessors. Such claims by either a person or a corporation are not within the Prescription Act, which applies only where there are dominant and servient tenements. By 32 Hen. VIII. *c*. 2 (1540) no person can make any prescription by the seisin or possession of his ancestor unless such seisin or possession had been within three score years next before such prescription made. (5) A prescription cannot lie for a thing which cannot be granted, as it rests upon the presumption of a lost grant.

Prescription must be carefully distinguished from custom. Some rights may be claimed by custom which cannot be claimed by prescription, *e* g., a right of inhabitants to dance on a village green, for such a right is not connected with the enjoyment of land.

International Law uses the term "prescription" in its wider or Roman sense. "The general consent of mankind has established the principle that long and uninterrupted possession by one nation excludes the claim of every other" (Wheaton, *Int. Law*, s. 165). Historic instances of rights which were at one time claimed and exercised by prescription as against other nations are the sovereignty of Venice over the Adriatic and of Great Britain over the Narrow seas, and the right to the Sound dues long exacted by Denmark. But such claims were rejected by the highest authorities on international law (*e.g.*, Grotius), on the ground that they were defective both in *justus titulus* and in *de facto* possession. In private international law prescription is treated as part of the *lex fori* or law of procedure. (J. WIL.; X.)

Scotland. — In the law of Scotland "prescription" is a term of wider meaning than in England, being used as including both *prescription* and *limitation* of English law. In its most general sense it may be described as the effect which the law attaches to the lapse of time, and it involves the idea of possession held by one person adverse to the rights of another. Though having its basis in the common law, its operation was early defined by statute, and it is now in all respects statutory. Prescription in Scots law may be regarded (1) as a mode of acquiring rights — the positive prescription; (2) as a mode of extinguishing rights — the negative prescription; (3) as a mode of limiting rights of action — the shorter prescriptions. It must, however, be observed with reference to this division that the distinction between (1) and (2) is rather an accidental (due to a loose interpretation of the language of the act of 1617, c. 12) than a logically accurate one. It is, moreover, strictly confined to heritable rights, having no application in the case of movable property.

Positive Prescription. — The positive prescription was introduced by the Act of 1617, *c*. 12, which regulated the prescription of land rights till 1874. The provisions of the Act of 1874 are repealed as from Jan. 1, 1930, by the Conveyancing Act, 1924 (s. 16). As from that date the prescription will be 20 years without allowance for legal disability. The Acts of 1874 and 1924 provide that possession for 20 years upon "an *ex facze* valid irredeemable title recorded in the appropriate register of sasines" should in future give the same right as 40 years' possession upon charter and sasine under the earlier laws. These Acts also provide that the 20 years prescription is not to apply to servitudes, rights of way and public rights generally.

Negative Prescription.—This prescription was introduced by the Act of 1469, c. 28, and was substantially re-enacted by the Act of 1474, c. 55 The negative prescription accordingly extinguishes *in toto* the right to demand performance of an obligation after 40 years, the years being reckoned from the day on which fulfilment of the obligation can be first demanded. Such a lapse of this period of time creates a conclusive presumption—one incapable of being reargued—that the debt or obligation has been paid or fulfilled. But it must be kept in view that the negative prescription does not per se—without the operation of the positive-establish a right to heritable property (Erskine, *Inst.* bk. iii. tit. 7. s. 8). The negative prescription of heritable debts (Act of 1617) is reduced to 20 years without allowance for legal disability as from Jan. 1, 1930, by the Conveyancing Act 1924 (s. 17). This reduction of period does not apply to the prescription of servitudes and public rights.

United States.—Prescription in the United States though often used synonymously with adverse possession is technically confined as at common law to the acquisition of rights to incorporeal hereditaments, chiefly easements The common law doctrine of presuming a lost grant after a certain period of undisturbed enjoyment of the right prevailed in the States. Upon an analogy to the period of limitations prescribed by the Statute of James I., undisturbed enjoyment of the right for 20 years was deemed to raise the presumption of a lost grant. Some differences of opinion have prevailed as to whether the presumption is a matter only of fact and hence rebuttable or is conclusive as a matter of law, the latter view being the majority rule. Thus prescription has in many States been assimilated to the acquisition of title to land by adverse possession. Statutes have commonly dealt with prescription, abolishing the lost grant presumption and substituting the doctrine of acquisition of title through adverse possession. As at English common law the adverse use must be open and notorious and not under licence of the owner; it must be uninterrupted for the statutory period, and the right acquired is limited to the extent of the use and the enjoyment of it during the period of prescription. No easement can be acquired save as appendant to an absolute estate in land. No right to maintain a nuisance can be acquired by prescription nor can a right of user be acquired by prescription against the State.

PRESERVING AND BOTTLING, terms used for methods of saving perishable foods from moulds, yeasts and bacteria. (See FOOD PRESERVATION.) In the United States the term "canning," instead of "bottling," is used for the preservation of food in containers, whether of glass or tin, and the word "preserves" implies that sugar is added to the food material.

The application of heat in some form is one of the commonest means of destroying bacteria, yeasts and moulds, and is utilized in jam-making (see JAMS AND JELLIES), bottling, canning, pickle-making, drying and crystallizing. Pickle-making is a method of preserving in which heat, vinegar, sugar or salt, or both, are used to destroy the micro-organisms contained in fruit and vegetables. The acetic acid in the vinegar acts as an antiseptic and prevents further growth of bacteria, moulds or yeasts. Chutneys, pickles, catchups and sauces are examples of foods preserved with vinegar.

BOTTLING FRUIT

The aim when bottling is to sterilize the contents of the bottle, and having done so to prevent any germs from entering by sealing it. Bottling is one of the simplest, but most useful methods of preserving fruit and vegetables, for their character and flavour is unaltered, whereas in jam and pickle-making both taste and appearance are changed. Provided attention be paid to a few important points success is assured, and a lavish supply of peas, beans, cherries, currants, etc., is available for winter use at little cost beyond the initial expense of buying a supply of vacuum jars. These are not essential, however, for ordinary jam jars can be used, although special care and precautions must be taken to obtain an airtight seal. When bottling is done regularly it is advisable to purchase a supply of vacuum jars and a sterilizer.

Vacuum jars or bottles consist of (a) a glass container with wide neck. It should be without flaws and it is important that the rim should not be chipped; (b) a metal or glass lid; (c) a rubber band, which acts as a washer between the bottle and lid; (d) a metal screw band or clip. When bottling is carried out on a large scale special sterilizers are employed, but in the home a large zinc bath, fish kettle, bath or even a large clothes boiler or copper, can be used. As bottles are liable to crack if they are placed in immediate contact with the heated bottom of the pan some good non-conductor of heat must come between them. A simple slatted wood board to fit the copper, bath or fish kettle makes an excellent false bottom.

Selecting and Preparing the Fruit.—(I) Select sound fruit which is very slightly under-ripe, with the exception of pears, which are better bottled when fully ripe. (2) Wash to remove dust, grade according to degree of ripeness and pack neatly and firmly, using a smooth piece of wood or bone spatula. The bottle should be shaken from time to time to ensure a tight pack. Loose packing is responsible for the fruit rising when sterilized, leaving a space of one to two inches at the bottom of the jar. (3) Fill each jar with cold water and pour away. This is to rinse the fruit as it is handled during the packing process. (4) Fill the jars with syrup or water, taking care that the fruit is completely covered. The flavour is improved when syrup is used, but if sugar is scarce or unavailable water can be used. (5) Put the rubber rings, lids and screw bands or clips in position. When screw bands are used, they should be screwed down tightly and then unscrewed for rather less than a half turn to allow the steam and air to escape. (6) Stand the bottles in the sterilizer or bath, which should contain sufficient cold water to cover the bottles completely, and apply gentle heat until the correct temperature is reached. This varies according to the variety of fruit' from 125° F for small soft fruit, such as raspberries and blackberries, to 185° F for fruit salad, plums, cherries and pears. The process must not be hurried and approximately $1\frac{1}{2}$ hours should be taken in bringing the water to the correct temperature. (7) Allow the bottles to remain at this temperature for from 10 to 30 minutes. Most soft fruit requires about 1j minutes and pears and apples about 30 minutes. (8) When sterilizing is completed remove the bottles from the boiler, stand on a wooden table or some other good non-conductor, tighten the screw bands and leave until cold. (9) Next day examine the bottles to see if they are airtight. To do this, remove the screw bands and clips, hold the bottles by the lid and raise them. If the lid is firm and secure the seal is perfect. Should the lid show the slightest signs of movement or come off the seal is imperfect, and the bottle should be re-sterilized

To Make the Syrup.—Dissolve four to six pounds of sugar in a gallon of water—according to the sweetness of the fruit being bottled—bring to the boil and when cool fill the bottles.

BOTTLING VEGETABLES

Vegetables require rather more severe treatment than fruit, particularly peas and beans, as they contain nitrogen, which renders them favourable to the growth of certain micro-organisms, Prepare brine of a suitable strength by dissolving 23 oz. salt in one gallon of water and adding 5 fluid oz. or $\frac{1}{4}$ pint lemon juice, when preserving peas and beans. Boil the water, add the salt and the exact quantity of lemon juice. When cold it is ready for use.

Peas must be cleaned thoroughly by washing, and as a precaution it is advisable to soak them for 15 minutes in a weak solution of permanganate of potash. Sufficient crystals should be added to the water to produce a deep magenta colour. Remove the pods and shell the peas. Put them loosely in muslin and dip in a saucepan of boiling water for $1-1\frac{1}{2}$ minutes Then place in cold running water for about 10 minutes. Pack into the bottles and fill with acidified brine.

French and Runner Beans.—Wash the beans thoroughly, using a nail brush if necessary to remove soil from the pods; string (the runner beans will also require slicing); pack lengthways in the jars. After packing, rinse out the jars with water, cover with acidified brine and place the rubber ring, glass lid and screw band in position. (See detailed instructions for fruit bottling.) Put in the sterilizer or boiler, bring very slowly to the boil and boil for $1\frac{1}{2}$ hours. If, after the bottles have been boiling the brine has boiled away, remove the jars and fill up with boiling brine. Replace the rings and complete the cooking. Next day examine and test the seal as when fruit bottling.

CANNING

The same principles and methods are used in canning as bottling, the chief difference being that metal, and not glass, containers are used, and the method of sealing is therefore different.

Canning has the advantage that it occupies less time than bottling and less care is necessary as there is no risk of breakage. It has not been widely practised by housewives, chiefly owing to the fact that until recently soldering was necessary, a process which the majority of women found difficult. This drawback no longer exists, for a small hand sealing machine is now available which eliminates soldering. Numerous tests with the machine have been carried out and the results are invariably extremely satisfactory and reliable. In conjunction with the hand sealer, special straight sided sanitary cans with open ends must be used. The cans may be either plain or lacquered. The latter are preferable, as they prevent the acid fruit coming in contact with the tin. The outer rim of the lid has a groove which is treated with rubber solution and which acts in the same way as the flat rubber band used when fruit bottling.

Method of Canning.—(I) Wash the cans thoroughly in hot water before use. Pack with prepared fruit or vegetables, and cover entirely with boiling syrup or brine. (2) Put the lids in position and with the aid of the sealing machine close the can. As the escape of steam exhausts the air it is important to seal the can whilst very hot; therefore only two or three should be filled with boiling syrup at one time, otherwise they cool down before there is time to seal them. (3) When all the cans have been sealed, place them in any large container, such as a clothes boiler, large pan or zinc bath containing sufficient boiling water to cover them completely. (4) Bring to the boil and boil gently for 15–40 minutes, according to the fruit. Small soft fruit requires 15 minutes only, and pears from 35 to 40 minutes. The time must be calculated from the moment the water boils again after all the cans have been put in. Small bubbles rising from the can whilst it is in the water indicates that it is not airtight, and has been sealed imperfectly. The contents must be removed, put into a new can and resealed. (5) When sterilizing is complete, cool the cans quickly by placing them in a bath or sink of cold water. When cold, dry and label. (See also FOOD PRESERVATION.)

(D. D. C.-T.)

In the United States processing is the term applied to the heating of the material to a temperature and for a length of time that will kill bacteria producing spoilage, and the following methods are used: (A) Water-bath canner, in which the containers are set far enough apart to allow free circulation of the water. This must be boiling when the sealed containers are set in (glass jars being preheated to avoid breakage) and must come over the top of the containers. (B) Steam-pressure canner, in which only enough water is put to come almost to the rack on which the containers are set.

The hot-pack method of canning is recommended by the United States Department of Agriculture. The food material is first heated to boiling point in a minimum of water, is packed while boiling hot into the containers, then processed. In the cold-pack method the material is packed cold into the container (often after first being blanched), then processed. (I. E. L.)

PRESIDENCY, an administrative unit of the Indian empire. The word is derived from the title of president or chief of the council of a principal factory under the East India Company—a title which lasted until governors were appointed under act of parliament in 1784. It thence came to be applied to the three original provinces of Bengal, Madras and Bombay. It is now restricted to Madras and Bombay, in distinction to the lieutenant-governorships. In Anglo-Indian usage, "presidency" was also applied to the capital city as opposed to the country beyond, termed the "mofussil"; and this usage lingers in such phrases as "presidency town," and "presidency magistrate."

PRESIDENT, a style of title of one who presides. In classical Latin the title praeses, or president, was given to all governors of provinces, but was confined in the time of Diocletian to the procurators who, as lieutenants of the emperor, governed the smaller provinces. In this sense it survived in the middle ages. Du Cange gives instances from the capitularies of Charlemagne of the style praeses *provinciae* as applied to the count; and later examples of praeses, or praesidens, as used of royal seneschals and other officials having jurisdiction under the Crown.

In England the word survived late in this sense of royal lieutenant. Thus, John Cowell, in his Interpreter of Words (1607) defines "president" as "used in common law for the king's lieutenant in any province or function; as president of Wales, of York, of Berwick, president of the king's council." In some of the British North American colonies (New Hampshire, Pennsylvania, South Carolina) there was a president of the council, usually elected by the council; and when Pennsylvania and New Hampshire became States, one member of the executive council was called president. The chief (and single) executive head in Delaware, South Carolina and New Hampshire (1784–92) was called president.

During the revolutionary struggle in America from 1774 onwards, the presiding officer of the continental congress was styled "president" and when the present constitution of the United States was framed in 1787 (in effect 1789) the title of president was transferred to the head of the Federal Government. "President" thus became the accepted style for the elected chief of a modern republic.

In the simple sense of "one who presides" the word "president" preserved its meaning alongside the technical use implying royal delegation. In ecclesiastical terminology *praesidens* was sometimes used for the head of cathedral chapters, instead of dean or provost; and it was sometimes the title given to the principal visitor of monasteries. In Great Britain the heads of many colleges are styled "president," the title being of considerable antiquity in the case of one college at Cambridge (Queens', founded in 1448) and four at Oxford (St. John's, Magdalen, Corpus Christi, Trinity). At five Cambridge colleges (Pembroke, Gonville and Caius, St. Catherine's, St. John's, Magdalene) the title "president" is borne by the second in authority, being the equivalent of "vice-master." In the United States "president is the usual style of the head of a college and also of a university wherever this has developed out of a single college. "President" is also the style of persons elected to preside over the meetings of learned, scientific, literary and artistic academies and societies, *e.g.*, the president of the Royal Academy (P.R.A.) in London; the title of the president of the Royal Society (P.R.S.) dates from its foundation in 1660. In the United States the style "president" is also given to the person who presides over the proceedings of financial, commercial and industrial corporations (banks, railways, etc.), in Great Britain usually styled "chairman," but in the Bank of England and certain other banks "governor."

In France, besides the president of the republic, there are presidents of the senate and of the chamber of deputies. In Germany the word Priisident is used in most of the English senses of "president," *e.g.*, of a corporation, assembly or political body.

PRESLAV, a village of Bulgaria, situated on the north edge of the Balkans, south of Shumen (*q.v.*). Preslav was the second capital of the mediaeval Bulgarian tsars, and was raised to great splendour by Tsar Symeon (893–927). It was then compared to Constantinople, and described as "full of high palaces and churches, with countless stones, woods and paintings, so adorned with marble and copper, silver and gold, that the visitor knows not wherewith he shall compare it." It fell into decay on the fall of the first Bulgarian Empire, and was later plundered to adorn the new capital of Trnovo (*q.v.*). It is now a heap of ruins.

PRESOV, a town in Presov region, Czech., 25 mi. N. of Kosice. Situated on the left bank of the river Tarcza, a tributary of the Theiss, it is a very old town but has been almost entirely rebuilt since a great fire in 1857. Following the foundation of the town by German colonists in the 12th century its history has been much affected by the nodal character of its site; today it is the seat of the district authorities, the centre of a Greek Catholic diocese and an important railway junction for the Carpathians and Poland. In the neighbourhood of the town is an opal mine and mineral springs, but importance rests on its administrative functions supplemented by small manufactures. Pop. (1950) 22,843.

PRESS. For the history of the liberty or freedom of the press *see* CENSORSHIP; CIVIL LIBERTIES; also NEWSPAPER and PERIODICAL. For the punishment of "pressing" see PEINE FORTE ET DURE. For the "press gang" *see* IMPRESSMENT.

PRESS ASSOCIATION, THE, the oldest and largest news agency operating exclusively in Britain, was founded by provincial newspapers on a co-operative basis in 1868, and began active work on February 5, 1870, when the post office took over the private telegraph companies which had previously supplied the provincial papers with news. For 50 years the P.A. transmitted news by press telegrams, but in 1920 it leased private telegraph wires from the post office. Its private wire system embraces over 3,000 miles of telegraph circuits radiating from London and serving either direct or through centres at Birmingham, Bristol, Manchester, Leeds, and Glasgow, about 120 provincial morning and evening newspapers. It also operates a direct printer system to offices in London. The P.A. has always had the exclusive right to supply in the provinces Reuters' (*q.v.*) imperial and foreign news services. The two agencies are closely associated. With the Exchange Telegraph Co., Ltd., the P.A. operates in the provinces a joint telephonic service for the rapid collection and distribution of racing results, etc., and cricket and football scores.

The P.A. is governed by a board of seven directors. One new director is elected annually by the shareholders (the provincial newspapers). The association's new headquarters' building, which it occupied in July, 1939, is at 85 Fleet Street, London. From this building it supplies news to all the London daily and Sunday newspapers, provincial newspapers, and trade journals and other periodicals. (H. C. Ro.; X.)

PRESSBURG: *see* BRATISLAVA.

PRESSED METAL, a broad term which includes that class of product made by the process of bending, shaping and forming sheets, strips, plates or bars of metal in either hydraulic or mechanically-driven presses. Metal formed in this manner is referred to as "pressed metal," "stampings" or, if deformation is severe, "deeply drawn stampings." All ductile metals and alloys may be pressed and for many. it is a process of industrial importance. Great amounts of low carbon steel sheets and aluminum and aluminum alloy sheets are formed in this way. Substantial amounts of alloy steel, stainless steel, brass, bronze, copper, nickel, magnesium, zinc, titanium and zirconium are pressed.

Pressed metal is generally assumed to mean the cold forming of metal at room temperature with suitable tools in power-driven presses. However, certain metals and alloys of hexagonal close-packed atomic structure are rather poor in ductility at room temperature. Their ductility is better at elevated temperature and in moderately difficult formations both sheet and die are heated to 500° to 1,050° F. Typical examples of this type material are magnesium, zinc, titanium, zirconium and their alloys. Castings and forgings constitute the classes of metallic products that have been heavily replaced by pressed metal. Pressed metal differs from both castings and forgings in that while either a casting or forging may have a solid section of varying degrees of thickness, pressed metal has a flat or hollow form, such as a shell, the walls of which are of the same order of thickness throughout. While in some shapes and by specially constructed tools it is possible to make a wall of varying thickness, it generally follows that if the sheet of metal which is used as raw material is $\frac{1}{8}$ in. thick, the walls of the finished pressed metal form will also be substantially $\frac{1}{8}$ in. thick. However, heavily formed parts may be reduced in thickness to $\frac{3}{32}$ in. or more.

Cold forming of metal first became industrially important through its adoption by bicycle manufacturers. When bicycles became popular, pressed steel replaced forgings and castings because of the need of producing a lighter vehicle at a lower cost. Cast iron cooking utensils were soon being replaced by enameled pressed steel and later by pressed aluminum and stainless steel. The really great advance in the use of pressed metal was by the automobile manufacturers. By the early 1930s, apart from units such as the engine and front axle gears, automobiles were being made almost entirely of pressed steel. Fortunately, at the same time great advances were being made in the method of rolling sheet steel. The old method of hot rolling of individual sheets by hand feeding into rolling mills and the further hot rolling of packs of three to the finished sheet thickness, was giving way to massive wide continuous hot mills. A slab comprising $\frac{1}{3}$ of an ingot was reduced, in a series of mills in line, from the original thickness of about 4 to 5 in. to as low as $\frac{3}{32}$ in. without any reheating. At the same time powerful cold mills were developed to reduce further the thickness to the popular thicknesses of $\frac{1}{32}$ to $\frac{1}{16}$ in. The cold reduced steel was then annealed. The product of these continuous mills was considerably lower in cost, and much better in quality from the standpoint of finish, uniformity of gauge and forming quality. Concurrently aluminum was becoming available in quantity and continuous mills were being introduced in the aluminum, brass and copper industry.

Other manufacturers, finding a good supply of quality sheets and strip at lower prices and perceiving the advantage of pressed metal over castings and forgings, changed their methods so that pressed metal went into many other manufactured products It is impossible here to give a complete list, but some of the better known products are kitchen utensils, appliances, lighting fixtures. home and office furniture, filing cabinets, office equipment. vending machines, gasoline pumps, cartridge cases and much general hardware such as bolts, nuts, nails, hinges and latches. Metal pressings are extensively used in the construction of railway freight and passenger cars, highway freight trailers, jet engines and aircraft structures. Wherever a large number of individual units are demanded pressed metal has in the majority of cases been utilized.

The equipment used for the manufacture of pressed metal carries the general term of press. Presses, which vary widely in size, are of two general classes: hydraulic and mechanical. The great majority, however, are belt-driven and mechanically powered. The press furnishes the power for forming and the means of holding the tools that do the actual forming of the metal. These tools, in their simplest form, consist of an upper or male section, which is known as a punch, and the lower or female section, which is known as a die. In the actual operation a piece of metal is accurately positioned over the lower section (the die) and the upper section (the punch) is brought down by the power press, thus pushing the metal into the die and cold forming the desired shape. In many of the more complex shapes the use of these simple tools results in a part with undesirable wrinkles or buckles. In these cases an upper and lower blank holder become essential additional parts of the forming tools. The punch is surrounded by a separate upper blank holder and a mating lower blank holder is an integral part of the die. A sheet of metal is accurately positioned over the die and lower blank holder, then the upper blank holder is brought down by the power press to hold the sheet, around its periphery, against the lower blank holder. The punch next descends and forms the part. The blank-holder pressure is adjusted to restrain the metal from flowing into the die excessively and thus a part is made without wrinkles. The majority of pressed metal parts are made by several successive operations. **A** certain shape of flat blank receives the first operation in one set of tools. It is then passed along to a second press carrying a second set of tools and is trimmed or further formed, and so on through various stages of forming, trimming, flanging, sharpening of radii and piercing of holes.

It is sometimes necessary to heat-treat the metal between these various operations as cold pressing makes metal harder, stronger and less ductile. A point is therefore reached, depending on the original ductility of the metal, when further formation results in breakage. The proper heat-treatment of cold pressed metal removes the effect of cold work and restores the ductility of the original blank. The strength of a metal or alloy may be increased as much as 30% in a forming operation. In most cases this increase is desirable in the finished part so that heat-treatment is avoided if at all possible. In certain metals and alloys going into service at elevated temperature a final heat-treatment becomes necessary to eliminate embrittlement and dimensional change at operating temperature.

A pressed metal part has a smooth surface that normally requires no metal finishing or machining, while both forgings and castings require extensive machining operations. Pressed metal has replaced wood in many cases. (R. W. E. L.)

PRESSENSÉ, FRANCIS DE (1853–1914), French politician and man of letters, was born in Paris on Sept. 30, 1853, being the son of Edmond de Pressensé, and was educated at the Lycée Bonaparte. He served on General Chanzy's staff in the War of 1870, and was taken prisoner at Le Mans, but after the war entered the public service. After a short period at the ministry of public instruction he entered the diplomatic service, and was appointed first secretary at Washington. In 1882 he returned to France and took up journalism, becoming in 1888, foreign editor of the Temps. At the time of the Dreyfus case (1895) De Pressensé identified himself with the cause of the prisoner. He wrote in support of General Picquart, and in consequence of his advocacy of Émile Zola's cause was struck off the roll of the Legion of Honour. This led to his resignation from the Temps, and he came forward as a socialist politician, being in 1902 elected socialist deputy for the Rhône. He took part in the debates on the question of the separation of church and state, and a bill brought in by him formed the basis of the one finally carried by Briand.

He died in Paris on Jan. 19, 1914.

His works include Le ***Cardinal Manning*** (1896), and ***L'Irlande et l'Angleterre depuis l'acte d'union jusqu'à nos jours, 1800–1888*** (1889), besides ***many*** articles in the ***Temps,*** the ***Revue des Deux Mondes, Aurore*** and ***Humanité.***

PRESS GANG. The press gang was the name given to the naval parties who, until the beginning of the 19th century, were used forcibly to take or impress men for service in the British fleet. From medieval times the crown claimed the power to impress able-bodied subjects for the defense of the realm, and as early as the time of Edward III complaints are recorded in parliament of the excessive use of this power. From the earliest time, England depended upon her professional seamen, the merchantmen, to man her fighting ships: but it was not until the end of the 16th century that fishermen, watermen and mariners were exempted by law from being pressed as soldiers: they remained liable to impressment for service in the navy. The needs of Elizabeth I's fighting fleet became so large that the Vagrancy act was passed, rendering all "disreputable persons" liable for impressment for service in the fleet: the sheriffs and mayors being bound, upon the production of the warrant of the "takers" or "press gang," to produce the number of men required. This naturally led to jail clearance; the law remaining unaltered, throughout the 17th and 18th centuries there were constant complaints from naval officers of the quality of men supplied. In the 18th century certain exemptions were made, in the case of apprentices, a proportion of fishermen, seamen employed in the coastwise coal trade, but even at the height of Britain's maritime power, from 1780 to 1815, the press gang was the chief means of recruiting the fleet.

The action of English cruisers in pressing men from the merchant ships of the American colonies was one of the causes that led to the War of Independence. A favourite means of completing the complement of warships was by stopping homeward-bound merchantmen and removing some of their seamen. Service became so unpopular that in 1795 the press gangs and the jails failed to provide sufficient men. An act was passed directing each county to provide a quota of men, with the result that the authorities of each district handed all malcontents and agitators over to the press gangs, by whom they were taken to the guard ships stationed round the coast for drafting into the fleet. The introduction of this bad element into the navy was one of the causes of the mutiny of 1797 which nearly brought disaster to the country. The insistence of the right to press British subjects in America was one of the chief causes of the war between Great Britain and the United States in 1812.

The press gangs were not used after the close of the Napoleonic wars in 1815, although it is lawful to this day to impress men for service in the navy, though not in the army. By an act of 1835 a pressed man is exempt after five years' service and seamen in the merchant service, fishermen and certain other persons are exempted from impressment. With the introduction of the long service system in 1853 all need for impressment disappeared and since that date there have always been more volunteers than could be accepted for service in the Royal Navy. (S. T. H. W.)

PRESSING: see PEINE FORTE ET DURE.

PRESS SYNDICATE. Press syndicates are intended to spread the cost of expensive features over as many subscriber newspapers as possible. These organizations sell the exclusive rights to a feature to one subscriber in each territory in contrast to the wire news services (see NEWS AGENCY), such as the Associated Press, United Press International and Reuters, which offer their reports to all papers in a given area. The business grew enormously after 1930, especially in the United States, with its extensive area and many markets.

Irving Bacheller of Brooklyn, N.Y., started the first modern syndicate (1883) which offered and distributed fiction and household departments. In 1884 S. S. McClure founded the syndicate which still bears his name. He first offered fiction and secured the rights to several stories by Rudyard Kipling that were widely published. He also helped to introduce the stories of Sir Arthur Conan Doyle and others in the United States.

The features then offered were mostly literary material and pictures (see PHOTOGRAPHY: *Photo* Syndicates). An important change came in 1896, however, when the big New York Sunday newspapers began to produce and publish comic pages such as "Foxy Grandpa," "The Yellow Kid" (originally called "Hogan's Alley") and "Li'l Mose." In 1907 the comic strip (see CARICATURE AND CARTOON) in daily papers was introduced. Two artists, "Bud" Fisher and George Herriman, were credited with drawing the first strips. Previously a strip by Clare Briggs had a brief run in Chicago. This form of art gradually changed the whole character of the business and made it more profitable. The strips are shipped in matrix form to the subscribers for simultaneous publication. Originally they were comic, intended to make readers laugh, but later many became continued stories with no humour. When "Mutt and Jeff" by "Bud" Fisher was first bought and published in England in 1920 many British readers scoffed at the idea. However, English editors later originated many of their own strips in competition with the U.S. products. By the latter 1950s U.S. comics were translated into several languages and sold all over the world.

Before the modern syndicate was developed there had been a few sporadic efforts to distribute political and fashion letters. In 1875 A. N. Kellogg of Chicago began to sell stereotyped plates carrying literary and pictorial material to weekly papers. Kellogg was followed in this technique by Major O. J. Smith in England (1882) and by directors of political parties and factions in Germany. The Community Press Service in the 1950s distributed plates and matrices to small dailies and weeklies.

In the 1950s a great variety of material was available from press syndicates, including columns on a wide range of subjects, dress patterns, crossword puzzles with substantial prizes offered for the correct solution, etc. No single newspaper could afford to produce strips and pages for itself alone, because of the high costs. Several newspaper chains had their own syndicates which were profitable.

The leading organizations in the latter 1950s were King Features, owned by the Hearst papers; United Features, an offspring of Scripps-Howard; Bell Syndicate; A.P. Newsfeatures; General Features; and Chicago Tribune-New York News syndicate. Prominent British syndicates were Central Press, Exchange Telegraph Co.. Ltd. and Incorporated Press of Great Britain.

(F. L. MT.; J. N. W.)

PRESSURE CHEMISTRY. Pressure has a pronounced influence on both the physical and chemical states of matter and on the changes that matter undergoes in industrial chemical processes. The study of this influence is pressure chemistry. The

Haber process for the synthesis of ammonia from hydrogen and nitrogen, developed in Germany prior to World War I by the Badische Anilin und Soda Fabrik, was the first industrial chemical process to use high pressure for a chemical reaction. Many other substances are manufactured under conditions which include elevated pressure. These include methanol, ethanol and other alcohols, phenol, polyethylene, amines and naphtha or gasoline from coal or gas. Pressure which ordinarily changes a gas or vapour into a liquid is used in the production of oil from wells, in purification and separation operations and in changing carbon into diamond.

Pressure performs several functions. It has an effect on some chemical reactions so that at equilibrium a greater amount of product is formed. It causes some reactions to take place at a faster rate, so that much more of the desired product is formed in a given time. It may maintain water or organic substances in a liquid state at a higher temperature than would be possible under ordinary pressure. This is beneficial in some chemical reactions.

Chemical Equilibrium.— According to H. L. Le Chatelier's principle, when a system at equilibrium is subjected to a constraint, the system will change in a manner to oppose the constraint. Thus, when a system in chemical equilibrium is subjected to pressure it will react to reduce its volume. Pressure favours a chemical reaction in which the volume of the products is less than that of the reactants. The effect of pressure on chemical equilibrium may be stated more precisely in terms derived from thermodynamics. *e.g.*, the reaction of hydrogen and nitrogen to form ammonia is favoured when it is carried out under elevated pressures. This reaction is $1/2N_2+3/2H_2 \rightleftharpoons NH_3$. Each mole of ammonia is formed from two moles of hydrogen and nitrogen and, according to Le Chatelier's principle, the reaction is favoured by elevated pressure. The fugacity f may be considered as a corrected pressure for each of the elements and compounds involved in the reaction. The ratio of the fugacities, as expressed below, must have a value fixed by the temperature according to the equation by Samuel Glasstone:

$$RT \ln\left[\frac{f\,NH_3}{f^{3/2}_{H_2}\,f^{1/2}_{N_2}}\right]=9{,}130-7.46T\ln T+3.69\times10^{-3}T^2-0.235\times10^{-6}T^3+12.07RT,$$

where R is the gas law constant in cal./(gram-mole$\times$°K.) and T is in °K. From this equation the extent to nhich the reaction proceeds may be determined. Starting with a mixture of 3 moles of hydrogen to 1 mole of nitrogen, the resulting mixture will contain 3.85% ammonia at equilibrium under 10 atm. pressure. 25.1% under 100 atm. and 79.8% under 1.000 atm., all at 400° C. This illustrates the effect of increasing pressure in forming more ammonia at equilibrium.

Pressure has a similar effect on the equilibrium between carbon monoxide and hydrogen to form methanol, according to the reaction $CO+2H_2 \rightleftharpoons CH_3OH$.

Rate of a Chemical Reaction.—A chemical reaction may reach equilibrium slowly or quickly. In many industrial processes it is important that reactions take place quickly, and pressure sometimes increases the rate of reaction.

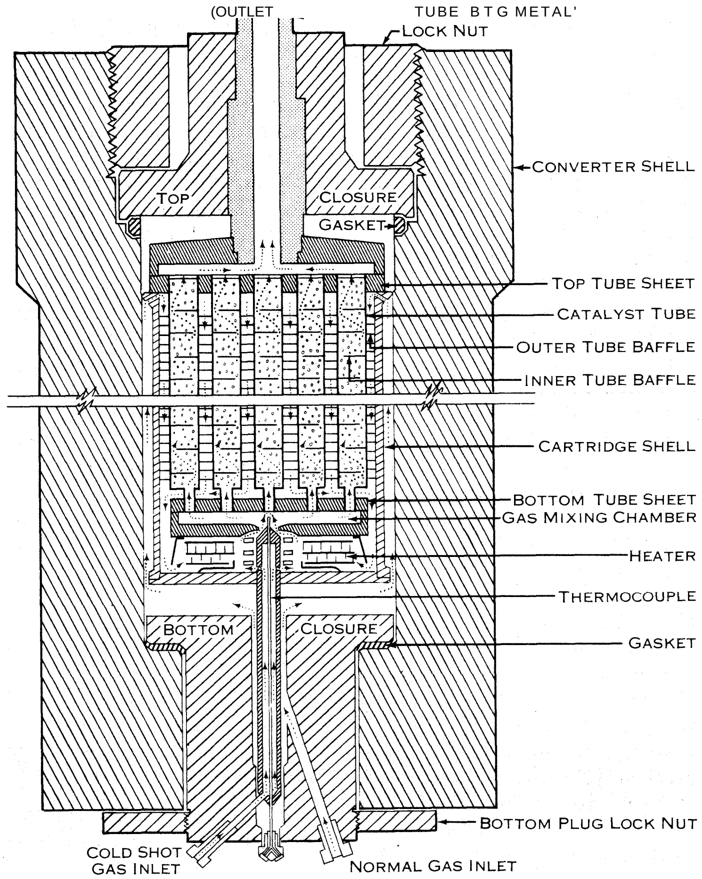
For example, when ammonia is formed in a reactor under identical conditions except that the pressure is varied, the rate of formation is 1 mole/(hr.$\times$cu.ft. of catalyst) at 100 atm. and 10.5 mole/(hr.$\times$cu.ft.) at 300 atm., representing a 10.5-fold increase in the rate of the chemical reaction as a result of a 200 atm. increase in the pressure.

Effects on the Physical State.—A pressure of 5,000 p.s.i. (pounds per square inch) is used to maintain a mixture of chlorobenzene and sodium hydroxide solution in a single liquid phase at 360° C. Under these conditions, a reaction occurs which produces sodium phenolate. The latter is neutralized with hydrochloric acid to produce phenol. In this process the caustic soda solution and chlorinated benzene are mixed and passed through a heated pipe autoclave under pressure. The pressure increases the mutual solubility of the components of the reaction mixture and provides suitable conditions for the hydrolysis of the chlorobenzene. This illustrates the action of pressure in maintaining a liquid phase.

The phase relation between liquids and vapours in equilibrium is often complex when mixtures of several components are considered. Mixtures of hydrocarbons under pressures as high as 10,000 p.s.i. are found in oil and gas wells. Normally, a vapour phase is formed when the pressure on a liquid mixture is decreased or when the temperature is increased. A liquid is formed from a vapour by the reverse procedure.

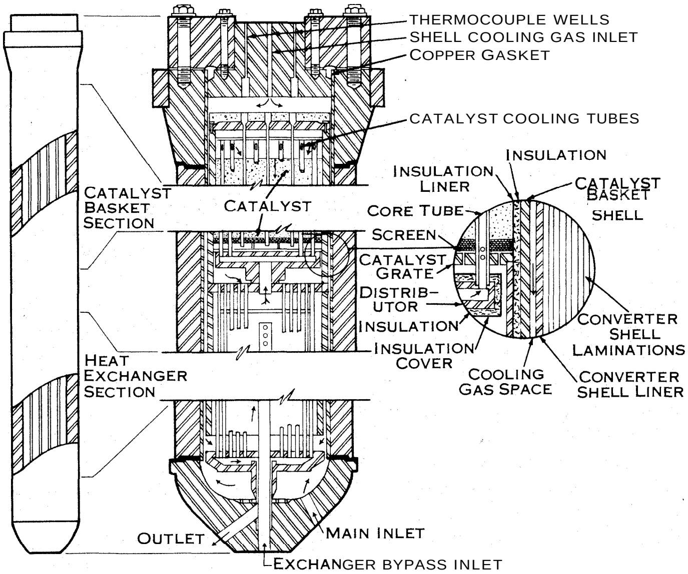
However, for many mixtures there are limited ranges of pressure and temperature near the critical point where retrograde condensation occurs. Within these ranges a liquid phase is formed when the pressure is lowered. Repressuring operations that take advantage of this situation are conducted in the oil fields. The pressure in the underground structure is not allowed to decrease beyond a certain point. This pressure maintains a single gaseous phase underground. The single phase is brought to the surface where the pressure is reduced somewhat and a liquid phase separates. The remaining gas phase is returned to the ground to maintain the high pressure there.

Synthetic Ammonia Process.—The synthesis of ammonia is an example of a high-pressure chemical process. Pressure increases the amount of ammonia formed from hydrogen and nitrogen at equilibrium. However, the reaction takes place too slowly to be of commercial importance unless a catalyst is used. In the presence of a catalyst. increased pressure also increases the rate of reaction. The process is then commercially successful. The catalyst is iron, but the method of preparation and the nature of the iron surface on which the reaction takes place are of great importance. A smooth iron surface or iron shavings are ineffective. Other noncatalytic agents should also be present in the iron to promote its activity. A typical catalyst, before it is made active, contains 66% Fe_2O_3, 31% FeO, 1.0% K_2O and 1.8% Al_2O_3. These materials must be free from impurities which would act as catalyst poisons. The mixture is fused into a solid mass by passing an electric current through it. Then it is broken up and screened. and the -3 to $+6$ mesh (per inch) fraction is used, although it



BY COURTESY OF CHEMICAL ENGINEERING PROGRESS

FIG. 1.— AMMONIA SYNTHESIS CONVERTER FOR OPERATION AT 1,000 ATM
(After H. L. Thompson, P. Guillaumeron and N. C. Updegraff)



BY COURTESY OF CHEMICAL ENGINEERING PROGRESS

FIG. 2.— AMMONIA SYNTHESIS CONVERTER FOR OPERATION AT 250–300ATM.
(After A. V. Slack, H. Y. Allgood and H. E. Maune)

must be activated before it will produce ammonia. Activation consists of reducing the iron oxides by passing the hydrogen and nitrogen synthesis gas over them according to a predetermined time schedule. with gradually increasing temperature. After the catalyst is activated it cannot be exposed to air and must be kept continuously in a reducing atmosphere. Impurities such as sulphur, phosphorus and arsenic will poison the catalyst permanently. reducing its activity! while oxygen. water vapour and carbon oxides are temporary poisons and reduce the activity only as long as they are present in the synthesis gas stream.

The synthesis reaction is carried out in a large complicated pressure vessel called a converter. The catalyst is maintained at a temperature in the range from 750° to 1,050° F., according to the process and the condition of the catalyst. The high temperature is confined to the inner regions of the converter; the walls which must withstand the pressure are at a much lower temperature, not over 120° F. in some cases. The synthesis gas entering the converter is relatively cool and is heated to the reaction temperature by heat exchangers within the converter. The heat generated by the reaction in the catalyst bed must be removed to prevent overheating and damage to the catalyst.

A typical converter designed for operation in the high-pressure range, at about 1,000 atm., is a thick-walled carbon steel vessel containing a basket, or cartridge, which includes both a heat-exchanger and tubes of catalyst. (See fig. 1.) The heat exchange is carried out in the same region as the catalytic reaction. The cold incoming gas enters at the bottom and moves upward through a narrow passage between the inside of the converter wall and the cartridge, keeping the wall cool. The catalyst tubes are arranged in closely spaced concentric circles and are fitted with internal baffles to aid in removing the heat of reaction. The region outside the tubes also is provided with baffles to improve the gas flow distribution and provide local high·velocity and turbulence to improve the heat transfer. Synthesis gas enters the cartridge near the top. flows downward around the catalyst tubes and into a mixing chamber where it may he heated electrically if necessary. It then flows upward through the catalyst tubes. The reaction is rapid in the lower part of these tubes and slow in the upper part so the gas is cooled considerably before it leaves the catalyst. Each converter contains about 16.5 cu.ft. of catalyst and produces from 250 to 400 lb. of ammonia per hour per cubic foot of catalyst.

For use at lower pressures. in the range from 250 to 350 atm., the walls of the converter are made of medium-carbon steel and are kept cool by a portion of the cool synthesis gas entering at the top and flowing down through an annular space inside the converter wall. The main flow of synthesis gas enters at the bottom and, after mixing with that from above: flows upward around the tubes of a heat exchanger. There it receives heat from the hot gases which have just left the catalyst and which are flowing down inside the tubes. The catalyst is in a continuous bed above the heat exchanger, and tubes for the partially preheated synthesis gas pass up through this bed. The reacting gas flows downward through the bed.

Such a converter contains about 144 cu.ft. of catalyst and produces about So lbs. of ammonia per hour per cubic foot of catalyst. (See fig. 2.)

In the high-pressure process, hydrogen for the reaction is obtained from steam and natural gas, while the nitrogen comes from the air. The synthesis gas is prepared and then carefully purified and compressed to reaction pressure. Only a part of the hydrogen-nitrogen mixture is converted to ammonia in one pass through a converter. This ammonia is condensed and removed and the remaining gas is passed through a second converter. The unconverted gas is then mixed with make-up gas and recirculated to the first converter.

At 1,000 atm. the conversion per pass through the synthesis reactor is considerably greater than at lower pressures. Approximately one-seventh as much catalyst and converter volume is required to produce the same quantity of ammonia, and about one-fifth as much gas must be pumped and piped on the basis of actual volume at synthesis conditions. Economic factors at each plant location dictate operating conditions.

Other High-Pressure Processes.—The process for synthesizing methanol is in general similar to that for ammonia. The catalyst consists of aluminum oxides, copper and zinc oxide containing chromium. Typical operating conditions are 200 atm. and 750° F. With a similar catalyst: which is made alkaline by the addition of potassium carbonate or chromate, and at temperatures from 750° to 1,000° F. and pressures from 200 to 1,000 atm., higher alcohols are formed.

Fig. 3 shows the manufacture of phenol from chlorobenzene; the raw materials are sodium chloride brine and benzene. The brine is fed to an electrolytic cell and the chlorine produced in this cell is used to chlorinate the benzene. An 18% sodium hydroxide solution derived from the cell is mixed with the chlorobenzene; this mixture is raised to a pressure of 5,000 p.s.i. and passed through a continuous-pipe pressure reactor constructed of 2 in. diameter pipe in long coils in a furnace. This mixture is heated to 360° C.; the pressure maintains a single phase and increases the mutual solubility of the ingredients; the hydrolysis reaction takes place, and sodium phenolate is formed. The sodium phenolate is neutralized with hydrochloric acid, regenerating a salt brine, and the phenol is distilled from the mixture.

The successful synthesis of diamonds was announced by the General Electric company in 1955. Diamonds are a crystalline form of pure carbon. They are formed when carbon is subjected to extremely high pressure and high temperature for sufficient

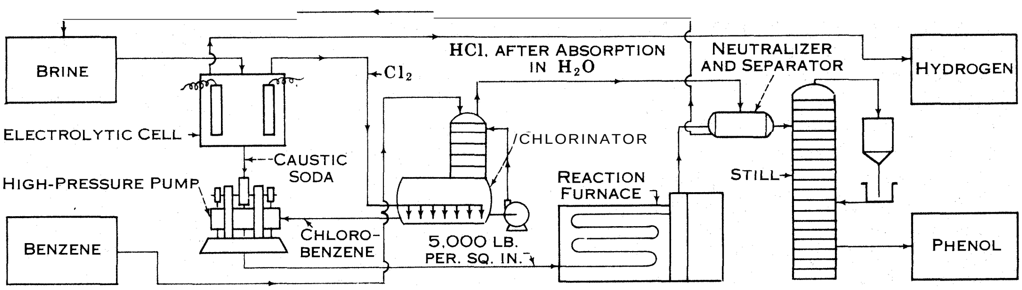


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FIG. 3.—FLOW SHEET OF A COMMERCIAL PROCESS FOR MANUFACTURING PHENOL FROM CHLOROBENZENE AT 5,000 LB. PER SQUARE INCH

time. The details of the synthesis mere not revealed but P. W. Bridgman stated that pressures of more than 100,000 atm. and temperatures of 2,500° C. were maintained for hours at a time.

Equipment. — Chemical reactions are carried out in steel or alloy vessels at high pressure. In continuous processes high-pressure tubing, fittings and compressors are required. Closures and fittings are frequently of a special design so that the internal pressure assists in making a tight seal. A large number of designs are available for high-pressure equipment to be used under a variety of special conditions.

A variety of alloys are often used in a single piece of equipment. The wall of an ammonia converter, for example, may be selected to resist the high internal pressure at low temperature, while the liner material may be chosen to resist the corrosive action of the contents. The catalyst tubes may be selected to resist the combined action of high temperature, hydrogen and nitrogen, but not to confine the high pressure.

At high pressure both hydrogen and nitrogen attack steel and certain alloys. Hydrogen apparently is absorbed on the surface of steel. It ionizes and the protons pass through the openings of the metal lattice. They slowly react nith carbon in the steel to form methane, which accumulates at the grain boundaries. The internal pressure built up by the methane forces the grains apart, resulting in such permanent damage as intercrystalline cracking, fissuring, blistering and decarburization.

The introduction of strong carbide-forming elements such as titanium and vanadium has helped materially to reduce the effects of hydrogen. Austenitic stainless steels and beryllium-copper are examples of alloys which do not seem to be subject to hydrogen attack.

BIBLIOGRAPHY.—P. W. Bridgman, The Physics of High Pressure (New York, 1931); new impression with supplement, (London, 1949); Harold Tongue, The Design and Construction of High Pressure Chemical Plant (London, 1934); D. M. Newitt, The Design of Hzgh Pressure Plant and Properties of Fluids at High Pressure (New York, 1940); E. W. Comings, High Pressure Technology (New York, 1956).

(E. W. C.)

PRESSURE GAUGE, in general terms, an instrument or instrument system for measuring pressures of gases and liquids. Types of pressure gauges include vacuum gauges (see VACUUM: *Measurement* of *Low* Pressures), barometers, manometers and dead weight piston gauges, as well as the more common Bourdon tube gauges. Also included is equipment for measuring rapidly changing pressures such as engine indicators, or piezoelectric crystal pickups or other pressure transducers, arranged to indicate or record pressure variations by use of an oscillograph, or other means. Pressure gauges may indicate or record pressure at the location of the pressure-sensing element, or pressure information may be transmitted to a remote point for observation.

Pressure gauges are available for accurate measurement of the minute pressures existing in vacuum systems, to pressures of several hundred thousand pounds per square inch necessary in research and some industrial processes. Various types of instruments are specifically designed for making measurements of pressures over a wide range of pressure rate-of-change, from static or slowly changing pressures. such as atmospheric pressure, to the very rapidly changing pressure transients of explosions.

Pressure gauges may be designed for measurement of absolute pressure, gauge pressure or differential pressure as explained below. Pressure measurement is of primary importance in the chemical process industry, in power plants, aeronautics and meteorology.

Industrial Gauges. — The present article is limited primarily to a treatment of pressure gauges used industrially, with only mention of the broader variety of gauges used in scientific research and development.

The pressure element of the majority of mechanical pressure gauges is usually in one of three forms: a Bourdon tube; a corrugated diaphragm or diaphragm capsule; or a bellows. Of these the Bourdon tube type is the most common.

Bourdon Tube. — The Bourdon gauge is one in which the pressure is indicated directly by an attached pointer and scale. The Bourdon tube is elliptical or flattened in cross section and bent into circular form. One end is soldered to a central block through which the fluid enters. and the other end is sealed and coupled by a link to a pivoted quadrant with teeth meshing with those of a pinion on the pointer spindle. Backlash between the teeth is absorbed by a hairspring exerting constant force on the pinion. An increase of pressure uithin the tube tends to change its cross section from elliptical to circular, and the tube consequently uncoils slightly, thus turning the pointer.

If the case enclosing the gauge is made airtight and the air is exhausted from within the case, the gauge measures absolute pressure (psia or pounds per square inch absolute); if the pressure inlet of such a gauge is then opened to the atmosphere the gauge would read atmospheric pressure, approximately 14.7 psia. If the airtight case is provided with a pressure inlet the gauge may be used to measure differential pressures existing betneen two sources of pressure connected to the two pressure inlets. Usually the case of the gauge is not airtight and the external surface of the Bourdon tube is thus subjected to ambient atmospheric pressure. Such a gauge measures "gage" pressure (psig or pounds per square inch gauge). *i.e.,* the value of the inlet pressure above atmospheric pressure. This instrument may be used as a vacuum gauge, measuring pressure, below atmospheric pressure; the reduction in pressure causes the Bourdon tube to coil further, and the mechanism must be arranged in reverse fashion to cause the pointer to move clockwise with increasing vacuum. A compound gauge reads for both pressure and vacuum. the dial markings for vacuum being placed to the left of the zero of the pressure scale.

Diaphragm Capsule. — One direct-reading gauge utilizes as the elastic pressure-sensitive element a hollow sealed disk-shaped capsule made from two corrugated metal diaphragms. Changes in pressure cause motion of the centre of the capsule, and this motion is amplified by a mechanical linkage to control movement of the pointer over a calibrated dial. When proper precautions are taken in design to reduce hysteresis, temperature effects and the like, sustained accuracies on the order of two or three parts in 1,000, or better, are obtainable.

For measurement of absolute pressure, as in the aneroid barometer, the capsule is evacuated. and the varying atmospheric pressure acts on the exterior surface of the capsule. A spring is arranged to supplement the elastic resistance of the capsule to the force of atmospheric pressure, and the motion of the centre of the capsule is transmitted to the indicating pointer by appropriate linkage.

Bellows.—A metal bellows may be used in a pressure gauge designed for pressure ranges of from a few inches of water (*i.e.,* the pressure produced by a column of water a few inches high) to 10 or 15 lb. per square inch. The large deflection of the bellows for small pressure changes provides the high sensitivity needed in gauges for such low-pressure ranges.

Materials. — Bourdon tubes are commonly of phosphor-bronze, beryllium-copper or Monel metal (a nickel-copper alloy), for pressures up to a few hundred pounds per square inch; above this pressure or for elevated temperatures. the tubes are made of steel to obtain a greater elastic range and a smaller change of elasticity with temperature. Diaphragms are most frequently made of phosphor-bronze, beryllium-copper or Ni-Span (a nickel-tin alloy). Bellows are usually of brass although bellows of stainless steel and beryllium copper are also available.

Reading Instruments. — All of these gauges are also available in designs to provide a continuous record of pressure. A circular-chart gauge, comprising a Bourdon element of several complete turns, has a pen arranged to trace a record on a circular chart driven by clock work. A microbarograph records absolute atmospheric pressure on a paper strip wound around a drum driven by clockwork. The necessary high sensitivity is obtained by use of an evacuated bellows element whose motion is magnified by the pen linkage. The pressure range of the instrument is generally 28.5 to 31 in. of mercury (about 14 psia to 15.2 psia), for which range the recording pen moves about 6 in.

Remote Indicators. — For remote indication of pressure, or for control purposes, the pressure is often converted into an analogue quantity. This quantity is commonly a direct current voltage or an air pressure. Direct current voltage is used frequently in telemetering systems, and air pressure in industrial recording and control equipment.

One such instrument, designed for use in measuring the pressure at points remote from a pressure recorder, has the elastic motion of a hollow metal cylinder exposed to the pressure arranged to vary the electrical resistance of strain gauges attached to the surface of the cylinder. The strain gauges are connected in a bridge circuit in such a way that the bridge output voltage varies in a linear fashion over the range from zero to perhaps jo millivolts as the cylinder pressure varies from zero to the rated pressure of the instrument, the rated pressure being from a few hundred psig to 50,000 psig. The output voltage, proportional to the pressure, may be recorded or displayed by use of appropriate electrical instruments. For rapidly changing pressures, to which this instrument will respond, the output voltage is usually recorded by use of an oscillograph.

A common system is that in which the pressure to be measured is converted by use of a force-balance mechanism into an analogue pneumatic pressure in the range 3 to 1j psig. The instrument may be adjusted to have an input pressure range from a small fraction of the analogue pressure range to several times the analogue pressure range. The analogue pressure may be transmitted to a remote location and connected to an indicator, recorder, or used for control purposes. The pressure-sensitive element of the pressure transmitter is a diaphragm acting against a coil spring. Slight motion of the diaphragm due to change in pressure causes a relatively large change in the pneumatic pressure in the force-balance bellows assisting the spring, and the analogue pressure is the pressure in the bellows necessary to maintain the diaphragm near its mid-position. The permitted motion of the force-balance bellows and of the diaphragm and main spring is extremely small, and the system is characterized by high sensitivity and low hysteresis.

Other methods for converting the motion of a mechanical pressure element to an analogue voltage include the use of variable resistors (potentiometers). differential transformers, variable capacitances and variable inductance or variable reluctance devices. In another method the motion of a diaphragm varies the tension, and thus the frequency, of a vibrating wire maintained in motion by a magnetic field acting on an alternating current passing through the wire. The pressure is then represented by an electrical frequency equal to the wire frequency.

Primary Pressure Gauges.—A11 instruments of the types described above require calibration against known pressures. The two principal instruments used for such calibration are liquid column instruments such as the manometer and barometer (*q.v.*) and dead-weight piston gauges.

A dead-weight piston gauge, comprises a vertical cylinder, the upper end of which is closed by a weight-loaded piston. The cylinder is filled with oil, and a pressure connection is provided at the lower end to which an instrument under test may be connected. A pump, operated by a handwheel, is provided to adjust the volume and pressure of the system so that the weight-loaded piston assumes a floating position in the cylinder. The pressure developed by a dead-weight piston gauge is nominally equal to the weight of the piston and its load divided by the cross-sectional area of the piston.

Such instruments are capable of high precision, on the order of one part in 10,000, or better; when precision greater than about one part in 200 is desired corrections must be made including corrections for a number of environmental variables. The following are the most important corrections that must be considered: change in effective piston area due to temperature changes, amounting to 10 to 20 parts per million per degree Centigrade; difference in value of local gravity from standard value of 980.665 cm./sec./sec., amounting to more than one part in 1,000 in some localities; variation in effective area of piston due to elastic distortion of piston and cylinder under pressure, amounting to perhaps 100 parts per million per 1,000 psi in some designs; the buoyancy of the liquid on submerged protuberances of the piston, applicable only for pistons of nonuniform cross-sectional area: the hydrostatic head of liquid between the bottom of the piston and the point of pressure measurement; and the buoyancy of air on the weights, frequently amounting to about one part in 7,000.

For high accuracy at high pressures the controlled clearance piston gauge has been developed, in which a variable hydrostatic pressure is applied to the exterior surface of the cylinder to reduce errors due to elastic distortion.

For pressures below about jo psig piston gauges are available in which the working fluid is air, and the piston and cylinder operate as an air bearing.

Bibliography.—W. G. Brombacher and T. W. Lashoi, *Bibliography and Index on Dynamic Pressure Measurement*, U.S. National Bureau of Standards Circular 558, 850 references (Washington, 1955); H. Diederichs and W. C. Andrae, "The Measurement of Pressure," *Experimental Mech. Eng.*, ch. iv, vol. i (New York, 1930); R. T. Eckenrode and H. A. Kirshner, "Measurement of Pressure Transients," 112 references, *Rev. of Scientific Instruments,* vol. 25, p. 33–40 (Rochester, N.Y., 1954). (E. C. Ld.)

PRESTEIGNE, an urban district and the county town of Radnorshire in the Brecon and Radnor parliamentary division of Radnorshire, Wales, 26 mi. N.W. of Hereford by road and on the Lugg, which there forms the boundary between Wales and England. Pop. (1951) 1,255. Area 4.3 sq.mi. The village, lying on the English side of Offa's dyke, was in the lordship of Moelynaidd until the 14th century, when Bishop David Martin of St. David's (1296–1328) conferred market privileges upon his native place. There is an annual May fair.

In 1542 Presteigne was named as the meeting place of the county sessions for Radnorshire in conjunction with New Radnor; a winter and summer assize court is held. It has the fine parish church of St. Andrew, dating chiefly from the 1jth century but with traces of Norman work; curfew is rung from it at eight o'clock every evening.

Presteigne is the most easterly spot on the Welsh border; hence the expression "from St. David's to Presteigne.!' The main industries are agriculture and forestry.

PRESTER JOHN, a fabulous medieval Christian monarch of Asia. The history of Prester John no doubt originally gathered round some nucleus of fact, though what that was is extremely difficult to determine. Before Prester John appears upon the scene we find the way prepared for his appearance by a kindred fable, which entwined itself with the legends about him. This is the story of the appearance at Rome (1122), in the pontificate of Calixtus II, of a certain oriental ecclesiastic, whom one account styles "John, the patriarch of the Indians." and another "an archbishop of India." This ecclesiastic related wonderful stories of the shrine of St. Thomas in India, and of the miracles wrought there by the body of the apostle, including the distribution of the sacramental wafer by his hand.

Nearly a quarter of a century later Prester John appears upon the scene, in the character of a Christian conqueror and potentate who combined the characters of priest and king, and ruled over vast dominions in the far east. This idea was universal in Europe from about the middle of the 12th century to the end of the 13th or beginning of the 14th.

The Asiatic story then died away, but the name remained, and the royal presbyter mas now assigned a locus in Ethiopia. Indeed, it is not improbable that from a very early date the title was assigned to the Abyssinian king, though for a time this identification was overshadowed by the prevalence of the Asiatic legend. At the bottom of the double allocation there was, no doubt, that confusion of Ethiopia with India which is as old as Virgil and perhaps older.

The first mention of Prester John occurs in the chronicle of Otto. bishop of Freisingen. This writer states that when at the papal court in 1145 he met with the bishop of Gabala (Jibal in Syria). who related how "not many years before one John, king and priest (*rex* et sacerdos), who dwelt in the extreme Orient beyond Persia and Armenia, and mas, with his people, a Christian but a Nestorian, had made war against the brother kings of the Persians and Medes, who mere called Samiards (or Sanjards), and captured Echatana their capital. After this victory Presbyter *John*—for so he was wont to be styled—advanced to fight for the Church at Jerusalem; but when he arrived at the Tigris and found no means of transport for his army, he turned northward, as he had heard that the river in that quarter was frozen over in wintertime. After halting on its banks for some years in expectation of a frost he was obliged to return home."

About 1165, a letter was circulated purporting to be addressed by Prester John to the emperor Manuel. This letter, professing to come from "Presbyter Joannes, by the power and virtue of God and of the Lord Jesus Christ, Lord of Lords," claimed that he was the greatest monarch under heaven, as well as a devout Christian. The letter dealt at length with the wonders of his empire. It was his desire to visit the Holy Sepulchre with a great host, and to subdue the enemies of the Cross. Seventy-two kings, reigning over as many kingdoms, were his tributaries. His empire extended over the three Indies, including that Farther India, where lay the body of St. Thomas, to the sun rising, and back again down the slope to the ruins of Babylon and the toner of Babel. All the wild beasts and monstrous creatures commemorated in current legend were to be found in his dominions, as well as all the wild and eccentric races of men of whom strange stories were told, including those unclean nations whom Alexander the Great walled up among the mountains of the north and who were to come forth at the latter day—and so were the Amazons and the Brahmans. His dominions contained the monstrous ants that dug gold and the fish that gave the purple; they produced all manner of precious stones and all the famous aromatics. Within them was found the Fountain of Youth. the pebbles which give light, restore sight and render the possessor invisible; the Sea of Sand was there, stored with fish of wondrous savour, and the River of Stones was there also, besides a subterranean stream whose sands were of gems. His territory produced the worm called "salamander," which lived in fire and which wrought itself an incombustible envelope from which were manufactured robes for the presbyter. which were washed in flaming fire.

In war 13 great crosses made of gold and jewels were carried in wagons before Prester John as his standards. and each was followed by 10.000 knights and 100,000 footmen. There were no poor in his dominions, no thief or robber, no flatterer or miser, no dissensions, no lies and no vices. His palace was built after the plan of that which St. Thomas erected for the Indian king Gondopharus. Before it was a marvellous mirror erected on a many-storied pedestal; in this speculum he could discern everything that went on throughout his dominions, and detect conspiracies.

Prester John was served by 7 kings at a time, by 60 dukes and 365 counts; 12 archbishops sat on his right hand, and 20 bishops on his left, besides the patriarch of St. Thomas's the protopope of the Sarmagantians (Samarcand?), and the archprotopope of Susa. where the royal residence was. Should it be asked why, with all this power and splendour, he calls himself merely "presbyter." this is because of his humility, and because it was not fitting for one whose chamberlain was a bishop and king, and whose chief cook was an abbot and king, to be called by such titles as these.

How great was the popularity and diffusion of this letter may be judged in some degree from the fact that Friedrich Zarncke in his treatise on Prester John gives a list of close on 100 manuscripts of it. Of these 8 were preserved in the British Museum, 10 at Vienna, 13 in the great Paris library, 1j at Munich. There are also several renderings in old German verse.

Many circumstances of the time tended to render such a letter acceptable. Christendom would welcome gladly the intelligence of a counterpoise arising so unexpectedly to the Mohammedan power, and the statements of the letter itself combined a reference to and corroboration of all the romantic figments concerning Asia which already fed the curiosity of Europe, which figured in the world maps and filled that fabulous history of Alexander which for nearly a thousand years supplanted the real history of the Macedonian throughout Europe and western Asia.

The only other surviving document of the 12th century bearing on this subject is a letter of which manuscript copies are preserved in the Cambridge and Paris libraries. and which is also included in medieval chronicles. It is a letter purporting to be written by Pope Alexander III on Sept. 22, 1177, to *carissimo* **in** *Christo filio Johanni, illustro et magnifico indorum* regi. The pope recites how he had heard of the monarch's Christian profession. diligence in good works and piety by various narrators and common report, but also more particularly from his physician and confidant Philip, who had received information from honourable persons of the monarch's kingdom, with whom he had intercourse in those (eastern) parts.

Philip had also reported the king's anxiety for instruction in Catholic discipline and for reconciliation with the apostolic see in regard to all discrepancies, and his desire to have a church in Rome and an altar at Jerusalem. The pope goes on to say that he mould dispatch Philip to communicate instruction to him. And on accepting Philip's communications the king should send back honourable persons bearing sealed letters, in which his wishes should be fully set forth. "The more nobly and magnanimously thou conductest thyself, and the less thou vauntest of thy wealth and power, the more readily shall we regard thy wishes both as to the concession of a church in the city and of altars in the church of SS. Peter and Paul, and in the church of the Lord's supper at Jerusalem, and as to other reasonable requests," the letter advises the king. There is no express mention of the title "Prester John" in nhat seem the more genuine copies of the letter. But the address and the warning against a boastful spirit in the passage quoted above (which evidently alludes to the vaunting epistle of 1165) indicate that the pope supposed himself to be addressing the author of that letter.

It is not known how far the imaginations about Prester John retained their vitality in 1221, 44 years after the letter allegedly written by Pope Alexander, for there was no mention of Prester John in the interval. In that year a rumour came out of the east that a great Christian conqueror was taking the hated Moslems in reverse and sneeping away their power. The name ascribed to the conqueror was David, and some called him the son or the grandson of Prester John of India. The conqueror was in fact the famous Jenghiz Khan: but the delusion was slowly dissipated.

European travelers in Asia looked for a prince to whom the legend of Prester John could be attached. Carpini (1248) makes him the king of the Christians of India the Greater; Rubruquis (1253) gives the title of "King John" to Kushluk, king of the Naimans, and makes him a brother of Ung Khan (d. 1203), the ally of Jenghiz. In Marco Polo's narrative "Unc Khan," alias Prester John, is the lord of the Tatars up to the advent of Jenghiz Khan. This story is repeated by other writers. Both Marco Polo and Friar John of Montecorvino speak of the descendants of Prester John as holding territory in the plain of Kuku Khotan (about 300 mi. northwest of Peking). Friar Odoric gives a circumstantial account of this kingdom, and with this Prester John disappears from Asia to figure in African legend.

It is indeed probable that, however vague may have been the ideas of Pope Alexander III respecting the geographical position of the potentate whom he addressed from Venice in 1177, the only real person to whom the letter can have been sent was the king of Abyssinia. The "honourable persons of the monarch's kingdom" whom Philip had met with in the east must have been the representatives of some real power, and not of a phantom. It must have been a real king who professed to desire reconciliation with the Catholic Church and the assignation of a church at Rome and of an altar at Jerusalem.

Moreover. we know that the Ethiopic Church did long possess a chapel and altar in the Church of the Holy Sepulchre, and, though we have been unable to find travelers' testimony to this older than about 1497, it is quite possible that the appropriation may have originated much earlier. We know from Marco Polo that about a century after the date of Pope Alexander's epistle a mission was sent by the king of Abyssinia to Jerusalem to make offerings on his part at the Church of the Sepulchre; and it is extremely likely that the princes of the "Christian families" who had got possession of the throne of northern Abyssinia should have wished to strengthen themselves by a connection with European Christendom, and to establish relations with Jerusalem, then in Christian hands.

From the 14th century onward Prester John had found his seat in Abyssinia. It is there that Fra Mauro's great map (1459) presents a fine city with the rubric, "Qui il Preste Janni fa residentia principal." When. nearer the end of the century (1481–1495), King John II of Portugal was prosecuting inquiries regarding access to India his first object was to open communication with "Prester John of the Indies." nho nas understood to be a Christian potentate in Africa. When Vasco da Gama went on his voyage from Mozambique northward he began to hear of "Preste Joham" as reigning in the interior — or rather, probably, by the light of his preconceptions of the existence of that personage in East Africa he thus interpreted what was told him.

More than 20 years later, when the first book on Abyssinia was composed — that of Alvarez—the title designating the king of Abyssinia is "Prester John," or simply "the Preste."

Bibliography.—For the older aspects of the subject, *see* Ludolf's *Historia Aethiopica* and its *Commentary,* passim. The excellent remarks of M. d'hvezac, comprising a conspectus of almost the whole essence of the subject, are in the *Recueil de voyages et de mémoires* published by the Société de Géographie, iv, 547–564 (Paris, 1839). Two German works of importance which have been used in this article are the interesting and suggestive *Der Presbyter Johannes in Sage und Geschichte,* by Gustav Oppert (2nd ed., Berlin, 1870), and, most important of all in its learned, careful and critical collection and discussion of all the passages bearing on the subject, *Der Priester Johannes,* by Friedrich Zarncke of Leipzig (1876–79). *See* also Sir H. Yule's *Cathay* and *the Way Thither,* p. 173 *seq.,* and in *Marco Polo* (2nd ed.), i, 229–233, ii, 539–543.

PRESTIDIGITATION: *see* Conjuring.

PRESTO (Ital., "ready, nimble") in music denotes an extremely high rate of speed, exceeded only by its own superlative, prestissimo. The term is occasionally applied to any passage or movement in very fast tempo.

PRESTON, ANN (1813–1872), U.S. physician, reformer and educator. who was a pioneer in medical education for women, was born in Westgrove, Pa.. Dec. 1. 1813. the daughter of a Quaker minister. Although at an early age she assumed the responsibility of caring for her invalid mother and six brothers, she found time to join the local literary society, and to write poetry. She published *Cousin Ann's Stories for Children* in 1848. She also joined the abolition, temperance and woman's rights movements and served as secretary of the Clarkson Anti-Slavery society, and as secretary (1848) of the Woman's Temperance convention of Chester county. She was sent as a delegate to the state legislature in 1848, to argue for temperance legislation.

Interested in medical problems, Ann Preston was preparing herself to lecture on physiology and hygiene when she heard that the Woman's Medical college was to be opened in Philadelphia. Deciding that a medical career offered a more useful and satisfying life, she dropped her lecture plans and enrolled with the first class, graduating in 1852. In the following year she was named professor of physiology and hygiene, the first woman to be appointed to the faculty of the Woman's Medical college.

Because her women students were barred from internships in the Philadelphia hospitals and unable to obtain clinical experience. Ann Preston undertook the task of establishing a hospital for women, staffed by women physicians. Her efforts were successful, and in 1861 the Woman's Hospital was established in Philadelphia. She served as consulting physician, corresponding secretary and member of the board of managers, and in 1866 was made the 'first dean of the college.

Her distinguished work as a physician lent weight to her defense of the right of women to practise medicine and added validity to her vigorous reply. made in 1867, to the Philadelphia County Medical society's resolution condemning women physicians. In her answer she said: "We must protest against the injustice which places difficulties in our way — not because we are ignorant or pretentious, or incompetent or unmindful of the code of medical or Christian ethics, but because we are women."

Ann Preston died in Philadelphia on April 18. 1872.

See F. E. Willard and M. A. Livermore, *A Woman of the Century* (1893).

PRESTON, HARRIET WATERS (1836–1911), U.S. author and translator, who was an authority on Provençal literature, mas born at Danvers. Mass., on Aug. 6, 1836. Educated privately, she lived in Europe for a number of years and traveled in England, France and Italy. In the United States she contributed articles to various periodicals and in 1868 published *Portraits of Celebrated Women,* a translation from C. A. Sainte-Beuve's nork in French.

Harriet Preston's translation of Frédéric Mistral's *Mirèio,* a Provencal poem, later won wide critical acclaim. Other contributions in Provençal literature were *Troubadours and Trouvères* (1876) and "The Troubadours 1090–1290" in C. D. Warner's *Library of tlze World's Best Literature,* vol. 20 (1897). She nrote a novel on New England life, *A Year in Eden* (1887), but is not remembered for her fiction.

With Louise Preston Dodge. a niece, she published *The Private Life of the Romans* in 1893. She had previously translated from the French, Paul de Musset's *The Georgics of Virgil* (1881) and also contributed translations from a number of Roman poets to volume 21 of Warner's *Library* (1897).

Other translations included *Memoirs of Madame Des-bordes Valmore,* by Sainte-Eeuve, and Paul de Musset's biography of Alfred de Musset (1877). She edited *The Complete Poetical Works of Elizabeth Barrett Browning* (1900). Harriet Preston died at Cambridge, Mass., on May 14, 1911.

PRESTON, THOMAS (1860–1900), Irish physicist, who made a number of interesting original contributions on heat. magnetism and spectroscopy, and carried out experiments on the influence of magnetic fields on spectral lines. was born in Kilmore, County Armagh, Ire., on May 23, 1860. He studied in Dublin and became professor of natural philosophy in University college, Dublin, in 1891. He mas elected a fellow of the Royal society of London in 1898. The same year Preston discovered an empirical rule concerning types and structures of P. Zeeman's patterns which contributed to the solution of a definite problem in spectroscopy.

He wrote two remarkable textbooks of a high standard, *The Theory of Light* (1890) and *The Theory of Heat* (1894), both of which continued to appear in revised form long after his death, the first reaching a fifth edition in 1928 and the second a fourth edition in 1929. Preston died in Dublin on March 7, 1900.

(D. McK.)

PRESTON, a municipal, county and parliamentary borough and port of Lancashire, Eng., 21 mi. S.S.E. of Lancaster. Pop. (1961) 113,208. Area 8.9 sq.mi. It is built on a ridge rising above the Ribble where that river is crossed (about 15 mi. above its mouth) by the west coast road and railway to Scotland. It is the administrative centre of the county of Lancashire.

From early days its geographical position made it a trade centre with an agricultural market. Its importance progressively increased after the advent of the cotton industry, to which have been added a wide range of manufactures including engineering. aircraft and vehicles, chemicals and soap, boilers and ships, paper, electrical appliances, textiles and optical goods.

Preston became an independent port in 1843, the corporation acquiring the docks in 1883. The main wet dock is 3,240 ft. long and 600 ft. wide. There is a total quayage of 8,500 ft. and the depth of the channel at ordinary spring tides is 22–25 ft.

Preston is the chief mart for the produce of the great Fylde agricultural district, with two large covered markets: for general produce (wholesale and retail) ; and for fish. There are also corn, butter and egg markets and a wholesale fish market at the railway station. The important cattle market holds thrice-weekly sales throughout the year. There are horse sales each month.

The numerous parish churches include that of St. John (18; 5) which occupies a site that has carried a church' from early times. Among several Roman Catholic churches is that of St. Walburge (1854). The town hall was almost destroyed by fire in 1947. The Harris art gallery, library and museum were established by the trustees of E. R. Harris in 1879, and a new building was opened in 1893. This contains William Shepherd's library, the Francis Thompson collection and the Spencer collection of children's books, the Newsham collection of pictures and collections of pottery, glass, costumes, etc. The grammar school, dating from 1550

(Preston had a schoolmaster as early as 1339) is housed in a modern building in Moor park. The parliamentary borough returns two members. The county borough was created in 1889.

History.— Preston, otherwise Prestune. was near the Roman station at Walton-le-Dale, and the great Roman road running from Warrington passed through it. It is mentioned in Domesday Book as one of Earl Tostig's possessions which had fallen to Roger de Poictou, and on his defection it was forfeited to the crown. Henry II (about 1179) granted the burgesses a charter—the first of 14 royal charters granted to Preston (there is evidence of an even earlier charter of 1100–01). Elizabeth I (1j66) granted the town its great charter which ratified and extended all previous grants. Charles II (1662 and 1685) granted charters, by which an additional weekly market on Wednesday was conceded and a three-day fair, beginning on March 16. The most important industry used to be woollen weaving. Other early industries were glovemaking and linen weaving. The first cotton-spinning mill was built in 1777 in Moor lane, and in 1791 John Horrocks built the Yellow factory. In 183j there were 40 factories, chiefly spinning, yielding 70,000 Ib. of cotton yarn weekly.

A guild existed perhaps in Saxon times, but the grant of a guild merchant dates from Henry II's charter, about 1179. The first guild of which there was any record was celebrated in 1328, at which time it was decided to hold a guild every 20 years. Up to 1542 they do not appear to have been regularly celebrated, but after that year they were held at regular intervals of 20 years except that the 1942 guild was postponed because of World War II. The mayor elected for the year in which the guild is held is known as the guild mayor. The first mention of a procession at the guild is in 1500. One of the most important items of business was the enrolling of freemen, and the guild rolls are records of the population. The statement that Preston was burned in 1323 by the Scots is probably false. The town suffered severely from the Black Death (1349–50), and again from pestilence in the year Nov. 1630 to Nov. 1631. During the Civil War Preston became the Lancashire royalist headquarters. In Feb. 1643 a parliamentary force marched from Manchester and successfully assaulted it, but in March the earl of Derby recaptured the town. The royalists did not garrison it, but after demolishing the greater part of the works left it unfortified. After the battle of Marston Moor Prince Rupert marched through Preston in Sept. 1644 and carried the mayor and bailiffs prisoners to Skipton castle. On Aug. 17. 1648, the royalist forces under the duke of Hamilton and Gen. Marmaduke Langdale were defeated at Preston by Cromwell. During the rebellion of 171j the rebel forces entered Preston Nov. 9. and after proclaiming the chevalier de St. George king, remained there for several days, during which the government forces advanced. The town was assaulted, and on Nov. 14, Gen. Thomas Forster surrendered his army to the king's forces. In 1745 Prince Charles Edward marched through on the way south and north. The borough returned two members from 129j to 1331, then ceased to exercise the privilege till 1529, but after that date (except in 16j3) it always sent two representatives to parliament. In the 18th century Preston had a high reputation as a centre of fashionable society, and earned the epithet still familiarly associated with it, "proud." Sir Richard Arkwright (1732–92) was born there.

See H. Fishwick, *History of the Parish of Preston* (1900); W. F. Fitzgerald, "The Ribble Basin," *Journ., Manchester Geog. Sac.* (1927).

PRESTONPANS, a small burgh and seaside resort of East Lothian, Scot., on the Firth of Forth, 9 mi. E. of Edinburgh by road. Pop. (1951) 2,907. The name refers to the pans. or ponds, in which the priests of Newbattle abbey (a 1zth-century Cistercian foundation now a college for adult education) made salt by evaporation.

The chief occupation is coal mining, and there are manufactures of firebricks, tiles and pottery, besides brewing and soapmaking. Fisheries are less important than formerly. There are harbours at Morrison's Haven to the west and at Cockenzie and Port Seton to the northeast, which form one small burgh with a population (1951) of 3,180.

A mile to the east of the village is the site of the battle of 1745, in which Prince Charles Edward and his Highlanders gained a complete victory over the royal forces under Sir John Cope.

PRESTWICH, SIR JOSEPH (1812–1896), English geologist, was born at Clapham, Surrey, on March 12, 1812. He was educated in Paris. Reading and at University College, London. He was a wine merchant in London, and devoted his leisure more especially to the study of the Thames basin. In 1853 he was elected F.R.S.

Prestwich published in 1851 *A Geological Inquiry Respecting the Water-Bearing Strata of the Country Around London,* which became a standard authority. With Hugh Falconer and Sir John Evans, Prestwich examined the implements discovered by Boucher de Perthes in the gravels of the Somme valley; their investigations proved that man existed contemporaneously with the Pleistocene mammalia (*Phil. Trans.,* 1861 and 1864). In 1874 Prestwich was appointed to the chair of geology at Oxford. During his professorship he wrote his great work. *Geology: Chemical, Physical and Stratigraphical* (vol. i, 1886); vol. ii, 1888). He died on June 23, 1896, at Shoreham.

See Life and Letters of Sir Joseph Prestwich, ed. by his wife (1899).

PRESTWICH, a municipal borough in the Middleton and Prestwich parliamentary division. Lancashire, Eng., 4 mi. N.W. of Manchester by road. Pop. (1961) 34,191. Area 3.8 sq.mi. It has cotton and rayon mills but is mainly residential. It is contiguous with the cities of Manchester and Salford. It was incorporated in 1939. There are traces of the Roman occupation but the place name is of Anglo-Saxon origin. The present parish church dates from the 15th century.

PRETORIA, city in the Transvaal province and administrative capital of South Africa. Pop. (1960) 298.632 (including 154.789 Europeans, 4,852 Asiatics, 7,167 coloured [mixed] and 131,824 natives).

BY COURTESY OF SOUTH AFRICAN TOURIST CORP

THE RAADSAAL. OVERLOOKING CHURCH SQUARE. CENTRE OF PRETORIA. BEFORE THE SOUTH AFRICAN WAR THE RAADSAAL HOUSED THE LEGISLATURE OF THE SOUTH AFRICAN REPUBLIC. AFTER UNION (1910) IT BECAME THE SEAT OF THE TRANSVAAL PROVINCIAL COUNCIL

The city is built in a hollow about the Apies river, a tributary of the Limpopo. The central area of Pretoria is laid out in rectangular blocks. At the centre is Church square. on the south side of which are the provincial council buildings and other public offices. erected in 1892 in the Renaissance style. On the north side are the Palace of Justice and the headquarters of the South African Reserve bank, and on the west. the post office. The Union government building. built in 1910–13 on Meintjes' Kop, cost £1.800.000

and overlooks the city. The lower slopes of the hill are laid out in beautiful terraced gardens in which stands the statue of Louis Botha, the Union's first prime minister. Pres. Paul Kruger's house was excellently restored and has been declared a national monument. The Voortrekker Memorial hall was opened in 1931 and to the south of the city stands the Voortrekker monument inaugurated on Dec. 16. 1949, as a lasting tribute to the *voortrekkers* (pioneers). Pretoria has an Anglican cathedral, a Roman Catholic cathedral, numerous English and Afrikaans churches, several high schools. a normal training college and the University of Pretoria, which includes an agricultural faculty, an experimental farm and the only faculty in South Africa for training veterinarians. Considerable industrial development took place during and after World War II. Production of iron and steel is the capital's most important industry.

Founded in 1855, Pretoria became capital of the South African republic (Transvaal) in 1860, when the *volksraad* held its first meeting there. Until 1864. however. when the civil war in the Transvaal ended, Potchefstroom remained the virtual capital of the country. As revenue flowed in from the gold mines on the Rand, many buildings were erected in the capital. which was linked by railway with Cape Town (and Durban) in 1893 and with Lourenço Marques in 1895. During the South African War Pretoria was declared an open city. On May 31, 1902, the articles of peace (known as the peace of Vereeniging) whereby the Boer leaders recognized British sovereignty were signed at Pretoria and five years later the first parliament of the Transvaal as a self-governing state of the British empire assembled there. On the establishment of the Union of South Africa in 1910 Pretoria became its administrative capital. (H. P. H. B.)

PRETORIUS, the family name of two of the early leaders of the Trek-Boers—Andries Wilhelmus Jacobus Pretorius and Marthinius Wessels Pretorius, father and son.

1. ANDRIES PRETORIUS (1799–1853), a Dutch farmer of Graaff-Rcinct, Cape Colony, and a descendant of one of the earliest Dutch settlers in South Africa, left his home in the Great Trek, and by way of what is now the Orange Free State crossed the Drakensberg into Natal, where he arrived in Nov. 1838, at a time when the emigrants there were without a recognized leader. Pretorius was at once chosen commandant general and speedily collected a force to avenge the massacre of Piet Retief and his party. who had been treacherously killed by the Zulu king Dingaan the previous February. Pretorius' force was attacked on Dec. 16 ("Dingaan's day") by over 10.000 Zulus, who were beaten off with a loss of 3,000 men. In Jan. 1840 Pretorius, with a commando of 400 burghers, helped Mpande (Panda) in his revolt against his brother Dingaan and was the leader of the Natal Boers in their opposition to the British. In 1842 he besieged the small British garrison at Durban. but retreated to hiaritzburg on the arrival of reinforcements under Col. (subsequently Sir) Josias Cloete and afterward exerted his influence with the Boers in favour of coming to terms with the British.

He remained in Natal as a British subject, and in 1847 was chosen by the Dutch farmers there to lay before the governor of Cape Colony the grievances under which they laboured as a result of the constant immigration of natives, to whom locations were assigned to the detriment of Boer claims. Pretorius went to Grahamstown. where Sir Henry Pottinger (the governor) then was; but Sir Henry refused to see him or receive any communication from him. Pretorius returned to Natal determined to abandon his farm and once more trek beyond the British dominions. With a considerable following he was preparing to cross the Drakensberg when Sir Harry Smith, newly appcinted governor of the Cape, reached the emigrants' camp on the Tugela (Jan. 1848). Smith promised the farmers protection from the natives! and persuaded many of the party to remain, but Pretorius departed, and on the proclamation of British sovereignty up to the Vaal fixed his residence in the Magalisberg, north of that river. He was chosen by the burghers living on both banks of the Vaal as their commandant general.

At the request of the Boers at Winburg Pretorius crossed the Vaal in July and led the anti-British party in their "war of freedom." occupying Bloemfontein on July 20. In August he was defeated at Boomplaats by Smith, and thereupon retreated north of the Vaal. where he became leader of one of the largest of the parties into which the Transvaal Boers were divided, and commandant general of Potchefstroom and Rustenburg, his principal rival being Commandant General A. H. Potgieter. In 1851 he was asked by the Boer malcontents in the Orange River sovereignty and by the Basuto chief Moshesh to come to their aid, and he announced his intention of crossing the Vaal to "restore order" in the sovereignty. His object. however, was rather to obtain from the British an acknowledgement of the independence of the Transvaal Boers. The British cabinet having decided on a policy of abandonment, the proposal of Pretorius was entertained. A reward of £2.000 which had been offered for his apprehension after the Boomplaats fight was withdrawn.

Pretorius then met the British commissioners at a farm near the Sand river, and concluded the Sand River convention (Jan. 17, 1852) by which the independence of th'e Transvaal Boers was recognized by Great Britain. Pretorius recrossed the Vaal, and at Rustenburg on March 16 was reconciled to Potgieter, the followers of both leaders approving the convention, though the Potgieter party was not represented at the Sand river.

Pretorius died at his home at Magalisberg on July 23, 1853. In 1855 a new district and a new town were formed out of the Potchefstroom and Rustenburg districts and named Pretoria in honour of the commandant general.

2. MARTHINIUS PRETORIUS (1819–1901), the eldest son of Andries, was appointed in Aug. 1853 to succeed his father as commandant general of Potchefstroom and Rustcnburg, two of the districts into which the Transvaal was then divided. In 1854 he led his burghers against a chief named Makapan, who had murdered a party of 23 Boers, including ten women and children. The natives were blockaded in a great cave in the Zoutpansberg, and about 3,000 were starved to death or shot as they emerged.

Having thus chastised Makapan's clan, Pretorius created a strong central government! and from 1856 onward set to work to form one Boer state to include the Orange River burghers. In Dec. 1856 representatives of the districts of Potchefstroom, Rustenburg and Pretoria met and drew up a constitution, and on Jan. 6 the "South African republic" was formally constituted, Pretorius having been elected president on the previous day. Though the Boers of the Lydenburg, Utrecht and Zoutpansberg districts refused to acknowledge the new republic, Pretorius, with the active co-operation of Paul Kruger (*q.v.*), endeavoured (1857) to unite the Orange Free State and the Transvaal, and a commando crossed the Vaal to support Pretorius. The attempt at coercion failed. but in Dec. 1859 Pretorius was elected president of the Free State. Pretorius had just effected a reconciliation of the Lydenburg Boers with those of the other districts of the Transvaal, and he assumed office at Bloemfontein in Feb. 1860. But the anarchy in the Transvaal effectually weaned the Free State burghers from any thought of immediate amalgamation with their northern neighhours. Pretorius, however, continued to intervene in the affairs of the Transvaal and at length (April 15, 1863) resigned his Free State presidency. Acting as mediator between the various Transvaal parties Pretorius in Jan. 1864 ended the civil strife, and in May following once more became president of the South African republic—now for the first time a united community.

To Pretorius more than any other man was due the welding of the Transvaal Boers into one nation. Pretorius contemplated indefinite expansion of the Transvaal state north, east and west. In April 1868, on the report of gold discoveries at Tati, he issued a proclamation annexing to the Transvaal on the west the whole of Bechuanaland and on the east territory up to and including part of Delagoa bay. Portugal at once protested, and in 1869 its right to the bay was acknowledged by Pretorius, who in the same year was re-elected president. The Boer claim to the whole of Bechuanaland was not pressed by Pretorius in the iace of British opposition, but in 1870, when the discovery of diamonds along the lower I'aal had led to the establishment of many diggers' camps, an attempt was made to enforce the claims of the Transvaal to that district. Pretorius held repeated conferences with the Bechuana chiefs, but failed to persuade them to join the Transvaal to "save" their territory from the British. Finally, without consulting his colleagues, he agreed to refer the question of the boundary to the arbitration of R. W. Keate, then lieutenant governor of Natal. The award, given on Oct. 17, 1871, was against the Boer claims. Pretorius loyally accepted the decision, but it aroused a storm of indignation in the Transvaal. The *volksraad* refused to ratify the award and thereupon Pretorius resigned the presidency (Nov. 1871). Pretorius then temporarily retired from politics, but after the first annexation of the state by Great Britain he acted (1878) as chairman of the committee of Boer leaders who were seeking the restoration of their independence. He was arrested in Jan. 1880 by order of Sir Garnet Wolseley on a charge of treason. (*See* the Blue Book [C. 2584] of 1880 for details of this charge.) He was admitted to bail, and shortly afterward urged by Wolseley to accept a seat, which he declined, on the executive council. In December of the same year he was appointed, with Paul Kruger and P. Joubert, to carry on the government on the part of the insurgent Boers. He was one of the signatories to the Pretoria convention, and acted as a member of the triumvirate until the election of Kruger as president in May 1883. He then withdrew from public life; but lived to see the country reannexed to Great Britain, dying at Potchefstroom on May 19. 1901. Within four months of his death he had visited Louis Botha and Schalk Burger, on behalf of Lord Kitchener, with the object of ending the war.

For the elder Pretorius *see* G. M. Theal, *Compendium of the History and Geography of South Africa*, 3rd ed. (1878), *History of South Africa*, vol IV [1834–54] (1893). For the younger Pretorius see vol. v of the same series.

PREVARICATION, a divergence from the truth, equivocation, quibbling, a want of plain-dealing or straightforwardness, especially a deliberate misrepresentation by evasive answers. It is often used as a less offensive synonym for a lie. The Latin *praevaricatio* was specifically applied to the conduct in an action at law in which an advocate (*praevaricator*), in collusion with his opponent, put up a bad case of defense. *Praevaricare* meant literally to walk with the legs very wide apart, to straddle, hence to walk crookedly. to stray from the direct road, *varicus*, straddling. being derived from *varus*, bowlegged, a word which scholars connected etymologically with German *quer*, "transverse," "across," and English "queer."

The word was used by Richard Vines before 1655 in *A Treatise on the Institution of the Sacrament of the Lord's Supper:* "I . . . shall clearly without any fraud or prevarication declare my opinion." Edmund Burke in *Two (Four) Letters . . . on the Proposals for Peace with the Regicide Directory of France* (1795–97) wrote, "Fraud and prevarication are servile vices."

PREVENTIVE MEDICINE. The prevention of disease is the true ideal of medicine. Its application is twofold — the preventive medicine of. the community, which is generally termed public health or state medicine, and the prevention of disease or its sequelae in the individual.

HISTORICAL DEVELOPMENT

Ancient Origins. — Hippocrates (b. 460 B.C.) classified causes of disease into those concerned with seasons, climates and external conditions and those more personal causes such as irregular food, exercise and habits of the individual. Through the middle ages the principles of preventive medicine were ignored, in spite of the scourges of leprosy and plague. Then with the Renaissance came the new learning on the nature both of health and disease, which revolutionized the whole content of medicine and gave it a fresh centre of gravity and new outlook. Leonardo da Vinci — whose genius suggested some of the great discoveries of modern science — and Andreas Vesalius of Padua were followed in the 17th century by Galileo, William Harvey, Jean Baptiste van Helmont and the experimentalists, and the great practitioners who observed the relation of the seasons, of telluric conditions and of contagion to the incidence of disease. This was followed by new knowledge of anatomy, physiology and pathology.

Practical Needs. — Concurrently with the growth of medical knowledge there was an empirical movement of practical prevention. Long before the days of Hippocrates men had sought to stem the tides of disease which threatened to overwhelm them. In Britain, also, it was the ravages of pestilence in the middle ages — of leprosy from the 12th century, of the Black Death from the 14th, of sweating sickness in the 16th and of cholera and smallpox subsequently — which compelled attention to the conditions which seemed responsible for these scourges. The great monastic orders and some of the historical cities — Rome, Venice and London — provided comfort, refuge and sustenance for the victims, and in 1388 there was passed the first Sanitary act in England, directed to the removal of nuisances. In 1443 came the first plague order recommending quarantine and cleansing; in 1518 the first rough attempts at notification of epidemic disease and isolation of the patient were made; as time passed men began to see that environment was one of the principal factors in the origin and spread of disease.

Experimental Method. — In the 17th century Harvey indicated the true experimental method; 50 years later Thomas Sydenham, another practitioner, laid the basis of epidemiology by his observation of cases, his deduction of laws of prevalence and his suggested hypothesis of "epidemic constitutions."

Bernardino Ramazzini, in Italy, published a treatise on occupational disorders in 1700. Richard Mead, an English practitioner in the first half of the 18th century, published works on poisons, on plague and methods of its prevention, on smallpox, measles and scurvy. John Fothergill described "putrid sore throat" and Haberman, chicken pox. John Huxham of Totnes, an authority on the treatment of fevers, recommended vegetable dietary in cases of scurvy and Devonshire colic. Sir George Baker traced the latter to lead in vats and cider presses. Edward Jenner introduced vaccination. James Lind issued the first treatise on scurvy and the health of seamen. John Howard pointed out the evils of typhus as a "gaol fever." Oliver Wendell Holmes demonstrated the contagiousness of puerperal fever. John Snow published his classic on cholera and William Budd on typhoid fever. P. L. Panum studied the epidemiology of measles in the Faeroe Islands.

Concurrently with these clinical discoveries, advances in related sciences, notably mathematics were occurring. John Graunt initiated the study of mortality statistics in England in the 17th century and William Farr firmly established this basic principle of preventive medicine in the 19th century. Sweden made a modern census in 1748, the U.S. in 1790, England in 1801.

Modern Era. — Louis Pasteur's discovery of the role of living microbes as the cause of infections opened a new era in preventive medicine. Robert Koch demonstrated the tubercle bacillus in 1882; Karl Joseph Eberth the typhoid bacillus in 1880. Soon many other disease-producing organisms were discovered.

In 1893 Theobald Smith established the principle of insect-borne transmission of infections. Shortly afterward Sir Ronald Ross demonstrated the *Anopheles* mosquito as a transmitter of malaria, and the team of Walter Reed, James Carroll, Jesse Lazear and Aristides Agramonte implicated the *Aedes* mosquito in yellow fever in 1900. William Gorgas promptly employed this discovery for control of yellow fever in the Panama Canal Zone.

Serological tests were developed, such as the Widal reaction of typhoid fever (1896), Wassermann (serological) test for syphilis in 1906. An understanding of the principles of immunity led to the development of active immunization to specific diseases. The discovery and culture of viruses provided new tools for control of virus diseases. Concurrently with these laboratory discoveries epidemiology emerged as a science. through the work of Charles Chapin, W. H. Frost, and Major Greenwood.

Parallel advances in treatment opened other doors for prevention — in diphtheria by antitoxin (Emil von Behring) and in syphilis by Salvarsan (Paul Ehrlich). In 1932 the sulfonamide drugs and later a group of antibiotics such as penieillin, streptomycin, aureomycin and chloromycetin afforded new opportunities of prevention and cure.

After 1900 there were many advances in medicine other than those related to infectious diseases. The use of X-ray, radium and radioactive substances in the diagnosis and treatment of disease (*e.g.,* tuberculosis and cancer) as well as in fundamental physiological research opened new possibilities. A greater understanding of endocrine functions, with the production of prepared extracts such as insulin (Sir Frederick Banting and Charles Best, 1921), thyroid, pituitary extract and hormones, led to preventive measures in certain metabolic diseases. The apparently dramatic effects of ACTH and cortisone offered new hope in the treatment and prevention of sequelae of hitherto recalcitrant conditions.

The role of nutrition in health and disease and the isolation of many essential food factors illustrated the importance to health of adequate diet. Other advances in preventive medicine include psychiatry and psychology in relation to total health, new surgical techniques, new methods of anaesthesia, genetics and the application of statistical methods to medical problems. (See BACTERIAL AND INFECTIOUS DISEASES; DIET AND DIETETICS; ENDOCRINOLOGY; EPIDEMIOLOGY; IMMUNITY; MEDICINE; PSYCHIATRY; RADIOLOGY; SERUM THERAPY; VACCINE THERAPY.)

INTERNATIONAL HEALTH

International co-operation in the prevention of the spread of disease had its origin in the dim past. In 1851 France called an international conference to formulate a plan for control of cholera. This and five succeeding conferences produced no definitive results. At the Paris conference of 1903 a proposal for a permanent bureau of health was adopted. By the Rome arrangement four years later the International Office of Public Health was set up in Paris. Under its auspices international sanitary conventions were drafted in 1912–26 and 1933. Each country consistently sought to protect itself against imported disease and to aid its commerce.

The Pan American Sanitary bureau was established in 1902 sponsored by all 21 American republics. The bureau received and relayed epidemiologic information, provided technical assistance and sponsored research co-operation and fellowships.

The Health section of the League of Nations, established in 1923, acted to halt epidemics, established international standards for biologics, sponsored studies on cancer, leprosy, syphilis, nutrition, malaria and rural hygiene and assisted in the reorganization of some national health departments. The World Health organization, established in 1946, assumed the functions of the International Office of Public Health and of the Health section of the League of Nations. The Pan American Sanitary bureau became a regional office of WHO in 1949. (See HYGIENE; PUBLIC HEALTH.)

THE UNITED STATES

Preventive medicine in early America was concerned with epidemics, primitive sanitary conditions and the over-all problem of enough competent doctors to care for a population rapidly conquering a vast continent. Urban centres were plagued by contaminated water supplies, sewage and filth. Epidemics of exotic diseases such as cholera, yellow fever, malaria and typhus fever entered the country and spread widely. Typhoid fever and dysentery took a heavy toll. Emergency local regulations and boards of health were set up for epidemic control but lapsed when danger passed.

Lemuel Shattuck, in his "Report of the Sanitary Commission of Massachusetts" in 1850, charted a course of action in a remarkable document virtually unrecognized for two decades. C.-E. A. Winslow in 1948 said of it, "I know of no single document in the history of that science quite so remarkable in its clarity and completeness and in its vision of the future."

Prompted by recurring epidemics, advances in medical science and a growing social consciousness, city health boards were created in Baltimore (1798), Charleston, S.C. (1815), Philadelphia (1818), and elsewhere. As a result of the growing need for greater co-ordination, state boards of health were formed. Massachusetts being the first (1869). By 1919 each state had an organized department of health and the number of full-time local departments continually increased after 1914. Yet, by mid-20th century more than a third of the nation's population lived in areas without such basic full-time health services.

Concerned initially with such matters as sanitation, nuisances, acute communicable disease control, state and local health services by mid-century embraced also improved nutrition, maternal and child health services. mental hygiene, treatment of tuberculosis and the venereal diseases, control of cancer, cardiovascular and other chronic diseases. Knowledge from the biological and social sciences made it possible for medicine to shift its emphasis from cure and alleviation of illness to prevention.

Federal Program. — Prior to the creation of local and state boards of health, the congress in 1798 passed an act for the care of seamen of the merchant marine. Under its provisions, physicians were appointed in each port to furnish medical care, 20 cents being deducted from monthly wages to finance the program. Thus was initiated the earliest compulsory medical insurance in the U.S. and the basis laid for the far-flung activities of the public health service 150 years later. In 1878 authority was granted to investigate the origins and causes of epidemic diseases. In 1901 the Hygienic laboratory was established and in 1912 the title of the "United States public health service" was conferred.

The federal government assumed increased responsibility for national health in 1935 with the passage of the Social Security act which authorized a national program of grants-in-aid to states and training of health personnel. The National Cancer act, 1937, and the Venereal Disease Control act, 1938, the Mental Health act of 1946, the Hospital Survey and Construction act of the same year and a greatly expanded program of research grants have broadened the preventive concept. In 1939 the Social Security board, public health service, children's bureau, office of education, Food and Drug administration and related services were brought together under the new Federal Security agency.

Over many years, many bills have been introduced into the congress to provide a system of national medical insurance. None have been passed and opinion has been sharply divided regarding each of the diverse proposals.

Voluntary Health Agencies.—Voluntary agencies in the U.S. have played a leading role as pioneers in health promotion. They are concerned with the prevention of specific diseases (*e.g.,* tuberculosis, poliomyelitis); with disorders of specific organs (*e.g.,* eyes, heart); with health of specific groups (*e.g.,* children, mothers). They depend entirely on private contributions for their existence and range from national to local in extent. Examples are the National Tuberculosis association, American Heart association and Commission on Chronic Illness.

Other types of nongovernmental organizations which have contributed greatly to the growth of preventive medicine are: (1) foundations financed by private philanthropy such as the Rockefeller foundation, Commonwealth fund, Milbank Memorial fund and many others; (2) professional associations such as the American Public Health association; and (3) industries and insurance companies and labour unions.

The inability of most families to pay the cost of prolonged medical care has resulted in the formation of many voluntary, nonprofit, prepayment medical or hospital insurance plans to meet this unpredictable risk. The insurance principle in relation to social problems of the poor was advocated as long ago as 1697 by Daniel Defoe, yet in the U.S. prepayment of sickness costs has been recent and on a nongovernmental basis. Labour contracts with employers increasingly include sickness insurance provisions.

Schools. — Preventive medicine in the United States has been stimulated by special schools for public health education. The Rockefeller foundation financed schools at Johns Hopkins university, Baltimore, 1916; Harvard university, 1922; the University of Toronto, Ont., 1925; and has aided others at the University of Michigan, Ann Arbor, the University of California, Berkeley, and elsewhere. In 1950, 11 graduate schools of public health mere accredited by the American Public Health association (California, Columbia, Harvard. Johns Hopkins, Michigan, the University of Minnesota, Minneapolis, the Cniversity of North Carolina, Chapel Hill, the University of Pittsburgh, Pa., Toronto, Tulane university, New Orleans, and Yale). The A.P H.A. also has set up qualifications for various types of public health personnel including accreditation by a specialty board for physicians especially skilled in preventive medicine and public health.

BRITISH PRACTICE

Legislative Action.—The applications of state medicine, in the 19th century, found their inspiration in England in two sources, the recurrent outbreaks of cholera and consequent commissions of inquiry, and popular demand for reform, which was realized after each of the four extensions of the franchise (1832–1918). Understandable alarm caused by ravages of cholera in 1831 led to the first steps in administrative sanitary reform; in 1849 there was a second visitation of cholera and in 1854 a third.

Concurrently with and following upon these epidemics there were various commissions of investigation. In 1838–39 the Poor Law commissioners drew attention to the prevalence of epidemic disease and its relation to poverty. The reports by Neil Arnott, Sir James Kay-Shuttleworth, Southwood Smith and Sir Edwin Chadwick were the predecessors of another famous series of investigations in 1859–65 by Edward Greenhow and his colleagues under the privy council into epidemic diarrhoea, pulmonary disease. infant mortality and ague; also into adequate food supply, sufficient house accommodation, healthful physical surroundings and wholesome industrial circumstances. They led the way to the new application of medicine for the removal of nuisances: the prevention of contagion and infection and industrial hygiene and welfare.

In 1843 Sir Robert Peel, at the instigation of Chadwick, advised appointing a royal commission to inquire into the outbreaks of disease in large towns and the best means of improving the public health. the report of which led to the passage of the comprehensive sanitary measure in 1848, the establishment of the general board of health and the appointment of medical officers of health. In 1869 the Royal Sanitary commission was appointed; on it sat Sir Thomas Watson. Sir James Paget, Sir Henry Acland. Sir Robert Christison and William Stokes, and before it Sir John Simon, Budd and Farr gave evidence. Speaking broadly, the 1843 commission found the existence of a serious national evil of insanitation and ill-health and recommended a legislative remedy, whereas the 1869 commission found that the remedy had proved ineffective and recommended that "the present fragmentary and confused sanitary legislation should be consolidated." They proposed for the first time a ministry of health; the case miscarried; the local government board was created in 1871.

Registration of Sickness and Death.—Although bills of mortality were published in London as early as the reign of Queen Elizabeth I it was not until the Births, Marriages, and Deaths Registration act of 1836 that any reasonably accurate measure of mortality was obtained. William Farr, the first registrar-general, established an efficient office of vital statistics; including in 1860 occupational mortality and morbidity analyses.

In 1889 the Infectious Disease Notification act was passed applying only to a limited number of diseases. Others have been added. such as tuberculosis in 1912. The Notification of Births act of 1907, made compulsory in 1915, required notice to the local health authority within 36 hours following birth, opening the way for more efficient maternal and infant care.

Public Health Act, 1875.—This act emerged from the labours of a royal commission. It led during 20 years to laws designed to prevent river pollution, to protect water supplies, to improve housing and isolation hospitals and to notification and prevention of infectious diseases.

Sir Robert Peel's commission in 1845 had recommended that each local governing body should have a medical officer "to ascertain the true causes of disease and death, more especially of epidemics increasing the rates of mortality. and the circumstances which . . . injuriously affect the public health." In the period 1845–75 the Vaccination acts and the elementary Education act (1870) also should be recorded.

After **1900.**—In the period 1900–24 the sanitary environment improved. It must always remain a foundation of preventive medicine. and in various new departures dependent upon the principles established by the growth of medical knowledge. Typical of this era was the progress in personal hygiene as distinct from environmental hygiene. Its centre is the person rather than the premises.

In 1909 a royal commission appointed to inquire into the "Laws relating to the Relief of Poor Persons within the United Kingdom" presented majority and minority reports. The latter, signed by George Lansbury, Frances Chandler, Russell Wakefield and Beatrice Webb, contained the significant findings of this commission, with suggestions adopted almost in their entirety in 1929.

The school medical service was organized in 1907 and the National Insurance act, passed in 1911, provided a system of insurance against ill-health for a large portion of the working population, although not for dependents. The act also allowed for the use of some of the funds for medical research, and the Medical Research committee was established. In 1920 it was reconstituted as the Medical Research council under the privy council.

In 1919 a comprehensive ministry of health was entrusted with the Health and Poor law powers and duties of the local government board, duties of the Insurance commission and supervision under the Midwives act, among others. The Local Government act of 1929 produced further changes in preventive medicine. The Poor law boards of guardians were abolished, health policy was separated from "pauperism," local authorities were authorized to provide general hospitals for the sick and co-operation with voluntary hospitals was encouraged. The Public Health act (1936), which incorporated, revised or repealed certain statutes relating to public health. greatly simplified administration.

Concurrently with these developments advances were made in industrial hygiene, commencing with the Factory act of 1878. In 1898 T. M. Legge, afterward Sir Thomas Legge, the first medical inspector of factories, pioneered in the study of occupational risks in health and in preventive legislation.

In relation to mental health, the Lunacy act of 1890 was the basis of the modern attitude. A royal commission report in 1926 resulted in the Mental Treatment act, 1930, which provided for the care of mentally ill and also for voluntary care in public mental hospitals.

The relationship of preventive medicine to all the social sciences as well as to the medical sciences emerged during this early period of the 20th century. The war period of 1939–45 further emphasized the need of closer integration of all preventive medical and social services. The Beveridge report of 1942 urged full employment, family allowances and comprehensive health services as fundamental for security of the individual and the family. With this came the concept of medical care for all as a right. In 1946 the National Health Service act was passed and came into force in 1948. This act unified the health services providing hospital and specialist services, services furnished by local health authorities, general medical, dental, ophthalmic and pharmaceutical services, bacteriological and blood transfusion service as well as research. These were made available to all persons at the time of need. Other acts of importance to health are the Education act, 1944; Family Allowances act, 1945; National Insurance act, 1946; National Insurance (Industrial Injuries) act, 1946; National Assistance act, 1948; Children act, 1948; Housing act, 1949; and the Food and Drug act, 1955. These acts have resulted both from a broad concept of the role of preventive medicine and from the need to consider all aspects of the environment in relation to health.

Bibliography.—F. H. Garrison, *An Introduction to the History of Medicine,* 4th ed. (Philadelphia, 1929); Sir William Jameson, and G. S. Parkinson, *Synopsis of Hygiene* (London, 1947); J. J. Hanlon, *Principles of Public Health Administration* (St. Louis, London. 1950).

(T. P.)

PREVEZA, or Prevesa, seaport, southern Epirus, in Greece; at the entrance to the Gulf of Arta, an inlet of the Ionian sea. Pop. (1951) 11,008. The town is surrounded by dense olive groves. The harbour is small, and closed to large vessels by a bar of sand. Préveza exports dairy produce, valonia, hides and wool, olives and olive oil. About 3 mi. N. are the ruins of Nicopolis (*q.v.*). Préveza was seized by Ali Pasha in 1798 and recovered by Greece in 1912 during the first Balkan War. In April 1941 it was occupied by Italy.

PREVOST, ANTOINE FRANÇOIS (1697–1763), French author and novelist, was born at Hesdin, Artois, on April *1*, 1697. He was educated at the Jesuit school of Hesdin, and in 1713 became a novice of the order in Paris, pursuing his studies at the same time at the college of La Fleche. At the end of *1716* he left the Jesuits to join the army, but he soon tired of life in barracks, and returned to Paris in 1719 with the idea, apparently, of resuming his novitiate. He is said to have travelled in Holland about this time; in any case, however, he returned to the army, this time with a commission. He joined in 1719–20 the learned community of the Benedictines of St. Maur, with whom he found refuge, he himself says, after the unlucky termination of a love affair. He took the vows at Jumièges in 1721 after a year's novitiate, and received in *1726* priest's orders at St. Germer de Flaix. He resided for seven years in various houses of the order, teaching, preaching and studying. In *1728* he was at the abbey of St. Germain-des-PrCs, Paris, where he was engaged on the *Gallia christiana,* the learned work undertaken by the monks in continuation of the works of Denys de Sainte-Marthe. who had been a member of their order. His restless spirit made him seek from the Pope a transfer to the easier rule of Cluny; but without waiting for the brief. he left the abbey without leave (1728), and, learning that his superiors had obtained a *lettre de cachet* against him, fled to England.

In London he acquired considerable knowledge of English history and literature, traceable throughout his writings, and he has left an interesting account of English life in his famous memoirs. Before leaving the Benedictines Prévost had begun his most famous romance, *Me'moires et aventures d'un homme de qualitd qui s'est retiré du monde,* the first four volumes of which were published in Paris in 1728, and two years later at Amsterdam. In 1729 he leit England for Holland, where he began to publish (Utrecht, 1730) a romance, the material oi which, at least, had been gathered in London—Le *Philosophe anglois, ou Histoire de Monsieur Cleveland, fils naturel de Cromwell, écrite par lui-mesme, et traduite de l'anglois* (Paris 1731–39, *8* vols., but most of the existing sets are partly Paris and partly Utrecht). Meanwhile during his residence at the Hague, he translated the *Historia* of De Thou, and, relying on the popularity of his first book, published at Amsterdam a *Suite* in three volumes, forming volumes v, vi and vii of the original *Mdmoires et aventures d'un homme de qualitd.* The seventh volume contained the famous *Manon Lescaut,* separately published in Paris in 1731 as *Les Aventures du chevalier des Grieux et de Manon Lescaut, par Monsieur D. . . .* The book was eagerly read, chiefly in pirated copies, as it was forbidden in France. In 1733 he left the Hague for London, and Miss M. Robertson gives an entry showing that he was in prison in London in December on a charge of iraud.

In the autumn of 1734 Prévost was reconciled with the Benedictines and returning to France, passed through a new, though brief, novitiate. In 1735 he was dispensed irom residence in a monastery by becoming almoner to the Prince de Conti. and in 1754 obtained the priory of St. Georges de Gesnes. He continued to produce novels and translations from the English and with the exception of a brief exile (1741–1742) spent in Brussels and Frankfort, he resided for the most part at Chantilly until his death on Dec. 23, 1763.

For the bibliography of Prévost's works, which presents many complications, and for documentary evidence of the facts of his life *see* H. Harrisse, *L'Abbé Prévost* (1896); also a thesis (1898) by V. Schroeder.

A critical edition by M. Robertson of the 5th vol. of the *Mémoires et Aventures* dealing with Prévost's adventures in London, was published in 1927.

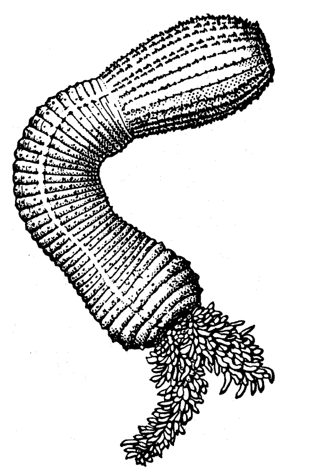
PRÉVOST, EUGENE MARCEL (1862–1941), French novelist, was born in Paris on May *1, 1862.* He was educated at Jesuit schools in Bordeaux and Paris, entering the École Polytechnique in *1882.* He published a story in the *Clairon* as early as 1881. but for some years after the completion of his studies he applied his technical knowledge to the manufacture of tobacco. He published in succession, *Le Scorpion* (1887), *Chonchette* (1888), *Mademoiselle Jauffre* (1889), *Cousine Laura* (1890), *La Confession d'un amant* (1891), *Lettres de femmes* (1892), *L'Automne d'une femme* (1893), and in *1894* he made a great sensation by an exaggerated study of the results of Parisian education and Parisian society on young girls, *Les Demi-vierges,* which was dramatized and produced with great success at the Gymnase on May *21, 1895. Le Jardin secret* appeared in *1897*; and in 1900 *Les Vierges fortes* and a study of the question of women's education and independence in two novels, *Frédérique* and *Léa. L'Heureux ménage* (1901), *Les Lettres à Françoise* (1902), *La Princesse d'Erminge* (1904), *L'Accordeur aveugle* (1905) and *Lettres à Françoise Mariée* (1908) were among his later novels. In 1904 *La* Plus *faible* was successfully produced at the Comédie Française. In 1909 he was elected to the Academy.

PRIAM, in Greek legend, the last king of Troy *(q.v.),* son of Laomedon. According to Homer *(Iliad,* iii *184)* in his youth he fought on the side of the Phrygians against the Amazons. He had fifty sons and twelve daughters and immense wealth. He was slain by Neoptolemus, son of Achilles, during the sack of Troy.

PRIAPEA, a collection of 85 or *86* short Latin poems in various metres. including hendecasyllables, choliambics and elegiacs, on the subject of the fertility god Priapus, who, with his sickle, protected gardens and vineyards against thieves and from whose axe-hewn image of figwood or willow protruded an erect, red-painted phallus. Though a few of the poems are inoffensive, the majority, despite occasional flashes of humour, are remarkable only for their obscenity. Most appear to belong to the Augustan age or to a date not much later and show evidence of indebtedness to Ovid. They in turn influenced Martial. Some may originally have been the leisure products of aristocratic voluptuaries; others, genuine inscriptions on shrines of Priapus. Donatus says that Virgil wrote some *Priapea,* and the first three poems of the *Catalepton* in the *Appendix Vergiliana* are of this genre; but, though Pliny says that Virgil composed "verses far from staid" *(aersiculos severos parum),* there is no proof that these are Virgil's. In *Tibullus,* i, *4,* an elegy of *84* lines, Priapus assumes the unique role of a professor of venery *(magister amoris)* and instructs the poet how best to secure the affection of the boy Marathus. A companion piece to this poem is Horace, *Satires,* i. *8* (50 hexameters), in which Priapus tells how he frightened away two witches from the site of the Esquiline cemetery when his figwood buttocks burst with a disconcerting pop. Martial's *Priapea* include epigrams *16, 49* and *73* in book vi, and *40* in book viii.

See F. Biicheler (ed.), *Petronius,* 6th ed. (1922). (H. H. HY.)

PRIAPULIDA, a small group of marine worms formerly included in the obsolete phylum Gephyrea. Of uncertain affinities, they are now generally conceded phyletic rank. Resemblances to the gephyrean groups Sipunculida (*q.v.*) and Echiurida (*q.v.*) appear to be of a superficial nature, and the same may be said of the theory, advanced by W. Fischer, that they are related to holothurians (a class of the Echinoderma, *q.v.*). According to O. D. Hammersten, whose observations were extended by K. Lang, the larva has features in common with Rotatoria, Kinorhynca (*q.v.*) and Gastrotricha (*q.v.*). Although this hypothesis, which would place the priapuloids among pseudocoelomate phyla, is an attractive one, it must be admitted that the homologies of the body cavity are uncertain; and Libbie Hyman, in *The Invertebrates: Protozoa through Ctenophora* (1940), has classified them as schizocoelous coelomates.



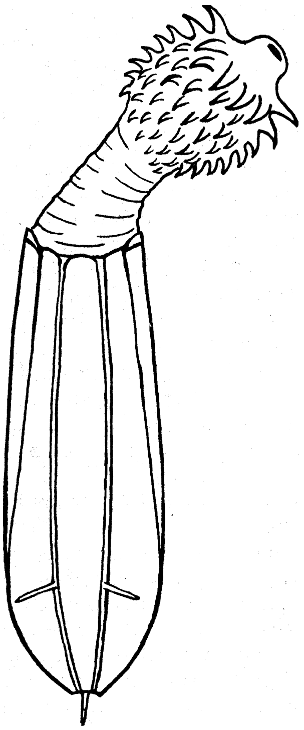
FROM THEEL, "NORTHERN AND ARCTIC INVERTEBRATES"

FIG. 1.—PRIAPULUS BICAUDATUS, A WORMLIKE MARINE ANIMAL OF THE ARCTIC AND NORTH ATLANTIC SEAS

The body is cylindrical and consists of an annulated but unsegmented trunk and a retractile proboscis. In the genus *Priapulus* there are one or two caudal appendages considered to be gills. The surface of the muscular body wall is provided with rings of spines and papillae, the latter possibly sensory in function. The epidermis secretes a thick cuticle, which is shed at intervals during growth. There are 25 rows of spines on the surface of the proboscis, converging toward the mouth, which is itself surrounded by several five-toothed rings of chitinous teeth, thus giving rise to the supposed resemblance to echinoderms. The mouth leads into a muscular, eversible pharynx anchored by retractor muscles originating in the trunk. The cuticular lining of the pharynx is provided with numerous small projecting teeth. The mid-gut is straight and communicates with a short hind-gut; the anus is either terminal or opens at the base of the caudal appendages when these are present. The body cavity, which in *Priapulus* extends into the ramifications of these hollow, gill-like structures, is extensive but its developmental homologies are unknown. There is no vascular system and the coelomic fluid must subserve, in part, a respiratory function.

The nervous system, consisting of a circumesophageal ring and ventral nerve cord, retains its primitive connection with the ectoderm. There is no evidence of segmental ganglia. A visceral plexus is connected anteriorly with the nerve ring.

The excretory system is protonephric; tufts of solenocytes discharge into the paired urinogenital ducts, which lie suspended in the body cavity and open posteriorly. The sexes are usually separate, but hermaphrodite individuals have been recorded; the gonads develop in the walls of blind evaginations of the urinogcnital ducts. Fertilization is external. The earliest stages of development were studied by K. Lang in 1939; segmentation differs irom that of polychaets and most nearly resembles that of the rotifer *Asplanchna*. Intermediate stages are unknown, but the gastrula is believed to develop, perhaps directly, into the loricate larva. This larva has a spiny, retractile proboscis, and the body is protected by chitinous shields; in *Priapulus* there are two pairs of feelers and a bifurcatcd tail.



BASED ON DRAWINGS AND PHOTOGRAPHS BY LANG, FROM "K. FYSIOGR. SALLSK, LUND, FORH," VOL 9

FIG. 2.—LORICATE LARVA OF PRIAPULUS CAUDATUS, SHOWING PLATES CONNECTED BY FLEXIBLE MEMBRANES' FEELERS AND FOOTLIKE CAUDAL APPENDAGE

There are only two genera: *Priapulus* and *Halicryptus*, the latter without caudal appendages. The animals are of small to medium size and live in burrows in the sand or mud which they ingest; a secretion of the circumanal glands is used to cement the walls of the burrows. Priapuloids are found in the cold seas oi both the northern and southern hemispheres but are confined to relatively shallow coastal waters.

BIBLIOGRAPHY.—A comprehensive review of the group, published in 1931, is given by F. Baltzer in Kukenthal and Krumbach's *Handbuch der Zoologie,* Bd. 2. Hfte. 2. Larval stages are described by K. Lang, K. *Fysiogr. Sällsk. Lund, Förh.,* vol. 9. (G. E. P.)

PRIAPUS, a god of fertility, personification of the fruitfulness of nature, chief deity of Lampsacus on the Hellespont (Dardanelles). He was represented as a man. usually grotesquely ugly, with an enormous and erect sexual organ. Locally, he was thought to he the son of Dionysus and Aphrodite. His cult reached Grcece somewhat late in the classical epoch, not becoming really important until Alexandrian times. Later still, it penetrated to Italy. Various legends, all of them late, bring him into connection with the gods of the Greek pantheon. particularly Aphrodite, often represented as his mother, Hermes, Dionysus and other deities connected with fertility. In Bithynia he is a warlike god, associated with Ares. He absorbed. or was closely identified with, a number of minor rustic deities of similar type; *e.g.,* Phales, Conisalus. Tychon, etc.

He is perhaps best known as a god of gardens, where his image was commonly erected. both to give supernatural protection against thieves and for practical use as a scarecrow. But as the phallus is a common luck-bringing object, he was worshipped by persons in need of luck, such as hunters and fishermen, and also was frequently employed to keep off the evil eye.

PRIBILOF ISLANDS (FUR SEAL ISLANDS). islands of Alaska, including St. Paul *(3j* sq.mi.), St. George (27 sq.mi.) and two islets lying in the Bering sea, about 180 mi. N. of Cnalaska. They were first visited in 1786, by the Russian sea captain Gerasim Pribilof. who discovered their famous iur seal rookeries. Control of the islands was transferred from Russia to the Cnited States with the purchase of Alaska in 1867 *(see* ALASKA: *History).*

Fur Industry.— The seals are a distinct species *(Cullorhinus ursinus)*, with fur superior to other species. They visit the Pribilofs from April to November. The older and stronger bulls gather harems, the younger "bachelors" congregating separately. By taking the "bachelors" when ashore, the herd may be conserved. However, sealing at sea (pelagic sealing) permits no selectivity, and half the animals killed are lost.

In 1870 sealing rights were leased to the Alaska Commercial company. During the 1880s vessels of several nations engaged in pelagic sealing, and the islands' herds were vanishing. In 1886 U.S. vessels began seizing Canadian schooners sealing off the Pribilofs. A tribunal ruled against the United States in 1893. Since 1910 the U.S. bureau of fisheries has had direct supervision of the sealing.

In 1911 the Cnited States, Great Britain, Japan and Russia signed the North Pacific Sealing convention abolishing pelagic sealing north of latitude 30° N., and providing that each nation should share in the skins collected on the Pribilofs. The treaty was ended by Japan's withdrawal in 1941, on its contention that the seals were despoiling Japanese fisheries.

In 1957 an interim convention on conservation of North Pacific fur seals was signed between the U.S., Japan, Canada and the U.S.S.R., which created the North Pacific Fur Seal commission to supervise research.

The herd increased from 125,000 to 4,000,000 between 1911 and the early 1950s. About 65,000 skins were being harvested yearly in the 1950s. See also ALASKA: History: *Diplomacy Involving Alaska.*

Population.—In 1950 the population consisted of 546 Aleuts and a few government officials.

Natural History and Climate.— The islands are of volcanic origin. The flora is restricted to ferns, mosses and grasses. creeping willows and small shrubs. White and blue foxes, gulls, auks and cormorants abound. The mean annual temperature is about 35.7° F. The rainfall is about 3j in. annually. Fogs are heavy and frequent. (J. E. CL.)

PRIBRAM, ALFRED FRANCIS (1859–1942). Austrian historian. was born in London, Sept. 1, 1859. He studied in London and Vienna and in 1894 became professor of modern history at the University of Vienna. being also elected a member of the Viennese Xkademie der Wissenschaften.

Pribram's main works are: *Oesterreich und Brandenburg* (2 vol., 1884–85); *Der Rheinbund* (1888); *Franc von Lisola und die Politik seiner Zeit* (1894); *Das böhmische Commerzcollegium* (1898); *Oest. Staatsverträge* (England) (2 vol., 1907–13); *The Secret Treaties of Austria-Hungary 1879–1914* (English, German and French ed., 1919–23); *Austria-Hungary's Foreign Policy 1908–1918* (1923); *England and the International Policy of the Great European Powers 1879–1914* (1931). Pribram also finished and issued vol. ii and iii of Friedjung's ambitious work *Das Zeitalter des Imperialismus.* His *Secret Treaties* threw much light on modern history in 1929.

PRICE, RICHARD (1723–1791), British moral philosopher, famous also in his own day as a supporter of the American and French Revolutions and as an expert on insurance and finance, was born at Tynton in Glamorgan on Feb. 23, 1723. The son of a dissenting minister, he himself ministered to English Presbyterian congregations in the vicinity of London, notably at Stoke Newington and at Hackney, where he died on April 19, 1791.

Price's *Review of the Principal Questions and Difficulties in Morals* (1758; 3rd ed., enlarged, 1787) criticizes the moral-sense theory of Francis Hutcheson and is one of the best statements of ethical intuitionism or rationalism, foreshadowing Immanuel Kant's ethics in some respects and 20th-century intuitionism in many. In 1767 Price published *Four Dissertations,* including a reply to David Hume's essay on miracles, and in consequence received the degree of D.D. from Marischal college. Aberdeen. Price and Hume met and corresponded with mutual esteem. Another of Price's philosophical opponents, Joseph Priestley, was a close personal friend. They published jointly A *Free Discussion of the Doctrines oj Materialism and Philosophical Necessity* (1778), which doctrines Priestley held and Price attacked.

Price was elected F.R.S. in 1765 for work on a problem in the theory of probability. which he then applied to actuarial questions. *Observations on Reversionary Payments* (1771) laid the foundations of a scientific system of life insurance and of old-age pensions. It also recommended the re-establishment of the sinking fund to deal with the national debt. a proposal amplified in *An Appeal to the Public on tlze Subject of the National Debt* (1772).

Price's views influenced French governmental policy through Robert Turgot and Jacques Necker and, later. British policy through Lord Shelburne (*see* LANSDOWNE, MARQUESSES OF), an intimate friend, and the younger Pitt.

Price was a friend of Benjamin Franklin and became a leading advocate of American independence. His *Observations on the Nature of Civil Liberty, the Principles of Government, and the Justice and Policy of the War with America* (1776) and *Additional Observations . . .* (1777) had an enormous sale in both England and America. He was given the freedom of the city of London in 1776, was invited by the U.S. congress in 1778 to advise it on finance and was made LL.D. together with George Washington by Yale college in 1781. Price welcomed the French Revolution in a celebrated sermon on *The Love of Our Country* (1789), to which Burke's *Reflections on the Revolution in France* was a reply.

BIBLIOGRAPHY.—Price published various other sermons and tracts. For his life and works *see* Roland Thomas, *Richard Price* (London, 1924); and C. B. Cone, *Torchbearer of Freedom* (Lexington, 1952). *The Review oj the Principal Questions in Morals* is ed. *by* D. D. Raphael (Oxford, 1948). For discussion of that work *see* J. Martineau, *Types of Ethical Theory,* 3rd ed. (Oxford, 1901); W. H. F. Barnes, in *Philosophy,* vol. xvii (London, 1942); C. D. Broad in *Aristotelian Society: Proceedings,* new series, vol. xlv (London, 1944–45); D. D. Raphael, *op. cit.* and *The Moral Sense* (London, 1947). (D. D. R.)

PRICE, STERLING (1809–1867), American general, was born in Prince Edward county, Virginia, on Sept. 14, 1809. He was educated at Hampden Sidney college and afterwards studied law. In 1830 he removed to Missouri and from 1840 to 1844 served in the Missouri State legislature as speaker of the house of representatives. He was elected a U.S. representative in 1844 but resigned in 1846 to raise and lead the 2nd Missouri Cavalry Regiment in the Mexican War. In 1847 he was commissioned brigadier-general of volunteers and made military governor of Chihuahua. He was governor of Missouri, 1853–57, and State bank commissioner, 1857–61. In 1861 he was appointed major-general of the State militia. Upon the outbreak of the Civil War Price gathered 9,000 Confederate troops at Carthage, Mo., and defeated a small force of Union troops under Franz Sigel. Joined by other troops from Arkansas, Price fought the battle of Wilson's Creek, defeating the Union forces under Gen. Lyons. In the battle of Lexington, shortly afterward, Price captured over 3,000 Union troops, but he was forced to retreat before Gen. Frémont. In March 1862, he was commissioned major-general in the Confederate forces. He commanded under Van Dorn at the battle of Pea Ridge, Ark., on March 7, 1862, and in several engagements around Corinth, Miss. On July 4, 1863, he fought a sharp battle at Helena, Ark., and later prevented Steele's advance to the Red river. In Sept. 1864 he invaded Missouri and advanced to the environs of both St. Louis and Jefferson City, but was repulsed in his attacks at these places. After the war Price went to Mexico in the interest of a colonization project but he returned to Missouri and died at St. Louis on Sept. 29, 1867.

PRICE, THOMAS (1852–1909), Australian statesman, was born at Brymbo, North Wales, on Jan. 19, 1852. He was educated at a penny school in Liverpool, and became a stonecutter. He went to Australia for his health in 1883, where after a time he again found employment as a stonecutter, working on the parliament buildings in Adelaide. He was secretary for two years (1891–93) of the Masons' and Bricklayers' Society of South Australia, and then obtained a seat as Labour member in the House of Assembly. In 1900 he was made secretary of the Labour Party, and in 1901 became its parliamentary leader. He held office as prime minister of South Australia from 1905 until his death on May 31,. 1909, at Hawthorn, near Adelaide.

PRICE. What prices are and what price, as a general conception, means would seem to be obvious enough. Yet economists, dealing with the relations of prices to different forms of economic activity and with their own interrelations find that they must take pains if they are to keep their conceptions of price clearly defined and consistent. Thus one may speak of the whole amount of money paid for a quantum of goods as their price, or—if the goods are of a homogeneous or standardized kind, sold by measure, weight, or tale—the amount of money given for each unit of the goods may be regarded as the price. Alternatively, price may be defined, not as a quantity of money but as a ratio between a quantity of money and a quantity of goods. This is generally the more useful conception, but the prices of unique goods, such as works of art, cannot be said to be ratios of quantities. The price ratio is usually stated as so many monetary units (shillings, pounds, dollars) per unit of commodity (ton, yard, bushel). In some markets, however, the ratio is expressed inversely, as so many ounces or yards per shilling, pound, or dollar. This would be a negligible difference if it were not that, as the makers of index numbers have found, where prices or percentage changes in prices are averaged or otherwise combined, precautions must be taken if the results are not to be affected by the particular form in which the price ratios are expressed.

A distinction may also be made between the conceptions of price as a ratio of quantities and as a ratio of values. If ten units of money are required to purchase one unit of a commodity, it may be inferred that a unit of the commodity is ten times as valuable as a unit of money and that the price ratio merely gives expression to that fact. That price is "value expressed in terms of money" is a standard definition. This should not be taken to mean that the values of goods are determined independently of or prior to the determination of their prices, or that the values of goods and of money are determined separately. The factors which determine the values both of goods and of money operate through the processes of exchange, and the values which are thus determined appear in the guise of money prices. It is probable, indeed, that the abstract notion of exchange value is nothing more than a generalization of the simpler idea of price. When we say that price is a ratio of values or that price is value expressed in terms of money, we logically imply, not that value is antecedent to price, but either that in respect of each particular transaction the limits within which the ratio of exchange can vary are established by the general state of the market, or that in analysing the factors which determine the price of any one commodity, the value or general purchasing power of money, may often, without too large an error, be assumed to be constant. The conception of the value of money, in turn, rests upon nothing more tangible than a broad view of all the various prices of different goods and services, but it is nevertheless a useful conception.

The Problems of Price.—The economic theory of price has two principal divisions. One division has to do with the interrelations of the prices of different goods and services, and with the way in which changes in production, consumption, and trade operate directly upon some prices and indirectly upon others. This division of price theory includes that important part of economics sometimes called the theory of value and distribution (or sometimes simply the theory of price-making) and also parts of other fields, such as the theory of international trade. It is concerned both with the tendencies which continually make for a coherent and consistent system of prices and with the subversive forces which make continuously for change. The other division of the theory of prices has to do with the causes of general movements of prices to a higher or lower level—movement which may continue gradually through a long period of years, but which may be broken by shorter movements, convulsive or cyclical in nature. The study of the long-continued general trends of price, and, in considerable measure, of their shorter movements as well, is commonly made a part of the general theory of money. The reason is not that general changes of prices are always attributable to the action of monetary factors alone, but that they are reflected in and in fact are changes of the value of money. They can be studied most conveniently and effectively by enquiring into the changing relations between the supply of money and credit and the volume of production and trade. In recent years especial attention has been given to what might be called the distortions of the whole interrelated structure of prices which accompany changes in their general level. The movements of certain classes of prices, for example, generally lag behind the movements of other classes of prices in a more or less systematic way.

Commodity prices are not the only prices with which economists are concerned. Securities such as bonds or debentures, stocks or shares and bills or notes, have their prices. Railway rates are prices. Foreign exchange rates express the price of current funds in one market in terms of current funds in another market. Wages, of course, may be regarded as the price of labour, rent as the price of the use of land or of other durable goods, and interest as the price of advances of money. Profits, however, are not prices, for they are not proportioned in any definite way to the amounts of goods or services supplied, but are contingent upon the success of particular undertakings. Nor are taxes prices, for the governmental services for which taxes pay are diffused, and not apportioned to different taxpayers in accordance with their respective contributions. Not even the fees which are paid to Government offices for licences or for particular services are in all respects like prices, for the amount of the fee is usually proportioned very loosely, if at all, either to the value of the service to the recipient or to its cost to the Government. But the charges which Governments make for supplying such things as water, gas, electricity and transport may be governed more or less completely, according to the circumstances of the particular case, by the principles in accordance with which prices are determined.

Equilibrium Price. — This is a price at which supply and demand are equal. A distinction has to be made between a temporary equilibrium, such as would express a balancing of the immediate factors which are operative in the market at any given time, and such an equilibrium as would be reached eventually if the particular factors now known to be at work could have their full effects. Equilibrium, then, is always relative to time. All economic equilibria are unstable, but it is convenient in analysis to take separate account of the factors which, if they were neither impeded nor deflected, might finally lead to a stable equilibrium. Market price is the price which will be found in a given market at a given time. It may be regarded as the limiting form of short-time or temporary equilibrium price. Normal price is a price just high enough to cover the expenses of production, including whatever profits are necessary to induce men to undertake the risks of productive enterprise. Because some firms produce at smaller expense than others, because the expense per unit of production often varies, directly or inversely, with the volume of output, and because of the difference, at any given time, between the average expense incurred per unit of product in a given establishment and the expense of producing an additional unit, the conception of normal price is attended with serious, though not altogether insuperable diiiiculties.

Competitive Price. — This is the price which results from the activities of many buyers and sellers, each of whom can affect the outcome only by buying or selling larger or smaller quantities according as the price is at one point or another. Monopoly price is a price fixed with a view to his or their own advantage by a single (exclusive) seller or buyer, or by a combination of sellers or buyers acting as a unit. Class price (or differential or discriminatory price) is possible only when a monopolist seller is able to deal separately with different classes of buyers or to manage in some other way to sell his goods in what are virtually separate markets. A speculative price is a present price which is influenced by estimates of what the price of the same commodity or security will be in the future. A contract price, or what is sometimes called in speculative markets a "future," is the present price for an exchange which is to be completed by delivery or by taking delivery in the future. Mint price is the price of gold in terms of money at a Government's mint or at a bank which acts as agent for the mint. Gold price is the rather misleading name sometimes given to the result obtained by dividing a price which is quoted in terms of some depreciated paper currency by the price, in terms of the same currency, either of gold or of funds payable in some other country where a gold monetary standard is at the time effective.

Demand Price. — This is the price at which some specified quantity of a given commodity will find purchasers. A schedule of demand prices or demand schedule, exhibits the general relation between the price of a commodity and the amount of it which will be purchased. Supply price, similarly, is the price at which a specified quantity of a given commodity will be offered in the market. The form of the supply schedule depends upon the conditions under which the particular commodity is produced and also upon the period of time which is taken into account. Thus a sudden general increase in demand (in the sense of a general upward movement of a schedule of demand prices) would have the effect of increasing the price at which a specified quantum of a given commodity would be offered for sale. But if the commodity is produced under conditions of increasing returns (*i.e.,* if the output can be increased without a proportionate increase of costs), an increase of demand, continued over a period of years, will have an opposite effect upon its supply price. Indeed, the gradual lowering of the supply prices of commodities produced under conditions of increasing returns need not wait upon a general increase of demand. It is necessary only that demand should be elastic, *i.e.,* that the demand price of successively larger quantities should not fall off too rapidly. It follows that when an adequate period of time is taken into account, a schedule of supply prices may show that larger quantities will be supplied at lower instead of higher prices. A corresponding schedule of supply prices for a commodity produced under conditions of diminishing returns (*i.e.,* with increased output procurable only at a more than proportionate increase of costs) would, of course, like a schedule of short-period or "instantaneous" supply prices, show higher prices associated with larger quantums of supply. (See also ECONOMICS, SUPPLY AND DEMAND, and VALUE.) **(A. Yo.)**

PRICE-CUTTING, the term used to indicate the practice of selling standard merchandise at a price below that advertised by the manufacturers. With many trade-marked articles the manufacturer attempts to maintain the price at which his products are sold to consumers. The idea is that both wholesalers and retailers should make a profit on his merchandise; otherwise they might refuse to handle it. When an article becomes so well known that it is widely accepted as a standard, it is a common practice for retailers having similar goods that they sell under the store label to reduce the price of the trade-marked article and use it in their advertising as a special attraction. Their clerks are instructed to try to sell the substitute bearing the store label instead of the trade-marked article requested. This practice is disadvantageous to the manufacturers inasmuch as the cut-price often makes the article unprofitable for other retailers and they also attempt to substitute other brands for the one advertised. When the distributor departs from the usual practice and sells for cash where most stores would extend credit, and when he refuses to deliver goods and requires the customers to carry their own purchases, he is expected to sell at a lower price because he gives less service. The reduced price of the "cash and carry" stores is not usually included in the term price-cutting. In most countries price-cutting is prevented by contract between the manufacturer and distributors. That form of contract was not legal in the U.S. until the passage of fair trade laws by most of the separate states. Price maintenance remained illegal, by contract, except in states having these enactments.

In 1951 the U.S. supreme court held that state fair trade laws did not apply to retailers who would not make pricing agreements with manufacturers. (H. E. A.; X.)

PRICE MAINTENANCE. The subject of price maintenance, or, more specifically, resale price maintenance, is one that demands special consideration among the various types of price fixing, both from the legal and the economic aspects. Other forms of price fixing are treated elsewhere. For agreements and understandings as to prices among competing manufacturers, wholesalers or retail dealers, see TRADE ORGANIZATION, and also POOLS, IN INDUSTRY and CARTEL; for concentrations of industry in monopolistic, or quasi-monopolistic, forms, see MONOPOLY; for price fixing by legal monopolies. such as railroads and other privately onned public utilities. see PUBLIC UTILITIES The following discussion relates to resale price maintenance exclusively.

Resale price maintenance is the term applied to various devices by which individual manufacturers or distributors of particular trade-marked, branded, or otherwise identified articles fix minimum resale prices. The most widespread and important manifestation of resale price control is seen where the manufacturer of an article, by contract, fixes a price below which retailers shall not sell it to the public.

The practice has been fostered in the United States by manufacturers who sell trade-marked and well advertised commodities such as breakfast foods, toilet goods, proprietary medicines, books and musical instruments, and has been supported by trade associations of manufacturers and dealers in various lines of products. Supporting dealer organizations have the further objective of inducing the fixing of minimum prices high enough to insure a margin satisfactory to the dealer. In Great Britain there exists an association, known as the Proprietary Articles Trade Association, whose main object is to encourage and enforce this system. A similar association was founded in Canada in 1925 but was later disbanded when it was adjudged to be a combination in restraint of trade.

It is contended by the advocates of resale price maintenance that the maker of an article which bears a trade-mark that he has made valuable by extensive advertising should be entitled to stipulate the price at which it shall be sold by dealers to the public. It is claimed that the manufacturer cannot adequately protect his intangible property—the good will attaching to his trade-mark or brand—unless he restrains dealers who sell his products at a lower price than he suggests, sometimes less than cost, as a "leader" or a "draw" to customers. This use of "leaders," it is maintained, sometimes causes competing retailers to refuse to handle the goods because they can neither make a profit by meeting the low prices, nor sell at the manufacturers' higher resale prices, thus destroying good will of the dealer and reducing the number of dealer outlets.

In England, the legal status of resale price maintenance is based largely upon court application of common law rules respecting freedom of contract and'the reasonableness of agreements in restraint of trade. The courts interpret the right of contract broadly and permit manufacturers to make resale price maintenance agreements among themselves and wrth their distributors provided undue restraint of trade is not shown. Resale price maintenance was considered by official committees in 1920 and again in 1931. The report of 1931 neither condemned, nor did it give unqualified approval to the practice.

Canadian policy follows quite closely that of England but is somewhat more restricted. In certain cases resale price maintenance has been declared to be against public policy, but the practice itself has not been passed upon. Resale price control by a combination of manufacturers, jobbers, and retailers of drugs was condemned in 1927, and a similar combination to control prices of tobacco products was likewise condemned as a combine within the meaning of the Canadian Combines Investigation Act.

In the United States prior to 1936, in cases coming before the U.S. Supreme Court, resale price maintenance was permitted in cases of goods distributed through bonafide agents rather than independent dealers, but otherwise goods sold under a trade name or mark were not exempted from the common law and statutory provisions against monopolies and restraints of trade. As early as 1907 the courts held that a system of contracts entered into by the manufacturer of a proprietary medicine with a large part of the wholesale and retail druggists stipulating the resale price of the product was unlawful and unenforceable on the grounds that it restrained trade (*Park and Sons* v. *Hartman,* 153 Fed. 24), and in 1911 the U S. Supreme Court rendered a similar decision in the Dr. Niles case (*Dr. Miles Medical Co.* v. *Park and Sons Co.,* 220 *U.S.* 373). Patented and copyrighted articles have also been held to be within the scope of the Dr. Miles case, and agreements to maintain resale prices thereon declared unlawful.

In 1915, the Federal courts refused to issue an injunction restraining the manufacturer of a breakfast food from carrying out the policy of refusing to sell to those dealers unwilling to maintain resale prices. In 1922, the US. Supreme Court held that a corporation may have and announce a policy of refusing to sell to cutrate dealers and withhold its goods but may not consistently go beyond this act and by contracts or combinations, express or implied, unduly hinder or obstruct the free and natural flow of commerce (*F.T.C.* v. *Beech-Nut Packing Co.,* 257 U.S. 441).

Throughout the period from the Dr. Miles decision in 1911 to the enactment of the National Industrial Recovery Act in June 1933 (48 Stat. 195), bills to legalize resale price maintenance in interstate commerce in the United States were continually presented to the Congress, but all failed of passage. In 1931, however, the State of California enacted a law legalizing resale price maintenance by contract between manufacturers or distributors and retail dealers within the State of California. With the setting up of the National Recovery Administration under the National Industrial Recovery Act, interest in the enactment of further State laws waned due to the fact that numerous codes contained price control provisions and a number provided for some form of resale price maintenance. Following the decision of the U.S. Supreme Court in the Schechter case (*Schechter Poultry Corp.* v. *US.,* 295 U S. 495) which declared portions of the National Recovery Act unconstitutional, the movement to enact State resale price maintenance laws again gained momentum. By the end of 1935, ten States had enacted such laws, generally similar to the 1931 California act. Late in 1936, the U.S. Supreme Court declared the State laws of California and Illinois to be constitutional (*Old Dearborn Distributing Co.* v. *Seagram Distillers Corp*, 299 U.S. 183, and *The Pep Boys, Manny, Moe & Jack of California, Inc.* v. *Pyroil Sales Co., Inc.,* 299 U.S. 198). These decisions provided such a stimulus that by 1939 44 of the States had legalized resale price maintenance. by laws commonly designated as Fair Trade Acts.

In 1937, the Tydings-Miller Act amended the Sherman Antitrust Act by exempting from the application of that act, "contracts or agreements prescribing minimum prices for resale of a commodity which bears, or the label or container of which bears the trade mark, brand, or name of the producer of such commodity, and which is in fair and open competition with commodities of the same general class produced or distributed by others when contracts or agreements of that description are lawful as applied to intrastate transactions, under any statute, law, or public policy now or hereafter in effect in any State. Territory, or the District of Columbia," and further declared that the making of such contracts "shall not be an unfair method of competition under the Federal Trade Commission Act." This exemption. however, is specifically stated in the act not to make lawful "horizontal" agreements or understanding on prices between competitors, whether they be manufacturers or distributors, and such "horizontal" agreements are still a violation of law when in restraint of trade or commerce among the States.

While resale price maintenance appears presently to find legal sanction in the United States and in the United Kingdom. consumer organizations and economists generally are opposed to the practice from the standpoint of its effects on the public, and many in the United States advocate returning to former policies on the ground that the evils inherent in a system of fixed retail prices outweigh the benefits of resale price maintenance to manufacturers of some lines of merchandise and a segment of the retail trade.

BIBLIOGRAPHY.—Report of Committee on Fixed Retail Prices, 662 (1920); Report of Registrar (1926) and of Commissioner (1927) under the Canadian Combines Investigation Act on the Canadian Proprietary Articles Trade Association; Reports of the U.S. Federal Trade Commission on Resale Price Maintenance (1929 and 1931); Report of the Commissioner under the Canadian Combines Investigation Act on an Alleged Combine in the Distribution of Tobacco Products (1938); E. T. Grether, *Resale Price Maintenance in Great Britain* (1935), *Price Control under Fair Trade Legislation* (1939).

(R. E. F.)

PRICES, STATISTICS OF. In the United Kingdom and the United States. and in some other countries. price quotations for a number of important commodities are available from the middle of the 19th century; there are some quotations in earlier periods. However, there have been many changes in the nature and quality of the commodity and in the type of price quotation; in only a few cases have the changes been small enough to permit the compilation of a continuous series of prices on a reasonably comparable basis. A series of single prices, however interesting they may be, cannot be taken as indicating general movements in prices. What is required for this purpose is a set of indicators shoning the general course of prices, in convenient major groups of commodities. over time in a particular country. Such indicators can only be constructed in the form of index numbers (see INDEX NUMBERS) which are generally averages of the changes in prices of certain commodities selected to represent the various groups. The averages can be computed in various ways giving different results. Moreover. the index numbers depend on the accuracy and continuity of the price quotations used and any one compilation is generally limited to comparisons of prices in a relatively short period, perhaps no more than 10 or 20 years. For longer-run comparisons. different index numbers need to be "spliced" together and the results are more approximate.

The most obvious feature in the general world picture is the effect of major wars on wholesale prices. During the French Wars (1793–181j) prices rose rapidly and were then maintained at a high level, though with considerable oscillations. Prices fell after Waterloo but it was not until the 1820s that they had fallen to the level of the years before 1793. The American Civil War (1861–65) gave rise to the second major peak in wholesale prices in the U.S. but the effect in the U.K., and in many other countries, was much smaller. World Wars I and II exercised an even sharper effect on prices. Moreover, the course of prices was broadly similar in the two mars. at least in the United Kingdom and the United States—an immediate and pronounced rise, followed by a slower increase as measures of price control became effective and finally another sharp rise after the close of hostilities. The main difference between the two mars was that price control was effective sooner in World War II, and the postwar increase in prices mas more protracted.

Between wars the trend of prices was generally downward and, at the outbreak of one war, the level of prices was little different from that immediately before the previous war. Closer inspection, however, reveals major fluctuations disturbing the general course of prices. One cause of disturbance was the discovery of new gold fields or the rapid development of gold production. A growth in the supplies of gold coming forward pushes up prices in domestic currencies which are based on gold. The discovery of gold in California and Australia raised wholesale prices after 1850 and prices did not sink below the level of 1849 until about 1880. The effect of the new gold supplies on prices is to be seen clearly in the series for the U.K. where the American Civil War mas a very minor disturbing factor. The development of the South African gold fields was the main influence in the steady rise in prices following the low point attained in 1896, a rise which continued until the outbreak of World War I.

Other major fluctuations. generally working themselves out in a period of less than ten years, are those associated with booms and depressions. The pattern is boom, commercial crisis, recession and recovery. Commercial crises generally appear as peaks in the course of wholesale prices; *e.g.,* those of 1839 and 1847 in the first half of the 19th century and that of 1907 at the beginning of the 20th. No earlier depression, however, had quite the same catastrophic effect as that following the crisis of 1929. Both in the U.K. and in the U.S., wholesale prices in 1929 stood about 35% higher than in 1913: by 1932–33, prices had fallen to nearly 10% below the 1913 level; *i.e.,* a decline of more than 30% in less than four years.

A remarkable feature of the course of prices in modern times is the broad similarity between the movements in the U.K. and the U.S. There are, of course, many factors which exert little more than a local influence. For example, the Franco-Prussian and South African wars had relatively little effect on prices in the U.S. and the American Civil War influenced prices outside the U.S. to a relatively small extent. However, major wars, severe commercial crises and gold discoveries are events which are international in their impact on economic affairs and they affect prices everynhere. For this reason it can be said that there has been a level of world prices, the movements of which can be distinguished in a broad historical survey.

In an index of the general level of nholesale prices, the movements in the prices of commodities of many different kinds are averaged. Individual price quotations are to be expected to show greater fluctuations than the general a erage as is nell illustrated by the price of English wheat (Table IV and fig. 3). Up to about 1880. imports of wheat into the U.K. uere small and the price was largely dependent on the supplies of domestic wheat available and hence on the condition of the harvest. The price of nheat showed very large fluctuations, many of which did not correspond at all with movements in the general price level. After 1880, with increasing supplies of wheat coming in from the western hemisphere and other overseas areas, the price of English wheat was determined more by world prices than by the British harvest. The result was. first, that the price was reduced in relation to other prices and, second, that there were less violent fluctuations in price Though still showing wider variations than the general price level, the price of English wheat followed fairly closely the general course of prices. (R. G. D. A.)

UNITED STATES

In the United States, as in other countries, statistics of prices became available in greater quantity and in more varied forms than data reflecting other major aspects of the economy such as production and employment. The wealth of price data was steadily enhanced by the contributions of government departments and private business and research groups, and information about historical prices and price movements was expanded by the painstaking work of individual scholars.

In this section of the article three main tasks are undertaken. First, an effort is made to indicate the nature and sources of the price data available in the United States. Secondly, the data are drawn upon to describe the movement of the general price level in the period between the founding of the republic and the latter 1950s, and to analyze changes in the relationships of prices for different kinds of goods within the last 50 or 60 years of this period. Finally, a summary is presented of the cyclical behaviour of the price level and of price relationships.

NATURE AND SOURCES OF U.S. PRICE DATA

Statistics on prices are available in two forms: (1) price quotations for specified commodities, services or securities; and (2) index numbers which usually are designed to summarize the average amount of change in the prices for a specified group of commodities, services or securities between two or more dates. Despite the careful efforts of price statisticians in business and government who supervise the collection of price data and the compilation of price indexes. the numerous practical and theoretical difficulties involved in their work cannot be completely overcome. Although these problems need not be considered in detail here, some understanding of their general nature is essential to proper interpretation of the price data discussed below.

The central problem of price collection is to gather a sample of prices representative of the various price quotations for each of the commodities under study. Sampling is almost always necessary because it is not feasible to obtain a record of every single transaction. Price collection must be planned so that observed diflerences betneen the prices of any two dates (any two places, when place-to-place rather than time-to-time price differences are being studied) will reflect changes in price and price alone. In order to exclude the influence of variation in quality, commodity prices are frequently collected in accordance with detailed specifications (i e, descriptions) such as "wheat, no. 2 red winter, bulk. carlots. f.o.b. Chicago, spot market price, average of high and low. per bushel."

When the correct average prices for a commodity for successive dates have been determined. they may be expressed as percentages of the price for a particular date or "base period." These percentages are called "price relatives." The problem of constructing price index numbers is to combine either the prices themselves or the price relatives in such a way that the central tendency of the movement of the whole group of prices from one period to another is accurately described. Although a number of problems are encountered at this stage, the one that is perhaps the most important to an understanding of the limitations of price indexes is the weighting problem. This arises because not all commodities for which prices have been obtained are of equal importance in the price universe under study. The price of wheat, for example, should be given more weight in an index of wholesale prices in the domestic economy than the price of pepper, because either in physical terms or in value terms wheat is much more important in trade. The difficulty is that the relative importance of commodities changes over time. Furthermore, some commodities drop out of use and new ones appear, and often an item changes so much in composition and design that it is doubtful whether it can properly be considered the same commodity. Under these conditions, the pattern of weights selected can correspond accurately to the relative importance of the various commodities in only one of the periods for which the index numbers have been calculated. The greater the lapse of time between the period of the weighting pattern and other periods, the less relevant the pattern is likely to be for one of the periods, and therefore the less meaningful the price comparisons become. Price indexes thus can give relatively accurate measures of price change only for periods close together in time. Mills found also that the dispersion of price relatives computed on a given base year tends to increase with time; this means that the price index numbers become less representative of the central tendency of the whole distribution of the price relatives for the various commodities.

Sources of Data on Actual Prices.—The most important single source of price statistics in the United States at mid-20th century was the bureau of labour statistics (BLS) of the U.S. department of labour. The BLS was publishing monthly prices for about 900 different commodities at the primary market level (*i.e.*, 'the stage of marketing at which the goods were first sold), and for approximately 50 foods and for various types of fuels at the retail level. All the retail prices and roughly half of the wholesale prices were obtained directly from sellers. Most retail prices were collected during store visits by price agents trained to price goods in accordance with established specifications. A few retail prices, such as those for fuel and those primary market prices obtained directly from sellers, were secured by mail. The other primary market prices were obtained from such recognized trade journals as *Iron Age* and the *Oil, Paint and Drug Reporter*.

Another important governmental source of price data was the department of agriculture, collecting both "local market prices" and "wholesale prices" of farm products, the latter referring to prices at central markets. Estimates of Dec. 1 crop prices and Jan. 1 farm values of livestock are available since 1867, monthly prices of commodities sold by farmers since 1908 or 1910. Prices of articles bought by farmers were published annually from 1910 to 1922 and quarterly (for most items) subsequently. At mid-century, the department was receiving reports on farm product prices from about 9,000 respondents (mostly buyers or dealers) and reports on prices paid by farmers from about 17,000 respondents (mainly independent retailers serving the farm population). The prices thus obtained were available in the department's publication *Crops and Markets*.

The trade journals were, perhaps, the most readily available nongovernmental source of commodity price data. Prices for highly standardized commodities traded on organized markets (*e.g.*, wheat, coffee and sugar) and prices for stocks and bonds were also reported in the financial pages of many metropolitan newspapers.

Survey of Available Price Indexes.—The prices from all these sources were being used to compute a wide variety of index numbers at mid-century. The most generally used index numbers were those computed by the bureau of labour statistics, particularly its wholesale price and consumers' price indexes. Before describing these indexes. it may be well to survey the more important price indexes in the U.S., taking into consideration first commodity price indexes at both wholesale and retail levels and then indexes of the prices of services, construction and securities.

In the group of predominantly commodity price indexes were the department of agriculture indexes of prices received and prices paid by farmers. These indexes, based on the department's price data collection described above, were used in the determination of parity prices. Among the more widely known nongovernmental price indexes published in the 1950s were indexes designed to measure price changes for commodities highly sensitive to business movements, particularly raw and semiprocessed materials prices. The Associated Press prepared a daily index of this character and many of the leading financial services (such as Moody's) and jour-

Table I.—Wholesale Price Movements of Specified Commodity Groups, United States, Selected Years, 1890–1953

(1947–49=100)

Year	All commodities	Farm products	Foods	Other commodites: Total	Textile products and apparel	Hides, skins, and leather products	Fuel, power and lighting materials	Chemicals and allied products	Rubber and products	Lumber and wood products	Pulp, paper and allied products	Metals and metal products	Machinery and motive products	Furniture and other household durables	Nonmetallic minerals—structural	Tobacco mfrs. and bottled beverages	Building materials
1890	36	28	34	—	42	26	32	58*	—	—	—	72	—	37	—	—	24
1896	30	22	26	—	30	24	34	51*	—	—	—	49	—	32	—	—	20
1913	46	40	38	50	40	37	52	63*	—	—	37*	63	—	41	—	—	30
1920	100	84	82	116	116	92	139	130*	—	—	113*	103	—	105	—	—	78
1926	65		60		70	54	85	79*	159	34	62*	69	—	74	74	88	52
1929	62		60		63	59	70	74*	84	32	55*	67	—	69	73	87	50
1932	42	27	37	50	39	40	60	58*	54	20	47*	50	—	55	63	81	37
1937	56	48	51	61	53	57	66	59	84	34	57*	66	—	67	73	76	50
1938	51	38	44	58	47	50			83	31	53*	63	—	66	71	76	47
1939	50	36	42	58	49	52	65	56	86	32	51*	63	65	65	70	76	47
1940	51	38	43	59	52	55	62	56	80	35	57*	63	66	67	70	77	49
1941	57	46	50	64	60	59	64	62	86	42	61*	64	69	71	71	78	54
1942	64	59	60	68	68	64	66	69	101	45	62*	65	71	77	74	79	57
1943	67	68	64	69	68	64	68	70	103	48	64*	65	71	76	74	83	58
1944	68	69	63	70	69	63	70	70	102	52	66*	65	71	78	76	83	60
1945	69	72	64	71	70	64	71	71	99	53	67*	66	72	79	79	86	61
1946	79	83	79	78	82	75	76	76	99	60	64*	74	80	83	84	90	69
1947	96	100	98	95	100	101	91	101	99	94	96*	91	93	96	94	97	94
1948	104	107	106	103	104	102	107	104	102	107	104*	104	101	101	102	100	104
1949	99	93	96	101	96	97	102	95	99	99	100*	105	107	103	104	102	102
1950	103	98	98	105	99	105	103	96	120	114	101*	110	109	105	107	104	110
1951	115	113	110	110	111	120	107	110	148	124	123*	123	119	114	114	109	120
1952	112	107	109	113	100	97	107	104	134	120	119*	123	122	112	114	112	118
1953	110	97	104	114	97	98	110	106	125	120	119*	127	123	114	118	116	120
1951 indexes as a per cent of indexes in selected years																	
1890	320	404	324	—	264	462	334	190	—	—	—	171	—	308	—	—	500
1896	383	514	423	—	370	500	315	216	—	—	—	251	—	356	—	—	600
1913	250	283	290	232	278	324	206	175	—	—	333	195	—	278	—	—	400
1920	115	135	134	100	96	130	77	85	—	—	109	119	—	109	—	—	154
1926	177	202	183	161	159	222	126	139	93	365	198	178	—	154	154	124	231
1932	274	419	297	232	285	300	178	190	274	620	262	246	—	207	156	135	324
1939	230	314	262	200	227	231	173	196	172	388	241	195	183	170	163	143	255

*Based on series as computed prior to 1952 revision.
Source: Bureau of Labor Statistics.

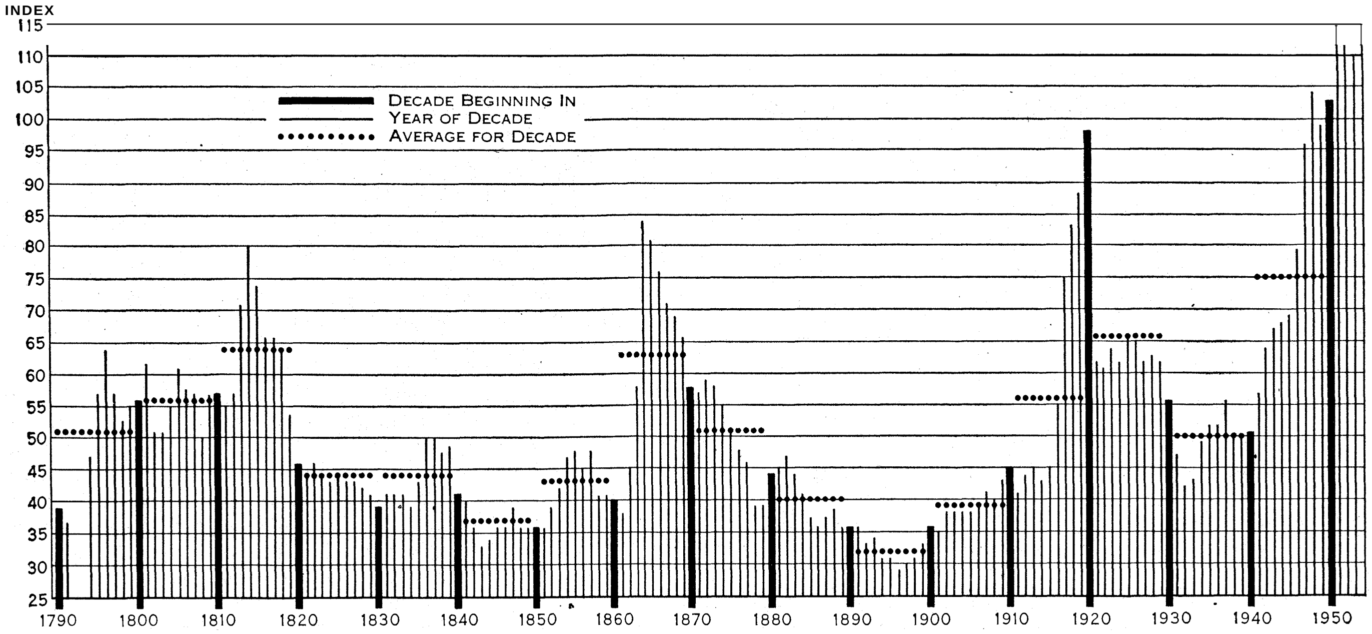


FIG. 1.— MOVEMENTS OF WHOLESALE COMMODITY PRICES IN THE UNITED STATES, 1790–1953 (1947–49=100). FROM 1790 TO 1889 THE WARREN-PEARSON-STOKER INDEX (STOKER BEFORE 1797) IS USED: FROM 1890 TO 1953 THE OFFICIAL INDEX OF THE BUREAU OF LABOR STATISTICS

nals (such as the *Journal of Commerce*) issued indexes of a similar nature. The National Bureau of Economic Research computed wholesale price indexes based on BLS prices but combined according to a different commodity classification (F. C. Mills, *The Structure of Postwar Prices* [1948]). A number of the privately computed indexes of the 1920s and 1930s were abandoned as the government indexes came into greater use.

A large number of wholesale price index numbers of more limited commodity coverage mere available in the trade journals. *Iron Age*, for example. published an index of finished steel prices which was a weighted average of the prices (in cents per pound) of ten major finished steel products.

In addition to these and similar commodity price indexes that were in the realm of public information, a number of business firms computed special-purpose price indexes for their own uses, especially in connection with marketing and purchasing activities.

At the retail level, a distinction must be made between those indexes including services and those including commodity prices only. The consumers' price indexes of the BLS and the National Industrial Conference board were in the former category. while the U.S. department of commerce and Fairchild Publications indexes of retail prices were examples of the latter group. The National Industrial Conference Board index, available since 1914, was similar to the BLS index (described below) but included a number of small cities not in the BLS sample and was based on prices obtained by mail questionnaires. The department of commerce index of prices at retail stores, which mas available for 1929 and 1933 and after 1939, differed from the BLS consumers' price index in that it omitted services (medical care. transportation, recreation, etc.) and included building materials, farm machinery and other nonconsumer goods sold through retail stores The index of the Fairchild Publications. available since 1930, covered the prices of piece goods, apparel and home furnishings. All four of the retail and consumers' price indexes just mentioned were published monthly.

Different in concept from any of the indexes treated thus far was Carl Snyder's "index of the general price level." This was designed to measure changes in prices of commodities at all Ievels from primary to retail markets and shifts in the prices of services and property as well as of commodities. The index was extended from 1938 back to 1791 *(Review of Economic Statistics*, p. 2j [Feb. 1934] and p. 40 [Feb. 1928]). Comprehensive price indexes embracing both services and commodities were also derived, largely with the aid of existing price index numbers. in the course of estimating national income in terms of constant prices. Such indexes were available for 1919–38 in S. Kuznets and others, *National Income and Its Composition, 1919–1938*, pp. 141 ff. (1941). Similar series, referring to price changes in the gross national product and 10 or 12 of its major segments are available for the period 1929–53 in *National Income, 1954 Edition: A Supplement to the Survey of Current Business*, pp. 216–217. U.S. department of commerce. These series will be carried on and, if the past custom is followed, will be found each year in the July issue of the *Survey of Current Business*.

Aside from the services included in the consumers' price index, the most readily available indicators of the changing price of services were indexes of hourly earnings and wage rates. The BLS series on average hourly earnings of production workers in manufacturing industries, available since 1909, was the most general of

TABLE II.—*Movements of Various Price Indexes, Selected Years, United States, 1913–53 (1947–49=100)*

Year	Whole-sale prices	Consumers' prices				Hourly earnings	Price received by farmers	Prices paid by farmers	Construction costs	Stock prices
		All items	Food	Apparel	Rent					
1913	46	42	40	36	77	17*	38	42	22	58
1920	100	86	84	105	100	42	78	88	56	55
1926	65	76	68	63	125	42	54	63	46	81
1929	62	73	66	60	117	42	55	63	46	163
1932	42	58	43	48	97	34	24	43	35	41
1937	56	61	52	54	84	47	45	54	52	96
1938	51	60	48	53	86	48	36	51	52	72
1939	50	59	47	52	87	48	35	50	52	77
1940	51	60	48	53	87	50	37	51	54	72
1941	57	63	52	56	88	55	46	54	57	65
1942	64	70	61	65	90	65	59	62	61	56
1943	67	74	68	68	90	73	71	69	64	75
1944	68	75	67	73	91	77	73	72	66	81
1945	69	77	69	76	91	77	76	75	68	103
1946	79	83	79	84	91	82	87	82	77	114
1947	96	96	96	97	94	93	102	96	92	100
1948	104	103	104	104	101	102	106	104	102	101
1949	99	102	100	99	105	105	92	100	106	98
1950	103	103	101	98	109	110	95	103	113	119
1951	115	111	113	107	113	120	111	113	120	144
1952	112	114	115	106	118	126	106	114	126	153
1953	110	114	113	105	124	133	95	109	133	153
1951 indexes as a per cent of indexes in selected years										
1913	250	264	283	297	147	706	292	269	546	248
1920	115	129	135	102	113	286	142	128	214	262
1926	177	146	166	170	90	286	206	179	261	178
1932	274	191	263	223	116	353	463	263	343	351
1939	230	188	240	206	130	250	317	226	231	187

*1914.

Sources: Whole-ale and consumers' price series are the BLS indexes described in text. Hourly earnings are HLS series for production workers in manufacturing. Prices paid (for living and production) and received by farmers are from Department of Agriculture. The construction cost index is from the Engineering Sews-Record and the stock prices are the Standard and Poor's composite index numbers of 400 to 500 stock prices.

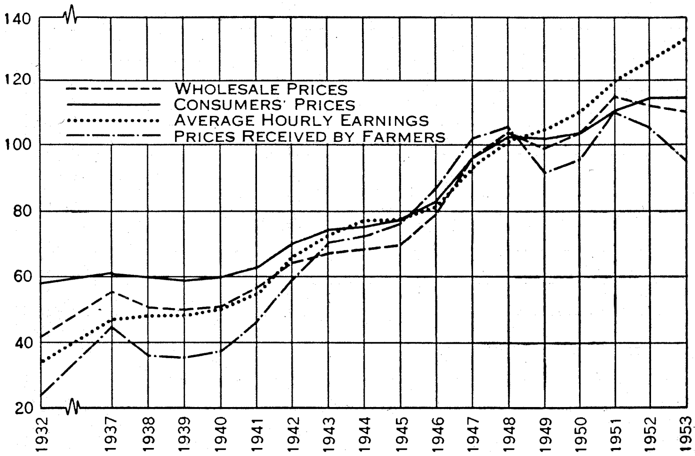


FIG. 2.— MOVEMENTSOF VARIOUS PRICE INDEXES 1932–53 (1947–49=100)

these series. Indexes of wage rates were restricted to particular groups of workers such as organized workers in the building and printing trades

A field in nhich it was necessary to combine wages and commodity prices to derive indexes was construction. These were not price indexes in the strict sense but construction cost indexes. A number of these indexes were being published in the 1950s by private business groups in or servicing the construction industry; in addition, government agencies were publishing index numbers of construction costs in such fields as railroad. highway and farm construction Most construction cost index numbers went back to the 1910–13 period. Mention may be made of the construction cost indexes of the *Engineering News-Record*, the Aberthan Co . the American Appraisal Co., the Associated General Contractors of America, Inc., and E. H. Boeckh and Associates, Inc.

The last category of price indexes deserving consideration here consists of the indexes of security prices. Among the leading indexes of stock prices at mid-century were those prepared by the New York Stock exchange. Moody's Investors Service; Standard and Poor's Corp. and Dow Jones & Co. The first of these indexes was based on the average price obtained by dividing the market value of all listed stocks at the end of the month by the number of shares. The other indexes were based on a more limited but more constant group of sample stocks selected to represent different groups of stocks. The Dow Jones averages, for example, were based on 30 industrials, 20 railroads and 15 utilities; the Standard and Poor's indexes, based on 400 to joo stocks, were available for a more detailed industrial classification. Indexes of bond prices were also computed by the New York Stock exchange, Standard and Poor's and others; such indexes generally derived the bonds prices from average yields.

The general user of price indexes could find data for almost all of the price index series mentioned above in the *Survey of Current Business*, monthly publication of the department of commerce. Sources of the statistics for former years and brief descriptions of many of the indexes were available in *Historical Statistics of the United States, 1789–1945, 4 Supplement to the Statistical Abstract of the United States*, and in the *Statistical Supplement to the Survey of Current Business*. The data in the former publication were carried down to 1952 in *Continuation to 1952 of Historical Statistics of the United States*.

The **BLS** Indexes.— The BLS official wholesale price index numbers date from 1890. The methods of computation and the number of commodities included in the index varied from time to time; but the revisions were made so as to retain comparability of the series. A major revision extending back to Jan. 1947 was issued early in 1952. The most significant changes were the extension of the commodity coverage of the index from about goo items to about 2.000, and the use of the 1947 Census of Manufactures as the source of weights. The larger number of commodities for which prices were collected made it possible to improve the sample of prices for some subgroups in the index and to include for the Erst time other groupings (*e.g.,* machinery) which had been omitted. The result was to make the index representative of prices in all primary market commodity transactions (including the domestic aspects of import and export transactions).

Since the index included the primary market price of goods of all degrees of fabrication. the same commodity was often priced at several stages of production. For example, cotton was priced in the form of raw cotton, cotton yarn. cotton gray goods, cotton piece goods and cotton clothing. Indexes were published monthly for 1 j major groups (*see* Table I), 88 subgroups and a larger number of "product classes" (*i.e.,* minor commodity groups). Indexes for individual commodities were also issued. Prior to 1952, prices for a specific day in each week were averaged to obtain monthly prices for most commodities; beginning in 1952, the price used in the index was generally the one that prevailed on Tuesday of the week containing the 15th of the month.

The BLS specified that the "official" wholesale price index consisted of the old series up to the end of 1951 and the revised series thereafter. This was done to avoid disputes between parties to private contracts in which the price to be paid was to be changed in accordance with movements in the official BLS wholesale price index. Such escalator clauses are sometimes put in contracts that run over a period of time.

The BLS also issued a meekly wholesale price index, which was intended to provide an estimate of what the monthly index would be were it computed each week. After 1952, the weekly index was no longer corrected subsequent to its issuance to make it conform to the movements shown in the monthly index. The BLS, in addition, published a daily index of spot market prices which was intended to serve as a sensitive gauge of changes in market conditions. The monthly, weekly and daily indexes were being published on a 1947–49 base in the mid-1950s.

The BLS wholesale price index had been extended back to 1801 on the basis of price indexes for 1801–40 computed by A. H. Hansen (*Publications* oi the American Statistical association: pp. 804–812 [Dec. 1915], and BLS *Bulletin S o . 367*, pp. 235–48) and data for 1841–89 contained in the Aldrich committee's comprehensive report, "Wholesale Prices. Wages and Transportation," *Senate Report No. 1394,* 52nd congress, 2nd session, part i. p. 9. Hansen's data were based on prices published in Boston. Mass., newspapers for the period 1801–25 and for the period 1825–40 on New York prices published in the "Report of the Secretary of the Treasury on the State of Finances" for the year ending June 30, 1863.

The BLS index was also extended by G. F. Warren and F. A. Pearson back to 1797, and H. Stoker extended it to 1720. This work was based primarily on New York city prices obtained directly or indirectly from newspaper sources and from the treasury report mentioned above (Warren and Pearson. *Prices* [1933]).

Although not directly linked to the BLS index, mention should be made also of a series of careful investigations of early price records in New York city, Boston. Philadelphia (Pa.), Charleston (S.C.), New Orleans (La.) and Cincinnati (O.). A summary of the results of these studies was prepared by A. H. Cole (*Wholesale Commodity Prices in the United States, 1700–1861* [1938]).

The BLS consumers' price index was designed to measure changes in prices of a fixed list of living essentials, not changes in the total amount families spend for living. (*See* COST OF LIVING.) The living essentials relevant for purposes of the index were those of urban wage earners and lower salaried clerical workers. The sample of items and the weights for the various prices were derived from a 1950 survey of the incomes and expenditures of about 12,500 families or single consumers. The weighting pattern of the index was modified from time to time on the basis of later though more limited family expenditure surveys. Methods of computation, the number of items priced and the number of cities covered varied after the index was initiated in World War I, but the revisions were made so as to maintain the continuity of the series as far as possible. In the mid-1950s the index was being published on a 1947–49 base and was derived from the price movements of about 300 items including go foods, 75 articles of apparel, 35 housefurnishings and 10 fuels. Prices were collected in 46 cities, but except for food, rent and certain other items not all cities were surveyed each month. Prices were collected so as to refer to a date near the 15th of each month.

In addition to the consumers' price index for all cities of the nation as a whole, the BLS published indexes measuring time-to-time changes in consumers' prices in 20 different cities. In a very different category were place-to-place comparisons of the cost of living which the BLS made between a number of cities.

Although consumers' price indexes, or cost-of-living indexes as they were formerly called, were calculated for the 100 years preceding the beginning of the BLS series (1913), most of these estimates were based on wholesale price changes in whole or part. Several of these indexes were linked together by the Federal Reserve Bank of New York to form a single series for the period 1820–1913.

The consumers' price index was the index generally cited in escalator clauses in labour-management agreements. It was estimated that early in 1951 wages of several million employees were being adjusted in accordance with changes in the index.

THE LONG-TERM MOVEMENT OF PRICES

It is difficult to describe the movement of prices because, as is evident from the preceding survey of prices and price indexes, there are many different kinds of prices in the economy. It is true that such broad groups of prices as primary market prices, retail prices, wages and security prices could be combined in some way to give an index of prices in general. Carl Snyder's "index of the general price level" represented such an attempt. However, it is hard to interpret the meaning of changes in such an index; it is composed of elements that are too heterogeneous, What is required for most business and public purposes is a knowledge of the behaviour of one or more of the broad groups of prices and sometimes of the major or minor subgroups or even of particular items. depending upon the nature of the specific problem.

It happens that data on wholesale commodity prices, which represent a group of prices of strategic importance in the economy, are available for a longer period than information about other broad groups of prices. Hence. discussion of the long-term movements of prices in the United States may most conveniently run in terms of wholesale prices.

Changes in the Price Level.—Two relevant questions about the long-term movements of prices are: (1) what was the direction of the trend? and (2) what was the degree of fluctuation around the trend? Answers to both of these questions will be sought largely in terms of the BLS wholesale price index which was previously discussed and is set forth in Table I and fig. 1. For the longer sweep of history, the index is extrapolated backward to 1790 by using the Warren-Pearson-Stoker index. Reference will also be made to other indexes which may be found in Table II.

The answer to the first question is that despite the popular notion that prices have been rising in the long run, the figures for the period 1790–1953 do no reveal any persistent upward movement extending over more than a few decades. The popular view is apparently based on a heavy weighting of later experience. During the last two decades of the period, a large and well-sustained upsurge carried prices to higher levels than had ever been reached before. Prices in the peak year, 1951, were more than double the average level for all but 4 of the 16 decades in the nation's history. For the period preceding 1790 the data summarized by Cole (op. *cit.*, pp. 106–107) seem to indicate a slowly rising trend from 1720 to a peak associated with the Revolutionary War. Cole suggested: however, that the period 1720–45 was characterized by level or moderately declining prices and that it was followed by a long price upswing to a Revolutionary War peak with the subsequent trough coming in 1789. By 1796, prices had recovered to a higher level which was only slightly above that of 1801.

As for the question relating to the degree of fluctuation: the answer is that the course of prices from 1790 to 1953 was characterized by relatively moderate changes except for the violent movements associated with war and postwar periods.

In examining these movements, it is easy to pick out the major price peaks, but the troughs are more difficult to select (see fig. 1). This is due to the fact that periods of high prices were confined almost entirely to well-defined short spans of war years, while relatively low prices generally characterized the long interwar periods. The index of wholesale prices passed the 80-mark only in years associated with the War of 1812, the Civil War and World Wars I and II; during almost half of the years from 1790 to 1953 the index was in the 35 to 50 range.

Bearing in mind the approximate nature of price comparisons over long periods of time and the more arbitrary aspect of the selection of trough years among years of generally low prices, the extremes of the historical movements in wholesale commodity prices are shown in Table III.

TABLE 111.—Peaks and Troughs in U.S. Prices

Troughs		Peaks		Trough to peak		Peak to trough*	
Year	Index (1947–49=100)	Year	Index (1947–49=100)	Total period	Annual rate	Total period	Annual rate
1789	38	1814	80	+112%	+3.1%	—	—
1843	33	1864	84	+154%	+4.5%	—58%	—2.9%
1896	29	1920	98	+235%	+5.2%	—65%	—3.2%
1932	42	1951(?)	115	+174%	+5.4%	—58%	—6.9%

*1814–43, 1864–96 and 1920–32.

The annual rates of change suggest that the amplitude of the later swings was greater. It is, however, impossible to generalize on the basis of so limited a number of long swings, particularly since there is such a great margin of error in the earlier index numbers. Furthermore, it must be borne in mind that the calculations are based on the differences between the index numbers at the terminal dates of each period and do not necessarily characterize the period as a whole. Thus, for example, while it is true that the decline in the index from 98 in 1920 to 42 in 1932 represented an annual rate of decline of 6.9%, the significant declines in the index came in 1920–21 and 1929–32; the computed average decline is a poor description of the behaviour of prices during the period as a whole, particularly for 1921–25 when the index rose slightly. The figures showing the fluctuations in the index from trough to peak and peak to trough must therefore be interpreted in the light of the original data in fig. 1.

The periods of upswing from the troughs to the peaks correspond to what have sometimes been referred to as long periods of predominantly good times and the downswings from peaks to troughs to what have been described as long periods of predominantly bad times. There is, indeed, some evidence that the contraction phase of business cycles was shorter during the long upswings both in terms of absolute length of time and as a proportion of length of the full cycle. Despite the likely existence of this relationship, however, it is impossible to state any simple causal connection between the duration of business cycles and the long-term movement of prices.

The first of the upswings indicated above, 1789–1814, was associated with the effects of the Napoleonic Wars and the Industrial Revolution; the second, 1843–64, with the discovery of gold, the building of railroads and the Civil War; and the third, 1896–1920, with electrification and motorization and World War I. The fourth, 1932–51 (if. indeed. 1951 proved to mark the end of this upswing), reflected World War II. the Korean war and the greatly expanded sphere of governmental activity in the economy. The downswings were generally explained in terms of the eventual loss of impetus in the technological innovations which played the major role in the preceding upswings.

Changes in Price Relationships.— The amplitude of fluctuations in the individual price series may have been greater than that of the composite index; unless the peaks and troughs of the various constituent prices come simultaneously, an index representing the average of all the prices would not reveal fully the extremes of the actual fluctuation in prices. Furthermore. the over-all index cannot show the changing relative positions of individual commodity prices or groups of prices in the whole system of prices. In any given movement of the price index. all prices will not, of course, change in the same proportion. Some idea of the changes in price relationships that occurred during the various shifts of the over-all index may be obtained by studying Table I, which shows the index numbers for the major commodity groups in the BLS wholesale price index. In the lower part of Table I, the 1951 group indexes have been expressed as percentages of the same indexes for 1890 (the first year for which the BLS official group indexes were available). for each peak and trough year (1896, 1920 and 1932) and for an intermediate year between each trough and peak (1913, 1926 and 1939). The results show that the major difference in the structure which prevailed after World War II from the price structures of the 50 years preceding that war was the rise in the prices of farm products and foods relative to other commodity prices. This shift in exchange values in favour of farm products was the result of government agricultural policies, high domestic incomes and large exports.

Another group index that rose by a much greater percentage than the over-all index was the building materials price index. This was attributable chiefly to the sharp rise in the price of lumber between 1939 and 1951; lumber prices nearly quadrupled, while most of the other types of building materials (cement, brick, tile, etc.) hardly doubled in price. The commodity groups that had low values in terms of other goods in 1951 relative to their exchange values of former years mere metals and metal products and chemicals (comparisons for this group were of limited validity because its composition was not the same before and after 1926). Hides and leather products and fuel and lighting materials had lower relative prices in the first 10 or 20 years of the period 1890–1949 than in the rest of the period.

These changes and the even greater diversity of changes in relationships among individual commodity prices both influence the price level and are influenced by the price level. Changes in the supply and demand conditions for the individual commodities or for groups of commodities may be active factors in affecting the general level of prices On the supply side, one of the most important factors affecting prices is technological change. Because the rate of technological change is uneven and affects particular industries rather than all industries at once, relative prices are often altered. This is illustrated by the behaviour of prices of tires and tubes in 1939–48. In 1938 these prices were not much different in dollar terms from 1939; since they failed to keep pace with the rise of other commodity prices! which more than doubled during this ten-year period, tire and tube prices fell relative to other commodity prices. An example of the influence of demand upon relative prices during the same period was provided by the great increase in lumber prices noted above; these increases might be attributed to the large quantities of lumber demanded during the war and postwar construction booms.

Relative prices are also influenced by changes in the price level, because some goods and groups of goods respond more readily than others to such changes. In this connection, it is interesting to contrast the price behaviour of the farm-product group and metals and metal-product group in Table I. In the 64-year period 1890–1953, the latter index numbers (annual averages) fell within a 20-point range (50 to 70) in 41 of the years; only 27 of the annual farm-product price index numbers could be found in any 20-point range. and even the range in which this number of observations was found (25 to 45) was typical only of the early years of the period. Such differences in price fluctuations are discussed below in connection with cyclical changes in prices.

F. C. Mills. studying the period 1893–1926 in The Behavior of Prices, estimated that about 40% of the shifts in relative prices could he attributed to changes in the general level of prices (assuming that the causal relation runs from price-level change to alterations of price relationships). while the other 60% would have occurred even if the general level of prices had been constant.

So much for the pattern of wholesale commodity prices, and how this pattern altered between 1890 and 1953. What happened to the relationship of 11-holesale commodity prices to other prices in the economy? The data required to answer this question. available only since 1913, may be found in Table II. In the lower part of this table. the 1951 indexes have been expressed as percentages of the indexes for five earlier years in order to facilitate the comparison of the 1951 price structure with former ones.

The relative increase in farm-product prices noted in connection nith the analysis of wholesale commodity prices is reflected in Table II in two nays: (1) the prices received by farmers had increased more between almost any of the five base dates and 1951 than any other wholesale or retail commodity price series in the table; and (2) among the consumers' price groups, food nas relatively more expensive, compared with other living essentials, than it had been in the 50 years before World War II.

Perhaps the most significant fact is the notably greater rise in average hourly earnings of production workers in manufacturing compared with the rise in consumers' prices; the spread between these two increases is a measure of the rise in average hourly earnings in real terms (*i.e.*, power to buy goods). The total increase in real earnings is not, of course. fully indicated in these figures; less unemployment existed in 1951 than in most of the base periods. The wholesale price index had wider amplitude of fluctuation than the consumers' price index (by about 50%). Stock prices recovered from the depression lows more quickly and generally remained farther above the depression levels than commodity prices. If 1939 rather than 1932 is taken as the basis of the comparison, however, stock price increases did not surpass commodity price indexes until after the sharp rise in stock prices that began in 1950.

THE CYCLICAL BEHAVIOUR OF PRICES

There is a close correspondence between the movements of commodity prices and the business cycle turning points used by A. F. Burns and W. C. Mitchell (Measuring *Business* Cycles, p. 78 [1946]). Mills, who studied 209 price series for cyclical variation during the ten cycles from the revival of 1892 to the revival of 1924, found that an average of 71% of the series had upturns during revivals and downturns during the succeeding recessions (op. *cit.*, pp. 387–389). Of course, some individual price series do not conform to the general business cycle at all, and there have been times when even the over-all wholesale price index moved in a different direction from business activity (*e.g.*, 1938–39). The fluctuations observed in the business cycle are, of course, in the broadest sense changes in aggregate values produced, traded or consumed; these changes in values may be regarded as the net results of changes in prices and quantities. Thus even as a symptom of what is transpiring in the business cycle, price changes must be considered in connection with concomitant changes in quantity.

The price and quantity movements of 64 commodity series during business cycles were analyzed by Mills in *Price-Quantity Interactions* in Business Cycles (1946). For the composite of all 64 commodities and of all cycles, the movement of prices and quantities at various points in the general business were summarized by expressing each of these series as a percentage of its average for the whole cycle:

	Prices	Quantities
Initial trough	94	90
Peak	112	112
Final trough	90	94

The average amplitude of each phase of the composite cycle was thus 20% for both prices and quantities. However, in expansion, prices rose only 80% as much as quantities did, but in contraction they declined 23% more than quantities. Also, quantities tended to rise in the final stage of contraction while prices were still falling. About five-sixths of the commodities studied conformed to the cycle, but with wide diversity in amplitude of price and quantity movements. For farm products, foods, consumers' goods and nondurable goods, prices varied more than quantities during the course of the cycle, but the combined variation of both price and quantity (*i.e.*, value) was characteristically low. On the other hand, for durable goods, capital equipment and nonfarm products, prices mere relatively stable and cyclical influences mere reflected in relatively large changes in quantities.

Mills pointed out that the groups of commodities with flexible prices are those close to the initial extractive stages or those close to the final stage oi consumption. The stability of output in the extractive industries and the relatively stable character of consumption (especially of nondurables) throws the burden of cyclical adjustment upon price.

Although there is general agreement that certain industries adjust to falling demand primarily through reduction in output with prices remaining relatively stable while in others the reverse is true, not all students interpreted the underlying factors in the same terms as Mills. G. Means, for example, attributed the inflexibility of certain prices mainly to control over prices placed in the hands of business administrators in industries characterized by a relatively small number of sellers. Means's measure of price flexibility was based on frequency of price change. According to this criterion, most commodity prices during the period 1926–33 were either very flexible or very inflexible; few fell in the middle range ("Industrial Prices and Their Relative

Inflexibility," *Senate Document* No. *13*, 1st session, 74th congress [1935]). Those prices changing least frequently were found to have the smallest amplitude of fluctuation (S. Nelson and W. Keim, "Price Behavior and Business Policy," Temporary National Economic Committee, *Monograph No.* 1, p. 170 [1940]).

Price Changes in World War 11.—Some aspects of the impact of World War II on the U.S. price structure have already been mentioned. The peak year of the price swing associated with World War II was in 1948 when the wholesale price index averaged 104 (1947–49=100). This was almost double the level of 1941, the year of Pearl Harbor, and more than double the average for 1939, the year of the beginning of hostilities in Europe. The rises in the index associated with World War I and with the Civil War were similar in magnitude to that of World War II, but the more than doubling of the index occurred over a somewhat shorter span of years (1861–64 and 1915–20). The consumers' price index rose by more than 70% between 1939 and 1948; it had doubled between 1914 and 1920. The price decline in the year following the peak year was much more moderate after World' War II than it was after World War I. The record of the later of the two wars was also unique in that price increases were held in check with remarkable success by price controls during the four years of actual hostilities despite the shortages of materials and labour involved in the unprecedented production of the war economy; in 1945, the year hostilities ended, the wholesale price index averaged 69 compared with 57 in 1941 and 50 in 1939, and the increases in the consumers' price index were comparable.

As a matter of fact, the wartime price increase in the United States was less than that of almost all other countries (Canada, and if consumers' prices are taken into account, possibly Australia and New Zealand, were the chief exceptions). The great inflation in U.S. prices came in the three pears after the end of the fighting, particularly after the abandonment of price controls in mid-1946. This rise brought the total increase in U.S. prices since 1939 beyond the increases that had occurred in most nations of the British Commonwealth, the Scandinavian countries and Switzerland. Elsewhere, the 1939–48 price inflation was generally greater than in the U.S.

The outbreak of the Korean war of 1950–53 brought another upswing in prices which reached a peak in 1951.

BIBLIOGRAPHY.—U.S. Bureau of Labor Statistics, Annual *Bulletins* on Wholesale Prices; A. H. Cole, *Measures of Business Change* (Homewood, Ill., 1952); F. C. Mills, *The Behavior* of *Prices* (New York, 1927), *Price-Quantity Interactions* in *Business Cycles* (New York, 1946); W. C. Mitchell, "The Making and Using of Index Numbers," U.S. Bureau of Labor Statistics *Bulletin 284,* part 1 (reprinted as *Bulletin* 656); A. C. Neal, *Industrial Concentration and Price Inflexibility* (Washington, 1942); U.S. Department of Commerce, *Historical Statistics of the United States, 1789–1945* (Washington, 1949), *Continuation to 1952 of Historical Statistics of the United States* (Washington, 1954). (I. B. K.)

UNITED KINGDOM

The movement of the general level of wholesale prices in the U.K. during the 19th century, between the close of the French Wars and the South African War, can be summarized best by reference to three periods. Between 1820 and 1850 there was a general downward movement, combined with considerable fluctuations, from about 155 in 1820 to about 90 in 1850 (1913=100). From 1850 to 1870 the price level was first raised and then maintained, apart from fluctuations, as a result of great economic developments (in industry, transport, etc.) backed by the new supplies of gold from California and Australia. The earlier downward trend was resumed after 1870, when the level was around 115 (1913=100), until a low point of a little over 70 was reached in 1896. Before the end of the century, therefore, wholesale prices in general were less than half the level ruling immediately after Waterloo.

Following the South African War and the development of the South African gold fields, wholesale prices moved upward fairly steadily until 1914. The immediate effect of the outbreak of war in 1914 was a sharp rise in prices. In the first three years, Aug. 1914 to Aug. 1917, wholesale prices rose by an average amount of 2% a month. Control of prices then began to take effect and there mas even some decline after the armistice in Nov. 1918. The postwar rise, however, was the most rapid recorded to that date; wholesale prices increased by more than 40% in the year April 1919–April 1920. The reaction was just as spectacular, and prices generally were halved by the end of 1921. The subsequent further fall, between 1924 and 1929, was caused at least in part by the restoration of the gold standard (May 13, 1925). The depression following the crisis of 1929 was severe, though the effect on wholesale prices mas somewhat offset by the abandonment of the gold basis (Sept. 21, 1931). The period of 25 years 1913–38 was marked by price fluctuations of the most violent kind; but at the end of the period mholesale prices in general were little more than 5% above the level of 1913.

There were differences of great significance between the movements of wholesale prices of different groups of commodities, and between wholesale prices on the one hand and retail prices of comparable commodities on the other. The broad comparisons of greatest interest are those between the prices of foodstuffs and the prices of textiles and clothing. The relevant data for the period of nearly 60 years up to 1938 are shown in Table *VI*.

TABLE IV.—*Wholesale Price, United Kingdom, 1790–1953*

Year	Wheat price* (*s* per qtr.)	Statist index† (1913=100)	Year	Wheat price* (*s* per qtr.)	Statist index† (1913=100)
1790	54.7	127	1872	57.0	128
1791	48.6	130	1873	58.7	131
1792	43.0	136	1874	55.7	120
1793	49.2	145	1875	45.2	113
1794	52.2	144	1876	46.2	112
1795	75.2	171	1877	56.7	111
1796	98.6	183	1878	46.4	102
1797	53.7	161	1879	43.8	98
1798	51.8	173	1880	44.3	104
1799	69.0	190	1881	45.3	100
1800	113.8	206	1882	45.1	99
1801	119.5	224	1883	41.6	96
1802	69.8	174	1884	35.7	89
1803	58.8	187	1885	32.8	85
1804	62.2	179	1886	31.0	81
1805	89.7	199	1887	32.5	80
1806	79.1	195	1888	31.8	82
1807	75.3	193	1889	29.7	85
1808	81.3	218	1890	31.9	85
1809	97.3	236	1891	37.0	85
1810	106.4	240	1892	30.2	80
1811	95.2	215	1893	26.3	80
1812	126.5	217	1894	22.8	74
1813	109.7	218	1895	23.1	73
1814	74.3	224	1896	26.2	72
1815	65.6	193	1897	30.2	73
1816	78.5	160	1898	34.0	75
1817	96.9	176	1899	25.7	80
1818	86.2	198	1900	26.9	88
1819	74.5	1	1901	26.7	82
1820	67.8	155	1902	28.1	81
1821	56.1	138	1903	26.7	81
1822	44.6	129	1904	28.3	82
1823	53.3	130	1905	29.7	85
1824	63.9	129	1906	28.2	91
1825	68.5	151	1907	30.6	94
1826	58.7	132	1908	32.0	86
1827	58.5	132	1909	36.9	87
1828	60.4	119	1910	31.7	92
1829	66.2	116	1911	31.7	94
1830	64.2	119	1912	34.8	100
1831	66.3	120	1913	31.8	100
1832	58.7	114	1914	35.0	100
1833	52.9	110	1915	53.9	127
1834	46.2	114	1916	58.4	160
1835	39.3	117	1917	75.7	206
1836	48.5	126	1918	72.7	226
1837	55.8	123	1919	72.9	242
1838	64.6	123	1920	80.6	295
1839	70.7	135	1921	72.7	182
1840	66.3	127	1922	47.8	154
1841	64.3	125	1923	42.2	151
1842	57.2	110	1924	49.3	164
1843	50.1	104	1925	52.2	160
1844	51.2	101	1926	53.3	147
1845	50.8	108	1927	49.3	144
1846	54.7	108	1928	44.7	140
1847	69.7	112	1929	42.2	134
1848	50.5	92	1930	34.3	113
1849	44.2	87	1931	24 0	96
1850	40.2	91	1932	25.0	93
1851	38.5	88	1933	22.8	92
1852	40.8	92	1934	20.2	
1853	53.2	112	1935	22.2	
1854	72.4	120	1936	30.8	104
1855	74.7	119	1937	40.0	120
1856	69.2	119	1938	28.9	106
1857	56.3	124	1939	21.4	111
1858	44.2	107	1940	42.8	151
1859	43.7	111	1941	62.8	167
1860	53.3	116	1942	68.5	178
1861	55.3	115	1943	69.7	182
1862	55.4	119	1944	63.9	188
1863	44.7	121	1945	61.8	193
1864	40.2	124	1946	63.6	219
1865	41.8	119	1947	71.8	271
1866	49.9	120	1948	90.0	305
1867	64.4	118	1949	99.5	323
1868	63.7	116	1950	110.7	381
1869	48.2	115	1951	122.8	473
1870	46.8	113	1952	129.0	447
1871	56.7	118	1953	138.0	433

*Wheat price: English *Gazette* price of wheat, in shillings per quarter of 480 lb
†Statist index: from 1847, index compiled by the *Statist* newspaper, London, continuing the original calculations of A. Sauerheck, with base shifted from 1867–77=100 to 1913=100; before 1847, index compiled by W. S. Jevons (*Journal* of the Royal Statistical Society, London, 1865) equated to the *Statist* index at the average of the decade 1853–62.

TABLE V.—Prices in 1948 (*1938=100*)

	Wholesale	Retail
Prices of food products before subsidies	255	200
Prices of food products after subsidies	175	150

Source: R. G. D. Alien, "Wholesale Prices, 1938–48," *Economic Journal* (London, 1949).

In the period of booms, depressions and wars, 1880–1938, there is one broad conclusion which stands out—foodstuffs tended to become relatively cheaper and textiles and clothing relatively dearer. Moreover, this divergence is greater in retail prices than in wholesale prices. Retail and wholesale prices of food (and also of textiles and clothing) marched together quite closely up to 1914 hut, in the general decline of prices between 1924 and 1938, wholesale prices fell more rapidly than retail. The increased margin between wholesale and retail prices arose, at least in part, because of the greater importance of distributive

TABLE VI.—*Wholesale* and *Retail Prices*, *United Kingdom*, *1880–1938*

Year	Wholesale prices* (1913=100)			Retail prices† (July 1914=100)		
	Food	Textile materials	Coal	Food	Clothing	Fuel
1850	I22	96	71	115	86	86
1881	118	92	79	111½	86	89½
1882	116	95	79	111	85	85
1883	116	83	84	111½	83	88
1884	103	81	77	103½	82	87
1885	96	77	77	94	81	87
1886	94	75	74	91	81	85
1887	91	77	74	88	81	84
1888	94	76	77	89	80	85
1889	97	83	82	91	79	86
1890	95	79	88	90	81	93
1891	100	70	88	92	81	91
1892	45	68	86	93	80	91
1893	94	70	91	88	79	99
1894	86	63	77	85	78½	85
1895	83	62	69	82	78	82½
1846	81	64	69	82	78½	84
1897	84	61	73	85	78	85
1898	88	61	78	88	77	85
1899	84	69	86	85	76	92
1900	90	79	109	89	79	116
1901	87	71	93	89	72	103½
1902	87	73	86	90	73	99
1903	86	79	77	92	79	94
1904	88	85	76	91	86	92
1905	90	86	71	92	86½	91
1906	90	95	77	91	96	92
1907	94	92	92	94	93	103½
1908	94	74	84	95½	74½	100
1909	95	76	82	96½	77	98
1910	96	87	80	97	88	98
1911	97	90	83	97	94	99
1912	105	90	101	102	94	101
1913	100	100	100	103	101	100
1914	105	96	99	100	100	100
1915	'39	110	143	131	122	122
1916	169	154	128	160	157½	134
1917	219	229	128	198½	207	145
1918	226	264	156	215	311	174
1919	240	271	210	219	361	193
1920	304	312	148	256	416	212
1921	205	167	150	229½	303	242½
1922	169	160	159	176	238	202
1923	158	167	150	169	222½	184
1924	169	202	128	170	225	186
1925	166	196	138	171	229	182
1926	155	158	141	164	221	205
1927	148	156	107	160	214	183
1928	148	162	99	157	219	169
1929	143	145	108	154	218	171
1930	125	100	115	145	211	172½
1931	108	75	114	131	196	174
1932	103	76	108	126	189	172
1933	96	80	105	120	184	170
1934	100	86	94	122	186	170
1935	99	95	94	125	187	170
1936	roj	99	107	130	189	174
1937	121	111	113	139	202	178
1938	109	89	119	140½	209	181

*Wholesale prices: constituents of *Statist* index (*see* Table IV); food and textile material; are group index numbers, coal is a single price quotation (Wallsend Hetton in London to 1916, then Rest Yorkshire house). †Retail prices: estimates by A. L. Bowley, *Wages and Income in the United Kingdom Since 1860* (Cambridge University Press, 1937), continued by constituents oi the cost of living index compiled from 1914 by the Ministry of Labour, London.

and marketing services. This mas particularly true of textiles and clothing: in 1937–38 wholesale prices of textile materials stood approximately at the level of 1913 but retail clothing prices were more than double those of 1913. A similar comparison for foodstuffs shows a less marked difference: retail food prices in 1937–38 were about 40% above 1913 while wholesale prices of foodstuffs had risen by about 10% in the same period.

Wholesale prices of coal and retail prices of fuel showed a similar divergence. Wholesale prices of coal increased in the late 19th century but, at the end of the 1920s, they stood little higher than they were before World War I. On the other hand. retail prices of coal, gas and electricity were 70% higher in 1928–29 than in 1913. The 1930s were characterized by an upward movement in fuel prices, while other prices generally tended to fall

The mocement of prices during World Wai 11 and the postwar period can be followed with the aid of index numbers of more elaborate construction than those used for earlier periods. The data are summarized in Table VII. Changes in the general level of wholesale prices in World Wars I and 11 were broadly similar (*see* fig. 3). According to the index shown in Table VII, there was a rapid rise in prices, amounting to about 55% in the first three years of war, 1939–42. This was followed by a period of slowly rising prices, as price control became effective, and prices at the close of the war mere generally only 5%–10% higher than in 1942. The price rise was accelerated in the postwar period and amounted to 30% in the three years 1945–48. The increases shown by the index of Table VII are less than those recorded by the *Statist* index (fig. 3). The latter comprises mainly the prices of basic commodities whereas the former includes prices of many mandfactured products which were subject to price control and, in particular, to the effect of subsidies. The general comparison with World War I, however, is clear Though the price movements were similar in general direction, the initial rise in prices after 1939 was more moderate, price controls were more effective and operated more quickly, and there was no repetition after 1945 of the postwar crisis of 1920.

The feature of price control, in the postwar period of 1945–48 as much as during the war, was the effect of subsidies (including trading losses in government purchasing) in moderating the rise in prices. Subsidies were largeiy, though by no means entirely, concentrated on the main foodstuffs and they affected both wholesale and retail prices. If a range of prices of food products is taken for comparison at wholesale and at retail, the results shown in Table V (in round figures) are obtained.

A similar result is found for clothing prices in the period before the removal of clothing subsidies at the beginning of 1948. Subsequently, the continued operation of the "utility" clothing scheme acted as a cushion in absorbing part of the rise in prices of textile materials. Another effective group of subsidies was that on iron and steel products, taking the form of trading losses in government purchases of imported ores, scrap, pig iron and steel.

The general upward movement in prices continued until the middle of 1948 (when there was a downturn in world prices of foodstuffs and raw materials) ; it was normal during the war in Korea in 1950–51. The effect of lower world prices in 1948–50 and after 1951 on British prices at wholesale and at retail, was more than counterbalanced by two particular factors. The first was the policy of limiting the cost of subsidies, introduced early in 1949 with increases in the price of iron and steel products and of certain foodstuffs. The second was the devaluation of sterling (Sept 18, 1949) which was followed by rises in the sterling prices of manv imported commodities and then by rising domestic prices, both wholesale and retail.

OTHER COUNTRIES

The course of prices in various countries can only be assessed and compared after reference to the rates of exchange between national currencies. A suitable standard of comparison is the course of prices in the U.S. and the rates of exchange required are then the rates between various national currencies and the U.S. dollar (see Table VIII).

As an illustration of the relevance of rates of exchange, prices in France, expressed in terms of the French franc and related to 1913 as a base year, should be considered. At parity in 1913 the French franc was equivalent to 19.3 U.S. cents. The rate of exchange varied after World War I before settling down, in 1927–31, at the devalued rate of 3.92 cents per franc. Later, on the devaluation of the dollar, the franc appreciated and the rate of exchange in 1934–35 was 6.60 cents per franc. Wholesale prices in the U.S. varied as follows: 1913, 100; 1929, 137; 1935, 115.

If wholesale prices in France had followed the same course, except that they were denominated in French francs instead of U.S. dollars, then the index figure in 1929 would have been nearly five times as great as that for the U.S. (19.3 divided by 3.92) and in 1935 nearly three times as great (19.3 divided by 6.60). Wholesale price index numbers for France would then be: 1913, 100; 1929, 675; 1935, 340. The recorded levels of wholesale prices in France (in round figures) were: 1913, 100; 1929, 630; 1935, 340.

There are many factors, such as changes in freight rates, domestic costs and taxes or subsidies, that operate to make domestic prices

TABLE VII.—*Wholesale* and Retail Prices, United Kingdom, *1929* and *1935–54* (*1938=100*)

Year	Wholesale prices*						Retail prices†				
	Total	Food and to-bacco	Coal	Iron and steel	Cot-ton	Wool	Total	Food	Drink and tobacco	Fuel and light	Clothing and household goods
1929	113	118	83	73	152	133	—	110	100	95	—
1935	88	89	83	72	104	89	—	89	101	94	—
1936	93	94	87	77	106	104	—	92	100	96	—
1937	107	105	101	93	117	126	—	99	100	98	—
1938	100	100	100	100	100	100	100	100	100	100	100
1939	101	100	98	95	106	104	102	102	107	101	102
1940	135	136	114	114	150	155	119	116	141	114	126
1941	150	150	129	130	165	168	130	123	160	121	155
1942	157	161	139	131	169	171	139	125	197	128	173
1943	160	164	151	131	164	175	143	125	225	128	171
1944	164	162	170	132	184	181	146	125	237	133	175
1945	167	162	192	136	194	181	148	127	231	138	176
1946	173	163	198	150	207	184	154	134	236	139	170
1947	189	169	204	159	239	209	163	142	267	141	178
1948	216	186	241	169	359	272	175	154	306	154	194
1949	227	202	247	182	384	301	180	161	305	157	203
1950	259	227	—	188	—	—	185	172	295	161	209
1951	315	254	—	211	—	—	202	191	298	177	243
1952	323	292	—	254	—	—	221	221	305	197	254
1953	324	315	—	260	—	—	228	233	307	207	249
1954	325	315	—	263	—	—	232	239	307	216	249

*Wholesale prices: index compiled by the Board of Trade. London. with base switched from 1930=100 to 1938=100.

†Retail prices: estimates by London and Cambridge Economic Service, London School of Economics (see *Bulletin* ior Feb. 1949); clothing and household goods is a combination of three groups (clothing; household durable.;; miscellaneous goods) in the interimindex of retail prices compiled since 1947 by the Ministry of Labour, London.

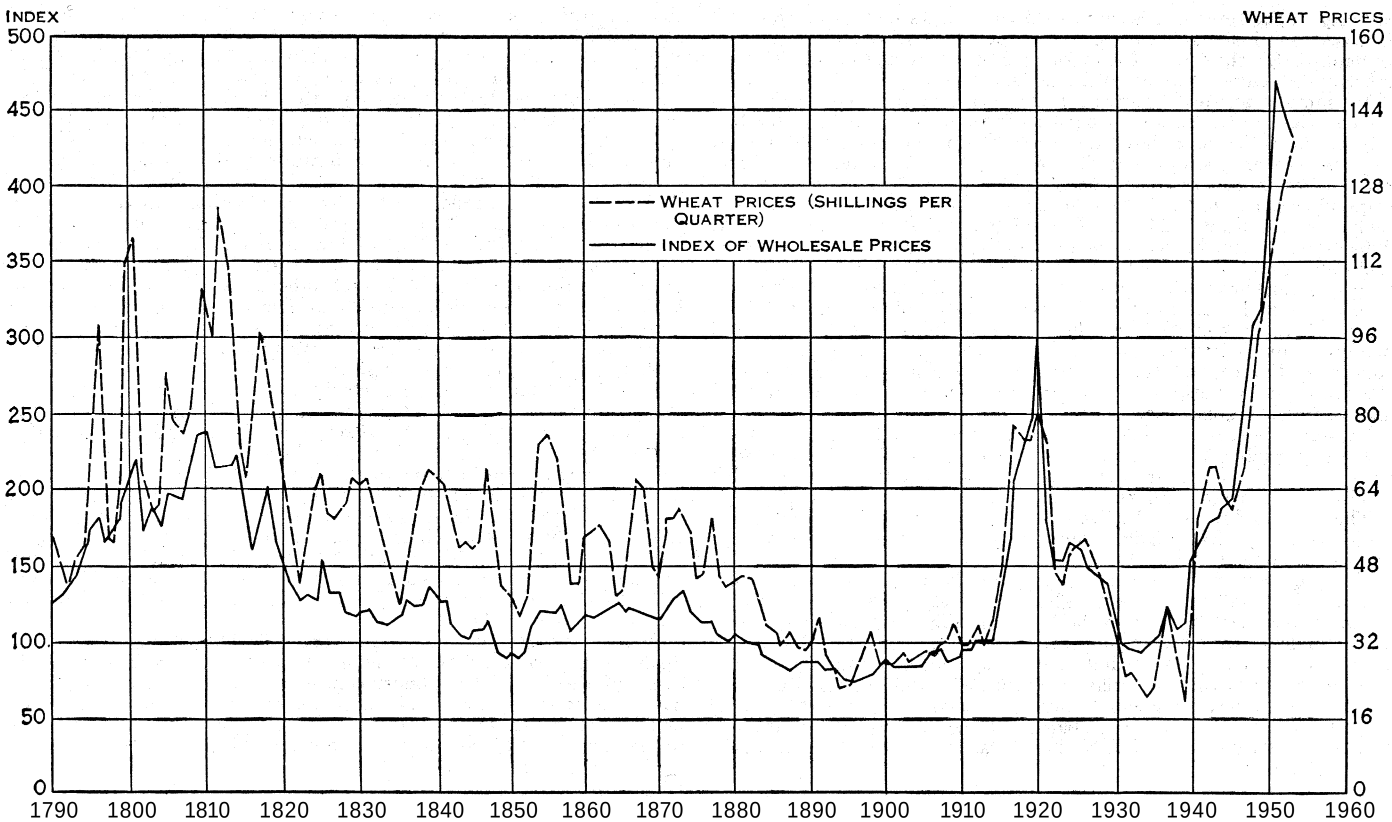


FIG. 3—WHOLESALE PRICES AND WHEAT PRICES. UNITED KINGDOM (1913=100)

diverge from world or import prices. In most important countries, however, wholesale prices are in fact largely determined by world prices, and particularly by prices in the U.S., at least during periods of stable rates of exchange. The correspondence between French wholesale prices in francs and U.S. wholesale prices was close in 1929 and 1935, each year being related to 1913.

In the period between World Wars I and II the pound sterling diverged little from parity with the U.S. dollar, except during the period before the restoration of the gold standard in the United Kingdom in 1925, and again briefly about 1932 when the gold standard mas suspended 18 months before the U.S took similar action. The general movements of prices (*e g* , a comparison of prices in 1929 or 1938 with those of 1913) are broadly comparable in the U.K. and the U.S. without modification for changes in the sterling-dollar exchange rates. The

TABLE VIII.—*Exchange Rates, 1921–53*
(U.S. cents per unit of national currency)

Year	Czechoslovakia (koruna)	Denmark (krone)	France (franc)	Italy (lira)	Netherlands (guilder)	Spain (peseta)	Sweden (krona)	Switzerland (franc)	U.K. (£)	Australia (£A)	Canada ($)	S. Africa (£[S.A.])	Egypt (£E)	India (rupee)	Japan (yen)	Argentina (peso)	Peru (sol)
1913 (parity)	20.30	26.8	19.3	19.30	40.2	19.3	26.8	19.3	487	487	100	487	—	—	49.8	42.4	48.7
1921	1.26	17.8	7.46	4.30	33.6	13.5	22.6	17.4	385	379	89.6	—	—	—	48.7	32.1	37.6
1922	2.41	20.9	8.19	4.75	38.5	15.5	26.2	19.1	443	441	98.6	449	—	—	48.1	36.0	38.5
1923	2.96	18.4	6.07	4.60	39.1	14.5	26.6	18.1	457	460	98.0	466	—	—	48.6	34.6	41.6
1924	2.95	16.7	5.23	4.36	38.2	13.3	26.5	18.2	442	450	98.7	454	—	—	41.2	34.3	41.0
1925	2.97	21.1	4.77	3.98	40.2	14.3	26.9	19.3	483	489	100.0	484	—	—	41.0	40.2	40.6
1926	2.96	26.2	3.25	3.89	40.1	14.9	26.8	19.3	486	486	100.0	483	—	—	47.1	40.5	37.5
1927	2.96	26.7	3.92	5.15	40.1	17.1	26.8	19.3	486	485	100.0	484	—	—	47.4	42.3	37.4
1928	2.96	26.7	3.92	5.26	40.2	16.6	26.8	19.3	487	485	99.9	484	—	—	46.4	42.4	39.7
1929	2.96	26.7	3.92	5.24	40.2	14.6	26.8	19.3	486	483	99.3	483	—	—	46.1	41.8	40.0
1930	2.96	26.7	3.92	5.24	40.2	10.4	26.8	19.4	486	471	99.8	484	—	—	49.4	36.5	36.1
1931	2.96	24.7	3.92	5.22	40.2	9.5	24.9	19.5	486*	411	96.3	481*	—	—	48.9	28.9	27.9
1932	2.96	18.7	3.93	5.14	40.3	8.0	18.4	19.4	350	306	88.1	482	—	—	28.1	25.7	21.3
1933	3.68	18.5	4.86	6.44	49.8	10.3	21.5	24.2	422	277	92.0	422	—	—	25.2	30.9	18.8
1934	4.23	22.3	6.57	8.56	67.6	13.5	25.9	32.4	504	390	101.0	501	—	—	29.5	25.3–33.6†	23.0
1935	4.15	21.8	6.60	8.24	67.6	13.6	25.2	32.5	490	392	99.5	487	—	—	28.6	26.3–32.7	23.9
1936	3.98	22.1	5.98	7.03	68.0*	13.5	25.6	32.7*	497	394	99.9	494	510	37.4	29.0	27.8–33.2	24.9
1937	3.49	22.0	3.98	5.26	54.9	11.7	25.4	22.9	494	393	100.0	492	507	37.2	28.8	30.0–33.0	25.3
1938	3.46	21.8	2.86	5.26	54.9	11.6	25.1	22.9	489	396	99.4	486	501	36.4	28.5	25.5–32.6	22.4
1939	3.41*	20.3	2.64*	5.20	53.2	10.7	24.0	22.5	467*	376	99.6*	443	457	33.0	26.0	23.1–30.6	18.7
1940	—	19.3	2.28*	5.05	53.2	9.3	23.9	22.7	403	328	90.5	403	413	30.1	23.4	22.9–29.8	16.2
1941	—	19.3	2.28	5.07	53.2*	9.1	23.9	23.2	403	322	90.5	403	413	30.1	23.4*	20.3–29.8	15.4
1942	—	20.9*	2.28	5.26	—	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1943	—	20.9	2.28	1.00*	—	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1944	—	20.9	2.28	1.00	—	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1945	2.00*	20.9†	2.01	1.00	37.7*	9.1	23.9	23.3	403	322	90.5	403	413	30.1	—	20.3–29.8	15.4
1946	2.00	20.8	.84		37.7	9.1	23.9*	23.3	403	322	100.0*	403	413	30.1	—	20.3–29.8	15.4
1947	2.00	20.8	.84	—	37.7	9.1	27.8	23.3	403	322	100.0	403	413	30.1	—	20.3–29.8	15.4
1948	2.00	20.8	.47*	.18	37.7	9.1	27.8	23.3	403	322	100.0	403	413	30.1	—	20.0–29.8	15.4
Aug. 1949	2.00	20.8	.47	.18	37.7	9.1	27.8	23.3	403	322	100.0	403	413	30.1	—	20.0–29.8	15.4
Sept. 1949	2.00	14.4	.29	.16	26.3	—	19.3	23.1	280	223	90.5	280	287	20.9	—	13.9–29.8	5.6‡
1950	2.00	14.5	.29	.15	26.3	9.1	19.3	23.1	280	224	90.9	280	287	21.0	0.28	13.9–29.8	6.7
1951	2.00	14.5	.29	.15	26.3	9.1	19.3	23.1	280	224	95.0	280	287	21.0	0.28	13.3–20.0	6.6
1952	2.00	14.5	.29	.15	26.3	4.6	19.3	23.2	280	224	102.2	280	287	21.0	0.28	13.3–20.0	6.5
1953	2.00	14.5	.29	.16	26.3	4.6	19.3	23.3	280	224	101.7	280	287	21.0	0.28	13.3–20.0	5.9

Figures are officially established rates or market rates (mid-point between buying and selling rates). From 1928, data from International Monetary Fund quoted in UN *Statistical Yearbook;* before 1928 from League of Nations *Statistical Yearbook*.
*Relating to part of year only. †Argentina, from 1934: different rates used for various transactions and a range (lowest–highest rate) shown. ‡Free (certificate) rate.

validity oi the foregoing account of price changes in the two countries is based on this fact. The same is true of other countries, such as Canada or South Africa, Denmark or Sweden, whose currencies were more or less closely related to the dollar or sterling.

In some, countries, however, there were limited depreciations or appreciations of the national currencies in terms oi sterling and the U.S. dollar. Australia depreciated the Australian pound in terms of sterling in 1930. In any comparison of periods before and after 1930, therefore, prices in Australia will be found to have risen more than corresponding prices in the U.K. On the other hand, the Netherlands and Switzerland did not follow the U.S. off the gold standard in 1933. and when their currencies were revalued in 1936, they did not depreciate them as far as the U.S. did. After 1933 the Netherlands and Switzerland had currencies which were appreciated relative to sterling and the U.S. dollar and their price levels were correspondingly lower. There were still other countries in which inflation following World War I proceeded much further than elsewhere. The interwar years in such countries — France and Italy being among the more important — were characterized by periods of instability iollowed by currency reforms and periods of greater stability. The exchange rate in terms of the U.S. dollar fluctuated between stability and instability, but always much depreciated as compared with the rate in 1913. The course of prices showed similar fluctuations but always around much higher levels (as compared with 1913) than reached in the U.K. or the U.S.

The year of highest prices aiter World War I was generally 1920. There mas a general fall in wholesale prices irom 1921, steep at first and then more gradual. In most countries the fall continued slowly until 1929, though there was a subsidiary rise in prices around 1924, followed by a fall in 1926–27. This is, in fact, the broad pattern set by the movement of prices in the U.K. and the U.S. The closeness of correspondence of price movements was greater for countries on the gold standard and these included, by 1925, the U.K., the British dominions, Sweden, the Netherlands, Switzerland and others, in addition to the U.S. There were some important deviations from the general pattern. In France and Italy in particular, depreciation of the currency relative to sterling and the U.S. dollar was resumed in 1922 and continued in the following years; the French franc and Italian lira were not stabilized until 1927–28. The fall in mholesale prices in France and Italy mas halted in 1922 and prices then rose rapidly in France, and more moderately in Italy, until 1926, in which year the price level was above that reached immediately after the war. From 1926, prices in both countries, as in other countries, decreased slowly until 1929. In Japan prices remained high in the whole period irom 1921 to 1925 and only began to fall with the stabilization of the currency in 1926.

Aiter the stock market crash in the U.S. late in 1929, wholesale prices declined everywhere, following to a greater or less extent the rapid fall in prices in the U.S. The gold standard was suspended in the U.K. in Sept. 1931, and in the U.S. in March 1933. The devaluations of the two currencies were approximately equal in amount so that they bore about the same relation to each other after 1933 as in 1929. In both countries, wholesale prices fell to a low point in 1932–33 when their level was not quite 70% of the 1929 level. The effect of the world-wide depression on prices in other countries was varied but three broad groupings can be distinguished.

In a first group are countries which devalued their currencies about the same time as the U.K. in 1931. Some countries devalued to the same extent hut others, like Sweden and Denmark and also Australia, decided upon a greater devaluation. The currencies of these latter countries depreciated in terms of the U.S. dollar, not only in 1931–33, but also aiter the devaluation in the U.S. in 1933. This depreciation of national currencies offset to some extent the fall in world prices and, though the low point of wholesale prices was still reached about 1932, the level was 75%–80% of 1929 rather than 70% or less. Japan followed much the same course; but wholesale prices had already fallen to 70% of the 1929 level by 1931 (before devaluation) and then recovered immediately.

In a second group of countries, represented in Tables VIII–X by Spain, Argentina and Peru, the national currencies were depreciated in terms of the U.S. dollar almost continuously irom 1929 to 1932–33. The offset to the fall in world prices mas greater, though the currency depreciation was in no case quite sufficient to prevent wholesale prices in the national units from falling. Low points in the level of wholesale

TABLE IX.—*Wholesale** and *Retail*† Prices, Certain Countries, *1913–14* and *1921–38*

Year	Czechoslovakia		Denmark		France		Italy		Netherlands		Spain		Sweden		Switzerland	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail
1913	—	—	100	—	100	—	100	—	100	100	100	—	100	—	—	—
1914	100	100	—	100	102	100	—	100	109	—	101	100	116	100	100	100
1921	—	—	—	225	345	309	531	559	182	202	190	189	222	247	200	200
1922	—	—	—	199	327	296	508	515	160	182	176	181	173	198	158	164
1923	—	—	—	207	419	334	512	499	151	174	172	177	163	178	170	164
1924	986	695	—	216	489	369	512	527	156	177	182	184	162	174	171	169
1925	997	724	210	211	550 ‡	400	596	611	155	179	185	189	161	176	161	168
1926	944	716	163	184	695	505	603	654	145	168	175	187	149	172	145	162
1927	968	747	153	177	642	514	495	588 ‡	148	168	168	189	146	171	142	160
1928	969	748	153	175	645	519	462	558	149	169	163	176	148	172	145	161
1929	913	744	150	173	627	556	446 ‡	570	142 ‡	168	168	181	140	170	141	161
1930	811	727	rgo	165	554	581	399	552	128	161	167	186	122	165	127	158
1931	738	695	114	155	502	569	348	497	109	151	169	194	111	159	110	150
1932	682	682	117	155	427	526	326	473	92	141	167	187	109	157	96	138
1933	658	675	125	161	398	520	297	455	90	139	159	180	107	153	91	131
1934	678	667	137	167	376	516	290	430	90	140	164	184	114	155	90	129
1935	704	687	140	172	338	483	319	437	88	136	165	179	116	156	90	128
1936	706	693	146	175	411	507	358	471	91	132	167	—	120	158	95	130
1937	748	702	16j	181	581	619	416	516	108	137	189	—	137	163	111	137
1938	742	734	156	183	653	698	447	558	102	139	212	—	130	167	107	137

Year	Australia		Canada		S. Africa		Egypt		India		Japan		Argentina	Peru	
	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Retail	Wholesale	Wholesale	Retail
1913	100	—	100	—	100	—	—	—	—	—	100	—	100	100	100
1914	106	100	102	100	97	100	100	100	100	100	97	100	101	104	104
1921	175	165	172	165	160	162	173	196	178	173	200	—	143	205	199
1922	162	146 ‡	152	152	128	135	146	176	176	164	196	236	130	190	190
1923	179	145	153	152	127	131	132	162	172	154	199	221	135	189	180
1924	173	143	155	148	129	133	143	161	173	157	207	221	145	192	187
1925	170	144	160	150	128	133	152	165	159	155	202	218	147	202	200
1926	168	146	156	152	123	131	132	160	148	155	179	199	133	203	201
1927	167	145	153	149	124	131	121	153	148	154	170	189	130	203	194
1928	165	146	151	150	129	131	120	152	145	147	171	184	131	192	181
1929	147	149	149	151	116	131	116	151	141	149	166	181	128	186	177
1930		141	135	150	103	128	104	148	116	137	137	155	122	178	169
1931	131	127	113	136	99	123	97	138	96	110	116	136	118	175	158
1932	130	121	104	123	92	118	84	132	91	109	122	137	119	170	151
1933	130	117	105	117	93	115	71	12j	87	102	136	146	114	180	148
1934	131	119	112	119	102	116	87	127	89	97	134	149	130	188	150
1935	134	121	112	120	95	116	95	130	92	101	140	151	129	189	152
1936	140	123	116	122	99	116	85	130	92	102	149	159	132	192	160
1937	148	127	132	126	101	119	88	128	102	107	180	174	150	205	171
1938	148	130	123	127	104	123	92	131	96	107	190	199	140	205	173

*Wholesale prices: official index numbers, based on or with base switched to average 1913 or 1914=100 with two exceptions, the index for Italy being computed by Riccardo Rachi (1921–29) and that for Japan by the Bank of Japan. The index numbers relate to general wholesale prices except for Australia (Melbourne only), Egypt (Cairo only), India (Calcutta only! and Japan (Tokyo only).

†Retail prices: official index numbers of the cost of living or retail prices to working-class families based on or with base switched to average 1914 or July 1914=100 except those for the Setherlands (average 1911–13=100) and Peru (average 1913=100). The index for Japan computed by the Bank of Japan. Some index numbers relate to the principal city, others to a group of large towns in the country concerned. All index numbers comprise prices of food, rent, fuel and clothing except those for Spain (food and fuel only) and **Japan** (rent excluded: Data extrarted from the League of Nations *Statistical Yearbook.*

‡Important break in the comparability of series of index numbers.

prices were reached, in 1932–33, at 90%–95% of the 1929 figures.

The last group of countries comprises those which did not devalue their currencies with the U.K. and the U.S. in 1931–33. Devaluation was postponed, generally until 1936. The Netherlands, France and Switzerland belong to this group and, despite some differences, Italy can be added to the list. The governing fact here is that national currencies appreciated in terms of sterling from 1931 and in terms of the U.S. dollar from 1933. The fall in world prices was amplified in translation into wholesale prices in national units. The fall in domestic wholesale prices was of greater extent and operated over a longer period than in the U.K. and the U.S. Low points were reached generally about 193j and at levels between 55% and 655% of 1929.

The recovery in prices from the bottom of the depression was almost as rapid as the preceding fall and, except in France and Italy, it had come to an end by 1937. In that year wholesale prices in the U.K. and the U.S. stood about 20% above the level of 1913 and a little below the 1929 figures. In some countries, like the Netherlands and Switzerland, whose currencies appreciated in relation to sterling and the U.S. dollar in the 1930s, the 1937 level of wholesale prices was rather lower—a little above the 1913 level but 20%–25% below 1929. On the other hand, in countries like Spain, Argentina and Peru where the national currency continued to depreciate in the late 1930s, wholesale prices in 1937 stood higher, often at levels about double that of 1913 and well above 1929. The price situation in France, and to a lesser extent in Italy, was exceptional in the years immediately before World War II. As in the Netherlands and Switzerland, the rise in prices began late because of the postponed devaluations of currency. But in France and Italy the revaluation of the currency was much more drastic and the price rise from 1936 was rapid and also continued beyond 1937. By 1939, the level of wholesale prices was above that of 1929 but the process of adjustment was not complete and prices would probably have risen further even if war had not inter\-ened.

TABLE X.—*Wholesale and Retail Prices,* Certain Countries, 1929, 1932, 1938 and 1946–54*

(1948=100)

Year	Denmark Wholesale	Denmark Retail	France† Wholesale	France† Retail	German Federal Republic Wholesale	German Federal Republic Retail	Italy Wholesale	Italy Retail	Netherlands Wholesale	Netherlands Retail
1929	43	57	5	—	—	—	2	2	50	—
1932	33	51	3	—	—	—	1	2	33	—
1938	44	60	5	6	51	64	2	2	36	49
1946	83	95	34	—	—	—	53	58	89	93
1947	91	98	52	—	—	—	95	94	96	97
1948	100	100	89	86	100	100	100	100	100	100
1949	102	101	100	100	97	107	95	101	104	106
1950	115	107	108	111	94	100	90	100	117	109†
1951	147	119	138	130	112	108	103	110	143	122
1952	143	123	145	145	114	110			140	122
1953	134	123	138	144	111	108		114	134	122
1954	134	124	136	143	110	108	97	120	136	129

Year	Spain Wholesale	Spain Retail	Sweden Wholesale	Sweden Retail	Switzerland Wholesale	Switzerland Retail	Australia Wholesale‡	Australia Retail	Canada Wholesale	Canada Retail
1929	22	—	56	67	61	72	77	79	64	79
1932	22	—	44	61	41	62	56	64	45	64
1938	28	—	52	65	46	61	63	69	53	66
1946	80	80	83	93	96	93	79	88	84	80
1947	93	94	93	96		97	84	92		87
1948	100	100	100	100	100	100	100	100	100	100
1949	107	105	101	102	95	99	116	109	103	104
	126		106		94	98	138	120	109	107
	162		140		105	102	176	146	124	118
1952	164	125	148	129	102	105	203	170	117	121
1953	175	127	139	130	98	104	214	186	114	120
1954	176	129	138	131	99	105	211	179	112	121

Year	South Africa Wholesale	South Africa Retail	Egypt Wholesale	Egypt Retail	India Wholesale	India Retail	Argentina Wholesale	Argentina Retail	Peru Wholesale	Peru Retail
	64	72	—	42	—	—	35	53	23	31
	59	65	—	36	—	—	32	41	21	26
1938	57	68	31	36	26	—	38	49	26	30
1946	89	91	98	102	74	79	85	78	59	59
1947	94	95	92	99	81	90	91	88	80	76
1948	100	100	100	100	100	100	100	100	100	100
1949	106	104	94	99	104	103	119	131	140	115
	113					183	—	165	163	129
	120					107	—	225	191	142
1952	148	126	113	113	105	105	—	312	201	152
1953	149	130	108	105	107	108	—	324	204	165
1954	150	133	105	101	105	104	—	335	225	175

*Official index numbers of general wholesale prices; and of cost of living or retail prices to working-class families, comprising prices of food, rent, fuel, clothing and miscellaneous items. Some index numbers relate to the principal city only. All have base switched to average 1948=100, except 15here noted otherwise. Data from UN *Statistical Yearbook.*
†Average 1949=100. ‡Domestic goods only.

Early in World War II, most countries devalued their currencies or allowed them to depreciate in terms of the U.S. dollar; after the war there were many adjustments, a few upward but most downward in relation to the dollar. The position in 1948 was that a small group of countries, including Canada, Sweden and Switzerland, had maintained or restored their currencies to parity with the U.S. dollar. Another group, including the Netherlands and Denmark as well as the countries of the sterling area, had devalued to a moderate amount in relation to the U.S. dollar. The difference was larger in Spain and many countries of Latin America, following long periods of almost continuous depreciation in terms of the dollar. The most drastic devaluations of all were in the French franc and Italian lira, occurring for the most part after the war.

The relative levels of wholesale prices in the various countries after the war were largely dependent on these currency adjustments, though there were considerable divergencies from the general pattern. Prices rose during the war and even more sharply in the early postwar years. By 1948 wholesale prices in the U.S. were rather less than douhle those in 1937; in the U.K. the change was somewhat greater, the 1948 price level being a little more than double that of 1937. The position in the British dominions, Denmark, Sweden and Switzerland was broadly the same, though there were some variations; for example, the price increase from 1937 in Australia was relatively small and in Switzerland relatively large. In the Netherlands, the price level in 1948 was higher, about two and one-half times the 1937 figure, following a rapid rise after liberation of the country. In Spain. and in some Latin American countries for which data were available, wholesale prices in 1948 were between three and four times the level of 1937, as were prices in Egypt and India. The most striking effects of inflation and currency devaluation are to be seen in price changes in France and Italy. French wholesale prices in 1945 were already more than 4 times those of 1937, but in 1948 they were about 20 times the 1937 figure and still rising. It was not until 1949 that prices in France were brought under control.

The inflation was even more rapid in Italy, particularly between 1944 and 1947, and wholesale prices in lire reached a level nearly 60 times that of 1937. A greater degree of stability in Italian prices was attained in 1948 and 1949; despite some fluctuations, the general rise in prices was halted in these years.

The countries of the sterling area, following the lead of the U.K., devalued their currencies in terms of the U.S. dollar in Sept. 1949. The currencies of most countries in western Europe were devalued at the same time. although not all to the same extent as sterling (*see* Table VIII). Wholesale prices in these countries rose immediately, reversing a tendency toward lower prices which had become evident earlier in 1949, and which continued throughout the year in the United States.

There is much less correspondence between retail prices in different countries (allowance being made for exchange rates) than between prices at wholesale. Many prices at retail are less dependent upon world prices of commodities and some are almost completely insulated against price changes outside the country concerned. Retail prices of commodities are influenced by domestic costs, controls, subsidies and taxation. and index numbers of retail prices, generally relating to the cost of living of working-class families, include rent and other services. A general pattern, however, does emerge. Following the boom and collapse after World War I, retail prices were generally higher (relative to 1913–14) than wholesale prices and the difference was accentuated during the interwar period. On the other hand, retail prices generally rose less between 1937 and 1948 than wholesale prices. This was largely the result of price controls, particularly on rents as well as important commodities, and to the continuation after World War II of wartime policies of subsidizing foodstuffs and other commodities purchased by working-class families. In those countries where wholesale prices in 1948 were about double those in 1937, retail prices had generally increased by about 50%–80% in the same period.

International comparisons of the purchasing power of national currencies are peculiarly difficult to make. The level of retail prices in one country needs to be compared, with allowance for the exchange rate, with the level of retail prices in another country; it is not sufficient to compare the movements of retail prices over time in one country with similar movements in another country. The most complete calculations are those made by Colin Clark (for his *The Conditions of Economic Progress*, see *Bibliography*).

BIBLIOGRAPHY.—A. L. Bowley, *Wages and Income in the United Kingdom Since 1860* (Cambridge, New York, 1937); Colin Clark, *The Conditions of Economic Progress*, 2nd ed. (London, New York, 1951); W. S. Jevons, *Investigations in Currency and Finance* (London, 1884); W. T. Layton and G. Crowther, *An Introduction to the Study of Prices*, 3rd ed. (London, New York, 1938); A. Sauerbeck. *The Course of Average Prices of General Commodities in England, 1818–1907* (London, 1908); G. Tintner, *Prices in the Trade Cycle* (New York, 1935); T. Tooke and W. Newmarch, *A History of Prices and of the State of Circulation from 1792 to 1856*, 6 vol. (London, 1838–57; reprint 1928). (R. G. D. A.)

PRICHARD, HAROLD ARTHUR (1871–1947), a leading member of the Oxford "intuitionist" school of moral philosophers, spent most of his life teaching at Oxford, where he was fellow of Hertford college from 1895 to 1898 and of Trinity college from 1898 to 1924 and White's professor of moral philosophy from 1928 to 1937.

Prichard held that the notion of duty or "ought" is ultimate and irreducible. We become aware of this notion by reflecting on instances of it; in particular circumstances we know directly and immediately. by intuition, that a particular action is our duty. regardless of proof or argument. Moreover, "good" and "ought" are two distinct and mutually irreducible concepts; no proposition about the first can entail a conclusion about the second. Nor can our particular duties be deduced from some more general rule of duty; on the contrary, the ordinary moral rules are themselves generalizations of what we see to be our duty in particular cases.

Prichard also maintained that the rightness of an action does not depend in any way upon its motive; if this seems paradoxical, it is because we are liable to confuse motive with intention. With regard to the experience of conflicting obligations, he held that different obligations have different degrees of stringency and that in a particular case we can see which of two conflicting obligations is the more stringent. To account for cases of disagreement about duty, he contended that the capacity of direct moral apprehension may be more fully developed in one man than in another. In his last years Prichard came to think that duty depends not upon the situation as it actually is, but upon what a person believes the situation to be. He also devoted much attention to the concept of promising and concluded that "I promise to do so and so" is not a statement conveying true or false information, but that the utterance of these words itself constitutes the act of promising.

Prichard's theory of knowledge was a development of the "realistic" views of Cook Wilson. Knowing, he held, is something ultimate and *sui generis*, which differs in kind from any sort of belief or opinion; it is, as it were, the direct confrontation of mind and reality. But he eventually came to be dissatisfied with the "realistic" theory of sense perception. Instead he held that sense perception is a kind of illusion and that what is called seeing a chair consists of two distinct factors: (1) seeing a colour, whose *esse* is *percipi*, as Berkeley had said; and (2) mistaking this colour for a body of a certain sort. On this view, the material world cannot be known at all, in Prichard's strict sense of the word "know." Nevertheless, by means of a complicated argument from perceptions to their causes, he thought we could find good grounds for *believing* that material objects exist and for believing many detailed propositions about them.

For his arguments see *Kant's Theory of Knowledge* (Oxford, 1909), *Duty and Interest* (Oxford, 1928), *Moral Obligation* (Oxford. 1949) and- nowl ledge *and Perception* (Oxford, 1950), the latter two ed. by Sir W. D. Ross. (H. H. PE.)

PRICHARD, JAMES COWLES (1786–1848), British physician and philologist, whose specialty was the study of human races, was born on Feb. 11, 1786, at Ross, Herefordshire. He received his early education at Bristol, and early acquired knowledge of European and oriental languages. After attending St. Thomas's hospital. London, he went to Edinburgh, where he took his M.D. in 1808. Later he spent some time at Cambridge and at Oxford, but in 1810 settled in Bristol. He was appointed physician to St. Peter's hospital in 1811 and to the Bristol infirmary in 1814.

His Researches as to the Physical History of *Man* (1813) was expanded into a five-volume work (1836–47). In 1843 appeared his classic *Natural* History of *Man*, in which he concluded, accurately, that all mankind belongs to a single species. He was also deeply interested in Egyptology and in 1819 traced the early connection between the Hindus and the Egyptians and published a hieroglyphic alphabet. His Eastern Origin of *the* Celtic Nations (1831) established the place of Celtic languages as a branch of Indo-European. Prichard was also a pioneer in the scientific study of mental diseases, and was responsible for the concept of moral insanity as a distinct disease. Prichard was elected a fellow of the Royal society in 1827, and at the time of his death was president of the Ethnological society. In 1845, on being made a commissioner in lunacy, he moved to London, where he died on Dec. 23, 1848. (W. J. BP.; X.)

PRICKLY ASH (Zanthoxylum *americanum*), a North American shrub or small tree of the rue family (Rutaceae), called also a toothache tree, found in woods and thickets from Quebec to Minnesota and southward to Virginia and Missouri. While usually a shrub it sometimes attains a height of 25 ft. and a trunk diameter of 6 in. It bears alternate, pinnate leaves, composed of from 5 to 11 ovate, dark-green, somewhat pointed leaflets, with the twigs and leafstalks usually prickly. The small greenish flowers, which appear before the leaves in early spring, are borne in short axillary clusters; the fruit is a black ellipsoid capsule about one-sixth inch long, containing one or two seeds.

The similar but larger Herculesclub (*Z.* clavaherculis), known also as sea ash and pepperwood, occurs along streams from southern Virginia to Florida west to Kansas and Texas. Hercules'-club or devil's-walking-stick, *Aralia spinosa* of the ginseng family, a spiny shrub or small tree common in rich woods and on river banks from New York and Illinois to Florida and Texas, is also known as prickly ash and angelica tree. See ARALIA.

PRICKLY LETTUCE (Lactuca scariola), an annual or biennial herb of the family Compositae, closely allied to the garden lettuce (*q.v.*), native to Europe and widely distributed in temperate regions as a naturalized weed. It is a whitish green, usually smooth plant, with a stiff, erect stem, two to seven feet high, bearing oblong, more or less toothed or cut leaves, with spiny midribs and edges, usually clasping the stem by a more or less eared or heart-shaped base. The numerous heads of yellow flowers are borne in a large open panicle. The plant is noteworthy in that the leaves exhibit a marked tendency to become vertical. Moreover, when growing in open places, equally exposed to the sun during either half of the day, the vertical leaves often assume a north and south direction. Because of this characteristic the designation compass plant is sometimes applied to this species of lettuce, as it also is to various other plants of similar habit.

PRICKLY PEAR, the name given to cacti of the genus Opuntia, from the appearance of their fruit. There are about 250 species, all originally American, but several have been introduced elsewhere and, in some places (*e.g.*, Australia), have overrun the countryside. Most species have flattened, jointed stems, and the flowers are white or red. The prickly pear proper is O. vulgaris; O. ficus-indica is Indian fig. The fruit of both of these forms is edible. O. subulata is remarkable in that the leaves are large and functional. From O. tuna, the tuna hedges are grown in the West Indies, where it is also used as a food plant for the cochineal insect (Coccus cacti). See CACTUS.

PRIDE, THOMAS (d. 1658), Parliamentarian soldier in the English Civil War, was of obscure origins and early life. At the beginning of the Civil War he served as a captain under the earl of Essex and was gradually promoted to the rank of colonel. He distinguished himself at the battle of Preston, and with his regiment took part in the military occupation of London in Dec. 1648, which was the first step toward bringing the king to trial. Pride is chiefly remembered for the expulsion (Dec. 6, 1648) of the Presbyterian and Royalist elements in the house of commons. This was resolved by the army council and carried out by Colonel Pride's regiment. Taking his stand at the entrance of the house of commons with a written list in his hand, he caused the arrest or exclusion of the obnoxious members, who were pointed out to him. After about 140 members had been thus dealt with ("Pride's

Purge"), the mutilated house of commons proceeded to bring the king to trial. and Pride was one of the judges of the king.

Pride commanded an infantry brigade under Oliver Cromwell at Dunbar and Worcester. He took no conspicuous part in commonwealth politics, except in opposing the proposal to confer the kingly dignity on Cromwell. He was knighted by the Protector in 1656, and was also chosen a member of the new house of lords. He died at Nonesuch house, Surrey, on Oct. 23, 1658. Alter the Restoration his body was ordered to be dug up and suspended on the gallows at Tyburn along with those of Cromwell, Henry Ireton and John Rradshaw, though it is said that the execution of this sentence was evaded.

PRIDEAUX, HUMPHREY (1648–1724), English clergyman and Oriental scholar. born at Place. Cornwall, on May 3. 1648. was educated at Westminster school and Christ Church, Oxford. His account of the famous Arundel marbles just given to the university, *Marmora* Oxoniensia (1676). won for him the favour of Heneage Finch, who secured his rapid preferment. Prideaux held several livings, was Hebrew lecturer at Christ Church (1679–86), and dean of Norwich (1702–24). He died on Nov. 1. 1724.

Prideaux's most important work was *The Old and New Testament connected in the History* of *the Jews* (1716), which not only displayed but stimulated research.

PRIDE OF CALIFORNIA (Lathyrus *splendens*), a name given to a North American plant of the pea family (Leguminosae), native to the mountains of southern California, called also campo pea. It is closely allied to the sweet pea of the gardens, and bears showy clusters of brilliant red flowers.

PRIENE (mod. *Samsun* kale), an ancient city of Ionia on the foothills of Mycale, about 6 mi. N. of the Maeander. It was formerly on the seacoast. but now lies some miles inland. It is said to have been founded by Ionians under Aegyptus, a son of Neleus. Sacked by Ardys of Lydia, it revived and attained great prosperity under its "sage," Bias, in the middle of the 6th century. Cyrus captured it in 545; but it was able to send 12 ships to join the Ionian revolt (500–494). Disputes with Samos, and the troubles after Alexander's death, brought Priene low, and Rome had to save it from the kings of Pergamum and Cappadocia in 155. Orophernes, the rebellious brother of the Cappadocian king, who had deposited a treasure there and recovered it by Roman intervention, restored the temple of Athena as a thank offering. Under Roman and Byzantine dominion Priene had a prosperous history. It passed into Moslem hands late in the 13th century. The ruins, which lie on successive terraces, were excavated mainly in the late 19th century. The city, as rebuilt in the 4th and 3rd centuries: was laid out on a rectangular scheme. It faced south. its acropolis rising nearly 700 ft. behind it. The whole area was enclosed by a wall 7 ft. thick with towers at intervals and three principal gates. On the lower slopes of the acropolis was a shrine of Demeter. The town had six main streets, about 20 ft. wide, running east and west and 15 streets about 10 ft. wide crossing at right angles, all being evenly spaced; and it was thus divided into about 80 *insulae*. Private houses were apportioned four to an *insula*. The systems of water supply and drainage can easily be discerned. The houses present many analogies with the earliest Pompeian. In the western half of the city, on a high terrace north of the main street and approached by a fine stairway, was the temple of Athena Polias, a hexastyle peripteral Ionic structure built by Pythias, the architect of the Mausoleum. Under the base of the statue of Athena were found in 1870 silver tetradrachms of Orophernes, and some jewelry, probably deposited at the time of the Cappadocian restoration. Fronting the main street is a series of halls, and on the other side is the fine market place. The municipal buildings, Roman gymnasium, and well-preserved theatre lie to the north, but, like all the other public structures, in the centre of the plan. Temples of Isis and Asclepius have been excavated. At the lowest point on the south, within the walls, was the large stadium, connected with a gymnasium of Hellenistic times.

PRIEST, the contracted form of "presbyter" (πρεσβύτερος, "elder"; see PRESBYTER), a name of office in the early Christian church, already mentioned in the New Testament. Rut in the English Bible the presbyters of the New Testament are called "elders," not "priests"; the latter name is reserved for ministers of pre-Christian religions. The reason of this will appear more clearly in the sequel; it is enough to observe at present that, before our English word was formed, the original idea of a presbyter had been overlaid with others derived from pre-Christian priesthoods, so that it is from these and not from the etymological force of the word that we must start in considering historically what a priest is. The theologians of the Greek and Latin churches expressly found the conception of a Christian priesthood on the hierarchy of the Jewish temple, while the names by which the sacerdotal character is expressed—ἱερεύς, sacerdos — originally designated the ministers of sacred things in Greek and Roman heathenism, and then came to be used as translations into Greek and Latin of the Hebrew *kōhēn*. *Kōhēn*, ἱερεύς, sacerdos, are, in fact, fair translations of one another; they all denote a minister whose stated business was to perform, on behalf of the community, certain public ritual acts, particularly sacrifices, directed Godwards. Such ministers or priests existed in all the great religions of ancient civilization.

Early Priesthoods. — Among the Babylonians and Assyrians magic and soothsaying were intertwined with priestly functions, as was the case in early Hebrew pre-exilian days with the *Kōhēn*. The *barû* (from *barû* to see, inspect) was a soothsaying priest who was consulted whenever any important undertaking was proposed, and addressed his inquiries to Samaš the sun god (or Adad) as *bêl biri* or lord of the oracle (accompanied by the sacrifice of lambs). (See DIVINATION.)

As contrasted with the *barû* or soothsaying priest we have the *ašipu*, who was the priest-magician who dealt in conjurations (*šiptu*), whereby diseases were removed, spells broken, or in expiations whereby sins were expiated. Now, as the conjurations were addressed to the deity, *ašipu,* according to the definition given above, comes more reasonably under the category of priest. In Babylonia priesthoods were endowed with great wealth and power, and even the king stood in awe of them. (See Johns, Babylonian and Assyrian Laws, Contracts and Letters, p. 212 sqq.) These powerfully-organized priesthoods, as well as the elaborate nature of their ritual and apparatus of worship, must have deeply and permanently impressed the exiled Jewish community. Thus arose the more developed system of Ezekiel's scheme (xl.–xlviii.) and of the Priestly code and the high dignity which became attached to the person of the High Priest (reflected in the narrative of Uzziah's leprosy in 2 Chron. xxvi. 16–20).

Among the ancient Egyptians the local god was the protector and lord of the district. Consequently it was the interest and duty of the inhabitants to maintain the cultus of the patron-deity of their city who dwelt in their midst. Moreover, in the earlier times we find the prince of the nome acting as the High Priest of the local god, but in course of time the state, represented by the king, began to an ever-increasing degree to take oversight over the more important local cults. Thus we find that the Egyptian monarch was empowered to exercise priestly functions before all the gods. We constantly see him in the wall-paintings, portrayed as a priest in the conventional attitudes before the images of the gods. In the chief sanctuaries the chief priests possessed special privileges, and it is probable that those in the immediate entourage of the king were elected to these positions. The highest nobility in the nome sought the honour of priesthood in the service of the local deity. One special class called kher heb was charged with reciting the divine formulae, which were popularly held to possess magical virtue. In the middle empire (VIIth to XIIth Dynasties) the lay element maintains its position in religious cultus despite its complexity. But under the new empire (Dynasties XVIIIth and following) the professional priest had attained to ominous power. Priests increased in number and were divided into ranks; temples possessed larger estates and became more wealthy.

Ancient Greece. — Homer speaks of special priests who preside over ritual acts in the temples to which they are attached; but his kings also do sacrifice on behalf of their people. The king, in fact, both in Greece and in Rome, was the acting head of the state religion, and when the regal power came to an end his sacred functions were not transferred to the ordinary priests, but either they were distributed among high officers of state, as archons and prytanes, or the title of "king" was still preserved as that of a religious functionary, as in the case of the rex *sacrorum* at Rome and the archon basileus at Athens. In the domestic circle the union of priesthood and natural headship was never disturbed; the Roman paterfamilias sacrificed for the whole family. On the other hand, gentes and *phratriae,* which had no natural head, had special priests chosen from their members; for every circle of ancient society, from the family up to the state, was a religious as well as a civil unity, and had its own gods and sacred rites. We cannot speak of priestly power and hardly even of a distinct priestly class.

In Greece the priest, so far as he is an independent functionary and not one of the magistrates, is simply the elected or hereditary minister of a temple charged with "those things which are ordained to be done towards the gods" (see Aristotle, Pol. vi. 8), and remunerated from the revenues of the temple, or by the gifts of worshippers and sacrificial dues. The position was often lucrative and always honourable, and the priests were under the special protection of the gods they served. But their purely ritual functions gave them no means of establishing a considerable influence on the minds of men, and the technical knowledge which they possessed as to the way in which the gods could be acceptably approached was neither so intricate nor so mysterious as to give the class a special importance. There was, indeed, one sacred function of great importance in the ancient world in which the Greek priests had a share. As man approached the gods in sacrifice and prayers, so too the gods declared themselves to men by divers signs and tokens, which it was possible to read by the art of Divination (*q.v.*). In many nations divination and priesthood have always gone hand in hand; at Rome, for example, the augurs and the XV. viri *sacrorum,* who interpreted the Sibylline books, were priestly colleges. In Greece, on the other hand, divination was not generally a priestly function, but it did belong to the priests of the Oracles. (See ORACLE.) The great oracles, however, were of Panhellenic celebrity and did not serve each a particular state, and so in this direction also the risk of an independent priestly power within the state was avoided.

In Rome, again, where the functions of the priesthood were politically much more weighty, where the technicalities of religion were more complicated, where priests interpreted the will of the gods, and where the pontiffs had a most important jurisdiction in sacred things, the state was much too strong to suffer these powers to escape from its own immediate control: the old monarchy of the king in sacred things descended to the inheritors of his temporal power; the highest civil and religious functions met in the same persons (*cf.* Cic. De dom. i. 1); and every priest was subject to the state exactly as the magistrates were, referring all weighty matters to state decision and then executing what the one supreme power decreed. And it is instructive to observe that when the plebeians extorted their full share of political power they also demanded and obtained admission to every priestly college of political importance, to those, namely, of the pontiffs, the augurs, and the XV. *viri* sacrorum. The Romans, it need hardly be said. had no hereditary priests.

Aryan Religions.—In historical times the priesthood in India is rigidly confined to members of the Brahman caste. But at an earlier date the warrior caste often became priests. The power of the priesthood began with the delegation by the king of his sacrificial duties to an appointed official. This power grew with the growing importance of the sacrifice and the complication of its ceremonial. In the post-Vedic period "right" or "wrong" simply meant the exact performance or the neglect, whether intentional or unintentional—of all the details of a prescribed ritual, the centre of which was the sacrifice. At this period the priestly caste gained its unbounded power over the minds of men. For further details as to the development of the priestly caste and wisdom in India the reader must refer to HINDUISM.

Among the Zoroastrian Iranians, as among the Indian Aryans, the aid of a priest to recite the sacrificial liturgy was necessary at every offering (Herod. i. 132), and the Iranian priests (bthravans, later Magi) claimed, like the Brahmans, to be the highest order of society; but they did not acquire the powers of the Indian priesthood; in particular, the priesthood, as it was not based on family tradition, did not form a strict hereditary caste. Nevertheless, it formed a compact hierarchy not inferior in influence to the clergy of the Christian middle ages, had great power in the state, and were often irksome even to the great king. But the monarchs had one strong hold on the clergy by retaining the patronage of great ecclesiastical places.

The Persian religion throughout all its multitude of purifications, observances and expiations was a constant warfare against impurity, death and the devil. Amid all the ceremonialism of its priesthood there were also high ideals set forth in Zoroastrian religion of what a priest should be. Thus we read in Vendidâd xviii., "Many there be, noble Zarathustra, who bear the mouth bandage, who have yet not girded their loins with the law. If such a one says 'I am an Athravan' he lies, call him not Athravan, noble Zarathustra, said Ahura Mazda; but thou shouldst call him priest, noble Zarathustra, who sits awake the whole night through and yearns for holy wisdom that enables man to stand on death's bridge fearless and with happy heart, the wisdom whereby he attains the holy and glorious world of paradise."

Semitic Races.—Among the nomadic Semites there was no developed priesthood. Religion partook of the general simplicity of desert life; apart from the private worship of household gods and the oblations and salutations offered at the graves of departed kinsmen, the ritual observances of the ancient Arabs were visits to the tribal sanctuary to salute the god with a gift of first-fruits or the like (see NAZIRITE and PASSOVER), and an occasional pilgrimage to discharge a vow at the annual feast and fair of one of the more distant holy places. (See MECCA.) These acts required no priestly aid; each man slew his own victim and divided the sacrifice in his own circle; the share of the god was the blood which was smeared upon or poured out beside the stone set up as an altar or perhaps as a symbol of the deity We find therefore no trace of a sacrificial priesthood, but each temple had one or more doorkeepers, whose office was usually hereditary and who had the charge of the Temple and its treasures.

The sacrifices and offerings were acknowledgments of divine bounty and means used to ensure its continuance; the Arab was the "slave" of his god and paid him tribute, as slaves used to do to their masters, or subjects to their lords; and the free Bedouin, trained in the solitude of the desert to habits of absolute self-reliance, knew no master except his god. The decision of the god might be uttered in omens which the skilled could read, or conveyed in the inspired rhymes of soothsayers, but frequently it was sought in the oracle of the sanctuary, where the sacred lot was administered for a fee by the *sādin.* The sanctuary thus became a seat of judgment, and here, too, compacts were sealed by oaths and sacrificial ceremonies. These institutions, though known to us only from sources belonging to an age when the old faith was falling to pieces, are certainly very ancient. The fundamental type of the Arabic sanctuary can be traced through all the Semitic lands, and so appears to be older than the Semitic dispersion.

With the beginning of a settled state the sanctuaries rose in importance and all the functions of revelation gathered round them. A sacrificial priesthood arose as the worship became more complex (especially as sacrifice in antiquity is a common preliminary to the consultation of an oracle), but the public ritual remained closely associated with oracle or divination, and the priest was, above all things, a revealer. That this was what actually happened may be inferred from the fact that the Canaanite and Phoenician name for a priest (*kōhēn*) is identical with the Arabic *kāhin,* a "soothsayer." Soothsaying was no modern importation in Arabia; its characteristic form—a monotonous croon of short rhyming clauses—is the same as was practised by the Hebrew "wizards who peeped and muttered" in the days of Isaiah. The *kāhin,* therefore, is not a degraded priest but such a soothsayer as is found in most primitive societies, and the Canaanite priests grew out of these early revealers. In point of fact some form of revelation or oracle appears to have existed in every great shrine of Canaan and Syria, and at Hierapolis it was the charge of the chief priest, just as in the Levitical legislation.

The Hebrews, who made the language of Canaan their own, took also the Canaanite name for a priest. But the earliest forms of Hebrew priesthood are not Canaanite in character; the priest, as he appears in the older records of the time of the Judges, Eli at Shiloh, Jonathan in the private temple of Micah and at Dan, is more like the *sādin* than the *kāhin*. The whole structure of Hebrew society at the time of the conquest was almost precisely that of a federation of Arab tribes, and the religious ordinances are scarcely distinguishable from those of Arabia, save only that the great deliverance of the Exodus and the period when Moses, sitting in judgment at the sanctuary of Kadesh, had for a whole generation impressed the sovereignty of Jehovah on all the tribes, had created an idea of unity between the scattered settlements in Canaan such as the Arabs before Mohammed never had. But neither in civil nor in religious life was this ideal unity expressed in fixed institutions, the old individualism of the Semitic nomad still held its ground. Thus the firstlings, first-fruits and vows are still the free gift of the individual which no human authority exacts, and which every householder presents and consumes with his circle in a sacrificial feast without priestly aid.

As in Arabia, the ordinary sanctuary is still a sacred stone set up under the open heaven, and here the blood of the victim is poured out as an offering to God. (See especially 1 Sam. xiv. 34, and cf. 2 Sam. xxiii. 16, 17.) The priest has no place in this ritual; he is not the minister of an altar, but the guardian of a temple, such as was already found here, and there in the land for the custody of sacred images or other consecrated things (the ark at Shiloh, 1 Sam. iii. 3; images in Micah's temple, Judges xvii. 5; Goliath's sword lying behind the "ephod" or plated image at Nob, 1 Sam. xxi. 9; no doubt also money, as in the Canaanite temple at Shechem, Judges ix. 4). Such treasures required a guardian; but, above all, wherever there was a temple there was an oracle, a kind of sacred lot, just as in Arabia (1 Sam. xiv. 41, lxx.), which could only be drawn where there was an "ephod" and a priest (1 Sam. xiv. 18, Sept., and xxiii. 6 seq.). The Hebrews had already possessed a tent-temple and oracle of this kind in the wilderness (Exod. xxxiii. 7 *seq.*), and ever since that time the judgment of God through the priest at the sanctuary had a greater weight than the word of a seer, and was the ultimate solution of every controversy and claim (1 Sam. ii. 25; Exod. xxi. 6, xxii. 8, 9, where for "judge," "judges," of A.V. read "God" with R.V.).

The temple at Shiloh, where the ark was preserved, was the lineal descendant of the Mosaic sanctuary and its priests claimed kin with Moses himself. In the divided state of the nation, indeed, this sanctuary was hardly visited from beyond Mt. Ephraim; and every man or tribe that cared to provide the necessary apparatus (ephod, teraphim, etc.) and hire a priest might have a temple and oracle of his own at which to consult Jehovah (Judges xvii., xviii.); but there was hardly another sanctuary of equal dignity. The priest of Shiloh is a much greater person than Micah's priest Jonathan; at the great feasts he sits enthroned by the doorway, preserving decorum among the worshippers; he has certain legal dues, and, if he is disposed to exact more, no one ventures to resist (1 Sam. ii. 12 seq, where the text needs a slight correction). The priestly position of the family survived the fall of Shiloh and the capture of the ark, and it was members of this house who consulted Jehovah for the early kings until Solomon deposed Abiathar.

Ultimately, indeed, as sanctuaries were multiplied and the priests all over the land came to form one well-marked class, "Levite" and legitimate priest became equivalent expressions, as is explained in the article LEVITES. But between the priesthood of Eli at Shiloh or of Jonathan at Dan and the priesthood of the Levites as described in Deut. xxxiii. 8 seq. there lies a period of the inner history of which we know almost nothing. It is plain that the various priestly colleges regarded themselves as one order, that they had common traditions of law and ritual which were traced back to Moses, and common interests which had not been vindicated without a struggle. The kingship had not deprived them of their functions as fountains of divine judgment (cf. Deut. xvii. 8 seq.); on the contrary, the decisions of the sanctuary had grown up into a body of sacred law, which the priests administered according to a traditional precedent. According to Semitic ideas the declaration of law is quite a distinct function from the enforcing of it, and the royal executive came into no collision with the purely declaratory functions of the priests. The invective of Hos. iv. equally with the eulogium of Deut. xxxiii. proves that the position which the later priests abused had been won by ancestors who earned the respect of the nation as worthy representatives of a divine Torah.

The ritual functions of the priesthood still appear in Deut. xxxiii. as secondary to that of declaring the sentence of God, but they were no longer insignificant. With the prosperity of the nation, and especially through the absorption of the Canaanites and of their holy places, ritual had become much more elaborate, and in royal sanctuaries at least there were regular public offerings maintained by the king and presented by the priests. (Cf. 2 Kings xvi. 15.) Private sacrifices, too, could hardly be offered without some priestly aid now that ritual was more complex; the provision of Deut. xviii. as to the priestly dues is certainly ancient, and shows that besides the tribute of first-fruits and the like the priests had a fee in kind for each sacrifice, as we find to have been the case among the Phoenicians according to the sacrificial tablet of Marseilles. Their judicial functions also brought profit to the priests, fines being exacted for certain offences and paid to them (2 Kings xii. 16; Hos. iv. 8; Amos ii. 8). The greater priestly offices were therefore in every respect very important places, and the priests of the royal sanctuaries were among the grandees of the realm (2 Sam. viii. 18; 2 Kings x. 11, xii. 2); but there is not the slightest trace of an hereditary hierarchy officiating by divine right, such as existed after the exile. The sons of Zadok, the priests of the royal chapel, were the king's servants as absolutely as any other great officers of state; they owed their place to the fiat of King Solomon, and the royal will was supreme in all matters of cultus (2 Kings xii., xvi. 10 seq.); indeed the monarchs of Judah, like those of other nations, did sacrifice in person when they chose down to the time of the captivity (1 Kings ix. 25; 2 Kings xvi. 12 seq.; Jer. xxx. 21).

The detailed steps which prepared the way for the post-exile hierarchy, the destruction of the northern sanctuaries and priesthoods by the Assyrians, the polemic of the spiritual prophets against the corruptions of popular worship, which issued in the reformation of Josiah, the suppression of the provincial shrines of Judah and the transference of their ministers to Jerusalem, the successful resistance of the sons of Zadok to the proposal to share the sanctuary on equal terms with these new-comers, and the theoretical justification of the degradation of the latter to the position of mere servants in the Temple supplied by Ezekiel soon after the captivity, need not here be dealt with. Already in the time of Josiah altar service and not the judicial or "teaching" function had become the essential thing in priesthood (Deut. x 8, xviii. 7); the latter, indeed, was not forgotten (Jer. ii. 8, xviii. 18), but by the time of Ezekiel it also has mainly to do with ritual, with the distinction between holy and profane, clean and unclean, with the statutory observances at festivals and the like (Ezek. xliv. 23 seq.). What the priestly Torah was at the time of the exile can be seen from the collection of laws in Lev. xvii.–xxvi., which includes many moral precepts, but regards them equally with ritual precepts from the point of view of the maintenance of national holiness. The holiness of Israel centres in the sanctuary, and round the sanctuary stand the priests, who alone can approach the most holy things without profanation, and who are the guardians of Israel's sanctity, partly by protecting the one meeting-place of God and man from profane contact, and partly as the mediators of the continual atoning rites by which breaches of holiness are expiated. In the old kingdom the priests had shared the place of the prophets as the religious leaders of the nation; under the second Temple they represented the unprogressive traditional side of religion, and the leaders of thought were the psalmists and the scribes, who spoke much more directly to the piety of the nation.

But, on the other hand, the material influence of the priests was greater than it had ever been before; the Temple mas the only visible centre of national life in the ages of servitude to foreign power, and the priests were the only great national functionaries, who drew to themselves all the sacred dues as a matter of right and even appropriated the tithes paid of old to the king. When the high priest stood at the altar in all his princely state. when he poured out the libation amidst the blare of trumpets, and the singers lifted up their voices and all the people fell prostrate in prayer till he descended and raised his hands in blessing, the slaves of the Greek or the Persian forgot for a moment their bondage and knew that the day of their redemption was near (Ecclus. 1). The high priest at such a moment seemed to embody all the glory of the nation, as the kings had done of old, and when the time came to strike a successful blow for freedom it was a priestly house that led the nation to the victory which united in one person the functions of high priest and prince. From the foundation of the Hasmonean state to the time of Herod the history of the high priesthood merges in the political history of the nation; from Herod onward the priestly aristocracy of the Sadducees lost its chief hold over the nation and expired in vain controversy with the Pharisees.

The influence of the Hebrew priesthood on the thought and organization of Christendom was the influence not of a living institution, for it hardly began till after the fall of the Temple, but of the theory embodied in the priestly code of the Pentateuch. Two points in this theory were laid hold of—the doctrine of priestly mediation and the system of priestly hierarchy. The first forms the text of the principal argument in the Epistle to the Hebrews, in which the author demonstrates the inadequacy of the mediation and atoning rites of the Old Testament. and builds upon this demonstration the doctrine of the effectual high priesthood of Christ, who, in His sacrifice of Himself, truly "led His people to God." not leaving them outside as He entered the heavenly sanctuary. but taking them with Him into spiritual nearness to the throne of grace.

The idea that presbyters and bishops are the successors of the Old Testament priesthood first appears in full force in the writings of Cyprian. The further development of the notion of Christian priesthood was connected with the view that the Eucharist (*q.v.*) is a propitiatory sacrifice which only a consecrated priest can perform. It is sufficient to remark here that the presentation of the sacrifice of the mass came to be viewed as the essential priestly office. so that the Christian presbyter really was a *sacerdos* in the ancient sense. Protestants, in rejecting the sacrifice of the mass, deny also that there is a Christian priesthood "like the Levitical," and have either dropped the name of "priest" in reference to any specific office, or use it in a quite emasculated sense.

BIBLIOGRAPHY.—J G. Frazer, *The Golden Bough* (esp. part i, "The Magic Art and the Evolution of Kings") (1907–15); M. Jastrow, *Die Religion Babyloniens u. Assyriens* (1905–12); *H.* Hackmann, *Buddhism as a Religion* (Eng. tr., 1910); R. F. Johnson, *Buddhist China* (1913); J H. Breasted, *A History of Egypt* (1906); J. E. Harrison, *Themis* (1912); *W* Robertson Smith, *Religion of the Semites* (1889); J Wellhausen, *Proleg. zur Geschichte Israels,* 6th ed (1905); E W. Hopkins, *The Religions of India* (1896); J. H. Moulton, *Early Zoroastrianism* (1913); W. W. Fowler, *The Religious Experience of the Roman People* (1911)

PRIESTLEY, J. B. (JOHN BOYNTON) (1894–), English novelist, playwright and critic. who distinguished himself in all three fields. was born in Bradford, Yorkshire, on Sept. 13, 1894. He served in World War I with the duke of Wellington and Devon regiments, rising from the ranks to become an officer and being three times wounded before he was invalided out. He was educated at Trinity Hall. Cambridge (1919–22), where he partly paid his way by writing critical and other articles. He went to London in 1922 and made his first reputation as a critic: many of his reviews appearing in the *Saturday Review* and the *Weekend Review*. Both in his novels and his plays Priestley depicted the English man in the street and represented his point of view. His first successful novel was *The Good Companions* (1929; dramatized with Edward Knoblock. 1931), which was followed by *Angel Pavement* (1930), *Faraway* (1932), and The *Doomsday Men* (1 9 3 Quickly mastering stage technique, he wrote such successful plays as *Dangerous Corner* (1932), *Laburnum Grove* (1933), *Time and the Conways* (1937), *Home is Tomorrow* (1948). He served as the United Kingdom delegate to the Cnited Nations Educational. Scientific and Cultural organization (UNESCO) in 1946–47. He also became a very popular radio broadcaster.

PRIESTLEY, JOSEPH (1733–1804), a dissenting English clergyman, by avocation a chemist and as such the celebrated discoverer of oxygen. He is equally well known in his native land and in the United States where he spent the last ten years of his life. Born at Fieldhead, near Leeds, on March 13, 1733, the son of strict Calvinists, he was destined for the ministry. Displaying an independent mind, he soon rejected the authority of the established churches and became a dissenting minister at 22. and five years later a teacher of classics and literature at a private school in Warrington. There he wrote an essay on education and a compilation on eminent men of all ages, which earned him a doctor of laws degree from the University of Edinburgh. This study necessitated frequent trips to several cities, including London, where he met and was befriended by Benjamin Franklin. At the latter's suggestion he wrote a *History of Electricity,* which proved so successful that he was admitted, at the age of 33, to the Royal society.

Following a disagreement with the trustees of Warrington academy he resigned in 1767 and became pastor of Mill Hill chapel, near Leeds. Living next to a brewery, he became interested in the "fixed air" (carbon dioxide) that lay over the liquids in the fermentation vats. On moving to another location he continued his studies with this gas, which he made by pouring acid on chalk. He dissolved the gas in water and obtained "an exceedingly pleasant sparkling water, resembling Seltzer water." For this application, which was his first contribution to the chemistry of gases. the Royal society awarded him the Copley medal in 1773. About this time Priestley was fortunate in meeting a fellow sympathizer with the cause of the American colonies, Lord Shelbourne (later marquess of Lansdowne). He became librarian and literary companion to this wealthy nobleman, with enough leisure to indulge in scientific pursuits.

With the aid of a newly acquired burning glass, he obtained on Aug. 1, 1774, a new gas from mercuric oxide that was five or six times as pure as ordinary air. He even foresaw its future uses: "it may be peculiarly salutary for the lungs in certain cases" and thus anticipated its use in oxygen tents. This discovery, which greatly increased his fame, led to a meeting in Paris with Antoine Lavoisier and other noted scientists to whom he related his findings. Lavoisier at once repeated Priestley's experiments with the new gas, which he named oxygen because of its acid-forming properties. It gave Lavoisier the clue to demolish the phlogiston theory of which, nevertheless, Priestley remained a lifelong adherent. Meanwhile, the theological heresies of Priestley strained the relations with his patron to such extent that he resigned in 1780 to become minister to a dissenting congregation in Birmingham. In this city Priestley found kindred souls with liberal outlooks in politics and religion who induced him to join the so-called "Lunar society" (outsiders called it "lunatic") which met on Monday nights nearest to full moon.

In Birmingham, where Priestley spent the happiest decade of his life, he wrote the final two of his six volumes *On Different Kinds of Air.* An abridged edition in three volumes appeared in 1790. Priestley's nontechnical writings, particularly his *History of the Corruptions of Christianity,* his espousal of the cause of the American colonists and later of the French Revolution, and especially his outspoken reply to Edmund Burke's attack on the new regime in France, made him exceedingly unpopular with the public. The smouldering resentment against Priestley and his friends came to a head on the second anniversary of the fall of the Bastille (July 14, 1791). Mob rule existed in Birmingham for three days. Priestley's church, his house and his laboratory were burned and he himself escaped in disguise to Worcester. Later he settled in London, where he spent three unhappy years. On April 7, 1794, he left for America to join his three sons who had already found new homes there. Arriving in New York city in June 1794, he was offered a professorship and a ministry, both of which he declined. He built himself a house and laboratory in the town of Northumberland. Pa.. and there he died on Feb. 6, 1804.

Priestley's multiplicity of interests has often been commented upon. Trained as a theologian, he was open-minded, fearless and progressive in matters of religion and politics; in science, to which he came later in life, he was orthodox, timid and as he himself stated "not apt to be very confident" about conclusions from his observations. Even so, he had the attributes of a born investigator: an intense curiosity, a passion for "experimental philosophy" and a native honesty and frankness. He was an ingenious manipulator. Being the first to collect gases over mercury. he discovered. in addition to oxygen. several other new gases. Some of these are highly soluble in water and thus had escaped the attention of contemporary chemists. Another significant contribution to chemistry was Priestley's work on "the purification of air by plants and the influence of light on that process." which provided the stimulus for subsequent studies by Jan Ingenhousz, Jean Senebier and others on respiration and photosynthesis.

BIBLIOGRAPHY.— An excellent account of Priestley's contributions to chemistry is found in J. R. Partington, *A Short History of Chemistry*, 2nd ed. (1948), which contains numerous references. For a popular account of his life and work see B. Jaffe, *Crucibles* (1934), and J. G. Gillam, *The Crucible* (1954). His work on oxygen has been republished in *The Alembic Club Reprints,* no. 7 (1901) and in H. M. Leicester and H. S. Klickstein, *A Source Rook in Chemistry* (1952). A good account of Priestley's relations with Lavoisier mas given by R. E. Oesper in *J. Chent. Educ.*, 13:403 (1936).

The centennial of the discovery of oxygen, celebrated by a group of American chemists at Priestley's home in Northumberland, mas followed by the founding of the American Chemical society in 1876. The semicentennial meeting oi the society led to the issue of a "Priestley Number" of the *J. Chem. Educ.*, 4:145–199 (1927), which contains illustrations and details of his life in America. (H. S. V. K.)

PRIEUR, PAUL (*c.* 1626–*c.* 1676), French enamel painter. He married Marie (1610–1677), sister of Jean Petitot, as her second husband. In 1669 he was in England, painting a miniature of Charles II and another of Lady Castlemaine, both after Cooper, for the king of Denmark. In 1670 he was in Poland, painting for the Danish monarch a portrait of King Michael. and in the following year was in Denmark executing a remarkable series of portraits of the children of Frederick III. All these, with some beautiful enamel badges for the Order of the Elephant, are in the Danish royal collection. By Christian V he is said to have been sent to Spain and Russia, where several examples of his work. dated 1676, are to be seen in the Hermitage, Leningrad. He died in Denmark, in 1676. He was a Huguenot, and was said to possess secret colours in enamel, especially a blue. which were not known to his Petitot relations. (G. C. W.)

PRIEUR DE LA MARNE [PIERRE LOUIS PRIEUR] (1756–1827), French politician. was born at Sommesous (Marne) on Aug. 1. 1756. He practised as a lawyer at Châlons-sur-Marne until 1789, when he was elected to the states-general. He became secretary to the assembly. and the violence of his attacks on the *ancien régime* won him the nickname of "Crieur de la Marne." In 1791 he became vice-president of the criminal tribunal of Paris and in May 1796 president of the convention, hiding from May 1795 until the amnesty proclaimed in the autumn of that year. In 1816 he was banished as a regicide. He died in Brussels on May 31, 1827.

PRIEUR-DUVERNOIS, CLAUDE ANTOINE, COMTE (1763–1832), French politician. was born at Auxonne on Dec. 2, 1763. and was known as Prieur de la Côte d'Or. He was a member of the legislative assembly and of the convention. In 1793 he was employed in breaking up the Federalist movement in Normandy, but he was arrested by the Federalist authorities of Caen, and only released in July 1793 after the defeat of their forces at Vernon. On Aug. 14, 1793, he became a member of the committee of public safety, allying himself with L. N. M. Carnot in the organization of national defense. Under the directory he sat in the Council of the Five Hundred, retiring after the coup d'état of 18 Brumaire (Nov. 9, 1799). In 1808 he was created a count of the empire, and in 1811 retired from the army with the grade of *chef* de *brigade*. He was one of the founders of the École Polytechnique, and shared in the establishment of the Institute of France: the adoption of the metric system and the foundation of the bureau of longitude were also due to his efforts. Prieur died at Dijon on Aug. 11, 1832.

PRILEP, a town in Macedonia, Yugoslavia. Pop. (1953) 29,776. The town owes its chief importance to a large annual fair. The town is famous in Serbian history as the birthplace and capital of Marko Kralyevich, one of the favourite national heroes, who held his kingdom, after the fall of Serbia in 1389. as a vassal of the Turks. Legend says that before his death he buried his sword deep in the rocks of Prilep and left his magic horse Sharatz to nibble the moss near by, with the promise of reappearing in his country's hour of need. In the Balkan Wars (1912–13) the Serbs successfully stormed the heights, reputed to be impregnable. In 1941 the town was occupied by Bulgaria.

PRIM, JUAN, MARQUIS DE LOS CASTILLEJOS, COUNT DE REUS (1814–1870), Spanish soldier and statesman, was born at Reus, Catalonia, on Dec. 12, 1814. He served in the volunteers of Isabella II in 1834, becoming lieutenant-colonel during the Carlist war. In 1839. as a progressist opposed to the dictatorship of Espartero, he was exiled. Elected deputy for Tarragona in 1843, he defeated Espartero at Bruch and entered Madrid in triumph with Serrano. The regent Maria Christina made him major-general and count of Reus. Narvaez, the prime minister, who did not understand what constitutional freedom meant, sentenced Prim to six years' imprisonment in the Philippine Islands; the sentence was not executed, and until the amnesty of 1847 Prim remained an exile in England and France. On his return he was made captain-general of Porto Rico and military representative with the sultan during the Crimean War. Elected to the *cortes* in 1854, he supported O'Donnell, who promoted him lieutenant-general in 1856. He was made marquis de los Castillejos and a grandee of Spain for his valuable services in Morocco (1860). A member of the opposition against Narvaez, at his death (1868) Prim and Serrano raised the standard of revolt at Cadiz, with Admiral Topete commanding the fleet. In July 1869 Serrano was elected regent, and Prim became president of the council and was made a marshal. He was shot by unknown assassins on leaving the chamber of the *cortes* on Dec. 28, 1870.

See F. Jimenez y Guited, *Historia militar* y *politica del general D. Juan Print . . .*, 2 vol. (1860); L. Blairet, *Le Général Prim et la situation actuelle de l'Espagne* (1867); Guillaumot. *Juan Prim et l'Espagne* (1870); H. Leonardon, *Prim,* bibl. (1901); F. González Llanos, *Biografiá politica y militar del . . . general . . . Prim . . .* (1860).

PRIMARIES are meetings of voters at which the first steps are taken toward the nomination of candidates for office. They may be informal gatherings or elections held under the same safeguards as final elections. They may be partisan in the sense that participation is limited to persons affiliated with the same party; or nonpartisan, in that nominees are chosen without regard to party affiliation. Partisan primaries may be indirect or direct. In the former, delegates are chosen to nominating conventions and the primary is equivalent to a caucus, but in the direct primary the party membership chooses the nominees and the primary becomes a preliminary election in the electoral process.

The formalized, legally regulated primary election and the direct primary are peculiar to the United States. Nominating conventions, instituted by the parties as reform measures, became subject to abuses which led first to their regulation and ultimately to their elimination for most offices. Observance of early laws relating to selection of delegates was optional, parties being permitted but not required to conform to their provisions, and the laws were limited to certain areas. After 1890 mandatory regulations of a sweeping character transformed the primary into an election conducted by public officers at public expense. Even before these laws were tested direct nominations were demanded. The direct primary was used by the Democratic party in Crawford county. Pa., as early as 1842, but it was not until the 20th century, when the Progressive movement tended to divide both parties, that the system came into general use. In 1903 Wisconsin, under the leadership of Gov. Robert M. La Follette. passed the first mandatory, state-wide direct primary law. The movement spread so rapidly that by 1917 all but four states had adopted the direct primary for some or all state-wide nominations. After the passage of laws in Utah (1937), New Mexico (1938), Rhode Island (1947) and Connecticut (1955), some form of direct primary was used in all states. By the 1950s primaries in most states were mandatory and covered nominations to all state and county offices, but optional primaries survived in several southern states, and Michigan. New York and Indiana mere among the states which used conventions for nominations to some state offices. In most states provisions applied only to parties polling a fixed minimum at the last election.

Beyond this, few generalizations are possible; direct primaries in the states vary widely in detail, and dates of primary elections vary from spring to fall. Various methods are used to place names on the ballot. The simplest is a declaration of candidacy, with or without a filing fee. The more popular method is by petition signed by a certain number of political supporters of the aspirant. These formal requirements are frequently supplemented by informal procedures. "Slates" of candidates are proposed by groups identified with the party organization or by unofficial gatherings of party members. An interesting development was the formalization by law of preprimary conventions in Colorado, Connecticut, Massachusetts and Utah. The Connecticut law limits the competition in the primary to those who received 20% of the vote on any roll call at the preprimary convention. In Rhode Island party committees are empowered to designate individuals whose names appear on the primary ballot as endorsed candidates and who are given preferential treatment as to position. In most states an aspirant for nomination may compete only in the primary of the party in which he claims membership, but in a few states it is possible for the candidate to seek the nomination of both parties simultaneously. This practice of "double filing" or "cross filing" has been used extensively in California, and the same person has sometimes won both nominations.

Particularly interesting and important are the variations in qualifications for voting in the primary. Some primaries are "open" in the sense that no declaration of party affiliation is required; the voter may participate in the primary of either party and move from one party to another in successive contests. Sometimes, as in Wisconsin, the participant receives the ballots of all parties and may decide which to use in the privacy of the voting booth, whereas in those states following the Minnesota plan a "blanket" ballot is provided on which the names of all candidates are arranged in party columns. In 1935 Washington adopted a blanket ballot which permitted the voter to cross back and forth between the parties at the same primary; *e.g.,* he might vote for a Republican aspirant for the gubernatorial nomination and at the same time express a choice for a Democrat for the nomination for United States senator. The "closed" primary, used in a majority of the states by the latter 1950s, limits participation in the primary to party members. Voters are required to enrol as members of a party at the time of registration, to state their party choice at the polling place, or to swear that they meet a specified test of party membership if their right to participate in the primary is challenged. The usual tests are support of the party's candidates at the last general election or the intention to support the candidates of that party at the next general election.

The merits of open and closed primaries have been widely debated. It is argued that the open primary permits participation by independents who are unwilling to declare a party affiliation and that it prevents intimidation of voters. Its opponents say that it destroys party responsibility by permitting those who have no continuing allegiance to the party to control its nominees, and that it permits members of one party to "raid" the primaries of the other party.

In most states the candidate polling the highest number of votes becomes the nominee, but by the mid-1950s ten southern states, in which Democratic nomination is equivalent to election: required a second or "run-off" primary if no candidate received a majority of the votes in the first contest. Preferential voting (*i.e.,* indication of a first, second and third choice), tried by several states, had been abandoned by all of them.

Studies made in the 1950s tended to support the hypothesis that the primaries had altered the character of political competition, at least in the case of nominations for state legislative posts. Even in two-party areas the effective choice had tended to be transferred to the primaries of the majority party, and the vitality of the minority party was weakened.

Attempts have been made to extend the idea of direct nominations to the presidency of the United States. By election of delegates to the nominating conventions, and by preference votes for president, or both, some states have attempted to bring the national conventions within the control of the party membership. The first presidential primary law was adopted by Wisconsin in 1905, and by 1916 laws varying widely in type and effectiveness were in operation in 24 states. After that the movement lost ground, and by the latter 1950s mandatory laws were in effect in only 17 states.

Nonpartisan primaries have been widely used for judicial and local offices in the United States and have been extended to members of the state legislature in Minnesota and Nebraska. In reality a double election system in which party labels play no part, nonpartisan elections and primaries were introduced in an attempt to remove these offices from influence by national party politics. Although nonpartisan in form, they frequently become partisan in fact.

The closest parallel to the U.S. primary has been the "preselection" ballot of the Australian Labour party, in which candidates in each locality have been selected by party members in that locality from those offering themselves for the preselection vote.

BIBLIOGRAPHY.—C. E. Merriam and L. Overacker, *Primary Elections,* rev. ed. (Chicago, 1928); C. A. Berdahl, "Party Membership in the United States," *American Political Science Review,* vol. xxxvi, pp. 16–50, 241–62 (1942); J. K. Pollock, *The Direct Primary in Michigan, 1909–1935* (Ann Arbor, 1943); B. A. Martin, *The Direct Primary in Idaho* (Stanford, 1947); L. M. Holland, *The Direct Primary in Georgia* (Urbana, 1949); V. O. Key and Alexander Heard, *Southern Politics in State and Nation* (New York, 1949); National Municipal League. *A Model Direct Primary System* (New York, 1951); V. O. Key, *Politics, Parties and Pressure Groups,* 3rd ed., pp. 399–476 (New York, 1952), and "The Direct Primary and Party Structure," *American Political Science Review,* vol. xlviii, pp. 1–26 (1954); H. A. Bone, *American Politics and the Party System,* 2nd ed., pp. 395–439 (New York, 1955); M. J. Dauer, "Toward a Model State Presidential Primary Law," *American Political Science Review,* vol. l, pp. 138–153 (1956). (L. Or.)

PRIMARY EDUCATION: *see* ELEMENTARY EDUCATION.

PRIMATE, a title applied during the 4th and 5th centuries A.D. to both secular and ecclesiastical officials. The Theodosian code mentions primates of towns, districts and fortified places (*Primates urbium, vicorum, castellorum*). A pragmatic sanction of Justinian also mentions primates governing a district, *primates regionis;* and in this sense the title survived, under Turkish rule, in Greece until the 19th century. An official called "primate of the palace" is mentioned in the laws of the Visigoths. Primas also seems to have been used loosely during the middle ages for "head" or "chief."

Charles du Fresne, Sieur du Cange cites *primas castri.* The title has been more generally used to denote a bishop with special privileges and powers. It was first employed almost synonymously with metropolitan to denote the chief bishop of a province having his see in the capital and certain rights of superintendence over the whole province. At the Council of Nicaea (A.D. 325) the metropolitan constitution was assumed as universal. and after this the terms metropolitan, and primate, to denote the chief bishop of a province, came into general use. The title of primate was used more generally in Africa, while elsewhere metropolitan was more generally employed.

At a later date primate became the official title of certain metropolitans who obtained from the pope a position of episcopal authority over several other metropolitans and who were, at the same time, appointed vicars of the Holy See. This was done in the case of the bishops of Arles and Thessalonica as early as the 5th century. The archbishop of Reims received the title of *primas inter primates.* By the False Decretals an attempt was made to establish such a primacy as a permanent institution, but the attempt was not successful and the dignity of primate became more or less honorary.

The overlapping of the title is illustrated by the case of England, where the archbishop of York still bears the title of primate of England and the archbishop of Canterbury that of primate of all England.

BIBLIOGRAPHY.—*See* Du Cange, *Glossarium;* Hinschius, *Kirchenrecht* (Berlin, 1869); Moeller, *History of the Christian Church,* translated from the German by Andrew Rutherford (1902); Bingham, *Origines ecclesiasticae* (1840).

PRIMATES, an order of mammals, including man, the apes, monkeys, tarsiers and lemurs. The name, meaning "chiefs," was given by Carolus Linnaeus in 1758. Linnaeus also included the bats, assigned to a separate order by modern zoologists.

Structure and Habits.—Primates are primarily arboreal animals tvith hands and feet adapted for climbing. The fingers and toes are provided with nails (rarely compressed as claws). The great toe of the hind foot is usually more or less divergent and the foot functions as a grasping organ, branches of trees being seized between the great toe and the four outer toes. The hands serve both for climbing and for manipulating food. The limbs are relatively long and slender, with free movements of rotation and supination. The lower primates (lemurs) are practically quadrupeds that run and leap in the trees but in the more advanced monkeys and apes there is an increasing tendency to climb with the arms extended above the head and the weight of the body suspended beneath the branches (brachiation). On the other hand, in the baboons the limbs plainly show secondary adaptation for running on the ground, both in their somewhat dog-like proportions and in the reduction of the great toe.

In the stem type of arboreal monkeys, vision is dominant over smell, whereas in typical ground-dwelling mammals the reverse is the case. Hence the occipital poles of the brain, which are connected with vision, are much enlarged. The adjustments for balancing in such actively climbing animals are extremely various and rapid; this requires a correspondingly complex development of the cerebellum and of the cerebral areas of the brain concerned nith the movements of the limbs and body. As intelligence increases the prefrontal lobes of the brain develop. Thus the brain of monkeys is proportionately larger and more complexly convoluted than in ordinary ground-living animals. As a whole the brain of the old world monkeys presents the ground plan of the human brain without the special developments and complications connected with man's superior mentality.

The bony brain case closely follows the shape of the brain, except in front, where the large eye sockets jut forward, thus enabling the achievement of binocular, stereoscopic vision. Owing to the forward growth of the temporal lobes of the brain the greater wings of the sphenoid are moved forward to form the backwall of the orbits, which are thus separated by a bony partition from the temporal fossae.

Hearing is acute and the temporal lobes are large. A thin bony shell, the auditory bulla, on the underside of the brain case behind the socket for the lower jaw, covers the lower side of the cavity of the middle ear and is connected by a bony tube tvith the root of the external ear; the latter resembles that of man but usually has a point on its upper rim and lacks a lobule below.

In the more primitive primates, *e.g.* lemurs, the jaws are long and slender and the muzzle pointed. In typical monkeys, however, the jaw is shortened and deepened and the muzzle broad, the nose and lips assuming more or less the human aspect. The opposite halves of the lower jaw are fused in front even in young animals. The dentition is adapted for a mixed diet, with fruits or vegetation prevailing. The teeth in an adult old world monkey number 32, as in man. The incisors are cutting teeth, the lower ones slightly inclined iormard There are two pairs in both upper and lower jaw The canines are sharp and adapted for biting; the upper premolars are bicuspid, *i.e.*, with single, outer and inner cusps: and the low-crowned molars are surmounted by low cusps.

The female reproductive organs are fundamentally as in man (except in details) and there is likewise only a single pair of breasts in the female. The placenta, except in the Lemuroids, is disk-shaped and intimately attached to the wall of the uterus.

Thus a typical monkey differs from an ordinary mammal such as a dog in its thorough adaptation to arboreal life, in the greater activity of the visual as coinpared with the olfactory powers. in its more advanced type of brain and in its much greater likeness to man in the entire ground plan of its anatomy.

Such a monkey is structurally connected on the one hand with lower primates (including new world monkeys, tarsiers and lemurs) and on the other hand with the higher primates, the anthropoid apes and man Even the still existing species of primates form a fairly gradual transition from the tree shrews at the base to highly specialized forms like the spider monkey, the orangutan and man, which stand far out on widely divergent branches.

SUBORDER PROSIMII

Here are included the lower primates, animals very different in appearance from monkeys and apes. Structurally they also differ widely, many authors considering the lemurs distinct enough to be given ordinal rank.

Tupaioidea.—The tree shrews are often classed as Insectivora (*q.v*) but they are undoubtedly much like the stock from which the other primates arose.

The pen-tailed tree shrew *(Ptilocercus)* of Borneo is a mouse-like arboreal animal. Its hands and feet are five-toed and provided with claws, the thumb and great toe somewhat divergent. Food includes insects and fruit; the upper molar teeth are tritubercular, the lower molars tuberculo-sectorial (see MAMMALIA). The skull is lemur-like, especially in the ring-shaped orbit and inflated auditory bulla, which completely encloses the ring-like tympanic bone and eardrum. The brain is pritnitive in having relatively unreduced olfactory parts and very feebly developed neopallium or higher part of the brain. *Tupaia* and related genera of India and the Malayan region are in many ways more advanced toward the lemur type. Fossil tree shrews not greatly different from modern forms were found in the Lower Oligocene of Mongolia.

Lemuroidea.—In the Palaeocene and Eocene of North America occur the fossil teeth and jaws of ancient primates belonging to several groups. The orbits open into the temporal fossae beneath the postorbital bar. The thumb and first toe are opposable

Family Plesiadapidae is the earliest of these groups; it also occurred in Europe. The incisors are shrew-like, the lower one large and procumbent, while the molar teeth resemble those of Recent lemurs.

Family Adapidae lived in the European and North American Eocene. The skull was broad, with large, forward-looking orbits, massive cheek arches and high crests. The molars were four-cusped, with sharp cross-crests. These ancient primates approached in many skeletal features the modern lemurs, to which they were either ancestral or closely related.

Family Norharctidae confined to the North American Lower and Middle Eocene, included forms ranging from the size of a squirrel to that of a cat. The first and second upper molar teeth gradually evolved from a three-cusped to a four-cusped stage. Apparently the entire family then became extinct. but some of them may possibly have given rise to the ancestral South American monkeys. In *Notharctus osborni* from the Middle Eocene of Wyoming, the hands and feet were of the grasping, climbing type, much like those of existing lemurs. The skull was far less specialized than that of contemporary tarsioids, both skull and dentition retaining the primitive features of lemurs on the one hand and monkeys on the other. Thus the dental formula of *Notharctus* ($i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{4}{4}$, $m\frac{3}{3} \times 2=40$) is the primitive one for all primates. The brain case is primitive with no great expansion of the brain and with an unreduced nasal chamber. The orbits were protected behind by a rim of bone, not by a fully developed partition. The auditory region and base of the cranium, backbone, forearm, pelvis and hind feet were like those of lemurs.

Family Lemuridae became confined in modern times to Madagascar and the smaller adjacent islands. The lemurs have a fully arboreal skeleton, with grasping hands and feet. The animals run and leap on the tops of branches. The second toe bears a claw, while the other digits are armed with flat nails The lower incisors and much reduced lower canines are sharply inclined forward, compressed and pointed. This structure was thought a "comb," used in grooming the fur, but it is more probably used in feeding on soft fruits. The upper canines are large, but the incisors are small, widely separated medially. The upper molars have two sharp outer cusps and a medial crescentic one; the first two molars, in addition, have two small internal cusps. The lower molars are four-cusped. The opposite halves of the lower jaw are not fused in front as in the higher primates but remain free. The placenta is diffuse with a large allantois, and separates from the uterine wall at birth, without destruction of maternal tissue; *i. e.*, it is not deciduous. In this feature the members of this family resemble the ungulates and differ widely from the higher primates. Lemurs have only one pair of mammae situated on the breast.

The true lemurs *(Lemur)* have a dental formula $i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{3}{3}$. The head has a fox-like muzzle and rounded occiput. The eyes are very large and protrude from their sockets, while the ears are large and movable. A long fringe of hair often surrounds their chin and cheeks. The ring-tailed lemur *(L. catta)* is one of the best known species, somewhat like a small. slender raccoon in appearance. It is ashy gray in colour, paler on the legs and sides, and white on the under parts, cheeks. ears and forehead. The blackish tail is ringed with white, giving this lemur its name. The ruffed lemur *(L. variegatus)* is characterized by the fringe of hair on the sides of the head and neck. This species varies greatly in colour. Usually the face is blackish, as are the under parts. tail and feet, while the upper parts and sides are white, cream-coloured or reddish. This species is the largest of the true lemurs. The black lemur *(L. macnco)* has tufted ears and a ruff. The male is black, while the female is said to have a white ruff and ears; the body is dark brown, lighter on the rump. Other races of this species are reddish or gray and may show stripes. The mongoose lemur *(L. mongoz)* is small, with dull reddish-brown. woolly fur; the face, chin, the middle of the forehead and a line above the eyes are black. The smooth-eared black lemur (L. *rubriventer)* lacks a fringe on the ears and has a small ruff; the female has reddish feet. The under parts are often reddish.

The gentle lemur (*Hapalemur griseus)* has a rounded head, short muzzle and small ears. Its colour is dark iron gray with a tinge of reddish. This species is said to be nocturnal and to feed on bamboo shoots and leaves. A closely related lemur mas described as H. *simus,* characterized by broader muzzle, and there are no spines on the forearm above the wrist.

The weasel or sportive lemur (*Lepilemur mustelinus*) is about 10 in. long. with a tail some 14 in. The small ears are naked, uhile the muzzle is long and pointed. Considerable variation in colour is shown by this species. There is frequently a black stripe down the back; the general colour is gray tinged with yellow or reddish, while the under parts are grayish or yelloxvish nhite. The upper incisors are generally lost in adults, but a single small pair may persist. *L. ruficaudus,* the red-tailed sportive lemur, is smaller than the preceding, the head shorter and broader, with the ears short-haired.

Subfamily Cheirogaleinae includes the mouse lemurs, referable to three genera. The face is short and the bony palate extends behind the last cheek tooth. *Cheirogaleus major* is about 8 in. long. with the tail about 9 in. The base of the tail becomes swollen with fat stored there during the summer and the animal hibernates in a nest in a hollow tree. The silky fur is grayish brown, often fawn-coloured or washed with rufous. A blackish ring surrounds the eyes. while between them the fur is pale. The eyes are large, while the ears are moderate in size, oval and sparsely haired. The heel bone is lengthened, while the hind limbs are larger than the fore. In habits the mouse lemur is nocturnal; it feeds on fruits and possibly honey. Several smaller species are known. *Microcebus* has four mammae, two on the breast. two on the abdomen. In the skull the brain case is high, while the facial region is reduced. The foot is long. the result of a lengthening of the cuboid and navicular bones. *M. murinus,* the typical form, is pale reddish gray. with nhite under parts; it is 5 in. in length with a 6 in. tail. M. *coquereli* is characterized by its soft woolly fur which is grayish brown washed with reddish. It is larger, 8 in. or more long, with the tail 13 in. It is said to build a nest of twigs in which it spends the daytime, to emerge at night in search of insects, fruit and leaves. *Phaner furcifer,* the forked-striped mouse lemur, receives its name from the blackish stripe running back from each eye to the occiput and continuing donn the back. The rest of the body is grayish.

Subfamily Megalodapinae includes a large extinct lemur of the Madagascar Pleistocene or early Recent. the skull about 12 in. long, which indicates an animal the size of a small hog. The three-cusped molars resemble those of the lemurs and mouse lemurs. The orbits were small and widely separated. The upper incisors were lost and the canines took their place. The skull vaguely resembles that of a hippopotamus.

Subfamily Archaeolemurinae contains two Lower Pleistocene genera, *Archaeolemur* and *Hadropithecus*. The former was about the size of a rhesus macaque and the skull was very monkey-like, with reduced face and large, rounded brain case. The eyes were large and directed forward. The dental formula is $i\frac{2}{2}$, $c\frac{1}{0}$, $p\frac{2}{2}$, $m\frac{3}{3}$, the first premolar functioning as a canine. *Hadropithecus* was much more specialized with massive zygomatic arch and large brain case.

Subfamily Indriinae contains the higher lemurs characterized by large, rounded brain case and small face, long hind legs; short thumb and short index fingers, but large first toes. The other toes are partly united by a web. They progress by leaps. The ears are generally naked, buried in the fur. The indriine lemurs live on vegetation and have a capacious caecum. The indri or endrina (*Indri indri)* has a short tail and large, tufted ears. The face, hands. feet and most of the body of this animal is velvety black; the lower back, tail, the sides of the hind limbs, the forearm and elbow region are white, as are a cheek fringe and the top of the head. The flanks are often pale. In contrast to the common lemurs, the indri is diurnal in habit. The cries of this species are plaintive and mournful. The sifakas (*Propithecus)* differ from the indri by their long tails; their ears are shorter, and they are largely white in colour, marked nith yellow. The face is black and nearly naked. *P. diadema,* the crowned sifaka, takes its name from the band of white hairs running across the forehead; this unites with grayish hair on the cheeks to surround the face. In southern Madagascar this species is almost white, while in the north the colour is blackish; the range of the species extends along the entire east coast of the island. Verreaux's sifaka *(P. verreauxi)* is a smaller species (head and body 18 in., tail 22 in.) restricted to the western, southern and northern parts of Madagascar. It has a crest of blackish hairs on the forehead. Some are largely white, with reddish patches on the thigh and arm; in others the head is reddish brown, with the limbs ashy gray. The avahi or woolly lemur *(Avahi laniger).* has a long tail and short muzzle. It is the smallest of this subfamily. the head and body about $12\frac{1}{2}$ in. long, the tail somewhat longer. In colour the avahi is mottled reddish brown and blackish, the sides and limbs are pale, while the under parts are grayish. Individuals may be whitish. Avahis are nocturnal and solitary; they leap considerable distances from branch to branch, but are awkward on the ground, as are their relatives.

Family Daubentoniidae contains only the ape-aye, *Daubentonia madagascariensis* (formerly known as *Chiromys*), one of the most extraordinary of all mammals. It is noted for the rodent-like incisor teeth, a single chisel-like pair in each jaw in nhich the enamel is restricted to the front and which are ever-groning. Canines are absent and the cheek-teeth, $\frac{4}{3}$, have flat crowns. There are, however, in the young aye-aye milk canines in the upper jaw, and the cheek teeth are more lemuroid. The general anatomy of the aye-aye is strongly lemur-like. The ears are large and naked, the head short and rounded. The tail is bushy. about 20 in. long. while the body is about 16 in. The thumb is clawed but opposable. The fourth finger is longest, while the third is almost as long and remarkably slender. The first toe is opposable with a flat nail, the other toes with pointed claws. In colour it is blackish, with the pale bases of the hair showing through. Arboreal in habit and nocturnal, the aye-aye feeds largely on the larvae of wood-boring beetles which it detects by its keen hearing The rodent-like teeth are used to gnaw through bark and wood, while the long, slender middle finger is said to be used as a grapple to insert into the holes of the insect prey and drag out the grub. In addition, it feeds on fruit, leaves and birds' eggs. Fossil jaws with gnawing front teeth suggestive of those of the aye-aye are known from the French Eocene. These are more or less intermediate between the primitive lemurs and the modern aye-aye.

Family Lorisidae includes the lemuroids of southeastern Asia and of Africa, which agree with the true lemurs in the curious comb-like lower front teeth, but differ in many features. The tympanic ring forms part of the auditory bulla, while in the lemurs it is ring-like, inside of the bulla. The internal carotid artery runs entirely external to the bulla instead of sending a branch, the stapedial artery, to run through it. The zygomatic or jugal bone is separated from the lachrymal by the maxillary, while the ethmoid forms part of the orbit.

Subfamily Lorisinae contains four genera. They have woolly fur, pointed face and broad, rounded head, large eyes. The index finger is small or rudimentary, the thumb and first toe are opposable, and the second toe is clawed. The tail is short, usually hidden by fur. *Loris tardigradus,* the slender loris, is confined to the lowland forests of southern India and Ceylon. It is a large-eyed, small-snouted, nocturnal animal, with extremely slender, long limbs and no tail. The limbs are generally strongly bent and the general appearance is that of an emaciated animal. In size this species is'about like a squirrel, the head and body about 8 in. long. Its colour is dark gray, with more or less reddish on the back, the underside pale gray; the young are more rusty in colour than adults. The index finger, though small, has three complete joints. The slender loris lives entirely in trees and sleeps during the day, grasping its perch by hands and feet. It is slow in movement, but is more active than its relatives. Succulent leaves, buds, honey, insects and birds' eggs form its diet.

Nycticebus coucang, the slow loris, is larger and much plumper than the slender loris, with smaller eyes and ears. It is about the size of a cat (15 in. long), tailless. The hind limbs are about the same length as the fore limbs. The colour varies considerably in different parts of its range, which extends from Assam, to Cochin China and the islands of Sumatra, Java, Borneo and some of the southern Philippines. This species is generally ashy gray with a buffy or reddish wash, although it may be silvery. Dark-brown markings surround the eyes, and a stripe of the same colour runs down the back, sometimes connecting with the circumocular rings, or there may be a large brown area on the crown. The fur is woolly and dense. The middle upper incisor tooth is much larger than the lateral one, and the upper canines are large. The female, as also in the slender loris, bears a single young one. The slow loris is nocturnal and hardly differsin habit from its slender relative. It lives solitary or in pairs, moving deliberately about the branches, upside down as readily as on top of them.

Perodicticus potto, the potto, closely resembles the slow loris in build. The muzzle is longer and broader; the eyes are farther apart, though large. The tail is about 2 in. in length while the head and body equal some 8 in. The potto is found in West Africa from Sierra Leone to the eastern Congo. Its close, woolly fur is reddish brown. A dorsal stripe of black runs down the back, and there is a dark ring around the eyes. The index finger is smaller than in the Asiatic lorises. Pottos feed on insects and vegetation; in stalking flies they move with extreme deliberation but are usually successful. So slow are their movements that African folk tales say a potto may starve to death travelling between one tree and another.

The awantibo, *Arctocebus calabarensis,* is much more rare than the potto, from which it differs by smaller size and lighter build, slender. pointed muzzle and rudimentary tail. The ears are large and pointed. The index finger is a small tubercle and the third finger is reduced. In the feet the second and third toes are about half the length of the fourth and fifth. In colour the awantibo is yellowish brown, somewhat paler below. A line down the nose is white. In the skull the palate has large perforations behind the incisors. This species is restricted to the Calabar coast of southeastern Nigeria. The African lorisids have strangely paralleled the Asiatic species, the awantibo showing many resemblances to the slender loris, while the potto is much like the slow loris.

Subfamily Galaginae are the long-legged lemuroids of Africa resembling in many ways the Madagascar mouse lemurs. The heel and navicular bones of the ankle are lengthened. The ears are large and naked; they can be folded up so as to lie nearly flat on the head. The galagos have molariform last premolars. *Galago crassicaudatus,* the greater galago, is widely distributed in eastern and southern Africa. It is the size of a small cat, some 13 in. long, with the tail 16 in. or more. The muzzle is longer and heavier than in the other representatives of this group. The feet are broad, with disk-like pads at the tips of fingers and toes. In habits these animals are agile and they leap great distances.

G. senegalensis is smaller, like a squirrel in size, with short face and large eyes. The tail is slender, with longer hair at the tip. In colour this species is pale gray, the tail yellowish or brownish, while the under parts are white. The pygmy galago, G. *demidoffi,* is about 6 in. long, with the tail some 43 in. It is generally reddish brown above, but the colour may be drab, the end of the tail somewhat darker and the under parts cream colour.

Euoticus elegantulus differs from its close relatives in having first upper premolar resembling the canine in shape and only a little smaller. This species is restricted to the forests of West Africa.

Tardoidea. — The tarsioids are of equal antiquity with the earliest lemurs, being represented in the Palaeocene and Lower Eocene of France, Wyoming and New Mexico. Even at this date the two groups were quite distinct and had become diversified into distinct genera and subfamilies.

Family Anaptomorphidae includes these ancient tarsioids. *Necrolemur* of France was distinguished by the angle of the mandible which was produced into a large hook-like flange. The canine teeth were not prominent. *Omomys* of Wyoming had a long jaw symphysis, with broad, tricuspate upper molars and unpaired anterior cusp on the lower molars. *Paromomys* of the Middle Palaeocene had enlarged lower incisors. The upper molars were broad, but short anteroposteriorly. Numerous related genera and species were described both from North America and Europe.

Anaptomorphus homunculus also from the Lower Eocene of Wyoming is well known from having been thought at one time to have been ancestral to man. The external upper incisor is small and set close to the canine which was small. The molars were broad, with three cusps. In size this species was about that of *Tarsius,* with eyes large but less extreme than in that species. Another species (*A. aemulus*) did not exceed the size of a squirrel.

Family Tarsiidae contains only the tarsiers (*Tarsius*) found in the forests of Sumatra, Borneo, Celebes, the Sangir Islands and the southern Philippines. The various island populations vary in colour and minor cranial characters, and several species may be recognizable. The tarsier is small, about 6 in. long, with tail 10 in. The hind legs are longer than the body and the hind feet are also long. permitting extraordinary leaps from branch to branch. The lower part of the heel bone and the navicular bone are lengthened and rod-like, somewhat like the foot bones of the frog. The fingers and toes are long and spreading, ending in flattened disk-like pads which aid in holding on to branches of trees in which the tarsier lives. The tail is long, terminating in a tuft. The head is rounded, with short, pointed muzzle, large, naked ears and enormous eyes, set close together, the orbits hardly separated by the nose. The thick, woolly fur is grayish-brown, the under parts are paler. The brain, although large. is remarkably primitive as compared to higher primates. Accordingly the skull, which largely reflects the character of the brain and sense organs, reveals enormous circular orbits, a swollen brain case, expanded auditory bullae and a reduced, greatly constricted nasal chamber. The jaws are slender and the teeth small, the upper molars being transversely widened with low, rounded cusps. *Tarsius* appears to be the rather specialized survivor of a very old primitive stock structurally intermediate between the tree shrews and lemurs below and the monkeys, apes and man above. Most of the known Eocene tarsioids are too specialized in their teeth to be the ancestors of monkeys (with possible exceptions noted below). The foot structure of at least two of these forms already showed more or less of the characteristic elongation of the heel bone and navicular.

SUBORDER ANTHROPOIDEA

The monkeys, apes and man differ from the lower primates in numerous ways. Cranially the orbits are separated from the temporal fossae by bony walls. The tympanic bulla is not inflated. The brain is highly developed, with numerous convolutions. The uterus is single and rounded; the placenta involves both embryonic and maternal tissue—at birth the lining of the uterus is lost (deciduous)—and it is discoidal or doubly so in shape.

Ceboidea.—The American monkeys are differentiated from those of the old world by widely separated nostrils facing laterally, whence the name "platyrrhine" (flat-nosed). The head is rounded with relatively small jams and the ears lack the pointed tip common in old world monkeys. The buttocks do not bear callosities and the thumb is never truly opposable to the other digits; it may be vestigial or even absent. The opposable great toe of the hind foot bears a flattened nail. but the nails of the other digits of both hand and foot are frequently compressed laterally and in the marmosets become claws.

The American monkeys are all arboreal The recent genera inhabit the tropical forests of South America. a few species extending northward into Central America. spider monkeys and howler monkeys even to Mexico. Except from Ecuador northward. the Andes limit the western range of monkeys, though some howlers spider monkeys and sapajous reach an elevation in Guatemala of 6,000 to 7.000 ft. A fossil cebid *Homunculus,* found in Lower Miocene formations in Patagonia, indicates the great antiquity and former wide range of the family.

Family Cebidae, comprising all the platyrrhine monkeys except the marmosets. is divided into some ten distinct genera. Many monkeys of this group have prehensile tails. capable of curling around a branch and supporting the weight of the body. When the tail is not so efficient a grasping organ it may assist in balancing. The teeth number 36 ($i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{3}{3}$) and the molars are four-cusped, the inner pair of cusps somewhat crescentic. The brain varies in development, but the cerebral hemispheres are convoluted and cover or almost cover the cerebellum. Many of the smaller species have brains that are large relative to the body's size The cebids are all forest-living; none of them is very large.

The titis, *Callicebus,* are probably the most primitive of the group. These monkeys range from Panama to the southern border of the forests. although best represented in Brazil and neiahbouring countries The species are usually reddish in colour; they are small; the head and body 12 to 14 in, the tail is about the same length and bushy. not prehensile. The eyes are medium-sized, the ears smaller than usual in the family. Titis are diurnal in habit They feed on fruit, insects, birds and birds' eggs.

Closely allied to the titis are the dourocoulis, *Aotus* (often called *Nycticebus*), the only nocturnal monkeys. The toil is long but not prehensile. The large, closely approximated eyes and short face. surrounded by a ruff of pale fur, and the large, white spot over each eye give these little animals a peculiarly owl-like expression A central and two lateral black lines border the pale spots. The nostrils are closer together than in other platyrrhines, probably correlated with the closeness of the eyes to each other. The ears are small, almost hidden by the fur. There is considerable variation in colour from iron gray to gray mixed with orange brown, and the fur may be short and soft, or long and lax. There may well be only a single species, although several are recognized by zoologists The face around the eyes and nose is naked The dourocoulis feed on fruits and insects which they hunt at night. remaining hidden by day From the behaviour of *Aotus* and the high development of the olfactory parts of the brain. it is thought that the sense of smell is well developed more so than in other monkevs. The eves, unlike those of other Anthropoidea are adapted for nocturnal vision, and the central area of the retina lacks the fovea or island of pure cones. *Aotus* is found from Panama to Peru and Brazil.

The sakis and their relatives ***(Pithecia)*** have procumbent lower incisors, somewhat like those of the lemurs, and separated from the large canines by a gap. The tail is bushy and not prehensile; it may be long or short. The nostrils are widely separated. The thumb is comparatively well developed. The hair is generally long, often forming bushy side whiskers. In the white-headed saki (P. *pithecia),* the males are black with white head, while the females are grizzled with a yellowish wash. This species is found in the Guianas and northern Brazil. The race found along the Rio Negro, Brazil, has the head of the male buffy and the hairs are short. The hairy or monk saki (P. *monacha)* has harsh, long fur, a hood of forwardly directed hairs on the head and neck. In colour both sexes resemble the females of the preceding species, but the hands and feet are white. The monk saki occurs on the Upper Amazon from eastern Peru. Ecuador and western Brazil. On the Lower Amazon a rare variety or closely related species (P. *albicans*) occurs; it has pale grayish head, neck and limbs, but is otherwise like *monacha.* These three species are about the size of large cats, nearly a yard in total length, of which the bushy tail is half. The red-backed saki (P. *chiropotes*) of Venezuela, the Guianas and Upper Amazon is smaller. with soft fur and less bushy tail. The long hair on top of the head is parted and suggests a poorly fitting wig, and the beard of the males is also divided. The black saki (P. *satanus*) resembles the preceding form but is blackish, the females and younger animals with brown overlay on the back. It occurs along the Lower Amazon and around Pará (Belem). The white-nosed saki (P. *albinasa)* of western Brazil, is a large black species with red nose and upper lip, a triangular white mark on the nose and naked face. The back may be grizzled. These three species show many cranial characters connecting the sakis with the uakaris. The uakaris (often considered a separate genus called *Cacajao* or, wrongly, *Brachyurus*) differ from all other American monkeys in their short tails (about 6 in. long). P. *melanocephala,* the black-headed uakari, is brown in colour except for black head and face; it occurs along the Rio Negro in northern Brazil. P. *rubicundus,* the red uakari, is brighter in colour than most mammals, rich rufous, the bare face bright vermilion; it is confined to the upper Amazon between this and the Ica river. The bald uakari (P. *calvus*) differs from its close relatives in having the fur sandy white; the face is red as that of the red species. The naked area of the face extends to the ears and the crown of the head, the underside of the body is dark brown. The uakaris are some 20 in. long.

The howling monkeys *(Alouatta,* often wrongly *Mycetes)* are the largest of the new world monkeys, the size of a small dog (some 20 in. long with tail about the same length). The howlers are notorious for their extraordinary vocal powers, their roars being audible for several miles. The powerful prehensile tail is naked at the tip and friction ridges similar to those on our hands and feet have developed. There is a beard in males. The head is high and the skull pyramidal, with greater prognathous development of the face than in other American species. The lower jaw is deep and the hyoid bone of the male is curiously expanded, forming a great bony cup, with the thyreoid cartilage also dilated. The intelligence of howlers is not high, and the brain is small and poorly developed, unlike that of other new world species. The Indians have tamed most monkeys of the Brazilian forest but not the howlers. The red howler *(A. senicula*) is dark reddish chestnut. paler on the back and sides. It occurs from Venezuela and northern Bolivia to the Guianas.

The black howler (*A. belzebul*) is found along the south bank of the Amazon to Rio Tapajoz. East of there a race with a reddish back and hands occurs, although individuals may be almost pure black. The carava *(A. caraya*) occurs from Goyaz province, Brazil, through the Matto Grosso to northern Argentina. The adult males are black, while the females and young are ashy gray. The brown howler (*A. guariba*) of the mountains of eastern Brazil, is either reddish brown or blackish mixed with buffv. The mantled howler (*A. palliata*) is found from southern Mexico to Ecuador: it is blackish, sometimes grizzled on the back, with a gray or brownish mantle along the sides.

The squirrel monkeys (*Saimiri,* often wrongly *Chrysothrix)* are handsome, diminutive forms, about the size of squirrels. The face is short, almost vertical, with large eyes set close together. The ears are large, the nostrils widely separated. The tail is long, rounded and somewhat club-shaped; it is not prehensile. Their heads are produced backwards, the skull articulating near its middle with the spinal column. The brain is relatively larger than even that of man; the cerebral hemispheres overhang the cerebellum to a greater extent than in any other primate. Although smooth externally, the main grooves or sulci are evident in dissection. *S. sciurea* of Brazil, eastern Peru and northern South America has a gray head, the back gray or washed with gold. *S. oerstedi* of Panama, Costa Rica and Guatemala has a black crown, reddish-gold body, gray tail with black tip, white cheeks and throat.

The sapajous or capuchin monkeys *(Cebus)* are the most familiar of the new world primates, aptly called by H. O. Forbes "the typical genus of the American monkeys." The common names sapajou and capuchin are applied to these familiar monkeys. They are vivacious and relatively hardy; individuals having been known to survive in captivity for 25 years in the North Temperate zone. The thumb is well developed, though not opposable and the hands are used in a great variety of manipulations. The tail is slightly prehensile and usually carried curved toward the underside. With the superior functional adaptation of the hands is correlated a large, highly-developed brain and an intelligence comparable to that of the old world monkeys.

C. capucinus, the white-fronted sapajou, occurs from Honduras to Colombia. The body is black, the face and forehead naked, flesh-coloured, the forehead, cheeks, throat and chest yellowish white. *C. albifrons* is similar, with dull brown instead of black; it is found in Colombia, Ecuador and Peru. The brown capuchin of Ecuador, C. *aequatorialis,* is grizzled brown in colour, the crown, limbs and tail darker. *C. apella,* the smooth-headed capuchin of the Guianas and Venezuela, is fuscous in colour, more grayish on the forelimbs and face, the tail and feet dark. The tufted capuchin *C. fatuellus,* is found from Colombia to the Matto Grosso of Brazil and northern Bolivia. It has a black crown, reddish body, the feet and tail dark dull brown. Considerable variation occurs even in members of the same band. *Cebus* ranges from near sea level to about 7,000 ft. elevation.

A group of closely related monkeys comprises the woolly monkeys, *Lagothrix;* the spider monkeys, *Ateles* (or *Ateleus*); and, intermediate between these, the woolly spider monkey, *Brachyteles.* These are fruit-eating monkeys, all considerably larger than *Cebus.*

Lagothrix has particularly soft, woolly fur, grayish or brownish in colour, and a naked black, peculiarly human face. The generic name means "hare-hair," from the resemblance between fur of the typical forms and that of the hare. The hair of the head is short and stands upright. The common woolly monkey (L. *humboldti*) is heavily bodied, iron gray in colour with darker head and feet. The tail is prehensile and the thumb is moderately developed. This species is found from Colombia to Peru and the Cpper Amazon. Throughout this range the colour varies from pale gray to dull reddish brown, and the pelage is long and woolly or short and soft. *L. hendeei* of Peru is very different. The back is rich reddish black, almost dark vinaceous, the head, sides and under parts black. The fur is silky, very long on the underside. A white triangular spot is on the nose; the long hair on the scrotum and the underside of the tail tip are pale golden colour.

The spider monkeys have coarse hair; the thumb is vestigial or absent externally, while the other fingers are elongated to form highly serviceable, hook-like hands for rapid swinging from branch to branch. The limbs and tail are also elongated. Spider monkeys frequently walk erect. The black spider monkey *(Ateles paniscus*) is represented by the typical form in the Guianas and northern Brazil. The face is red and naked, while the hair of the back is long. The variegated spider monkey (A. *belzebuth*) is black with buffy or whitish under parts, the inner sides of the lower legs and forearms similarly buffy. A white or golden triangular or band-like forehead patch is often present. The cheeks are often white or buffy. This species ranges from the Upper Orinoco to eastern Peru and the Lower Amazon on its southern bank. A Colombian race is pale grayish brown sprinkled with black. The brown-headed spider monkey *(A. fusciceps)* is black or blackish brown with head distinctly paler than the back. The hair of the crown is shorter than usual and does not project over the forehead. The black-handed species of Central America, north to Veracruz district, Mexico, *(A. geoffroyi*) may be recognized readily by the black hands, feet and head and reddish-brown or yellowish body fur.

Brachyteles arachnoides, the woolly spider monkey of southeastern Brazil, forms a link between *Lagothrix* and *Ateles.* Its fur is woolly; the thumb is small but still visible externally. The body is yellowish brown, darker on the back of the head. The females are grayer. The hairs on the head are directed backward.

These three genera all have long and powerful prehensile tails, of which the extremity is naked on the underside and provided with friction ridges like a finger. This organ is used not merely in climbing but also for picking up objects. These monkeys are easily tamed, affectionate and intelligent. The brain, especially in *Ateles,* is exceptionally large and complex.

Callimico, a peculiar type previously assigned to the genus *Callithrix,* has most of the external features, including claws, like the Callithricidae, but the skull, though essentially that of a marmoset, has certain likenesses to the Cebidae, the most important being the retention of the third molars. O. Thomas proposed a new subfamily, Callimiconinae, which he was inclined to place in the Cebidae. The callimico is about 8 in. long with a tail little more than a foot in length. Its colour is dark brown, the limbs, under parts and tail black, with white tufts in front of the ears and on either side of the back near the loins. The place of origin is between the Rio Ucayali and the Madeira, western Brazil.

Family Callithricidae contains the marmosets, the smallest of the Anthropoidea. They are handsome little animals, some smaller than squirrels. These were considered by some the most primitive American monkeys. but they probably represent dwarfed descendents of ancient cebids. Marmosets have only 32 teeth ($i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{3}{3}$, $m\frac{2}{2}$); the last molar was lost rather than one of the premolars, as was the case in the old world monkeys. The digits, except the hallux, bear sharp, curved claws in place of nails, forming in such small creatures highly efficient organs for climbing. The hands are used for grasping food, but they are not used much in manipulation as in higher primates, and the intelligence of the marmosets is decidedly inferior to that of the cebids. In the hind foot the great toe is smaller and less opposable than in other primates. The cerebrum, though large, is almost devoid of convolutions. Marmosets live in small bands; they are diurnal and feed on insects and fruit. They commonly breed in captivity, producing two or three young at a birth, instead of one as in monkeys in general.

The common marmoset or ouistiti. *Callithrix jacchus,* is an inhabitant of eastern Brazil, between Pará and Bahía west to the Rio Tapajoz. It is some 9 in. long with a tail of 12 in. The back is barred with black and grayish, as is the tail. while white ear-tufts distinguish this species from its close relative, the black-eared marmoset (C. *pencillata*) of southeastern Brazil which, except for its black head, is otherwise similar. The white-tufted marmoset (C. *aurita*) has the back variegated black and reddish or yellowish, and a ringed tail. A spot on the forehead and the ear-tufts are whitish. This species occurs in São Paulo province, Brazil. The white-headed marmoset (C. *geoffroyi*) of east-central Brazil has black ear-tufts and resembles the black-eared species in body colour, but the head is pure white in front of the ears. It is about 8 in. long, with a tail of the same length.

The yellow-headed marmoset, *C. flaviceps,* also from the east coast of Brazil above Rio de Janeiro, has a whitish face and forehead, the head, neck, shoulders and arms yellowish buff or reddish. The body is variegated black. gray and tawny. the latter colour disappearing on the lower back leaving black and gray bands which extend on the tail. The elegant marmoset (*C. petronius*) of Minas Geraes, Brazil, has long hair, coal black except for a few yellowish bands on the back. The forehead and upper parts of the ear-tufts are white; the hands and feet, as well as the pale bands of the tail, are pale gray. The golden marmoset (*C. chrysoleuca*) of lower Rio Madeira, Brazil, has silky hair, white on the body with golden under parts, limbs and tail, the latter obscurely barred with white. The silvery marmoset (C. *argentata)* is silky white with the tail black, the limbs are dark fuscous in one race and the body ashy gray. The white-shouldered marmoset *(C. humeralifer)* of Bahia, Brazil, is blackish, mottled with white on the back and with whitish nape, shoulders and ear-tufts. *C. leucippe,* the gilded marmoset of the Rio Tapajoz, is white with legs and tail pale gold. Unlike the similarly coloured golden marmoset, the ears are without tufts. The pygmy marmoset *(C. pygmaea)* is found in the upper Amazon region, eastern Ecuador and Peru and western Brazil. It is about 6 in. long with tail about 7 in. The head and shoulders are ticked black and buffy, the back mottled black and buff and the tail is vaguely banded. The ears are untufted.

The tamarins *(Leontocebus)* have short lower incisors, leaving the canines projecting high above the tooth row. The tail is unbanded and almost always black, and the ears lack the tufts characteristic of *Callithrix.* The white-lipped tamarin *(L. labiatus*) of the Upper Amazon is mostly blackish, the hack mixed with gray, the under parts and inner sides of limbs rich orange red. The tail. rusty at the base, becomes purplish black. The red-headed tamarin *(L. pileatus*) is found along the upper tributaries of the Amazon in eastern Peru and western Brazil. It is blackish except for the rufous forehead and crown, while the sides are brownish and the back somewhat mixed with gray. Around the mouth there are long white hairs. The imperial tamarin *(L. imperator*) ranges from eastern Ecuador and the Rio Negro to northern Bolivia; it has a long, upward-curling, white moustache, extending beyond the face. The body is gray, with a red-orange rump and base of the tail, black ear-tufts and end of the tail. The red-handed tamarin (*L. midas*) is relatively large, with large ears; its back is grizzled while the hands and feet are reddish golden. This species comes from the Guianas and was one of the first to become known to science. The negro tamarin *(L. ursulus*) lives along the Lower Amazon, is closely allied to the preceding species, but is distinguished by its black hands and feet; the back and outside of the legs have a reddish mixture. The face is hairy, the hair of the head not elongate, while the ears are large and naked. *L. leucopus,* the white-footed tamarin of northeastern Colombia, is dark gray with white hands, feet and head, the latter parts short-haired; the tail is black with a white tip. The brown-headed tamarin *(L. fuscocollis*) of the Upper Amazon is black variegated with yellowish ochre colour, the head yellowish buffy. The lion or golden tamarin *(L. rosalia),* found around Rio de Janeiro, is characterized by an extensive mane, suggesting that of a lion; its naked face is blackish violet. It is about a foot long, with slightly lonrer tail. The gold-and-black tamarin *(L. chrysomelas*), which comes from the coastal region of Bahia, Brazil, has body, face, underside and upper arms black, the legs blackish red, the head and forearms golden yellow. The pinché or silky marmoset (L. *oedipus*) of northern Colombia has a plume-like crest on the head, white in colour, as are the under parts and limbs. The back and thigh are brownish. The base of the tail is brown while the distal end is black. Geoffroy's marmoset (L. *spixi*) represents this species in Panama. It is similar in colour, but the hair on top of the head is not elongated, while the crown and nape are reddish brown.

A number of other species are known; the variation in colour and hair pattern is astonishing in this group.

Origin of the New **World** Monkeys.—The monkeys of South and Central America form an entirely different series from the monkeys of the old world and in spite of their general similarity to the latter, they probably were derived from a different ancestral stock.

In the first place the face in new world monkeys differs widely from that in old world monkeys, especially in the fact that in the new world or platyrrhine series the nostrils are usually widely separated at the base and are directed laterally. Other external differences from the old world monkeys were noted above. The new world monkeys may also be at once distinguished by the fact that there are three bicuspid or premolar teeth on each side, both in the upper and in the lower jaws, whereas in old world monkeys there are two. In the region of the middle ear, on the lower side of the skull, new world monkeys have a large ring-like tympanic bone, whereas in old world monkeys the same element forms a bony gutter, completely covering the drum-membrane on the lower side of the skull. Moreover, the cheek-bone of new world monkeys has a broad contact with the parietal bone, which is never the case in old world monkeys. The placenta in new world monkeys is disk-like, without the secondary placenta seen in old world monkeys.

All known new world monkeys both living and fossil stand on a rather high plane of evolution and there are no "living fossils" to connect the group definitely with any older fossil family. It is also difficult to be sure which is the most primitive living genus, but after repeated analyses of the characters of the skull and teeth it seems probable that the most primitive are certain small monkeys of the family Cebidae, especially the owl monkey (*Aotus*) and *Callicebus.* As noted above, the olfactory region of *Aotus* is less reduced than in most Cebidae and marmosets. These little monkeys have large orbits, short deep lower jaws, short muzzles and unreduced molar teeth. They agree with certain North American Eocene tarsioids in their dental formula $(i\frac{2}{2}, c\frac{1}{1}, p\frac{3}{3}, m\frac{3}{3}) \times 2 = 36$ and in the general form of the skull, but they differ from all known tarsioids in that the tarsal bones are not elongated. On the other hand, it is not impossible that the skeleton of the South American monkeys may have been derived from the type illustrated in the Iiorth American Eocene *Notharctus,* but in the present state of knowledge this inference is unsafe in view of the prevailing resemblances of the dentition and skull of *Aotus* to the tarsioids rather than to the notharctids. Finally there is the possibility that the new world monkeys may be derived from early extinct lemuroids resembling *Archaeolemur.*

Typical platyrrhine monkeys (*Homunculus*) in the Lower Miocene of Patagonia were found in association with a peculiar mammalian fauna which for millions of years had its headquarters in South America; but some of the ancestral stocks of this fauna were found in far earlier (Eocene) deposits of Iiorth America. In view of other available evidence, an ultimate North American origin for the new world primates seems quite possible. The monkeys now inhabiting Central America are closely related to those of Guiana and Brazil.

The new world monkeys as a whole exhibit a profound adaptation to arboreal life and probably originated in some heavily forested region such as they now occupy.

The old world or Catarrhine primates comprise two superfamily groups.

Cercopithecoidea.—Only family Cercopithecidae, the tailed monkeys, is included here; these monkeys are distinguished from the American species by features mentioned above. Two subfamilies are recognized: Cercopithecinae, including the macaques, baboons, mangabeys and guenons; and Colobinae, comprising the langurs and guerezas or colobus monkeys.

Subfamily Cercopithecinae all have cheek pouches in which food may be temporarily stored. The stomach is simple and these monkeys feed on insects and other animal matter as well as vegetable matter. Of this group the macaques, probably the best known of all monkeys, are widely distributed in India and the East Indies, north to China and Japan, while one species inhabits North Africa and the Rock of Gihraltar.

The macaques are among the most generally adaptable of monkeys and are hardy and long-lived in captivity. Though agile climbers, they are by no means exclusively arboreal and some are entirely terrestrial. They are usually omnivorous, and the crab-eating macaque of India lives chiefly on Crustacea. They have fore and hind limbs of about equal length. The thumbs, though short, are opposable and the animals have considerable manual dexterity. There is a median air sac connected with the larynx. The ischial callosities are well developed. The tail may be long, short, or practically absent as in the Barbary ape, *Macaca sylvana.* The lion-tailed macaque (*M. silenus)* occurs in India. Its colour is black with an enormous gray beard and ruff which surrounds the black face with the exception of the middle of the forehead. The tail is tufted at its extremity like that of a lion. The crab-eating macaque (*M. irus*) also has a long tail but lacks a mane. These monkeys feed on crustaceans along the shores and river-banks and swim readily. The colour is grayish or brownish and this species ranges from Siam to Timor in the East Indies, the Nicobars and the Philippines. The bonnet and toque macaques (*M. sinica* and *M. radiata)* have odd wig-like topknots, radiating from a central point; the former lives in southern India, the latter in Ceylon. They have long tails, about the same length as the head and body. The commonest species and the hardiest is the rhesus or Bengal macaque (*M. mulata*) found all over northern India, Burma, Indo-China and southern China. The tail is short, about half the length of the hind leg. The colour is grayish brown, becoming reddish on the rump and tail. The Himalayan macaque (*M. assanensis)* is similar but lacks the reddish on the rear parts and has woolly, thick hair. The Formosan macaque (*H. cyclopsis*) is also closely allied to the rhesus. but is olive gray in colour. The pig-tailed macaque (*M. nemestrina*) is larger, reaching the size of a large dog, and has a long face. The tail is only about 8 in. long. The fur is olive brown. The pig-tailed monkey is found from Burma to Sumatra and Borneo. The stump-tailed macaque (*M. speciosus*) has also a short tail; it is found from Tibet to Malaya, while the short-tailed brown Japanese macaque (M. *fusca*), with its red face, is confined to the Japanese Islands. The Celebes or Moor macaque (*M. maura*) is brownish black, with grayish limbs and a stump of a tail.

The black ape (*Cynopithecus niger*) with baboon-like face, has no tail. The head bears a tuft or crest of hair and the brow ridges are large. This species, a close relative of the macaques, is found in Celebes and Batjan Island.

Mangabeys (*Cercocebus*) are long-tailed monkeys found in the forested parts of tropical Africa. Their upper eyelids are white and their hairs are not banded. *C. torquatus*, the collared mangabey of southeastern Nigeria and the Cameroons, is blackish gray in colour with a bright bay crown and white collar, cheeks and chest. *C. atys,* the sooty mangabey, lives in West Africa from French Guinea to Liberia; it is grayish black above, paler below; the crown patch is speckled with olive. The face is flesh coloured except for the nose, mouth and chin, which are blackish. A race from the Gold Coast (*C. a. lunulatus*) has a white crescentic spot on the crown; the colour is more brownish. *C. agilis,* the gray mangabey of the Congo and eastern Cameroons forests, is dark grayish brown speckled with yellowish buff, especially on the front part of the body and thighs. The side whiskers are outstanding. The underside of the typical race is dirty whitish, but a race south of the Belgian Congo forests (*C.* a. *chrysogaster*) has under parts which are orange. The crested gray mangabey (C. *galeritus*) is found only along the Tana river, Kenya; it resembles the preceding species except for the long, pointed tuft on the top of the head, and it is smaller. The gray-cheeked mangabey (*C. albigena*) is dull black with horn-like eyebrows and a sooty bronn or grayish mantle on the shoulders; the typical race comes from the southern Cameroons and probably also Gabun. The eastern race, from Uganda and the Ituri forest. has a paler mantle and the head is more brownish, while a slightly different form occurs in the northern Cameroons and southeastern Nigeria. *C. aterrimus,* the crested black mangabey. is glossy black, with a vertical peak-shaped sagittal crest of fur and long, grayish cheek whiskers; it lacks the eyebrow tufts and mantle. This species inhabits the forests south of the Congo river.

The gelada or lion baboon (*Theropithecus gelada)* inhabits the mountains of Ethiopia. It is a large, blackish, ground-living monkey, with a long mantle of dark hair, the cheeks and rear parts grayish, while the end of the tail is tufted. The face is long and baboon-like, with nostrils tubular and well back from the end of the muzzle. thus resembling the macaques.

The true baboons *(Papio)* have the nostrils at the end of the muzzle, the tail is shorter than the head and body, and in some forms it is much shorter. These large, ground-living monkeys are a modified branch of the macaque group. In captivity there have been cases of hybrids between macaques and baboons. The sacred baboon *(P. hamadryas)* is the species represented in the ancient sculptures of Egypt. It is found in the Sudan, Ethiopia, Eritrea, Somaliland and southwestern Arabia and is characterized by its speckled gray colouration and the long mantle of the males. Typical baboons are found from the Cape to the Sudan, chiefly where the country is rocky. They are referred to several species, chiefly because of their colouration, which varies from golden and red to dark olive brown. The chacma *(P. comatus)* of South Africa, and the anubis baboon *(P. doguera)* of Kenya and Uganda are dark, while the yellow baboon *(P. cynocephalus)* of Tanganyika, the small yellow species (P. *kindae*) found in Northern Rhodesia and the Katanga and the red baboon (P. *papio*) of the Guinea region, are brightly coloured forms.

The mandrill (P. *sphinx)* might be called the rib-faced baboon, from the ridges on either side of the muzzle in the adult male. The massive head with its swollen blue muzzle, lined with reddish, the yellowish beard and the stump of a tail are distinctive. The general colour is dark olive brown, while the naked skin of the buttocks is bright crimson. The females are much smaller and are difficult to separate from the next species. The mandrill lives in West Africa, from the Sanaga river in the Cameroons to the Gabun and Middle Congo of French Equatorial Africa. The drill (P. *leucophaeus*) of the northern Cameroons is similar in build but the face is black; each side of the muzzle bears a single ridge, the top of which may be flesh coloured; the lip is crimson as are also the bare buttocks, while the face is outlined with white. These two species are frequently considered to form a distinct genus, *Mandrillus.*

The guenons, *Cercopithecus* (or *Lasiopyga)* comprise a number of species found over most of Africa south of the Sahara. The last lower molar tooth has only four cusps rather than the five found in old world monkeys considered thus far. The fur is ticked, the hairs many-banded with dark and light colours, and some species are brightly coloured. Guenons are mostly small monkeys living in trees and subsisting on fruit, leaves and insects. They have well-developed cheek pouches. The Diana monkey *(C. diana*) of West Africa (Liberia and the Ivory Coast) is named from the white crescent on the forehead above the eyes. The face and front of the beard are black, but the cheeks, throat, chest, front of shoulders and a bar on the thigh, are white. The body is blackish, finely speckled white, a broad bay streak runs down the back and the back of the thighs. In Nigeria the local race, *C. d. roloway,* has a longer white beard. The dryas guenon *(C. dryas*) lives in the forests south of the Congo river; it is closely allied to the Diana, with a short, full beard, but the general colouration is greenish gray. The De Brazza guenon *(C. neglectus)* is found from the Cameroons to the eastern and southern Belgian Congo. This species has a white beard and muzzle, and white hip-stripe; its orange-buff forehead band is broad, margined above with black: the body is a pale olive gray and the arms, hands, feet and tail are black. It takes readily to water, unlike most of its relatives.

C. aethiops, the common guenon, is found from Senegal to Ethiopia and south to the Cape, but avoids the rain forest areas for the most part. The grivet (*C. a. aethiops)* is olive gray with cheeks and eyebrow marking white; this race lives in Ethiopia and adjacent lands. The vervet of South Africa *(C. a. pygerythrus*) is more greenish with black hands, feet and distal third of the tail; the root of the tail is reddish. In Mozambique this is represented by a more reddish form *(C.* a. *rufoviridis*); in East Africa there is a yellowish race *(C. a. johnstoni*), while *a* dull grayish type invaded the eastern Belgian Congo *(C.* a. *centralis*). In West Africa is found the green monkey *(C. a. sabaeus)* with fur mixed black and yellow; the tail is yellowish, sometimes quite orange and the forehead is blackish although a narrow white band sometimes occurs. Another race, the malbrouck *(C. a. cynosuros*), with flesh-coloured face, well-marked white forehead band, grayish cheeks, and grayish-green colouration, comes from Angola and southern Belgian Congo.

The moustache monkey (C. *cephus*) is small, with a short face, the upper lip and nose ornamented by a broad bluish-white marking. It has well-developed cheek whiskers of yellow, bordered below by black, whitish under parts and reddish tail. This species is found from the mouth of the Belgian Congo river, north to eastern Nigeria. *C. erythrogaster* of *W.* Cameroons is closely related but lacks the light markings on the face. The nose is black, there is a large light cheek patch and reddish under parts. The lesser spot-nosed monkey (C. *petaurista*) is reddish in colour with a heart-shaped white spot on the nose and white or yellowish cheek whiskers often divided by black, and the brows are also black. The underside is white. Various local races of this monkey are found in forested regions from Liberia to Katanga and East Africa (North of Lake Victoria Nyanza.)

The hocheur or large spot-nosed monkey *(C. nictitans)* is found on the island of Fernando Po, and from Liberia to the Ubangi river. The tail is long, the colouration of the body and basal half of the tail dark blue gray, the back of the head, forelegs and end of the tail black. The white nose-spot is large and is somewhat rhombic in shape. In the western parts of its range the under parts become white or whitish (C. *n. martini)*.

The mona *(C. mona)* comes from West Africa. It is dark reddish olive, becoming blackish on the lower back, and there is a white spot on the rump on either side of the tail. The under parts are white, while the cheek whiskers are straw-coloured. A crescentic band of gray extends across the forehead from ear to ear, bordered below by black. Closely related forms, lacking the white spot beside the base of the tail, and with several minor differences in colour range from Sierra Leone to the eastern Belgian Congo. *C. pogonias,* from Fernando Po, the Cameroons and Gabun, has three black stripes on the head, one medial and one on either temple, while the hands, feet and tail are black. The extensive side whiskers are yellowish and the general colouration of this monkey is yellowish gray.

The diadem monkey *(C. mitis)* is typically bluish gray, with black limbs, under parts and tail. The forehead has usually a whitish bar, and the throat is white. In the Kivu mountains an orange-red race (C. m. *kandti)* occurs, while in East Africa *(C.* m. *albogularis*) the under parts and throat are white, the back is reddish. The golden Stair's monkey *(C. m. staiusi)* of Mozambique also belongs to this group, yellowish having replaced the whitish bands and the black bands having become pale. The owl guenon, *C. hamlyni,* is a large greenish-gray guenon of the eastern Belgian Congo, with black under parts, limbs and face, except for a white stripe down the nose. and frosted thighs and tail. The white-ruffed guenon *(C. l'hoesti)* has black face, under parts, tail-tip and limbs; the white ruff and throat contrast strongly with this; the head and tail are blackish gray, while the back is dark, rich reddish. The white ruff extends up on the cheeks and the hairs are directed upward. There is strong resemblance in this colour pattern to that seen in the white-throated diadem monkey of East Africa, but the upwardly directed hairs of the ruff and the black limbs distinguish it. This species is found in the eastern Belgian Congo, while a race (C. *l'h. preussi*) with speckled thighs is found in the west (Mt. Cameroon and Fernando Po).

The talapoin or dwarf guenon (C. *talapoin*) is found from the Cameroons to Angola and the eastern Belgian Congo, although in large parts of this range it was not found. It is about 10 in. long with the tail about 16 in.; the general colouration is grayish buff, the nose is black and the cheek whirl whitish as are the under parts. The face is extremely short and the last upper molar tooth has generally three cusps instead of four.

The huzzar or nisnas monkeys *(Erythrocebus patas*) are large and reddish, ground-living animals. The western race (E. *p. patas*) has the nose, a band above the eyes and the outer side of the upper arm black. In East Africa *(E. p. pyrrhonotus*) has a white nose and the upper arms are reddish. The huzzar monkey lives in the savanna country from Senegambia to the Upper Nile; this species is represented on ancient Egyptian monuments and was probably the Cebus of ancient writers.

The blackish green guenon (*Allenopithecus nigroviridis*) is found only along the middle section of the Congo river. It is blackish olive in colour, the face, hands, feet and upper side of the tail black and this colour predominates down the back. The cheeks, throat and under parts are grayish white, the latter mixed with ochraceous and black. The cheek teeth are high-crowned, the cusps drawn together, leaving narrow, longitudinal grooves between them and the limbs are short and stout.

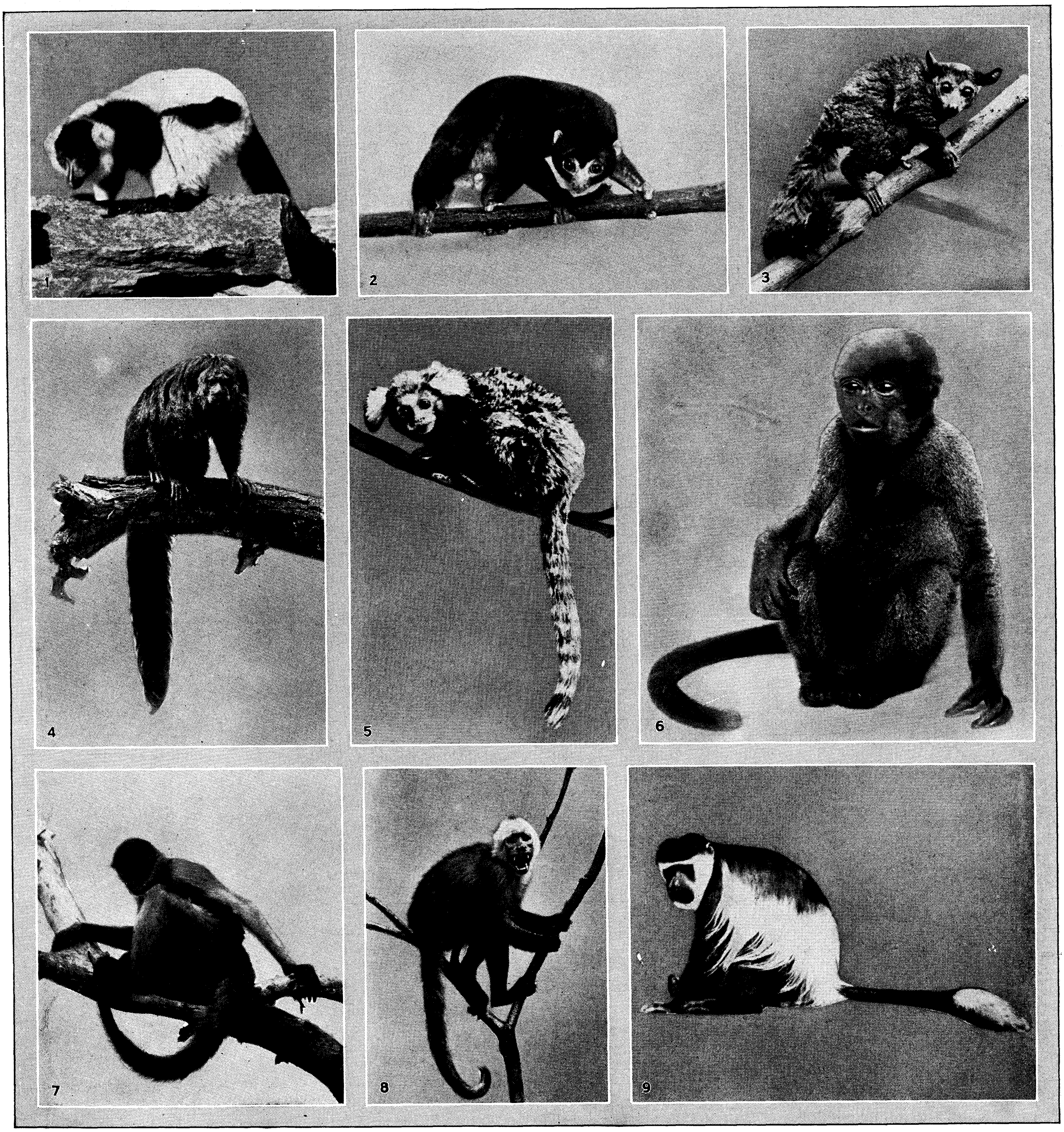
The monkeys of subfamily Colobinae have a sacculated stomach and lack cheek pouches. The teeth are sharp-cusped and the diet is largely leaves, shoots and young twigs of trees, although fruit is also eaten. The African colobus monkeys *(Colobus)* are thumbless. The ursine colobus (C. *polykomos)* of West Africa (Ivory Coast to Sierra Leone) is black, with whitish cheeks, throat and tail. A white-thighed race (C. *p. vellerosus)* represents it in the Gold Coast and Togo. The black colobus (C. *satanus*) is similar to the preceding but lacks white markings; it is found in Fernando Po, the Cameroons and the Gabun. The guereza or mantled colobus *(C. abyssinicus)* occurs from Ethiopia to Tanganyika, the mouth of the Congo and eastern Nigeria. It is black with a long mantle of white along the sides, white cheeks, beard and supraorbital bar, and white-tufted tail. The extent of white varies somewhat and several races are recognizable. The Angola colobus *(C. angolensis)* ranges from the lower Congo to East Africa. The white hairs of the cheeks are long, the shoulder tufts are white and so is the distal part of the tail. The face is pinched, like that of a frail old woman, while the broad muzzle of the guereza suggests an elderly but healthy sailor with white whiskers and beard. The olive colobus *(C. verus)* is the smallest species (the head and body about 21 in., the tail 24 in.). The back is greenish brown, the limbs and tail dark olive, while the under parts are silvery gray. This species is restricted to West Africa, Liberia to the Gold Coast. The bay colobus monkeys (C. *badius)* vary locally and in consequence numerous races are recognized. The typical form comes from West Africa (Sierra Leone to the Ivory Coast) ; it is black, with bay forearms, legs and under parts. In French Congo a red form (C. *b. tholloni)* occurs, while farther east in Belgian Congo *C.* b. *powelli* is reddish brown, with dull yellowish-brown limbs. The Zanzibar colobus (*C. kirkii*) is also reddish, its hands, feet and shoulders are black, while a pale yellowish crest on top of the head is parted and falls over the ears and forehead. The red-crowned colohus (*C. rufomitratus*) is brownish gray in colour, with a reddish crown, black supraorbital band and a black transverse crest above the ears. This rare species is known only from the vicinity of Tana river, Kenya.

The langurs or leaf monkeys of Asia are slender-bodied, the limbs are long, as is usually the tail. Unlike their African relatives, the thumb is well developed. The sacred langur or hanuman (*Semnopithecus entellus)* of India and Ceylon is white or pale grayish in colour, the hands, feet and face are black, as are the overhanging eyebrows of stiff hair.

The black langurs of Peninsular India (*Kasi johnii*) are small, about 2 ft. in length with tail nearly 3 ft. The hair is fine and glossy, blackish in colour, while the head is yellowish brown and the rump is grayish. The young are black or grayish. The purple-faced monkey *(Kasi senex*) of Ceylon is closely allied to the preceding, but its face is distinctive, the hairs of the cheeks, chin and throat whitish. The general colour varies from uhite to black.

The shaggy langurs (*Trachypithecus*) have golden young, the hair of the crown is generally smooth going back to a peak. The nasal profile of the skull is straight. The capped langur (T. *pileatus)* of Assam and Upper Burma is dusky gray with golden, reddish or whitish under parts, a blackish tail. The white-mouthed langur (T. *phayrei*) lacks the cap, the hairs of the crown being like those of the cheek and neck; the areas around the eyes and the mouth are whitish. This species ranges throughout Burma, south to Tenasserim and east to Indo-China. The white-naped langur (T. *obscurus)* is found in the Malay peninsula; like the preceding species, it has a white mouth and white eyelids, but the nape and back of the head are pale, sharply contrasting with the brownish colour of the rest of the upwer parts. The silvered leaf monkey (T. *pyrrhus*) occurs from Indo-China and Tenasserim to Borneo and Bali. It is blackish, dark brown or gray, with a frosting. of pale gray or buffy on the hair tips. A red phase occurs in the islands.

The lesser leaf monkeys (*Presbytis*) have the young .whitish with a blackish cross-like marking on the back and dark hands and feet. One or several whorls of hair on the head give an odd. tousled appearance to these animals. The skull has the nasal profile convex. A great variety of colour and hair patterning occurs in these monkeys and they are difficult to describe. Even in the same species colour



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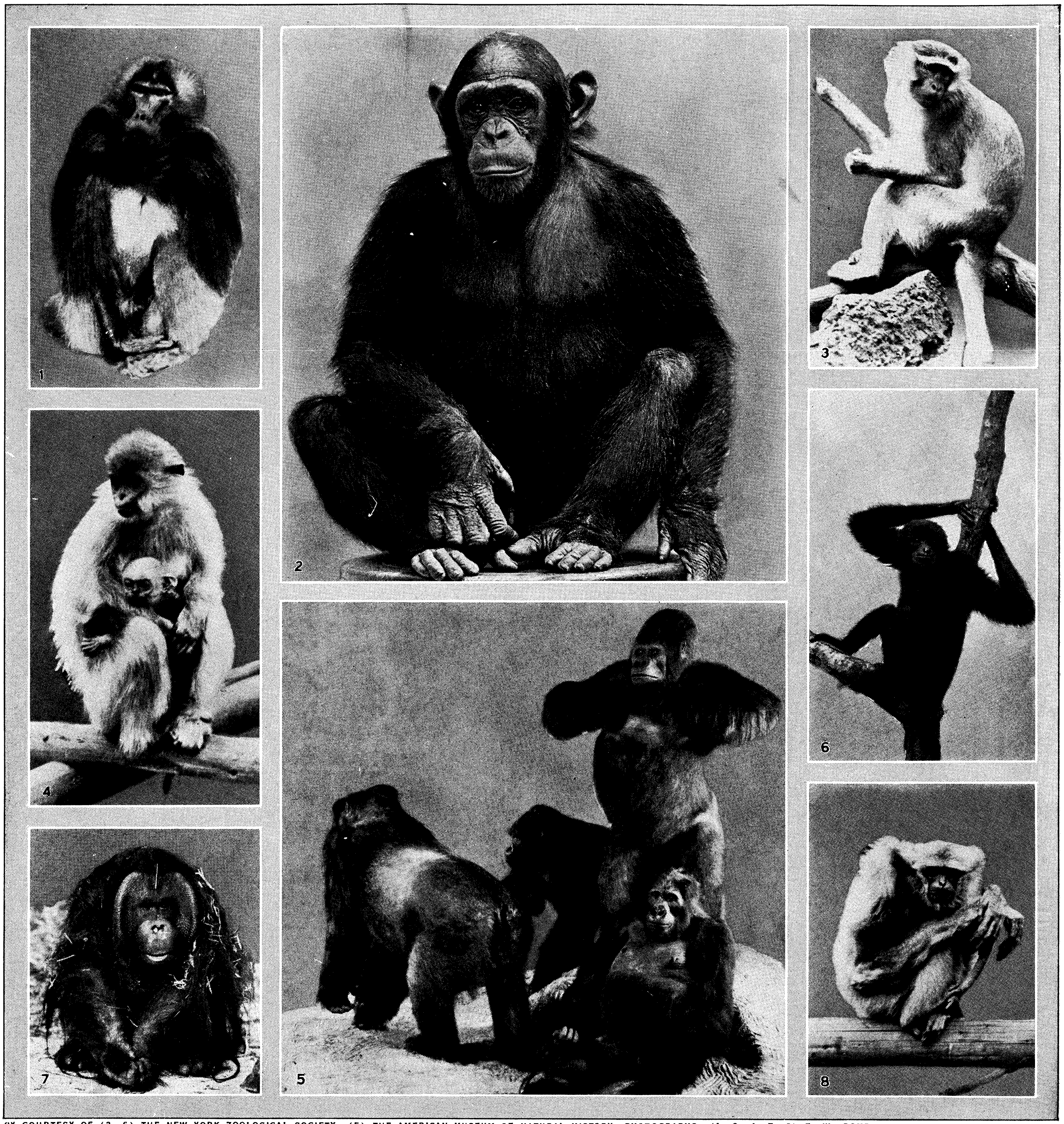
LEMURS AND MONKEYS OF THE OLD AND NEW WORLDS

1. The ruffed lemur (Lemur *variegatus*) of the Malagasy region. It is coloured either black and white or reddiih brown, and feeds on birds, reptiles, eggs, insects and fruit
2. The potto (*Perodicticus potto*) or West African slow lemur, an almost tailless primate somewhat larger than a squirrel
3. Bush baby (*Galago crassicaudatus*) of Africa, a small arboreal lemur with long pointed muzzle and very large eyes and ears
4. Woollv saki (*Pithecia* monacha), a tropical American monkey characterized by a bushy tail and whiskers of long, loose fur
5. The common, or white-eared marmoset (*Callithrix jacchus*), a diminutive American monkey that feeds on insects and fruit
6. An immature woolly monkey (*Lagothrix lagotricha*) of tropical America, distinguished by the naked, singularly human face and the powerful prehensile tail used for picking up objects as well as for climbing
7. Spider monkey (*Ateles geoffroyi*) of tropical America, so designated because of its extremely slender limbs. The tail Is very long and prehensile and the hand is thumbless. It is easily tamed
8. White-faced capuchin monkey (*Cebus capucinus*), a vivacious American species that derives its name from the cowl-like form assumed by the hair on the crown of the head. It is common in captivity
9. Guereza (*Colobus abyssinicus*), an arboreal African monkey hunted for its fur which forms a black and white mantle on the sides and back

PLATE II

PRIMATES



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OLD WORLD MONKEYS AND APES

1. Gelada baboon (*Theropithecus gelada*), a large terrestrial monkey of southern Abyssinia. On the old males the hair develops into a mantle-like mane which covers the forequarters, leaving the chest bare

2. Chimpanzee (Pan troglodytes), the smaller of the two great man-like apes inhabiting equatorial Africa. It seldom exceeds $4\frac{1}{2}$ feet in height and is almost completely arboreal, sleeping in nests in trees

3. Guenon (*Cercopithecus aethiops*), a small arboreal monkey of the African savannas. It subsists chiefly on fruits and leaves

4. Capped langur (Trachypithecus *pileatus*) female and young of the Malay Peninsula. In common with other langurs it has slender limbs and a very long tail, and feeds on leaves

5. Group of mountain gorillas (Gorilla *beringei*), Belgian Congo, showing two males and two females, the standing male being in characteristic posture of thumping his chest. The male at the left is in the position generally assumed by the gorilla when moving about on the ground

6. Siamang (*Hylobates [Symphalangus] syndactylus*) Malay Peninsula and Sumatra: largest of the gibbon group with an average height of 3 feet. It is distinguished from other gibbons by a laryngeal air sac

7. Orangutan (Pongo *pygmaeus*), "man of the forest," the least man-like of the three great anthropoid apes. It inhabits Borneo and Sumatra

8. The silvery gibbon (Hylobates *moloch*), one of the small arboreal apes of the Indo-Malay peninsula and East Indies

varieties red, black and white often occur. These monkeys are restricted to the Malay region, reaching the islands of Borneo, Sumatra, Java and Bali, where 25 forms are known.

The snub-nosed monkeys (*Rhinopithecus*) inhabit western China and eastern Tibet. Four species are known: R. roxallanae, the golden monkey of western Szechwan, has a bright-blue iace, the under parts and lower limbs are golden, while the back is more or less grayish black, overlaid by silver hair-tips. Females are paler. R. bieti, from northern Yunnan, is brown with white under parts. R. brelichi is the largest Asiatic monkey. It is slate-coloured, with an oval white patch between the shoulders; the head is yellowish and the tail black. R. *avunculus* of Tonkin is blackish with yellowish under parts, creamy cheeks and white-tufted tail.

The doucs or pied langurs (*Pygathrix*) are found in Indo-China. The body in P. *nemaeus* is mottled grizzled gray, the face, hands and feet are yellow. The outsides of the upper limbs black, but the lower legs are chestnut, the forearms are white, as well as the tail and the loner back. P. *nigripes* has the posterior limbs black, the forearms gray, the body also gray.

The proboscis monkey (*Nasalis larvatus*) is restricted to Borneo. It is buffy brown with yellowish-gray rump, tail and limbs. The nose in old males is enormous and inflatable. This monkey lives in trees along river banks. The pig-tailed langur (*Simias concolor*) of the Mentawei Islands, off Sumatra, is the only short-tailed langur. It is smoky brown in colour and has a short, upturned nose. These monkeys are probably related to the golden monkeys and the pied langurs of the mainland.

The old world or catarrhine monkeys are widely distributed, mostly in tropical Asia and Africa, a few outlying forms reaching as far north as Tibet, China and Japan, while the baboons extend southward to South Africa. A single species, the Barbary ape oi North Africa inhabits the Rock of Gibraltar in Europe. In the Pliocene, however, fossil monkeys of various species were recorded in England, Germany, France, Italy, Greece, North Africa and India. In the Miocene of Tuscany there was a large form (*Oreopithecus*), in which certain features of the molar teeth suggest remote relationship with the anthropoid apes. In the Lower Oligocene of Egypt was found a small lower jaw fragment, *Apidium*, the lower molars of which may be transitional from the tuberculo-sectorial or primitive mammalian type to the bilophodont form (with two cross-crests) of the old world monkeys. The group seems to have originated somewhere either in Africa or in the European-Asiatic landmass and negative palaeontological evidence indicates their complete absence from America and the Australian region.

No known fossil forms definitely connect the old world stock with the new world series, tarsioids, lemuroids or tree shrews. The new world series, for reasons given above, seems entirely independent; while the known fossil tarsioids appear too peculiarly specialized to be direct ancestors of the old world stock; get such tarsioids as *Necrolemur* and Microchoerus are the only forms so iar known that have even the appearance of evolving toward the catarrhine stage. This is broadly characterized as follows.

Nostrils, closely approximated and opening downward, tending to form a V; molars with two cross-crests; dental formula $i\frac{2}{2}$, $c\frac{1}{1}$, $p\frac{2}{2}$, $m\frac{3}{3}$. Tympanic bone forming a gutter leading to the outer ear; stomach simple or (in Colobinae) highly complex; habits primarily arboreal, the animals climbing as pronograde quadrupeds, mostly on top of the branches. Hands and feet prehensile. Thumb opposable, more or less flattened nails on all digits. Tail long, short or wanting, never prehensile. Cheek pouches in most genera. Large callous areas on buttocks, with corresponding flattening on lower ends of pelvis. Placenta double, consisting of a primary and secondary discoidal area, except in the baboons, with smooth chorion between them.

Although it has not yet been possible to trace the direct fossil ancestors of the old world group into formations older than at most Lower Oligocene, even the known living and extinct tree shrews, lemuroids and tarsioids preserve the broad stages by which arboreal insectivorus mammals with a relatively low type of brain were transformed into monkeys with a relatively high type of brain, with binocular, stereoscopic vision and an advanced method of intra-uterine nourishment of the young.

Hominoidea.—The anthropoid apes and mankind form a group distinct from other old world Primates. The anthropoid apes include the gibbons, the orang, chimpanzee and gorilla (*q.q.v.*); these are recognized as resembling man more closely than monkeys; they are tailless, their teeth and internal anatomy are very like those of man, and the placenta and embryonic stages show the same agreement. The gibbons are frequently considered to form the family Hylobatidae ("tree-walkers"), while the great apes are grouped in the family Pongidae.

Family Hylobatidae's range is now restricted to southeastern Asia, especially the Malay peninsula, Borneo, Sumatra and some other East Indian islands, though in the Miocene gibbons extended into Europe and in the Pliocene as far north as central China. They are slender, long-limbed, monkey-like apes, the most striking feature being the enormously elongate arms, which reach the ground when the animal stands erect. Like other anthropoids, they are tailless. They differ widely from the tailed monkeys in their mode of progression, as they do not run on all fours, either in the trees or on the ground, but hang and swing from branches by their long arms and hook-like fingers, making almost incredibly long leaps in the manner of a trapeze gymnast. This mode of arboreal locomotion was called "brachiation" by Sir Arthur Keith. While travelling thus by the hands, gibbons use the feet for prehension and carrying food. They sit upright and when on the ground run swiitly in an erect position, holding the arms out as balancers. Gibbons differ from most old world monkeys in the absence of cheek pouches and in the pattern of the molars, which is essentially that of the great apes and man. They also in common with these iorms have a vermiform appendix and flattened sternum. They nevertheless retain some old world monkey characters; for example, the small ischial callosities are present, and the central bone in the wrist is retained as a separate element. Air sacs, formed as extensions of the laryngeal ventricles, well-developed in the Pongidae, are present only in the siamang. Gibbons have remarkable vocal powers, their high-pitched cries being audible ior a mile or more.

Seven species of gibbons (Hylobates) may be distinguished. The hoolock (H. hoolock) of Burma, Assam and Western Yunnan (China) varies from pale yellowish gray to black; the brow is white and the hands and feet are never pale. The white-handed gibbon (H. *lar*) ranges from Lower Burma and Cambodia, Indo-China to Sumatra; it also occurs in pale and black colour phases. The hands and feet are always paler than the rest of the limbs, and the face is framed in white. The agile gibbon (H. *agilis*) is found from the Malay States to Sumatra; it differs from H. lar in having dark hands and feet. The gray gibbon (H. *moloch*) of Java and Borneo is ashy gray, sometimes with a brownish tinge, and the top of the head is usually dark. The under parts are blackish in some races. The black gibbon (*H. concolor*) generally has the hands and feet, and a patch on the head white or pale, but may be entirely black. The white forehead band is lacking. This species occurs in Siam, Indo-China and Hainan.

The large, black siamang, H. (*Symphalangus*) syndactylus, is found in Malaya and Sumatra. It stands 3 ft. or more in height; the second and middle toes are joined by a web. The chin is better developed than in other anthropoids, but the most conspicuous character is the large, inflatable laryngeal air sac. The dwarf gibbon (*H. klossi*) of the Mentawei and Siberoet Islands, west Sumatra, is intermediate in many characters between the siamang and the other gibbons. It is the smallest of the gibbons and is black in colour.

The three genera of great apes constituting family Pongidae, the orangutan of Borneo and Sumatra, and the chimpanzee and gorilla of the African forests, are by far the closest of all animals to man. Their divergences from man, striking though some of them are, are nearly all differencesin degree rather than in kind, and these apes are nearer anatomically and physiologically to man than to any of the tailed monkeys. Their differences from man are largely correlated with habit. Man has become terrestrial, while the apes have retained their primary arboreal habit, and have even developed further arboreal adaptations in varying degrees. In the orang these have become greatly exaggerated, while in the gorilla, which has become partly terrestrial, they are less marked. The chimpanzee is intermediate. The arms have become long and the relatively short legs retain the opposable great toe. This disproportion of limbs results in a peculiar secondary type of quadrupedal progression on the ground, the hands resting on the knuckles and the fore part of the body somewhat elevated. The spinal column has a suggestion of the curves seen in man, but the balance of the head on the neck, the weight of the long arms, form of pelvis and weak gluteal and calf muscles, collectively preclude an habitual erect bipedal gait, though the animals often stand erect. Divergence from the old world monkeys and likeness to man is seen in the absence of ischial callosities and cheek pouches and in the presence of the vermiiorm appendix. The development of laryngeal air sacs, apparently a point of difference, is in reality a likeness, since man retains homologous vestiges of these in the laryngeal ventricles. In the chimpanzee and gorilla (but not in the orang) the central bone of the wrist becomes fused with the scaphoid during embryonic life, as in man. The menstrual cycle has the same phases as man and in the chimpanzee the interval is the same. In the three apes the period of gestation is nine months and the placenta is essentially of the human type. The secondary placenta, present in old world monkeys, is absent. Even the brain, though roughly only about one-third the size of that of man, is essentially a miniature of the human brain, no part or organ of one being absent in the other, but the differences being differences of proportion of certain parts. The susceptibility of anthropoids to many human diseases to which other animals are relatively immune, indicates the close chemical similarity, and the well-known precipitin tests bv G. F. Nuttall showed the blood of these anes to be essentially identical with that of man, while differing from' that of old world monkeys.

Of the three great apes, the least man-like is the orangutan (Malay, "man of the forest") which inhabits swampy coastal forests of parts of Borneo and Sumatra. This animal is completely arboreal, rarely descending to the ground, and exhibits exaggerated brachiating adaptations. It is a large ape, over 4 ft. high, with heavy body and short feeble legs but very long arms extending to the ankles when the animal stands erect. The digits of both hands and feet are elongated and hook-like, except the relatively short thumb and great toe. Though the orang is rather deliberate in his motions and does not leap through the trees as does the gibbon, the elongation of the arms permits an extended reach from branch to branch and enables it to progress with considerable rapidity. Among structural characters the following may be noted: there are but 12 pairs of ribs as in man; the cranium is rounded and lacks the prominent supraorbital crest of the African anthropoids; the carpus retains the central bone as in monkeys and gibbons; the laryngeal air sacs are enormously developed, extending far down under the arms and on the chest in adult animals; the hair is coarse and sparse but very long and bright red in colour; a feature frequently, but not always, present in old males is a pair of prominent ridges of connective tissue on the cheeks. The orang feeds on fruits, especially the durian. There is probably only one species, with several local varieties. It is properly known as *Pongo pygmaeus,* but is often called *Simia satyrus.* A fossil jaw ascribed to Pongo in the Upper Pliocene and a molar tooth *(Palaeosimia)* from the Upper Miocene, indicate the ancient differentiation of the orang line.

The chimpanzee, properly known as *Pan* (= *Antropopithecus*), and the gorilla *(Gorilla)* inhabit the rain forests of central Africa, the chimpanzee having far the wider range. The latter is smaller, more agile and more completely arboreal in habit. The gorilla, probably owing to its great weight (males exceed 400 lb.), is largely terrestrial, though it climbs readily and in the west coast species the females and young are said to sleep in nests built in trees. Though the arms are somewhat longer than those of the chimpanzee, the hands have shorter fingers and are less adapted for brachiation; the feet show distinct secondary adaptation to walking on the ground. The foot of the mountain gorilla (*G. beringei*) of the eastern Belgian Congo presents the closest approach to the human foot found among primates. In both chimpanzee and gorilla the ribs number 13 pairs, one more than in man, but the total number of presacral vertebrae is the same, and a 13th rib in man is not uncommon. In both apes the hair is mainly black. In the chimpanzee the skin is usually light coloured in early life, tending to become dusky later; in the gorilla the face is intensely black. In both animals a heavy brow ridge overhangs the eyes and in the gorilla the cranial form in adult males becomes greatly altered by the development of huge crests for muscle attachment. The gorilla has well-marked alae of the nose, separated from the cheeks by distinct grooves. *See* CHIMPANZEE, GORILLA.

Origin and Evolution.— Of the fossil gibbons the best known is *Pliopithecus antiquus* from the Miocene of middle Europe. This differs from the recent gibbons in the lesser specialization of the canines and front lower premolar. A fossil humerus and femur of *Pliohylobates eppelsheimensis* from Eppelsheim, Germany, are close to those of the recent gibbons.

The earliest known forerunner of the gibbons and possibly also of the great apes and man is the fossil lower jaw named *Propliopithecus haeckeli,* from the Lower Oligocene of Fayûm, Egypt. This little jaw, while no bigger than that of a small monkey, already shows the relatively great depth characteristic of all anthropoids and of early man; its molar teeth also have the five main cusps arranged substantially as in the higher forms. Many nominal species of fossil anthropoid apes of the genera *Dryopithecus, Sivapithecus* and others are known.

MAN

The origin and evolution of man is fully discussed in other articles (ANTHROPOLOGY; BRAIN; MAN, EVOLUTION OF, etc.).

BIBLIOGRAPHY.—General: W. H. Flower and R. Lydekker, *Mammals, Living and Extinct (1891)*; H. O. Forbes, *A Handbook to the Primates (1894)*; various authors, *Harmsworth Natural History,* vol. i (1910); D. G. Elliot, *A Review of the Primates* (1912); W. L. H. Duckworth, *Morphology and Anthropology* (1915); M. Weber, *Die Saugetiere,* vol. 2, (1928); E. A. Hooton, Man's Poor Relations (1942).

Tree shrews: W. E. LeG. Clark, *Proc. Zool. Soc. London* (1924–25–26–27).

Tarsioids: W. D. Matthew and W. Granger, *Bull. Am. Mus. Nat. Hist.* (1915); various authors, "Discussion on the Zoological Position of *Tarsius,*" *Proc. Zool. Soc. London* (1925); H. H. Woollard, *Proc. Zool. Soc. London* (1925); W. E. LeG. Clark, *Proc. Zool. Soc. London* (1924); W. Cook, *J. Mammal.* (1939).

Lemuroids: A. Milne Edwards and A. Grandidier, "Histoire Naturelle des Mammifères" in A. Grandidier, *Histoire Physique . . . de Madagascar* (1875); H. F. Standing, *Trans. Zool. Soc. London* (1908); H. G. Stehlin. *Abhand. Schweiz. Palaeont. Gesell (1912)*; R. I. Pocock, *Proc. Zool. Soc. London* (1918); W. K. Gregory, *Mem. Am. Mus. Nat. Hist.* (1920); J. P. Hill, A Subba Rau and F. Ince, *Proc. Zool. Soc. London (1928)*; E. Schwarz, *Proc. Zool. Soc. London* (1931).

New world monkeys: See general works above; also R. I. Pocock, *Proc. Zool. Soc. London* (1920); W. K. Gregory, *Origin and Evolution of the Human Dentition* (1922); A. Cabrera and J. Yepes. *Mamiféros Sud-Americanos* (1940); C. R. Carpenter, *J. Mammal.* (1935).

Old world monkeys: R. I. Pocock, *Proc. Zool. Soc. London* (1926, 1934); *Fauna of British India,* Mammalia, vol. I (1939); P. Rode, *Les Primates de l'Afrique* (1937); C. G. Hartman and W. L. Straus, *The Anatomy of the Rhesus Monkey* (1943).

Anthropoid apes and man: See general works above; also Sir A. Keith, *Engines of the Human Body* (1920); *Brit. Med. Journ.* (1923); W. K. Gregory, *Origin and Evolution of the Human Dentition* (1922); also K. Landsteiner and Miller, *J. Experim. Medicine* (1925); *Proc. Am. Philos. Soc.* (1927); *Quart. Rev. Biol.* (1927); C. F. Sonntag, *Morphology and Evolution of Apes and Man* (1924); G. Elliot Smith, *Essays on the Evolution of Man* (1924); W. Koehler, *The Mentality of Apes;* R. M. Yerkes, *Almost Human;* Yerkes and Yerkes, *The Great Apes* (1929); F. Weidenreich, *Palaeontologica sinica,* n. s. D., No. 10 (1943); H. W. Nissen, *Comp. Psych. Monogr.* (1931); H. C. Bingham, *Comp. Psych. Monogr. (1929)*; *Carnegie Inst. Washington Publ. No. 426* (1932); H. C. Raven, *Nat. Hist.* (1931); C. R. Carpenter, *Comp. Psych. Monogr.* (1940); A. Urbain and P. Rhode, *Les Singes Anthropoides* (1946).

(W.K.G.; J. H. McG.; J. E. HL.)

PRIME MINISTER, BRITISH. Though a Wolsey or a Cecil might achieve for a time a predominant position among the counsellors of the English crown, the persistence of the doctrine that ministers were all equally royal servants, severally responsible to the sovereign for their respective departments. was for centuries fatal to the recognition of any such predominance in theory. Thus G. Burnet describes Clarendon as "chief, or the only, minister." but the latter knew only too well that the style "first minister" was "a title so newly translated out of French into English that it mas not enough understood to be liked. and every man would detest it for the burden it was attended with." Even in the 18th century it is more usual to find partnerships of two or three individuals, such as Marlborough and Godolphin, Harley and St. John, Stanhope and Sunderland, Townshend and Walpole. Newcastle: Henry Pelham and Hardwicke, sharing the principal burden of government. But the place vacated by the sovereign when, from 1717 onward, he ceased to attend cabinet meetings, had necessarily to be filled by a single individual, and this presiding officer developed almost inevitably into a prime minister. Sir Robert Walpole, though he "unequivocally denied" the title, is usually reckoned the first of the linc, and certainly during his last spell of office (1721–42) he developed many of the attributes of premiership. He was master of his cabinet; he insisted on a general subscription by his colleagues to the Whig principles; he dismissed his opponents; he dispensed the royal patronage; and, with reservations. he may be described as commanding a majority in the house of commons. How novel, how unpopular. such a position still was may be gathered from the proceedings of both houses in 1741. "According to our Constitution." said Sandys, "we can have no sole and prime minister . . . every . . . officer has his own proper department; and no officer ought to meddle in the affairs belonging to the department of another." And the minority in the house of lords was, if possible. even more downright. "We are persuaded," they protested. "that a sole, or even a first minister, is an officer unknown to the law of Britain, inconsistent with the Constitution of the country and destructive of liberty in any Government whatsoever."

On the fall of Walpole the further development of the office was checked, first, by the group system and consequent group coalition governments of the latter half of George II's reign, and later, by the interference of George III, who aspired to be himself "the only element of coherence in a ministry." Thus Grenville (1763–65) thought that "Prime Minister is an odious title," and North (1770–82) would not countenance it even from his own family. It was the younger William Pitt who, on the fall of personal government, consolidated the work of his predecessors and by his long tenure of power (1783–1801) accustomed the nation to the office, if not to the name. The extent of his achievement can be measured by the terms of his famous interview with Lord Melville in 1803. He "stated not less pointedly and decidedly his sentiments with regard to the absolute necessity there is in the conduct of the affairs of this country, that there should be an avowed and real minister, possessing the chief weight in the council, and the principal place in the confidence of the king. In that respect there can be no rivalry or division of power. That power must rest in the person generally called the first minister, and that minister ought, he thinks, to be the person at the head of the finances. . . ." Nevertheless. old prejudices die hard. In 1806 it could still be said in parliament that "the Constitution abhors the idea of a prime minister," and in 1829 that "nothing could be more mischievous or unconstitutional than to recognize by act of parliament the existence of such an office" Such recognition was not granted until 1905, when the prime minister became known to the law merely as one who had precedence next after the archbishop of York.

The prime minister is appointed by the sovereign. "I offered," said Sir Robert Peel (1834–35, 1841–46) on his resignation of office. "no opinion as to the choice of a successor. That is almost the only act which is the personal act of the sovereign; it is for the sovereign to determine in whom her confidence shall be placed" And. as late as 1894, Queen Victoria could call Lord Rosebery (1894–95) without consulting the retiring prime minister. Gladstone (1868–74, 1880–85, 1886, 1892–94), or the wishes of the parliamentary majority. Nevertheless, the Crown's freedom of choice is narrowly circumscribed. The "economic" reforms of Rockingham's administration (1782), by reducing the royal patronage, made it less easy for the sovereign to put ready-made majorities at the disposal of whatever minister he might fancy. and the Reform bills of the 19th century made the ministry dependent on parliament and the electorate rather than on the royal favour. The prime minister is normally the acknowledged head of the party commanding a majority in the house of commons. and it is only. therefore. on occasions when no party commands an absolute majority of the house, or when the majority party has no acknowledged head. that there is room for the exercise of the royal discretion.

The prime minister has no salary as such. He merely draws the emoluments of whatever office he may happen to hold. At the close of the 17th century the lord treasurer was already regarded as the most important government official, and since the treasury came to be put into commission. the leading minister has normally held the office of first commissioner, or first lord. and it is by virtue of that office that he draws his salary of £10,000 a year. But Chatham (1766–68) was lord privy seal: Salisbury (1885–86, 1886–92, 1895–1902), successively secretary of state and lord privy seal; and Ramsay MacDonald (1924, 1929–35), simultaneously first lord of the treasury and secretary of state. In addition, the prime minister is usually the leader of the house, though David Lloyd George. Clement Attlee and Winston Churchill each at times found this burden excessive and transferred it to other shoulders. In the 18th century, when cabinets were almost exclusively composed of peers, the leading minister, curiously enough, was recruited most of the time from the commons; in the 19th century, when commoners came to form the bulk of the cabinet, the prime minister was, more often than not, a peer But with the expansion of the franchise and the reduction in the powers of the lords (notably by the Parliament act of 1911) it became increasingly difficult for a peer to exercise the premiership effectively. No peer was prime minister after Lord Salisbury. and when Lord Curzon was passed over for the premiership in favour of Stanley Baldwin in 1922 this was generally regarded as a decisive demonstration of the need for a prime minister to be in the commons.

"As the cabinet stands between the sovereign and parliament," wrote Gladstone, "so the prime minister stands between the sovereign and the cabinet." He it is who, with the king's consent, appoints his fellow ministers to their respective posts. Originally, of course. the sovereign exercised an unfettered choice. Even so old and faithful a servant as Cecil never knew whom the queen would appoint to her council. In Anne's reign it required the united and persistent pressure of a ministry to get a Harley out or a Sunderland in. Pitt, at the close of the 18th century, had to put up with Thurlow, "the king's chancellor:" and. at the dawn of the 19th century, to do without Fox, the king's *bête noire*.

So even today, when the prime minister's choice is theoretically as free as was originally the crown's, the pressure of party, the claims of talent and the prescriptive rights of previous officeholders render that freedom largely nugatory. Finally, it is the prime minister individually and not his cabinet collectively who advises the king to dissolve parliament. In the event of a cabinet dispute this places him in a very strong position, especially since with it is coupled the right of dismissal. However the responsibility of the cabinet to the prime minister and the remaining functions of the latter belong properly to the history of the cabinet (*q.v.*).

The history of the second quarter of the 20th century, with its recurring crises, showed that the position held by the prime minister was still subject to development and still dependent upon personal factors. In the financial crisis of 1931 the king exercised his prerogative of choosing a prime minister other than the leader of the largest parliamentary party. He chose. as leader of a "national" coalition. James Ramsay MacDonald. the leader of a minor section in a defeated and divided Labour party. not Stanley Baldwin, who was leader of the largest party. For a time the office of prime minister was inevitably weakened. The abdication crisis (1936), on the other hand, temporarily gave to the prime minister (Baldwin) the sovereign's prerogative of acting as liaison between the prime ministers of the dominions. The much greater crisis of 1940 produced further drastic changes. When Winston Churchill was appointed he was not the acknowledged leader of any party. The stresses of war and the personal ascendancy of Churchill increased the importance and prestige of the prime minister as such. He assumed a responsibility for the armed forces and for their direction almost equivalent to the responsibility held by the president of the United States. He became more of an ambassador-at-large than any predecessor and spoke for his country even before the U.S. congress. Radio broadcasting put him into an intimate relationship with the whole country. quite without precedent and far transcending his indirect relationship with the electorate through parliament.

The prime minister's position was, on the whole, strengthened vis-à-vis his cabinet colleagues, vis-à-vis parliament and perhaps vis-à-vis the electorate. He commands a significantly increased volume of patronage: almost 80 ministerial posts alone are his exclusive appointment. In the 19th century Gladstone was thought to be abnormal in having a policy of his own, and most prime ministers before 1914 were, at best, no more than strong chairmen in their cabinets. Later prime ministers were in this respect far more Gladstonian than Gladstone. This met with criticism, but. by concentrating its attacks upon the central figure, the opposition unwittingly did much to consolidate the prime minister's dominance More than once too, a prime minister has seemed to say to his parliamentary critics what Benjamin Disraeli accused Gladstone of saying in 1873: "Unless you are prepared to put someone in my place. your duty is to do whatever I bid you." Although in 1945 the electorate appeared to be offered a choice between a party program (Labour's) and a party leader (Churchill) and appeared to prefer the program to the personality, yet in general 20th-century elections were increasingly a choice between rival candidates for the premiership. (For lists of the prime ministers and other principal government officials, see MINISTRY.)

BIBLIOGRAPHY.—Such books as *The Prime Ministers of Britain, 1721–1921*, 4th ed. (1924), by Clive Bigham, give certain dates and facts, but the history and functions of the office can be authoritatively studied only in the memoirs and biographies of the statesmen themselves and in the party, ministerial and cabinet histories.

(F. L. B.; G. C. Ms.; H. G. N.)

PRIMER (percussion or friction), flame-producing device actuated by impact or friction and intended to ignite either the powder charge in a gun or the detonator of a high explosive charge. Electrically ignited primers are also in use. (See DETONATORS; EXPLOSIVES; MERCURIC FULMINATE.)

PRIMITIVE METHODISTS, a community of nonconformists. formed in consequence of the belief that Methodism as founded by the Wesleys tended, after the first generation, to depart from the enthusiasm that had marked its inception and to settle down to the task of self-organization. There were some ardent spirits who continued to work along the old lines and whose watchword was revivalism; and from their efforts came the Bible Christian, the Independent Methodist and the Primitive Methodist denominations. One of the zealous evangelists to whom Primitive Methodism owes its existence was Hugh Bourne (1772–1852), a millwright of Stoke-upon-Trent, Eng. He joined a Methodist society at Burslem. but, business taking him at the close of 1800 to the colliery district of Harrisehead and Kidsgrove, he was so impressed by the prevailing ignorance and debasement that he began a religious revival of the district. His open-air preaching mas accompanied by prayer and singing. One of the afterfruits of this revival was the conversion (Jan. 1805) of the joint founder of Primitive Methodism, William Clowes (1780–1851) of Burslem, who threw his house open for love feasts and prayer meetings and did a great deal of itinerant evangelization among the cottages of the countryside. Lorenzo Dow, U.S. revivalist, introduced the idea of the "camp meeting." The first camp meeting was held on Mow Cop, since regarded as the Mecca of Primitive Methodism. It lasted from 6 A.M. to 8 P.M., and Bourne and his friends determined to continue the experiment as a counterblast to the parish wakes of the time, which were little better than local saturnalia; but serious difficulties were presented by the antagonism of the Wesleyan Methodist circuit authorities. But Bourne and his friends persisted against both conference and the local superintendent, who issued bills declaring that no camp meeting would be held at Norton in Aug. 1807. The meeting was held, and ten months later Bourne was expelled by the Burslem quarterly meeting. Camp meetings went steadily on, and in 1810 the methods of the meetings organized by Bourne and Clowes were found to be incompatible with those of Wesleyan Methodism. A chapel was built at Tunstall, which became the nucleus of a circuit. In May 1811 the Camp-Meeting Methodists and the Clowesites united to form the connection which took the name "Primitive Methodists" in 1812. Clowes and James Crawfoot, a former Wesleyan local preacher, were set apart as preachers to "live by the Gospel."

The period 1811–43 was a time of rapid expansion for the new sect. Enthusiasts pressed forward through the "Adam Bede" country to Derby (which became the second circuit in 1816); Nottingham, where a great camp meeting on Whit Sunday 1816 was attended by 12,000 people; Leicestershire, where Loughborough became the third circuit, with extensions into Rutland, Lincolnshire and Norfolk; and ultimately to Hull, which became the fourth circuit and where a meeting which deserves to be called the first conference was held in June 1819. The Hull circuit during the next five years, through its Yorkshire, western, northwestern and northern missions, carried on a vigorous campaign with great success, especially among the colliers of Durham and Northumberland. Simultaneously Tunstall circuit, having thrown off its lethargy, was carrying on an aggressive evangelism. Work in the Black Country was extended to Liverpool and Manchester on the one side and south Shropshire on the other; and thence to Herefordshire, Glamorganshire and Wiltshire. Thenceforward, while the Oxford movement was awakening one section of the people of England the Primitive Methodists mere making themselves felt among other classes of the population. The early Primitive Methodists had to meet mob violence that oiten amounted to sheer ruffianism, especially in Wessex and the home counties. On the other hand, there was legal persecution all over the country, and the preachers suffered many things from the hands of rural clergy and county magistrates. There are a score of cases of serious imprisonment, and a countless number of arrests and temporary detention. Local preachers received notice to quit their holdings, labourers were discharged, those who opened their cottages ior meetings were evicted and to show any hospitality to a travelling preacher was to risk the loss of home and employment.

The years 1842–53 mark a transition period in the history of Primitive Methodism. From being a loosely jointed home missionary organization, the movement developed on the lines of a real connectionalism. One of the first steps was to move the Book Room and the meeting place of the executive committee to London. Soon after came the gradual process by which the circuits handed over their mission work to a central connectional committee. The move to London was proof that the leaders mere alive to the necessity of grappling with the rapid growth of towns and cities, and that the connection, at first mainly a rural movement, had also urban work to accomplish. The period 1853–85 finds Primitive Methodism as a connection of ten federated districts, a unity which may be described as mechanical rather than organic. Conierence—the supreme assembly—was a very jealously guarded preserve, being attainable only to preachers who had travelled 18 and superintended 12 years and to laymen who had been members 12 and officials 10 years. This exclusiveness naturally strengthened the popularity and power of the districts, where energy and talent found a scope elsewhere denied. Thus, Hull district inaugurated a bold policy of chapel buildings; Norwich that of a foreign mission; Sunderland and Manchester the ideal of a better-educated ministry; Nottingham district founded a middle-class school; Leeds promoted a union of Sunday schools, and the placing of chapel property on a better financial footing. The period as a whole had some anxious moments; emigration to the gold fields and the strife which afflicted Wesleyan Methodism brought loss and coniusion between 1853 and 1860. Yet when conference met at Tunstall in the latter year to celebrate its jubilee it could report 675 ministers and 11,384 local preachers, 132,114 members, 2,267 chapels, 167,533 scholars and 30,988 teachers.

Work in Australia and New Zealand prospered, and the former country finally contributed more than 11,000 members to the formation of the United Methodist Church oi Australia, New Zealand with its 2,600 members preferring to remain connected with the home country. In the United States there had been a quiet but steady growth since the first agents went there in 1829. There are three conferences—the eastern, Pennsylvania and western, with about 70 ministers, 100 churches and 7,000 members. The Canadian churches had a good record, consummated in 1884 when they contributed 8,000 members and 100 ministers to the United Methodist Church oi the dominion. In Jan. 1870 the first piece oi real foreign missionary work was begun at Fernando Po, followed in December of the same year by a mission on the Orange river in South Africa. This station is the centre of a polyglot circuit or district and carries on an efficient institution for training teachers, evangelists and artisans. In 1899 another South African mission was started, and a few years later work was begun in southern Nigeria.

Following 1885 Primitive Methodism developed from a connection into a church, the designation employed since 1902. In England a union for social service was formed in 1906, the natural outcome of Thomas Jackson's efforts for the hungry and distressed in Clapton and Whitechapel, and of similar work at St. George's hall, Southwark. Other significant episodes have been the unification of the funds, the equalization of districts and the reconstruction of conference on a broader basis, the Ministers' Sustentation fund and the Church Extension fund, and the enlargement and reorganization of the college at Manchester. This undertaking owed much to the liberality of Sir William P. Hartley, whose name the college, which is affiliated to the Victoria University oi Manchester, now bears. The Christian Endeavour movement in Great Britain derives, perhaps, its greatest force from its Primitive Methodist members; and the appointment of central missions, connectional evangelists and mission vans, which tour the more sparsely populated rural districts, witness to a continuance of the original spirit of the denomination, while the more cultural side is fostered by the Hartley lecture. In 1932 the Primitive Methodists contributed 222,021 members to the Methodist Church in England through merger. In the United States in the early 1950s there were approximately 12,000 members. (*See* also METHODISM.)

BIBLIOGRAPHY.—H. B. Kendall, "The Primitive Methodist Church and the Independent Methodist Churches," in W. J. Townsend, H. B. Workman and George Eayrs, *A New History of Methodism* (1909); on the history *see* H. B. Kendall, *The Origin and History of the Primitive Methodist Church*, 2 vol. (1906); *What Hath God Wrought? A Centenary Memorial of the P.M. Church* (1908). (A. J. G.; X.)

PRIMO DE RIVERA, MIGUEL (1870–1930), Spanish soldier and statesman, known as the marquis de Estella, was born at Jerez de la Frontera Jan. 8, 1870, and studied at the Rladrid Military academy. After four years in Toledo, he went to Morocco in 1892 as lieutenant of the infantry regiment of Extremadura, and in Oct. 1893 became a captain. In 1895 he was adjutant to Gen. Arsenio Martínez de Campos in Cuba, and rose to be major commanding the infantry battalion of Zamora.

He served in the Philippines in 1897, and negotiated the treaty of Biagnabato (Biacabato) on Dec. 12, 1897. He then held commands at Barcelona, on the general staff and at Algeciras. In 1915 he was appointed governor of Cadiz, but he was relieved from the office after advocating the exchange of Gibraltar for Ceuta or other North African territory and criticizing the government's policy in Morocco. However, he was soon afterward promoted to general and chief of the 1st infantry division in Madrid. In 1921 Estella was elected senator for Cadiz, but after urging the nation to relieve itself of the Moroccan burden he once again lost his post. He then became captain general of Catalonia with a view to ending the reign of terror there, and he soon reaped a measure of success. He saw the chaos in Catalonia as an indirect consequence of the parliamentary breakdown, and issued the manifesto dated Sept. 12, 1923, suspending the constitution and proclaiming in its place a directorate consisting of military and naval officers. (*See* SPAIN: *History: Dictatorship of Primo de Rivera* (1923–30).) Primo dissolved the directorate on Dec. 3, 1925, and substituted a government of civil as well as military ministers. The dictator became premier. He resigned on Jan. 28, 1930, and died in Paris on March 16, 1930.

PRIMOGENITURE, a term used to signify the preference in inheritance which is given by law, custom or usage to the eldest son and his issue, or in exceptional cases to the line of the eldest daughter.

The history of primogeniture is given in the article LAW OF SUCCESSION. *See* also INHERITANCE; INTESTACY.

PRIMROSE, common name for the genus *Primula,* containing about 300 species distributed throughout the cooler parts of. Europe and .Asia, and found also on the mountains of Ethiopia and Java; a few are American. They are herbaceous perennials. with a permanent rootstock from nhich arise tufts of leaves and flower stems which die down in winter; the new growths formed in autumn remain in a budlike condition ready to develop in spring. They form the typical genus of the primrose family (Primulaceae; q *v.*), the floral conformation of which is very interesting botanically.

The variation in the length of the stamens and of the style in the flowers of Primula has attracted much attention since Charles Darwin investigated them. Some of the flowers have short stamens and a long style, while others have long stamens or stamens inserted so high up that the anthers protrude beyond the corolla tube, and a short style. Gardeners and florists had for centuries been familiar with these variations. calling the flowers from which the anthers protruded "thrum-eyed" and those in which the stigma appeared in the mouth of the tube "pin-eyed."

Darwin showed by experiment that the most perfect degree of fertility as shown by the greatest number of seeds and the healthiest seedlings, mas attained when the pollen from a short-stamened flower was transferred to the stigma of a short-styled flower, or when the pollen from the long stamens was applied to the long style. Since in any given flower the stamens are short (or low down in the flower tube) and the style long, or conversely, it follows that to insure a high degree of fertility cross fertilization must occur, and this is effected by the transfer of the pollen from one flower to another by insects. Incomplete fertility arises when the stigma is impregnated by the pollen from the same flomer. The size of the pollen grains and the texture of the stigma are different in the two forms of flower.

The best-known species are the common primrose (*Primula* vulgaris), a European perennial with basal, wrinkled leaves and prevailingly yellow flowers — some are purple or blue — but now found in many varietal colours; the cowslip (P. veris), also with basal leaves and a long-stalked flower stem bearing a cluster of generally yellow flowers with a dark-coloured eye at the centre and scalelike folds at the mouth; and the oxlip (P. elatior), similar to the cowslip, but without the folds at the flower's mouth. All of these are found wild in Great Britain and elsewhere and are widely cultivated, especially in the fine horticultural varieties of many colours. The above plants are cool-loving sorts which will grow well in heavy soils in slight shade; sloping land (especially an eastern exposure). quite moist in summer but with good drainage, is an ideal situation. In the U.S., about 15 species are native in the region of Oregon and Washington where their needs are satisfied.

The *auricula* (*q.v.*) of the garden is derived from P. *auricula,* a yellow-flowered species, native of the Alps and the easiest of all the primroses to grow. The Himalayas are rich in species of primrose, often difficult of determination or limitation: certain forms being peculiar to particular valleys. Of these P. *denticulata, stuarti, sikkimmensis, nivalis* and *floribunda* may be mentioned as frequently cultivated, as well as the lovely rose-coloured species *P. rosea.* The royal cowslip (P. *imperialis*) resembles P. *japonica* (see below) but has leaves measuring 18 in. long by 5 in. wide. It grows at an elevation of 9.000 ft. in Java and has deep-yellow or orange flowers. Several small-growing hardy species, among which are the choice alpine varieties, afford fine rock garden displays in cool locales; they must be placed where they are secure from excessive dampness (their worst enemy) during the winter and excessive sunlight in the summer.

One of the most popular of winter and early spring decorative plants is the Chinese primrose *Primula sinensis,* of which some superb strains have been obtained. P. *japonica,* a bold-growing and very beautiful Japanese plant. is hardy in sheltered positions in England but must be grown in the cool greenhouse over most of the U.S. *Primula cortusoides* of Siberia and P. *sieboldi* of Japan, of which there are many lovely forms, are suitable for outdoor culture and under glass. Many of these are beautiful potted plants of the florist trade. Among the greenhouse primroses, P. ohconica has hairy leaves which may cause a skin rash in susceptible persons. Two other Chinese species. *P. forresti* and P. *bulleyana,* orange-yellow flowered. 2½ to 3 ft. in height, are hardy in favoured spots in the rock garden.

Cultivated primroses may be found in a considerable variety of colours. ranging from the palest yellow to deep crimson and blue. Most hardy sorts may be propagated by seed sown indoors in early spring; seedlings, kept cool and moist in moderate shade, should be transplanted a few times until they are set in the permanent spot in the garden in early autumn. **A** light mulch will give adequate protection in the winter. Since primroses do not reproduce true to seed, special varieties may be increased by the division of crowns in early autumn.

JOHN MARKHAM

COMMON PRIMROSE (PRIMULA VULGARIS)

Evening primrose belongs to the genus Oenothera (*q.v.*) of the evening primrose family (Ongraceae). The Cape primrose comprises hybrid forms of Streptocarpus, a South African genus belonging to the family Gesneriaceae. The Arabian primrose is *Arnebia* cornuta of the borage family (Boraginaceae) a garden annual. (N. TR.)

PRIMULACEAE, the primrose family of gamopetalous dicotyledons belonging to the order Primulales and containing about 800 species in 25 genera (the genus Primula has nearly 500 species). The family is cosmopolitan in distribution but the majority of the species are confined to the temperate and colder parts of the northern hemisphere and many are arctic or alpine. Eight genera with 21 species are represented in the British flora; there are in North America, 9 genera with about 80 species.

The plants are herbs, sometimes annual as in scarlet pimpernel (*Anagallis* arvensis), but generally perennial, rarely suffruticose. In *Primula* the plant persists by means of a sympodial rhizome and in *Cyclamen* by means of a tuber formed from the swollen hypocotyl. The leaves form a radical rosette as in *Primula* (primrose. cowslip, etc.) or there is a well-developed aerial stem which is erect as in species of *Lysimachia,* or creeping as in *Lysimachia nummularia* (creeping jenny or moneywort). Hottonia (water violet) is a floating water plant with submerged leaves cut into fine linear segments. The leaves are generally simple, often with a toothed margin: their arrangement is mostly opposite or whorled but may be alternate. The flowers are solitary in the leaf axils as in scarlet pimpernel, moneywort, etc., or umbelled as in primrose. where the umbel is sessile, and cowslip, where it is stalked, or in racemes or spikes as in species of *Lysimachia.* Each flower is subtended by a bract, but there are no bracteoles, and corresponding with the absence of the latter the two first developed sepals stand right and left. The flowers are hermaphrodite and regular with parts in fives (pentamerous) throughout, though exceptions from the pentamerous arrangement occur. The sepals are leafy and persistent; the corolla is generally divided into a longer or shorter tube and a limb which is spreading as in primrose, or reflexed as in *Cyclamen* and *Dodecatheon;* in *Soldanella* it is bell-shaped; in *Lysimachia* and others the tube is often very short. the petals appearing almost free: in *Coris* and *Omphalogramma* the corolla is zygomorphic; in *Glaux* the petals are absent. The five stamens spring from the corolla tube and are opposite to its lobes; this anomalous position is generally explained by assuming that an outer whorl of stamens opposite the sepals has disappeared, though sometimes represented by scales as in *Samolus* and *Soldanella.* The suoerior ovarv — half-inferior in *Samolus*—bears a simple style ending in a capitate entire stigma, and contains a free-central placenta bearing generally a large number of usually semianatropous ovules, which are exceptional in the group Sympetalae in having tno integuments. The fruit is a capsule, dehiscing by five, sometimes ten. teeth or valves, or sometimes transversely (a pyxidium) as in *Anagallis.*

ROCHE

SHOOTING STAR (DODECATHEON), AMERICAN GENUS OF THE PRIMROSE FAMILY

Cross pollination is often favoured by dimorphism of the floner, as shonn in species of *Primula.* The two forms have long and short styles respectively. the stamens occupying corresponding positions half-way down or at the mouth of the corolla tube. The pollen grains are also dimorphic and their size corresponds with that of the stigmatic papillae of reciprocal flowers (*see* PRIMROSE). Basic to these morphological differences the plants exhibit a certain amount of genetic self-incompatibility.

The family is divided into five tribes by characters of the corolla, ovary and capsule, and by the presence or absence of tubers. Despite its sympetalous corolla it is generally thought. on flower and ovary characters, to be allied to the polypetalous Caryophyllaceae.

The chief British genera are *Primula, Lysimachia* (loosestrifes) and *Anagallis.* The principal American genera are *Primula, Samolus* (water pimpernels or brookweedsj, *Lysimachia* and *Dodecatheon* (shooting stars or American cowslips). In cultivation the chief genera are *Primula, Cyclamen, Androsace, Omphalogramma* and *Lysimachia.*

See F. Pax and R. Knuth, "Primulaceae," *Pflanzenreich* 22, iv, *237:* I-386 (1905). (P. S. GR.)

PRINA, GIUSEPPE (1768–1814), Italian statesman. He was an adherent of Napoleon Bonaparte, and when Eugène Beauharnais became viceroy of Italy, uas appointed minister of finance His skill in devising fresh taxes to meet the enormous demands of Napoleon's government made him the best-hated man in Lombardy. After the emperor's forced abdication in 1814 Prina's party moved in the senate that delegates should go to Vienna to request that Eugène Beauharnais be raised to the throne of a free Italian kingdom. This provoked the formidable riot in which Prina mas dragged about the town for four hours, until almost torn to pieces, he received his death-blow.

PRINCE, MORTON (1854–1929), U.S. psychologist and physician, a distinguished pioneer in and contributor to the development of a psychological orientation in the study of functional nervous disorders, was born in Boston. Mass., Dec. 21. 1854, and was educated at Harvard university (B A., 1875; M D., 1879) uith subsequent study at Vienna. Strasbourg, Paris and Nancy. Prince formulated such concepts as "neurograms" (the neurological record of psychological behaviour); the "co-conscious" (a parallel, possibly rival, well-organized system of awarenesses comparable with ordinary consciousness); and the derivation of the psychoneuroses from the total experiential life of the patient, with dissociation, subconsciousness and varying levels of integration regarded as primary considerations. He recognized the motivational forces of emotional conflict but disagreed with Freud's rigid insistence upon a fundamental underlying theme of sexuality. Prince's concept of psychotherapy was based upon a resynthesis of dissociated or amnesic complexes and experiences by means of a deep integrational process. He was a pioneer in utilizing hypnosis as a fundamentally significant exploratory agent and for reeducational therapy.

In addition to studying and teaching abnormal psychology at Harvard, Prince practised medicine. was president of both the American Neurological and the American Psychopathological associations and founded (1906) and edited (1906–29) the *Journal of Abnormal Psychology.* He died Aug. 31, 1929.

He was the author of six books, the best known of which was his study of a multiple personality, *Dissociation of a Personality* (1906). Among others were *The Nature of Mind and Human Automatism* (1885), *The Unconscious* (1913) and *Clinical and Experimental Studies in Personality* (1929). (M. H. EN.)

PRINCE, a title implying either political power or social rank. The Latin word *princeps* originally signified merely "the first." As an honorary title it was applied in the Roman republic to the *princeps senatus; i.e.,* the senator first on the censor's list. The assumption of the style of *princeps senatus* by Augustus (*q.v.*) first associated the word with the idea of sovereignty and dominion. From Italy the title spread — first, with the crusaders, to the Holy Land. where Bohemund, son of Tancred. took the style of prince of Antioch; next: with the Latin conquerors. into the East Roman empire, where in 1205 William de Champlette. a cadet of the House of Champagne, founded the principality of Xchaea and the Morea. This example was followed by lesser magnates. who styled themselves loosely, or were so styled by the chroniclers. "princes." From the east the fashion was carried back to France: but there the erection of certain fiefs into "principalities." which became common in the 1jth and 16th centuries: certainly implied no independent sovereignty, and the title of "prince" ranked below that of "duke," being sometimes borne by cadet branches of ducal houses. On the other hand the title of "prince" was borne from the time of Charles VII or Louis XI by the sons of the royal house. so-called "princes of the blood." To these were added, from the time of Louis XIV, the *princes légitimés,* recognized bastards of the sovereign.

In Germany. Austria and other countries formerly embraced in the Holy Roman empire the title of "prince" had a somewhat different history. During the first period of the empire the "princes" were the whole body of the *optimates* who took rank next to the emperor. In the 11th century. with the growth of feudalism. all feudatories holding in fief of the Crown ranked as "princes." Toward the end of the 12th century, however, the order of princes *(Furstenstand)* was narrowed to the more important spiritual and temporal feudatories who had a right to a seat in the diet of the empire in the "college of princes" (*Fürstenbank*). Finally, in the 13th century, seven of the most powerful of these separated themselves into a college which obtained the sole right of electing the emperor. These were called "prince electors" (*Kurfürsten*) and formed the highest rank of the German princes (*see* ELECTORS).

In Germany. with the decay of the empire the title "prince" received a sovereign connotation, though it ranked. as in France, below that of "duke." There were, however, in the countries formerly embraced in the Holy Roman empire other classes of "princes." Some of these inherited titles, sovereign under the old empire but "mediatized" during the years of its collapse at the beginning of the 19th century; others received the title of "prince" at the end of the empire as "compensation" for ceded territories. There were also in Austria and Germany "princes," created by the various German sovereigns: and some dating from the period of the old empire, who took a lower rank as not being "princes of the Holy Roman empire" nor entitled to any royal privileges. All these princes were styled *Fürst,* having the predicate "Serene Highness" (*Durchlaucht*). The word *Prinz,* actually synonymous with *Fürst,* was reserved as the title of the nonreigning members of sovereign houses and. nith certain exceptions (*e.g.,* Bavaria), for the cadets of mediatized ducal and princely families. The heir to a throne was "crown prince" (*Kronprinz*), "hereditary grand duke" (*Erbgrossherzog*) or "hereditary prince" (*Erbprinz*). The heir to the crown of Prussia, when not the son of the monarch, had the title of "prince of Prussia" (Prinz von *Preussen*). In Italy the title "prince" (*principe*) is also of unequal value. Heads of great families sometimes bear the title of "prince," sometimes that of "duke." The title of "prince of Naples" is attached to the eldest son of the king of Italy.

"Prince" is also the translation of the Russian title *knyaz*. In general, though the title "prince" implies descent from one or other of the ruling dynasties of Russia, it is in itself of little account owing to its being borne by every member of the family.

The title of "prince" is also borne by the descendants of those Greek Phanariot families (see PHANARIOTES) who formerly supplied hospodars to the Turkish principalities on the Danube. One of the few instances in Europe of "prince" as a completely sovereign title is that of the prince of Monaco.

Great Britain. — In Great Britain "prince" and "princess" as titles are confined to members of the royal family, though nonroyal dukes are so described in their formal style (see DUKE). Nor is this use of great antiquity, the custom of giving the courtesy title of "prince" to all male descendants of the sovereign to the third and fourth generation being foreign to English traditions. It was not till the reign of Henry VII that the king's sons began to be styled "princes"; and as late as the time of Charles II the daughters of the duke of York, both of whom became queens regnant, were called simply the Lady Mary and the Lady Anne. The title of "princess royal," bestowed on the eldest daughter of the sovereign, was borrowed by King George II from Prussia. Until recent years the title "prince" was never conferred on anybody except the heir apparent to the Crown, and his principality is a peerage. Since the reign of Edward III the eldest sons of the kings and queens of England have always been dukes of Cornwall by birth and. with a few exceptions, princes of Wales by creation. Before that Edward I had conferred the principality on his eldest son, afterward Edward II, who was summoned to and sat in parliament as prince of Wales. But Edward the Black Prince was the original grantee of the principality as well as of the dukedom under the special limitations which have continued in force to the present day. The entail of the former was "to him and his heirs the kings of England" and of the latter "to him and his heirs the first-begotten sons of the kings of England." Hence when a prince of Wales and duke of Cornwall succeed to the throne the principality in all cases merges at once in the Crown and can have no separate existence again except under a fresh creation, while the dukedom, if he has a son, descends immediately to him or remains in abeyance until he has a son born. If, however, a prince of Wales and duke of Cornwall should die in the lifetime of the sovereign, leaving a son and heir, both dignities are extinguished, because his son. although he is his heir, is neither a king of England nor the first-begotten son of a king of England. But, if instead of a son he should leave a brother his heir, then —as was decided in the reign of James I on the death of Henry, prince of Wales, whose heir was his brother Charles, duke of York—the dukedom of Cornwall would pass to him as the first-begotten son of the king of England then alive, the principality of Wales alone becoming merged in the crown.

But even now the children of the sovereign other than his eldest son, though by courtesy "princes" and "princesses," need a royal warrant to raise them de *jure* above the common herd; and even then they remain "commoners" till raised to the peerage. In 1905 King Edward VII established what appeared to be a new precedent, by conferring the titles of "princess" and "highness" upon the daughters of the princess Louise, duchess of Fife, created "princess royal."

PRINCE ALBERT, a city in the province of Saskatchewan, Can., is on the North Saskatchewan river 220 mi. ndrth of Regina, near the central northern extremity of the settled part of the province. Founded in 1866 as an Anglican mission station. near the site of a fur trade post established in 1776, it became a centre for the lumbering industry in the early 1900s. Now Saskatchewan's northern "capital," it serves a large agricultural and forest region and a vast northern hinterland. It is a northern provincial government headquarters and has good railroad, highway and air services, a television and radio station and a daily newspaper. It is the site of a federal penitentiary. Its industries include an oil refinery, wood preserving plants, a plywood plant, woodworking shops and a packing plant. Pop. (1961) 24,168. (C. S. BR.)

PRINCE EDWARD ISLAND, in the gulf of St. Lawrence, is the smallest province of Canada. The arc of the crescent-shaped island roughly parallels the curving southern shore of the gulf; it is separated from the mainland by Northumberland strait, which has a maximum width of 25 mi. The province has less than 1% of the population and area of Canada and plays a very minor role in the economy and politics of the country. Yet "the island" is cherished by thousands of its former residents and their families, widely scattered over North America. The almost feudal system in which its lands were held for nearly a century makes its history of unique interest; and L. M. Montgomery's Anne of Green Gables made its national park, which enshrines a near replica of "Green Gables," a tourist mecca.

Size, Shape and Location. — The curving island has a maximum length of 145 mi. From a maximum width of 34 mi. it narrows to isthmuses which in two places. northeast of Charlottetown (the capital) and near Summerside (the other town), are less than 3 mi. from tidewater to tidewater.

The three lobes thus pinched off roughly correspond to the three counties. from east to west, Kings, Queens and Prince. The land area is 2,184 sq.mi.

Physical Geography. — The bedrock, well covered by dune sand on the gulf shore and glacial ground moraine elsewhere, is exposed in low cliffs on the eastern and southern shores. An unusually uniform red sandstone, it does grade off both to sandy siltstones and shales and coarser conglomerates. The age of the formation is thought to be Permian (150.000.000 years). The apparently horizontal strata actually dip toward the northeast and must be younger than similar beds exposed on the mainland to the south. The dip and cliffing suggest the remnants of an old cuesta, elsewhere dismembered or drowned beneath the waters of the gulf. In this soft sandstone block stream erosion has carved a gently rolling plain grading to rougher hills of over 400 ft. elevation west of Charlottetown and to some few stretches really flat to the eye west of Malpeque bay. The intricate serration of the shoreline with many deep estuaries bring sea and land into intimate relation; no point of the island is more than 10 mi. from tidewater.

The soils. everywhere developed from the thick mantle of glacial drift, tend to be coarse-textured sandy loams. There are more clayey phases and a good deal of swamp and bog; at the other extreme are the dunes that line much of the northern shore. The soils are strongly acid Podzols, rather low in plant nutrients.

As elsewhere in the Atlantic provinces and New England states the weather is markedly variable; the island lies on one of the most heavily traveled storm tracks in North America. There is much sunshine but, on the average, every third day has some precipitation; the annual 40 in. normally includes 9 or 10 ft. of winter snow. An occasional dry summer month and extremes of open, or deeply snowbound, winters point up the variability. Monthly temperature means lie between February's 17° F. and July figures in the upper 60s; the effect of the sea is seen in a long, laggard. chilly spring and in a late, warm and truly glorious autumn.

When Jacques Cartier visited the island in 1534 it was covered with a dense mixed forest, its trees of both boreal coniferous and northern hardwood types. There is a good deal of tree cover, predominantly spruce. on farm woodlots but the 16th-century forest has disappeared. With it have gone most of the larger animals (bear, moose, caribou. deer, seals, walrus and even beaver) but smaller animals and a wide variety of birds, including migratory ducks and geese. are still plentiful as are the fish and shellfish (cod, hake, halibut, herring, gaspereaux, mackerel, trout. salmon, eels, lobsters and clams) of its streams, estuaries and offshore coastal banks.

History. — Cartier was the first European of record to visit the island. Afterward it was largely ignored by the French until the

18th century, although, much earlier, it acquired the name Île St. Jean (St. John's Island) which it was to retain until 1798, when its present name was chosen (after that Duke of Kent whose daughter was to become Queen Victoria).

It received more attention from the French, as an adjunct of Louisburg on Île Royale (Cape Breton) and a refuge for Acadians from the mainland, especially after the treaty of Utrecht, and when Lord Rollo invested it for the British in 1758 it may have held as many as 5.000 settlers, mostly Acadian. Most of these were deported and the island was surveyed and divided into 3 counties. each with a townsite and "royalty." 14 parishes and 67 lots or townships. These nere then awarded, by lot, to upward of 100 applicants for royal favour (Scots predominated) under conditions which should have guaranteed rapid settlement. The grantees (proprietors) did little, however, and by 1800 there were scarcely more settlers than in the 1750s. But the few Highland Scots, American Loyalists and remaining Acadians of the turn of the century were soon joined by thousands of others, dominantly Highlanders and southern Irish and, as the tenant farmers slowly won representative and responsible government (the colony was separated from Nova Scotia in 1769). pressure was increased on the often absentee proprietors to open their lands and the freehold was gradually enlarged. At the time of union with Canada in 1873 only the most recalcitrant of the landlords remained to be bought out.

The little colony joined the new dominion six years late and rather reluctantly; it has been said to have been "bought" into confederation by Canada's assumption of its overwhelming railway debt, promises of better communications across the strait and a large subsidy to take care of the extensive land purchases from the proprietors. Since then it has been ever in the forefront of moves by the smaller provinces to obtain a larger share of federal revenues to help them support schools and other local services at levels nearer those prevailing in central Canada.

Government. — The form of government is that defined by the British North America act (see CANADA: History). The province at first sent 6 members to the Canadian house of commons; it now sends 4 to a house of 262 and 1 of these is occasionally given a cabinet post, usually minor. It has a local assembly of 30 members elected in pairs (a relic of the period of two houses) from 15 constituencies and the government is organized by the majority party in the usual British parliamentary system.

Population.—The population, roughly 30.000 in 1830, reached 80 000 in 1860 and over 110 000 in the 1880s. when immigration had largely ceased and the outflow of population began. The highest census total was 109.078 in 1891; by 1921 it had dropped below 90.000 but rose to 99,285 in 1956 and to 104,629 in 1961. The great tide of emigration affected chiefly descendants of Scots and Irish. A population over half Scots and one-fourth Irish (and about 10% Acadian) in the 1860s had changed to about 30% each of Scots and English (in claimed ultimate origin), about 20% Irish and something under 20% Acadian in the mid-1950s. Other elements in the population are negligible; only a handful of Micmac Indians remain.

The population density is over 47 per square mile but more than one-fourth of the people live in the city (Charlottetown, pop. 18,318 in 1961) and town (Summerside. pop. 8.611 in 1961) and the rural population is much denser west of Charlottetown than in the east. "Farm" population has been declining even more rapidly than "rural" population; it numbered 43,112 in 1956.

Education and Religion. — Public primary school3 provide education to the tenth grade. Four more years of schooling are available at Prince of Wales college in Charlottetown (also the principal teacher-training centre), through the second year of a university course. Full collegiate education is offered by St. Dunstan's Roman Catholic university, also in Charlottetown. Roman Catholics compose the largest single denomination. with about 45% of the population, divided among those of hcadian, Irish and Highland Scots origin. The Protestant majority is made up chiefly of four groups, United Church 26%, Presbyterian 14%, Anglican 6% and Baptist 5%.

Production. — In 1956 about 43% of the population was classed as agricultural and its farms (averaging over 110 ac.) occupied about three-fourths of the surface (much of the rest of which had been farmed in the 19th century). A mixed livestock-and-crop agriculture received most of its revenue from animal products: sales of cattle. swine and dairy products alone yielded half of it. Potatoes (largely seed), which provided about 15% of the total. was the only cash crop of significance. Most farms were self-sufficient to a degree, with 17% of all farm production consumed thereon by farmers. More than 19 out of 20 farms were operator-owned. In 1959 agriculture constituted 36% of the total net value of production.

Fisheries in 1959 yielded about 9% of the total net production. Lobsters. taken in limited seasons, provided two-thirds to three-fourths of that value, cod and related ground fish, herrings. smelts and oysters the rest. Most fishermen and boats were unspecialized. shifting from one fish to another with the season; many of the men were part-time farmers.

The island was the birthplace of silver fox farming, for which it was world famous from 1910 to 1940, but after 1950 foxes all but disappeared and the few fur farms left raised chiefly mink. Forest products, derived from indifferently managed farm ood-lots, played a steady but minor role in the economy.

The net product of manufacturing industries comprised 15% of the total in 1959 but they were chiefly processing industries for agricultural. fishery and forest products; butter and cheese making. meat slaughtering and packing, fish processing and feed milling and mixing predominated. There is an interesting textile industry (bag making for fertilizer and potatoes) and a significant woodworking enterprise although plants are small. The tourist industry. still not strongly developed. offers excellent opportunities if transportation could be improved.

Communications. — The island's railway was begun in 1871 as a narrow-gauge (3 ft. 6 in.) line notable for its curves and grades. The establishment of a car-ferry connection with the mainland (Borden to Cape Tormentine in New Brunswick) during World War I led to a change to standard gauge; by 1960 that service across the strait to and from Charlottetown and Summerside was the chief function it performed. A highway-building program begun in the 1950s greatly increased the mileage of paved roads on the island.

Communication across the strait has been a central problem of island life since the 18th century. Even a supplementary automobile ferry from Wood Islands in the southeast to Caribou (near Pictou) in Nova Scotia has only widened the bottleneck. Good air connections to Summerside and Charlottetown have relieved the situation somewhat.

BIBLIOGRAPHY.—A. H. Clark. *Three Centuries and the Island* (1959); D. C. Harvey. *The French Régime in Prince Edward Island* (1926); "Prince Edward Island," *Canadian Geog. Jour.* (May 1938) by F. Walker and (Aug. 1941) by A. McAnn; J. Croteau, *Cradled in the Waves* (1951); Frank Mackinnon, *The Government of Prince Edward Island* (1951). (AN. H. C.)

PRINCES' ISLANDS, a cluster of nine islands in the Sea of Marmora. forming the Adalar district in the *il* of Istanbul, Turkey. They figure in Byzantine history chiefly as places of banishment. A convent in Prinkipo was a place of exile for the empresses Irene, Euphrosyne, Zoe and Anna Dalassena. Antigone was the prison of the patriarch Methodius, and its chapel is said to have been built by the empress Theodora. In Khalki the monastery of the Theotokos (originally of St. John), after 1831 a Greek commercial school, was probably founded by John VI or VII. Area 5.4 sq.mi.; pop. (1960) 19,864.

Palaeologus was rebuilt about 1680, and again in the 18th century by Alexander Ypsilanti, hospodar of Moldavia. Hagia Trias (a school of theology since 1844) was rebuilt by the patriarch Metrophanes. On Prote were the monasteries to which Bardanes (Philippicus), Michael I Rhangabes, Romanus I (Lecapenus) and Romanus IV (Diogenes) were banished.

PRINCETON, a borough of Mercer county. N.J., U.S., the seat of Princeton university (*q.v.*), is located midway between New York city and Philadelphia. Capt. Henry Greenland established a plantation on the site of the present village in 1681 and 15 years later a number of Quaker families settled in the area.

During the colonial period, because of its location. Princeton was the principal luncheon stop for stagecoach passengers traveling between Philadelphia and New York. In the pre-Revolutionary period the College of New Jersey, now Princeton university, became a centre of anti-British feeling; John Witherspoon, its president, Richard Stockton, a resident of the town, and John Hart, from nearby Hopewell, were three of the five New Jersey men to sign the Declaration of Independence. Nassau hall, principal structure of the college, completed in 1756, changed hands three times in the battle of Princeton and it was within its walls that the engagement ended, with Washington's troops defeating the British under Col. Charles Mawhood on Jan. 3, 1777, following the battle of Trenton. The legislature of the state of New Jersey convened in Princeton the following summer and the Continental congress was assembled there from June until Nov. 1783.

Educational institutions in Princeton in addition to the university include the Institute for Advanced Study, established in 1930; Princeton Theological seminary, a Presbyterian seminary established in 1812; Westminster Choir college, a private college established in 1926, and its affiliated Columbus Boychoir school; and several distinguished private schools. The Educational Testing Service, with headquarters there, develops and publishes achievement tests used in schools and colleges throughout the nation. Research laboratories operated by industrial firms and nonprofit organizations have been attracted to Princeton by the presence of the educational facilities.

In addition to a community of scholars who come from many nations, there reside in Princeton business and professional men and women who commute daily to Newark, New York city, Philadelphia and Trenton. Mid-town Palmer square. a business district, is an outstanding example of urban redevelopment emphasizing colonial architecture.

"Morven" in Princeton is the official executive mansion of the governor of New Jersey. The oldest portion was built in 1701 by Richard Stockton, grandfather of the signer of the Declaration of Independence. Walter E. Edge, then governor, purchased it in 1944 and ten years later presented it to the state. The first occupants under its new function, Gov. and Mrs. Robert B. Meyner, moved into it in 1957.

For comparative population figures see table in NEW JERSEY: *Population.* (E. R. D.)

PRINCETON UNIVERSITY, a privately endowed nonsectarian institution of higher learning for men, at Princeton, N.J., until 1896 called officially the College of New Jersey. Its buildings are grouped in the central portion of a campus of about 2.100 ac.. one of the most beautiful in the country. Nassau hall, the oldest and historically the most interesting building on the campus, was at the time of its completion in 1756 the largest academic building in the American colonies. It was designed by Robert Smith, architect of Independence hall in Philadelphia. and named in honour of William of Nassau, William III of England. There in 1783 George Washington received the formal thanks of the U.S. congress for his conduct of the Revolutionary War.

Characteristic of life at Princeton, in addition to the university's rural location and consequently its active outdoor interests, are the residential dormitory system, the system of elective upper-class eating clubs and the form of student self-government illustrated particularly by the honour system, under which undergraduates participate in the administration of university discipline.

In all admissions, regard is given to character, personality and promise as well as to scholarly attainment. Enrollment is limited in both the undergraduate department and the graduate school.

The university offers undergraduate courses in the liberal arts and sciences leading to the degree of bachelor of arts and bachelor of science in engineering. In addition to the arts and sciences, graduate work leading to the master's and doctor's degrees is also ofiered in architecture, engineering and public and international affairs. In 1923, Princeton initiated a "four-course program" for all upper-class candidates for the bachelor of arts degree. Under this program, a student carries on independent study and writing under an assigned supervisor in lieu of a course each term, culminating in the senior year in a major thesis and a comprehensive examination. In 1947, a program requiring the exploration of the major fields of learning by underclassmen was added. Special programs include those in the humanities. American civilization, European civilization. near eastern studies, and public and international affairs.

A feature of instruction is the preceptorial method, introduced in 1905, by which large classes are broken into small groups or informal conferences with preceptors on prescribed reading. Princeton has no professional schools for utilitarian ends, except the school of engineering and possibly the school of architecture, although both of these are strongly humanistic in their curriculums and methods. The school of architecture developed directly out of the department of art and archaeology, and on successful conclusion of the course confers the degree of master of fine arts.

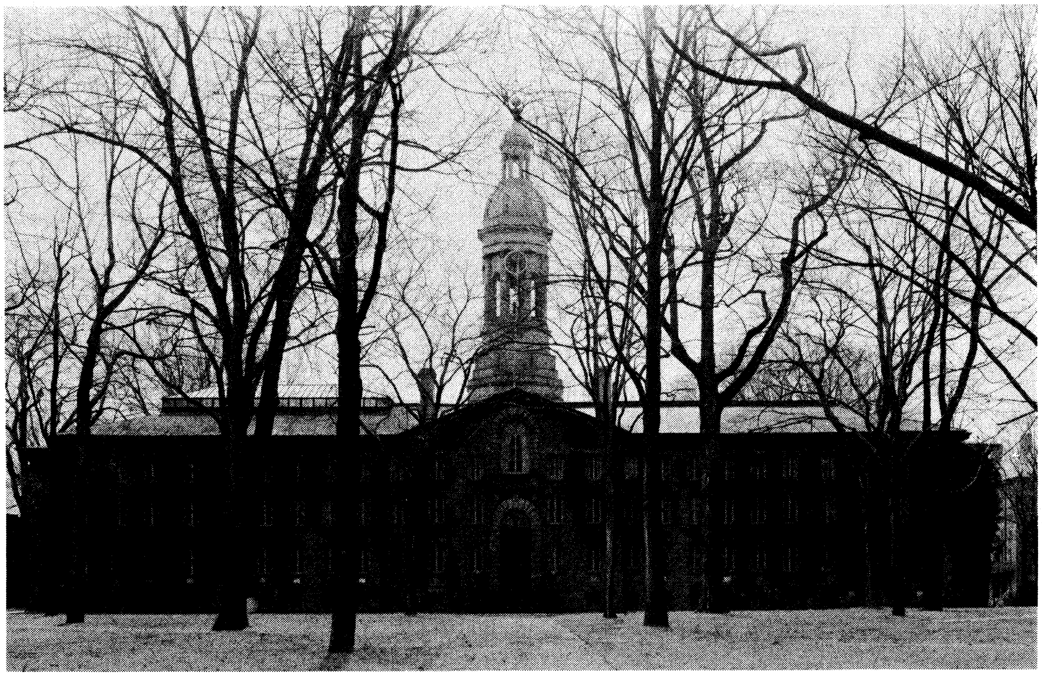
In assuming the university title in 1896, it was definitely concluded that Princeton's future did not lie in developing professional schools but in upholding pure learning and in devoting itself "to the liberal aspects of those studies which underlie and broaden professional and technical education." The university, therefore, became not a congeries of professional schools overshadowing an undergraduate department but a large, homogeneous and well-organized body of undergraduate students, with a small, carefully selected graduate school devoted to the liberal arts and sciences.

History. — The university owes its origin to a movement set on foot by the synod of Philadelphia in 1739 to establish in the middle colonies a college to rank with Harvard and Yale in New England and William and Mary in Virginia. As a result of dissension in the church, no progress was made until 1746, when the plan was again broached by the synod of New York, formed by the secession of the presbytery of New York and the presbytery of New Brunswick, radical (New School) presbyteries of the synod of Philadelphia. Most of the leaders of the presbytery of New Brunswick had been educated at Log college, a school with restricted curriculuin at Seshaminy, Pa., about 20 mi. from Philadelphia, founded in 1726. The opportunity was taken by the synod of New York to found a larger institution of higher learning, broader in scope and training, and to transfer to the new project the Log college interests. On Oct. 22, 1746, John Hamilton, acting governor of New Jersey, granted a charter for erecting a college in New Jersey, which was opened in May 1747, at Elizabeth, S.J. A second charter was granted by Gov. Jonathan Belcher, who on his arrival in the province in 1747 had at once taken the college under his patronage. The college was removed to Newark where the first graduation exercises were held in 1748; but the situation was unsuitable, and in 1752 the trustees voted to remove the college to Princeton. While additional funds were being collected in Great Britain, work was begun in Princeton in 1754 on the first college building, Nassau hall.

John Witherspoon, president during the Revolutionary period, influenced the college strongly by his personality and political prominence, and graduates of his training became leaders in public affairs. The history of the college during the first half of the 19th century was uneventful. Because of its large southern clientele, it suffered in the U.S. Civil War a blow from uhich it recovered only under the energetic administration of Pres. James McCosh (1868–88). The undergraduate enrollment was nearly trebled. gifts amounting to more than $2,000.000 were contributed, only half of which sum was for endowment, 14 new buildings were erected, and important changes were made in the curriculum.

Fellowships were established in 1869, the elective system was introduced in 1870, the John C. Green school of science was erected in 1873, the graduate department was systematized in 1877 and the faculty grew from 17 to 40 and the number of volumes in the library from 25,000 to 65,000.

Under Pres. Francis L. Patton (1888–1902) a school of electrical engineering was established, the honour system was instituted and the plan of electing alumni trustees adopted, 17 buildings were erected, the student body was doubled and the faculty increased to 100. while the endowment reached $2,500,000. In 1902 Woodrow Wilson. of the class of 1879, mas elected president. In his administration the undergraduate curriculum was again revised, the departmental system was organized, and an extensive building



BY COURTESY OF PRINCETON UNIVERSITY

NASSAU HALL. PRINCETON UNIVERSITY. WHEN COMPLETED IN 1756, IT HOUSED THE DORMITORY. REFECTORY, CLASSROOMS AND CHAPEL; IN THE EARLY 19TH CENTURY IT BECAME THE ADMINISTRATIVE BUILDING

program was completed. To obtain the necessary funds, a committee of 50 alumni was formed, later changed into a Graduate council. Through their agency in the eight years of President Wilson's administration the university received more than $4,500,000, the, faculty was greatly strengthened and the library increased to 271,000 volumes. A plan for grouping the university into small self-contained units was prematurely proposed by the president in 1907 and was withdrawn by the trustees. The Princeton plan of a residential building for graduate students was successfully tested on a small scale. and a bequest in 1908, although inadequate for the full project which included professorships and fellowships, gave the plan its first semblance of permanent realization. Additional funds being conditionally offered in 1909, controversy developed as to the site for the building and finally as to the plan itself, the president no longer favouring it. A further bequest of about $2,000,000 for the project brought matters to a head and the president recommended acceptance of the legacy. In Sept. 1910, having received the democratic nomination for governor of New Jersey, he resigned the presidency.

John Grier Hibben. of the class of 1882, professor of philosophy in the university, was the 14th president of Princeton. January 1912 to June 1932. His administration was marked by extended administrative reorganization, by large additions to the endowment and by extensive expansion along material and scholastic lines. Faculty autonomy was made complete: a joint committee of trustees and faculty was organized to consider all matters of educational policy and administration; the faculty was given voice in forming its committees and initiating appointments, promotions and increases of salary; the rights of the individual in cases of dismissal were safeguarded; faculty retiring allowances and insurance were arranged.

In 1913 the erection of the residential graduate college rendered permanent what had been an experimental feature of the Princeton graduate school. The school of architecture was opened in 1920. The school of engineering was reorganized in 1921, and the school of public affairs, designed to give its students a broad background for an understanding of and active participation in local, state, national and international affairs, was founded in 1930. Edward Dickinson Duffield of the class of 1892 and a trustee of the university served as acting president until the election of Harold Willis Dodds, professor of politics, as 15th president in June 1933. The university commemorated the academic year 1946–47 as its bicentennial anniversary and in 1949 established ten bicentennial preceptorships to encourage scholarship and teaching.

In 1951 Princeton established the James Forrestal Research centre in the former plant of the Rockefeller Institute for Medical Research, comprised of 15 buildings and laboratories. The centre was established for the immediate purpose of permitting the university to expand its program of basic research for national defense, and for the long-term purpose of providing additional laboratories and facilities to meet the more exacting requirements of modern scientific and engineering research.

The many research programs are concerned with problems in the fields of aeronautical engineering and jet propulsion, chemical kinetics, catalysis, metallurgy, biochemistry, applied mathematical analysis and applied nuclear sciences.

Buildings include the John C. Green Engineering building (1927), with the engineering laboratory added in 1951; the Palmer Memorial stadium (1914); and the New observatory (1934), with a dome 45 ft. in diameter and a 23-in. telescope. Buildings erected after World War II include the Herbert Lowell Dillon gymnasium (1947); the Harvey S. Firestone Memorial library (1948); the Architectural laboratory and the Class of 1915 Dormitory (1949); Hayes Engineering laboratory (1951); Woodrow Wilson Hall (1952).

In 1953 the university re-emphasized its long interest in the humanities by the establishment of the Council of the Humanities which has the function of assisting members of the faculty and graduate and undergraduate students in interdisciplinary studies in the area. The council provides senior and junior fellowships for such study and supervises several special programs of instruction in which the broad range of the humanities and the social sciences is brought to bear upon programs of fundamental value or upon the civilizations of particular areas of the world.

In 1956, in order to provide more effective channels of communication with industrial corporations, a program of conferences was established to cover general and specialized problems of common interest to industry and the faculty in all areas of the university. The conferences were planned and directed by the various departments and attended by both faculty and interested corporation officers.

On July 1, 1957, on the retirement of President Dodds. Robert Francis Goheen of the department of classics became the 16th president of the university.

Princeton University Press.—Organized as a nonprofit association, closely affiliated with. but legally independent of, the university, the Princeton University press was founded in 1905 and incorporated in 1910. In 1912 it published its first book; approximately 50 new titles are published annually.

The broad aim of the Princeton University press was defined as "the promotion of education and scholarship," and it serves the university by publication and distribution of its research and offers other services to scholars there and elsewhere. (J. D. BN.)

PRINCIPAL AND AGENT refers to the law of agency dealing with salesmen, brokers, managers and other commercial agents having power to make contracts for their employers. This branch of agency came to be treated separately as a result of the great increase in shipping, banking, insurance and other mercantile transactions that occurred during the late 18th and early 19th centuries. See AGENCY.

PRINCIPE ISLAND, a Portuguese island in the Gulf of Guinea, of volcanic origin, 90 mi. N.E. of São Tomé Island with an area of 42 sq.mi. The highest point is Pico-Papagaío, 3,110 ft. above sea level. The island forms, along with São Tomé Island. a Portuguese overseas province.

The population was 4,332 (81 white) in 1950 and 3,108 (56 white) in 1940. The chief settlement is Santo Antonio.

The tsetse fly (which is not found in São Tomé) infested the wooded part of the island, and through it sleeping sickness was spread. Coconuts, coffee and cacao are exported.

PRINGLE, SIR JOHN (1707–1782), British physician, the founder of modern military medicine, was born on April 10. 1707, at Stitchel, Roxburghshire, and educated at St. Andrews. at Edinburgh and at Leiden. He settled in Edinburgh as a physician, but after 1734 also acted as professor of moral philosophy in the university.

In 1742 Pringle became physician to the earl of Stair, then commanding the British army in Flanders, and in 1744 was appointed physician general to the forces in the Low Countries. In 1749, having settled in London, he was made physician in ordinary to the duke of Cumberland, and subsequently received other court appointments as physician, being made a baronet in 1766. In Nov. 1772 he was elected president of the Royal society, but resigned his presidency in 1778. Pringle died on Jan. 18. 1782.

Pringle remedied camp sanitation and the ventilation of hospitals and laid down the principles for preventing dysentery and hospital fever, at the same time showing that the different forms of dysentery were varieties of one disease and that jail fever was the same as hospital fever.

Pringle's chief works are: *Observations on the Nature and Cure of Hospital and Jayl Fevers* (1750); "Experiments on Septic and Antiseptic Substances" in the *Philosophical Transactions* of the Royal society (1750); and especially the *Observations on the Diseases of the Army* (1752). His *Six Discourses* (1783) contains a biography by A. Kippis.

PRINGSHEIM, NATHANAEL (1823–1894), German botanist. who made outstanding contributions to the study of algae, was born in Cpper Silesia on Nov. 30, 1823. He studied at the universities of Breslau, Leipzig and Berlin; graduated in 1818 as doctor of philosophy with a thesis on the form and development of the thickening layers of plant cells; and rapidly became a leader in the great botanical renaissance of the 19th century. His contributions to scientific algology were of striking interest and, together with the French investigators G. Thuret and E. Bornet, he ranks as a founder of the scientific knowledge of the algae. Pringsheim mas among the first to demonstrate the occurrence of a sexual process in this class of plants, and he drew from his observations weighty conclusions as to the nature of sexuality. The conjugation of zoospores, regarded by Pringsheim as the primitive form of sexual reproduction, was a discovery of fundamental importance.

A work (1873) on the course of morphological differentiation in the Sphacelariaceae, a family of marine algae, is of great interest, inasmuch as it treats of evolutionary questions: the author's point of view is that of K. W. von Nägeli rather than that of Darwin. Connected with Pringsheim's algological work was his investigation of the Saprolegniaceae, a family of aquatic algalike fungi. His career as a morphologist reached its peak in 1876 with the publication of a memoir on the alternation of generations in thallophytes and mosses.

From 1874 to the close of his life Pringsheim's activity nas chiefly directed to plant physiology. He founded the *Jahrbuch für wissenschaftliche Botanik* and the German Botanical society. His nork was, for the most part. carried on in his private laboratory in Berlin, he held a teaching post of importance for only four years, 1864–68, when he was professor at Jena. Pringsheim died in Berlin on Oct. 6, 1894.

He wrote memoirs on *Vaucheria* (1855); the Oedogoniaceae (1855–58); the Coleochaeteae (1860); *Hydrodictyon* (1861); and *Pandorina* (1869). His complete norks were published by his children (*Gesammelte Abhandlungen,* 4 vol., 1895–96).

PRINTED CIRCUITS are electrical circuits in which the usual wiring—and. occasionally, resistance elements—are replaced by patterns of conductive material applied on sheets of ceramic, glass. or laminated or solid plastic. The circuit patterns are produced by photographic and mechanical printing procedures much like those used in the graphic arts.

First developed on a large scale after World War II. the techniques for producing printed circuits helped meet the demands of industry for more efficient mass production of electrical equipment. The increasing application of electronic equipment in business and industry during the postwar years created problems of weight, size. reliability and production cost. Most of these problems were solved to a large extent, particularly in the radio and television industries in the United States, by the use of printed circuits.

Of the numerous processes used in the fabrication of printed circuits, the most common were etching, plating, metalizing and printing.

In the photoetching process, a photosensitive film is applied to the copper surface of a copper-clad plastic sheet, and a photographic negative of the circuit pattern is superimposed on the sensitized film. The film is then exposed to ultraviolet light in a manner similar to that used in producing a photographic positive. The exposed film hardens and the unexposed areas dissolve readily in an alcohol solution. The hardened film protects the printed circuit pattern during the subsequent etching process. The exposed copper is dissolved in an acid or ferric chloride etchant bath, leaving the copper circuit pattern.

In stencil etching, a protective film to form the circuit pattern is applied by a printing process such as silk screening, which deposits a film sufficiently thick to protect the copper from the etchant solution. The protective film, an enamel, is dried and the exposed copper is etched as described previously.

In the plating process a plastic laminate is first coated with a material which will conduct electricity. This may be done by forming a ,0001-in. silver coating on the surface of the laminate in much the same way that mirrors are silvered. The silver film is then coated with a plating resist, usually an enamel, by a stenciling process, leaving exposed areas to form the circuit pattern. The plating process is similar to the plating of decorative metals. After a sufficient thickness (0.001 in. to 0.005 in.) of copper is deposited, the plating resist is removed by a solvent. The exposed silver film is removed by acid etching, leaving the much thicker copper plating to form the circuit pattern on the plastic sheet. Another technique, especially for electronic components (switches. commutators and other low-current-carrying parts), is to evaporate metal such as silver directly on an insulating plate through a stencil.

The printing method of producing circuits uses ceramic or glass as a base material in most cases. A silver paste is applied through a silk screen to form the circuit pattern. After the silver paste has dried. the circuit is fired in a furnace at about 750° F., thus bonding the silver pattern to the base. This process also makes it possible to print resistance elements, composed of various forms of carbon. on the circuit pattern.

Printed circuits assumed an important role in industry because they opened the way to mechanized production of electronic equipment. Mechanized production in turn offered the advantages of lower labour costs and better uniformity and quality of product.

Printed circuitry also eliminated one major cause of unreliability in electronic equipment, poorly soldered joints between the electronic component and conductor, by permitting the use of the dip soldering process. In dip soldering, the joints between the electronic component and the conductor are exposed to molten solder and joined in one operation.

Printed circuits were used in practically all types of electronic equipment. including radio and television sets, guided missile controls, electronic computers and industrial control equipment.

BIBLIOGRAPHY.—*Printed Circuit Techniques,* National Bureau of Standards, Circular 468; *New Advances in Printed Circuits,* National Bureau of Standards, Miscellaneous Publication *192*; *Proceedings* of the Symposium on Printed Circuits, sponsored by the Engineering Department of the Radio, Electronics, Television Manufacturers Association (Jan. *1955).* (L. K. L.; Co. *Bi.)*

PRINTING is the mechanical multiplication of text, pictures or designs by putting ink on paper or some other suitably receptive surface, such as cardboard, cloth, cellophane or metal. Broadly speaking, printing encompasses all production and use of printed matter. This article discusses first the history of printing and then the modern printing processes.

There are three main methods of printing: letterpress (or relief). in which the image is transferred from a printing surface raised slightly above the body of the type or printing plate: intaglio (gravure), from a design engraved below the surface of the printing plate; and offset lithography (planographic printing). from a flat surface. Letterpress, which was used by the first European printers in the 15th century, is still the most common method.

Modern printers use techniques and processes that are continually improved through science and engineering, although the basic machines and methods change slowly. Printers choose the printing process best suited for the work to be done, and frequently they use different methods interchangeably or in combination.

THE HISTORY OF PRINTING

The East. — Printing as western civilization knows it began about the middle of the 15th century in Germany. The Chinese, Japanese and Koreans used printing long before that time, but western printing was invented independently of the oriental art and developed along dissimilar lines. The major reason for the separate development is the difference between Asian and European scripts. Mass production of movable letters for the 15th-century European alphabet of 23 letters was a simple affair; for a language demanding thousands of complicated ideographs, it was impossible.

Chinese printing was until modern times achieved mainly from wood blocks engraved in relief, each with one or more pages of text. printed not under pressure but by rubbing the paper against the inked surface with a dry brush or some other rubbing device. As both sides of the thin, porous Chinese sheet cannot be printed, the traditional Chinese accordion book is folded and stitched at the side so that blanks do not show. The skilled Chinese craftsmen not only could engrave the blocks rapidly and cheaply but also could duplicate with remarkable fidelity the beauty and delicacy of brush calligraphy, esteemed in the orient for aesthetic as well as utilitarian reasons.

How or when printing was first accomplished in China is not known with certainty. It may have derived from engraved seals. used in China from at least the 3rd century B.C. to make impressions in soft clay. The first-known inked impressions on paper date from the 5th century A.D. Similar stamps, used with a red ink made from cinnabar, are still commonly employed in the east for signatures on documents. In the 6th century A.D. large wooden seals were cut and used for printing Taoist charms.

Another hypothesis is that printing developed from the ancient Chinese practice of making inked rubbings or squeezes from stone inscriptions. About A.D. 165 the standard text of the Confucian classics was cut upon stone to ensure permanence and accurate transmission, and soon thereafter the practice of making copies by means of ink rubbings began. The earliest extant rubbing dates from the 7th century. In the east and later in the west the first great patrons of the printer were officials of church and state, who saw in him a useful ally for maintaining canonical purity of Scripture and law. They recognized the value of printing's ability to transmit an almost exact facsimile, so that once an accurate text was established it was possible to minimize the corruption caused by accretion of scribal errors.

The oldest-known true printed piece. dating from A.D. 768–770. comes from Japan, where Buddhist missionaries had introduced printing from China during the previous century. It is a Buddhist charm, printed by order of the empress Shōtoku, from wood blocks or thin cast-metal plates, in an edition of 1,000,000 copies. Numerous examples have survived. The oldest printed book in existence also is of Buddhist origin. It is an edition of the *Diamond Sutra* consisting of six sheets of text and one smaller leaf with a woodcut illustration. printed in A.D. 868. The sole known copy, found in a cave in Turkistan in 1900 and acquired by Sir Aurel Stein in 1907, is now in the British museum. Religious texts, however, did not constitute the whole of eastern printing. Textiles, playing cards and paper money also were printed from blocks. (See also BOOK: The Invention *of Printing.)*

The Chinese attempted to use typography, as distinguished from block printing, despite the difficulties of trying to cast, compose and redistribute the thousands of characters required. The first trials are attributed to one Pi Sheng, who made individual characters of thin. fired earthenware for assembly in an iron form. These proved too fragile to be practical. The Chinese later cast letters in tin and cut them from wood, but none of these methods gained wide popularity. A type foundry was established in Korea late in the 14th century, where numerous fonts of type were cast in bronze. Although the use of metal type spread back to China and Japan from Korea, it superseded the use of the wood block as the principal printing method only in the 20th century.

The West. — Although any attempt to describe the invention and spread of printing in Europe can be based on somewhat firmer premises than the development in the east, there are still many gaps in our knowledge. The year 1440 has traditionally (and arbitrarily) been chosen as the date of the invention, and Johann Gutenberg (*q.v.*) is credited with the feat. However, Gutenberg mas but one of many seeking to speed book production through mechanization; others were carrying out similar experiments in the Netherlands. France, Germany, Italy and elsewhere. Gutenberg was the first to assemble the necessary components of the printing process — type production, ink manufacture, the press, paper supply — into a coherent whole. The 15th century was a propitious time for the work. There existed a great market for books among the students of the rapidly expanding universities and the many literate members of the rising middle class. for reading was no longer a clerical monopoly. There was a well-organized book trade to market the sudden explosion of production. Paper, introduced into Europe through Spain and Sicily in the 11th century, was in abundant supply and no longer suspect as an impermanent material.

As in the far east, block printing was the predecessor of printing from movable type in Europe. By the early 15th century blocks were being used to print textiles. playing cards and religious pictures. Block books, which combined pictures with simple texts and were printed by rubbing from inked blocks, made an appearance in the west soon after the first typographic pieces.

Gutenberg possessed two skills essential for successful volume production of individual movable types: metallurgy and engraving. He was able to develop an alloy of lead, tin and antimony that would cast easily and would be durable. More important, he could engrave single letters on the hardened steel punches used to strike matrices for the casting of type—a technique already in use for the manufacture of coins and medals. Gutenberg's major invention was the mold that could be adjusted to receive matrices of various width (both the letters i and m, for example. had to be accommodated). The other technical problems of printing could be solved by adaptation of existing materials: presses were commonly used to make wine, oil, paper, etc.; the inks used for writing or block printing could be stiffened to the proper consistency for typographic printing. The best of the incunabula (*q.v.;* books printed before A.D. 1501) attained a degree of beauty and technical excellence rarely equaled since.

What little is known about Gutenberg and his invention comes from legal records. Unable to finance his work, he had to borrow from a fellow townsman: Johann Fust (*q.v.*), who became impatient for a return on his investment and in 1455 foreclosed on the inventor. Before then Gutenberg apparently had produced a few small pieces and probably had begun work on the Bible known by his name. Fust employed Peter Schoeffer, later to become his son-in-law, to assist in the new enterprise. Their firm produced many notable books, among them the great Psalter of 1457, the first book to use more than one printed colour and the first to carry a colophon naming its printers and the date and place of publication. The types for these first books copied the hands written at the time; and consequently they contained a great number of ligatures and contractions that were gradually eliminated later as economy demanded simplicity.

Printing spread with extraordinary rapidity. From Mainz it proceeded throughout Germany in the 1460s, chiefly along the Rhine, the principal trade route By 1500 there were presses in more than 60 German towns. The first printers in most European countries were itinerant Germans who had been lured by the promise of patronage or forced to emigrate by the intensity of competition at home. The first Italian press was established at Subiaco, near Rome, in 1464; Basel, Switz., had a press in 1465; Paris and Utrecht, Neth., had printers in 1470, Spain and Hungary in 1473, England in 1476 and Sweden in 1483. All Europe except Russia, which had no press until 1563, had printers during the 15th century. By 1500 more than 1,700 presses in almost 300 towns had produced one or more books. It is estimated that almost 40,000 editions were published during the 15th century, comprising somewhere between 15,000,000 and 20,000,000 volumes. These were mainly liturgical, theological and legal works, but by 1500 many texts of the Greek and Latin classics had appeared, as well as literary works in the various vernaculars. William Caxton (*q.v.*), the first English printer, published almost every important work of literature written in his native language before his death in 1491.

From Germany the centre of the printing industry moved to Italy during the late 15th century, especially to Venice, then at the height of its political and commercial importance. There Nicolas Jenson (*q.v.*), a Frenchman, established his press in 1470 and printed some of the noblest early books. His types included a roman face, based upon Italian book hands, that was widely copied and is still used in modern adaptations. Among modern type designers inspired by it were William Morris and Bruce Rogers. The most influential Venetian printer was the scholar-publisher Aldus Manutius, whose output included the first printed editions of many of the Greek and Latin classics. His three chief roman type faces were cut for him by Francesco Griffo of Bologna, who in 1500 was responsible for the first italic type, based on Italian cursive writing. These types, in small sizes, made possible the most important innovation of Aldus—small books that were the prototype of modern pocket-sized editions. (*See* also MANUTIUS.)

Early in the 16th century Italy lost its printing supremacy to France as a result of political and economic upheaval. Lyons and Paris became the great printing centres. French books had at first a distinctly national character, being printed mostly in *bâtarde* and other French Gothic types and illustrated in local style. Then, like architecture and painting, they began to show a strong italianate influence. A series of elegantly designed and printed volumes produced by Geoffroy Tory (*q.v.*), printer, engraver and philologist, employed various types, decorative initials and architectural borders borrowed from Italian sources. These were highly influential in changing the appearance of French books from the Gothic to the Renaissance style. France's greatest contribution was in type design. Early printers had generally cast their own type, but during the first half of the 16th century type manufacture became an independent trade, highly specialized and centralized in cities with a concentration of printers, notably Paris, Frankfurt and Leipzig. Among the most notable of the early type designers was Claude Garamond (*q.v.*), who established himself in Paris about 1530 and sold his punches and matrices throughout Europe. His roman, italic and Greek types, either in their pure form or as adapted by subsequent cutters, dominated type design until the late 18th century and are highly successful in the modern revivals. Robert Granjon (fl. 1560), who worked primarily in Lyons, was another important type cutter; his work included the earliest *caractères* de *civilité* (a typographic version of the French secretary hand then in use) and flowered ornaments (*fleurons*), which could be combined into innumerable decorative designs.

The wars of religion provided setbacks to the progress of printing in France. Many Huguenot printers emigrated to Switzerland, England and the Low Countries. Censorship and rigid trade regulations impeded French printing until after 1789. The centre of printing activity moved to the Low Countries, especially to Amsterdam and Xntwerp. In Xntwerp the establishment of Christophe Plantin (*q.v.*) became one of the strongest in Europe, with its foundry, bindery and bookshop. The firm remained in the family's possession until 1876, when the city acquired the premises and established the Plantin-Moretus museum. In the museum has been reconstructed a great 16th- and 17th-century printing establishment, with cases of type, punches and matrices, and ancient presses.

The New World.—In the new world printing began in Mexico City in the 1530s. Lima, Peru, had the first press in South America in 1584. In 1638 the first press north of Mexico City was set up at Cambridge, Mass., by Stephen Day (*q.v.*), assisted by his son Matthew. The first two products of this press, which came under the control of Harvard college, were the *Freeman's Oath* and *An Almanac for 1639, Calculated for New England by Mr. William Pierce, Mariner,* of which no copies are known. The *Bay Psalm Book (The Whole Book of Psalms, Faithfully Translated Into English Metre)* of 1640 is the earliest extant colonial book Another interesting volume is the Indian Bible, the first American printing of the Scriptures, translated by the missionary Rev. John Eliot into the Indian language. Samuel Green and Marmaduke Johnson printed it at Cambridge in 1663.

Printing spread with colonization. William Bradford (*q.v.*) started in Philadelphia, Pa., in 1685 and moved to New York in 1693. William Nuthead began printing in Jamestown, Va., in 1682 but was not permitted to continue and moved to Maryland in 1685. Thomas Short, who set up a press at New London in 1709, was the first Connecticut printer, and others established the trade in locations from New Hampshire to South Carolina. Isaiah Thomas, himself a successful printer and the first historian of printing in America, noted that 50 printers were active in the 13 colonies in 1775. The stamp tax on newspapers and advertising was one of the main stimuli for the independence movement in the American English colonies. Printing proved its political power for the second time in the world's history: the book had been the intellectual foundation of the Reformation; the newspaper and the pamphlet prepared America for the War of Independence.

The 18th Century.—The 18th century was the first in which England developed any strong national typographic style and produced any influential innovators. Two are especially noteworthy: William Caslon (*see* CASLON), a gun engraver turned type founder, whose reworkings of Dutch type faces dominated British and American printing for at least a century and still are widely used; and John Baskerville (*q.v.*), a Birmingham writing master, who used a fortune made as a japanner to finance his unprofitable efforts as a printer and publisher. In his first book, the 1757 *Virgil,* Baskerville used wove paper, the first printer to do so. His sharp, thin types, demonstrating his mastery of calligraphy and letter cutting, were a transition to the "modern" types of the early 19th century; and his severe, unornamented pages anticipated the neoclassic style of the 19th century. His most important influence was on the continent, where Giambattista Bodoni (*q.v.*) of Parma and the Didots of Paris (see DIDOT) were admirers of his craftsmanship and his taste

The two most important printing developments of the 18th century, however, were not aesthetic but technical. The first of these was the invention of stereotyping—a method of making duplicate printing plates by casting hot metal in a matrix molded from the original type. William Ged, a Scottish goldsmith, invented a method of stereotyping in 1725; it was not commercially successful, mainly because of opposition from the type founders and compositors. The Didots in France and Lord Stanhope in England improved upon the process, and it gained wide acceptance about 60 years later. The other notable 18th-century invention was lithography, the only major printing method whose development can be fully documented. Aloys Senefelder of Munich discovered and introduced the process during 1796–98. Lithography, which depends upon the immiscibility of grease and water, is the basis of all modern methods of offset or planographic printing. (For a detailed account, *see* LITHOGRAPHY.)

The late 18th century saw the beginning of enormous changes in printing, for during the Indusfrial Revolution printing became one of the first industries to utilize automation. Various technical problems had to be solved and a series of bottlenecks had to be eliminated before the partially mechanized handicraft could be transformed into a high-speed factory operation. The most serious of these was shortage of paper, caused by a scarcity of rags. Various 18th-century scientists, particularly the German J. C. Schaffer, proved that paper could be made from the pulp and fibres of many plants, shrubs and trees. Use of vegetable pulp made practical the development of a machine for making paper in an endless web. The next requirement was a speed-up of the printing process itself, and this was accomplished primarily through modernization of the printing press.

Development of Modern Presses.—The wooden hand press, still essentially the same machine used in the 15th century. was the point of departure in the development of high-speed printing machinery. In this development there were two different avenues of approach.

One group of inventors wanted to maintain the basic design of the hand press but to improve its power and there ith its speed, size and general efficiency. The first steps were to replace wood parts with metal and to design every part on the basis of theoretical mechanics. The first man to do so was Wilhelm Haas (1741–1800) of Basel in 1772. But the local guilds prevented exploitation of this press, and it took a quarter of a century for other inventors to develop workable iron hand presses. Étienne Anisson-Duperon in France, Lord Stanhope in England, George Clymer in America and many others did notable work in this field.

The other approach was to connect the vertical and horizontal motions of the press in such a manner that they would form a complete cycle. The first record of this idea exists in the notebooks of Leonardo da Vinci. More than two hundred years later Friedrich König, a German. independently conceived the idea. He built the first flat-bed cylinder press powered by steam for the *Times* (London). On Nov. 29, 1814, the *Times* proudly announced that the issue in the reader's hand, the first printed on the cylinder press, was the result of "the greatest improvement connected with printing since the discovery of the art itself." The press had inking rollers and its capacity was 1,100 impressions an hour, in contrast to the 300-per-hour capacity of the hand-inked press it replaced. In 1848 Augustus Applegath and Edward Cowper constructed for the *Times* a press capable of 8,000 impressions an hour, which was handfed by men at eight stations on a platform above an upright cylinder of cast iron that carried the type. In 1866 in the Walter press (named for John Walter III, then publisher of the newspaper), the *Times* achieved the prototype of the modern newspaper press—a true rotary press that printed both sides of a continuous web of paper fed from a roll; the rate was 25,000 impressions an hour. In the United States, meanwhile, Richard Hoe (*q.v.*) also developed rotary presses for newspaper work. Most of the changes in press construction since the 1860s have resulted from the demand of periodical publishers for faster, more economical production. (See also PRINTING PRESS.)

Once the press had been mechanized printers faced the problem of the supply of type, type composition and distribution of the individual types after use. Application of a pump to the type mold, which speeded production considerably. was one of a number of advances in hand casting in the early 19th century. Complete mechanization of type founding began with the casting machine of William Church. patented in 1822. which was capable of forming 3.000 sorts (individual pieces of type) per hour.

After the evolution of a number of impractical typesetting machines. the work of many inventors, Ottmar Mergenthaler (*q.v.*) in 1884 patented his Linotype machine, which cast thin slugs of type metal with a printing surface on one edge. Each slug was one line of type, molded from a row of brass matrices assembled by a keyboard operator. After the lines of type were used in printing the metal was melted for re-use. Almost simultaneously (1885) Tolbert Lanston invented the Monotype process. which casts type in individual letters. Both these machines, requiring large numbers of matrices. were made feasible by L. B. Benton's invention of the mechanical punch cutter.

The Linotype, Monotype and other similar composing machines involve the casting of metal type with the printing image in relief. Tremendous growth in the use of lithography, which does not require a raised surface for printing and which is prepared for the press by photographic processes, has intensified in recent years the search for composition methods that avoid the use of metal type. A number of photocornposition machines have been developed to assemble and transfer letters directly onto a sensitized plate from film matrices. (See also TYPESETTING.)

Acceleration of text printing in the 19th century was accompanied by parallel changes in the printing of illustrations as photography was applied to the making of printing plates. J. N. Niepce produced the first photomechanical plate in 1822 when he etched a reproduction of an engraving of Cardinal d'Amboise upon a sensitized metal plate that was subsequently used for printing. Shortly before his death in 1833 Niepce became associated with L M. Daguerre, who subsequently perfected the first practical method of photography. Many experimenters sought to make line engravings on metal by photographic means, and Firmin Gillot succeeded in 1850. William Henry Fox Talbot, the Englishman who in 1839 introduced the calotype, the forerunner of most modern photographic processes, invented photogravure in 1852; Karl Klič (Klietsch) invented rotogravure in 1890. Other important 19th-century inventors include James Clerk Maxwell and Louis Ducos du Hauron, who during the 1860s established the principle of colour separation with filters to pave the way for colour-separation engravings and colour-process printing, and George Meisenbach and Max Levy, who late in the century perfected the halftone screen. which makes possible printed reproductions of paintings and photographs possessing light and shade. (See also GRAVURE; PHOTOENGRAVING; PHOTOGRAPHY.) (J. M. W.)

MODERN PRINTING PROCESSES

In America the word printing (originally restricted to letterpress printing exclusively) is used more and more generically for all kinds of graphic reproduction. Letterpress, before the perfection of photoengraving, was excellently suited for the reproduction of reading matter but much less suited for reproducing pictures and illustrations. Lithography and gravure, on the other hand, were strong in picture printing but weak in reproduction of reading matter. Application of science and photography to all printing techniques wrought a radical change. Letterpress became capable of printing pictures; gravure, lithography and other picture-printing processes were adapted to reproduce typographic copy. The gap between all of them was narrowed, resulting in the concept that "everybody who is concerned with putting ink on paper belongs to the printing industry." This idea found organizational expression in 1945 with the formation of Printing Industry of America (P.I.A.) as the common representative of letterpress, offset, gravure and allied industries.

All printing processes combine four elements: (1) the printing surface or printing-image carrier (*e.g.*, type face, printing plate, gravure cylinder); (2) the press; (3) the ink; and (4) the paper or other printing stock. Each printing process employs its own printing surface, press and ink. The stock, on the other hand, may or may not be specialized.

Letterpress, also called relief printing or typographic printing, is the oldest form of printing and is still the most commonly used. Its range and diversification are vast. It is the only process in which metallic type can be used on the press. It is used in producing books, magazines. newspapers, catalogues, packaging, and commercial printing of all kinds (*e.g.*, letterheads. sales forms, etc.). (For further details see the section Letterpress Printing, below.)

Lithography is also called offset. offset lithography, photolithography, photo-offset and planography. Lithographic plates are in the main made photographically. Metal type cannot be used directly but is used indirectly in the form of a print or procf that is photographed for platemaking; a handwritten manuscript or drawing can be photographed in the same way. In the platemaking process the facsimile reproduction can be made larger or smaller than the original. Lithography is widely used in commercial, book, magazine and newspaper printing. In many instances, such as reprinting a letterpress book job after the type has become worn, it is feasible to convert to offset by photographing proofs from the original type or pages from the first edition. Offset is particularly suitable for making full-colour reproductions of paintings and colour photographs. (*See* also LITHOGRAPHY.)

Gravure is an intaglio printing process in which the printing image consists of small wells in the surface of the printing plate. Ink is carried in the wells, and their depths control the amount of ink transferred to the paper. The process is described by two unfortunately similar words, photogravure and rotogravure. Photogravure includes both sheet-fed gravure printing (used mainly for short-run printing of high-quality work) and rotogravure, the high-speed web-fed process used for big mail-order catalogues. newspaper supplements, packaging materials and other long-run work. As in lithography, text matter is photographed from type proofs or from films prepared in photocomposition machines, and since reading matter as well as illustrations is broken into a screened pattern. fine lines of letters may become weak or ragged. To overcome this condition, a fine screen can be used. (*See* also GRAVURE.)

A fundamentally different kind of printing is silk screen printing (*q.v.*), also called screen printing. The printing-image carrier is a stencil applied tightly against silk or some other fine fabric stretched tautly on a frame. Although the screen process is the youngest of printing methods, it utilizes the oldest principle of graphic reproduction of words and designs. Silk screen printing is the preferred method when a heavy, opaque layer of ink (or paint) is to be applied to a poster, book cover or sheet of glass. Fine detail can be reproduced by photographic methods developed by silk screen printers, and halftones of suitable pictures can be printed as well.

Flexography, originally known as aniline printing, is a form of rotary letterpress printing in which flexible rubber plates and fluid inks are used, mainly to print packaging. The process originated in Germany in the late 19th century, and at first aniline dyes in alcohol were employed instead of ink. After packaging engineers took the process to the United States in the 1920s. thin inks consisting of finely ground pigments in a vehicle of solvent and resin were developed. Extensive use of cellophane as a packing material increased the importance of flexography as a printing method.

Other printing processes include collotype (*q.v.*), also called the photogelatin process, which is a planographic method of printing continuous-tone images without a screen pattern; steel-die engraving, an intaglio process that produces a raised impression on letterheads and calling cards; bank-note printing, another version of intaglio; and xerography, which is fundamentally electrical rather than chemical or mechanical in nature. Through principles of photoconductivity and electrostatics, xerography transfers the printing image (which can be simply a typewritten sheet or a printed proof) to another sheet of paper. Fine powder, used instead of ink, is electrically deposited on the paper and fused into the surface by heat. Related to the processes called printing are the duplicating methods used in offices (see also OFFICE MACHINES AND APPLIANCES).

LETTERPRESS PRINTING

Graphic-arts terminology is neither precise nor fully descriptive. Originally the names of the processes were more or less exact but in the course of history techniques changed and expanded while names remained the same. Letterpress as a term refers to movable types. as does typographic printing. Neither of the two includes or implies the printing of illustrations. Relief printing is a much newer term that overcomes these semantic differences and indicates that only the raised surfaces of the printing-image carrier print. But relief printing as a generic term includes many special fields, such as newspaper printing and flexography. not normally subsumed in current parlance under the term letterpress printing. As used here letterpress printing means the general range of applications, such as commercial. book and magazine printing.

Typesetting.—Letterpress printing is based on type for text and photoengravings for illustrations. Typesetting is done in several ways, Most reading matter for books. newspapers and magazines as well as commercial printing is machine set, either on line-casting machines, like the Linotype and Intertype, which mold each line in one piece, or on the Monotype, which produces lines made up of individual types for each letter, space and punctuation mark. Hand composition, whereby a skilled worker (called compositor) assembles individual foundry types (as many as 60 or 70 for a line of reading matter), has not died out because of the use of mechanical typesetting but the function of the compositor has changed He now devotes himself to setting display type (headlines and artistic arrangements of larger sizes of type) for advertising, title pages and similar typographic art. (Foundry type is type purchased from a type foundry.) The composition of display type was technically advanced by the Ludlow system, which utilizes hand-set matrices in a special composing stick. After assembling and spacing the matrices, the compositor makes a hot-metal casting of the entire line.

Many printers set their own type but others buy type composition from specialized typesetting houses. These typesetters, who are most numerous in large printing and publishing centres, offer printers a broad choice of type faces, or styles. They also set type for advertising agencies and other users of printing who simply want reproduction proofs for offset or gravure printing, or electrotypes or stereotype mats for letterpress work. The type composition specialists do not maintain a pressroom for printing runs but have proof presses to make the desired proofs on glossy paper or cellophane. Some composition companies use photographic composition exclusively. (*See* also TYPESETTING.)

Photoengraving.—Photoengraving converts pictures and artistic decorations into a printable form. The process combines photography, etching and manual engraving in making pictorial relief printing plates known as cuts, blocks or engravings. The illustration to be reproduced is called copy, just as longhand or typewritten reading matter is known as copy for typesetting. Photoengraving copy may be photographs, paintings, wash drawings or other illustrations containing tonal values, which must be reproduced by the halftone process; or it may be pen-and-ink, crayon or pencil-line drawings, a written signature to be reproduced in facsimile or any other similar material that can be rendered in "line cuts" with no tonal values. Such copy is photographed and its image transferred to a metal surface by means of photoprinting. In photographing the image. it can be made either larger or smaller than the original. After the image of the engraver's copy has been photoprinted on the metal surface, the nonprinting areas are removed by etching. This leaves the halftone dots of a tonal picture or the lines of a drawing standing in relief a fraction of an inch above the nonprinting areas.

To obtain tonal values in his reproduction of a photograph or similar copy, the engraver uses a halftone screen when he makes a new negative and prints it on a metal plate. This breaks the image into small dots (65 or more to the lineal inch, or 4.225 or more per square inch) that form the printing surface after etching. The dots vary in size and shape and produce light and dark tones that approximate the highlights and shadows of the original picture when printed. The resolving power of the human eye is not great enough to permit recognition of individual dots of such small size; they blend with the colour of the paper and appear as appropriate tones of the printed colour. The technique of reproducing pictures by this method is known as the halftone process.

In the 1940s a German manufacturer introduced an automatic electronic halftone engraving machine that scans photographs and controls a stylus to cut, rather than etch, the necessary pattern on the printing plate. This machine has been developed to make colour-printing plates from photographic transparencies and other colour copy. (See also PHOTOENGRAVING.)

Duplicate Printing Plates.—Type and relief engravings are used not only directly on the press as printing surfaces but also as originals in the making of duplicate printing-image carriers. Short runs are mostly printed directly, if machine-set type is used, but long runs require duplicate plates. Even for short runs in which some or all of the type is foundry type, duplicate plates are preferred in order to prevent wear of the relatively expensive foundry type, which generally is used only for making electrotypes or reproduction proofs. Rotary printing and other specialized branches of relief printing cannot use type or engravings at all but must have duplicate printing plates.

Duplicate plates (1) preserve photoengravings and foundry type; (2) are suitable for much longer runs than are type and photoengravings; (3) permit combining type and engravings into a single plate that replaces a locked form containing various elements; (4) can be curved for use in rotary printing; (5) make possible the printing of multiples (many units of the same subject) in one press run; and (6) permit simultaneous printing of a subject in several different places, an essential feature for national and international advertising.

The four most important kinds of letterpress duplicate plates are: (1) stereotypes; (2) electrotypes; (3) plastic plates; and (4) rubber plates. Each of these kinds has its own field of application. Stereotypes are most important in newspaper printing, but also are used in bookwork and trade-paper advertising; electrotypes are used for duplicating forms containing fine halftones and for most rotary colour work done on presses other than newspaper presses; plastic plates are used as printing surfaces in bookwork and as intermediaries in machine plates for magazine advertising; rubber plates are used for continuous forms, corrugated containers and flexographic printing.

All letterpress duplicate plates require at least one intermediary step between the original (type or photoengravings, or both) and the final duplicate plate. Both the original and the duplicate are in relief. and it is impossible to make a relief plate from a relief plate without an intaglio intermediary or mold. The intaglio mold is made by pressing some suitable material (either hot or cold) against the original. The duplicate plate formed from the intaglio mold then is a relief plate that is suitable for letterpress printing.

Three qualities are essential in duplicate printing plates: retention of original detail, dimensional stability (or accuracy) and correct printing height. Detail must not be lost during the several steps whereby a duplicate plate is made from an original plate, a requirement particularly important in halftone printing; dimensional exactness is prerequisite for register (the correct position of all printing on the sheet), particularly in colour work; printing height determines fineness of printing quality of all plate areas.

Stereotypes. — Stereotypes for newspaper printing are made routinely in newspaper plants, especially in those using rotary presses where entire pages are cast in stereotypes for mounting on the press. Stereotypes are formed by first making a mechanical imprint of the printing form (type and engravings) in a matrix: or mat, made of a material such as papier-mâché. If many mats are needed, *e.g.*, of a grocery advertisement to be printed in many newspapers on the same day, the original printing form is first converted into an electrotype relief pattern plate that will withstand repeated moldings better than the form itself. The mechanical imprint is thus an intaglio mat, and the final product of stereotyping is obtained by casting hot metal in this mat. Stereotypes are suitable for printing type matter, line cuts, such as cartoons and trade-marks, and coarse halftones.

Assembling the printing form is the first step in matmaking. Thereafter the mat is pressed by one of three methods to produce (1) cold-rolled mats; (2) cold direct-pressure molded mats; or (3) baked direct-pressure molded mats. Cold-rolled mats are made by rolling in a press. The other two kinds are made in a hydraulic press that applies pressure over all the surface of the printing form at the same time. After pressing, the mat is separated from the form, trimmed and made ready for use as the mold for casting hot type metal. Newspaper stereotypes to be used on rotary presses are cast curved; those to be used on flat-bed presses or as part of the printing form for a rotary mat are cast flat. Those for book and publication work usually are used on flat-bed presses and therefore are cast flat. Curved casting is done on equipment that casts, cools, shaves and delivers the completed curved stereotypes ready for the press; equipment is available for performing these functions automatically. Flat casting is much less mechanized. The mat is first backed up (*i.e.*, filled in with pieces of stiff paper) in the nonprinting areas, which would otherwise be flattened by the weight of the metal during casting. Then the mat is baked, or "scorched;" to remove moisture that would turn into steam during casting and could by rapid expansion produce an explosion. After scorching, the mat is placed in a casting box and cast in a vertical position. Stereotypes are either made type high or are shell cast for mounting on a base. They are subjected to various finishing operations and are nickel plated whenever long-wearing qualities are desired.

Electrotypes. — Electrotypes are duplicate printing-image carriers that can combine various kinds of type with photoengravings. They are suitable for long runs: retain the detail contained in the original printing-image carriers with high fidelity, are of excellent dimensional stability, can have premake-ready (adjustment for the proper printing height) incorporated and are well suited for rotary printing. While stereotypes are the press plates used almost exclusively for newspaper printing, electrotypes are the plates used for the rotary letterpress printing of magazines, catalogues and a variety of other products. (See also ELECTROPLATING; ELECTROTYPING.)

Plastic Plates.——Plastic plates are used primarily to print books, multiple forms and newspaper advertisements. Plastic plates can be made either directly from the original printing-image carrier or from an electrotype pattern plate. After the pattern plate is prepared, an intermediary intaglio mold is made with thermosetting material; this mold can be used for making more than one plastic relief plate. If the pattern plate is unnecessary because of the nature of the work, the thermosetting intaglio mold is made directly from the original printing-image carrier. The plastic relief printing plate is then made in the usual manner.

Rubber Plates. — Rubber printing plates offer many advantages. They can print on a wide variety of materials, can be curved and attached to the form cylinder easily and are suitable for long runs. The main use of rubber plates is in flexography; they also are used in letterpress printing; *e.g.*, the printing of forms, envelopes and books. They exhibit good printability except for halftone details.

Rubber plates are made from a thermosetting intaglio intermediary. The original printing-image carrier: which may be type, photoengravings or electrotypes, and the thermosetting molding sheet are preheated and then assembled in a hydraulic press. The pressure does not exceed 400 lb. per square inch for type matter and 1.000 lb, per square inch for photoengravings or electrotypes. The time required for curing the thermosetting mold is approximately 15 minutes; the platen temperature approximates 300° F. After curing, the intaglio intermediary is separated from the relief original and is ready for use in molding the rubber relief plate. Various kinds of synthetic and natural rubber are used for making rubber plates. Molding takes place in a hydraulic press; the pressure does not exceed 1,000 lb. per square inch, the temperature on the platen is 300° F. and the time required is 6 to 12 minutes. After molding, the rubber plate is stripped from the intaglio intermediary and mounted for printing.

Rubber plates can be mounted flat or curved by use of pressure-sensitive adhesives or double-coated adhesive tape. Rubber plates can be mounted directly on the impression cylinder or prepositioned on heavy paper or on a light metal sheet that in turn is mounted on the press cylinder.

Presswork. — During presswork the printing image is transferred to the stock. usually paper. Four elements must be coordinated in this operation: (1) the press (called, except for proof presses, printing machine in Great Britain) ; (2) the printing-image carrier; (3) the ink; and (4) the paper or other printing stock.

Printing presses perform four main functions: (1) they position the unprinted stock (usually paper) for receiving the impression; (2) they ink the printing-image carrier; (3) they make the impression by transferring the ink from the image carrier to the paper; and (4) they remove the printed paper. Four different units that correspond to these four functions can be distinguished on printing presses. They are: (1) the feeding unit; (2) the inking unit; (3) the printing unit; and (4) the delivery unit. In letterpress printing the ink is transferred directly to the paper in all cases but one. This exception is dry offset, in which the printing image is transferred to a rubber blanket and from there to the stock. Dry offset is indirect relief printing; the term dry offset is used to distinguish this process from the usual form of lithographic printing, commonly known as offset. Dry refers to the fact that indirect relief printing dispenses with the dampening necessary in offset lithography.

From the beginning of printing until the first quarter of the 19th century all four main operations — feeding, inking, printing and removing the printed sheet — were done by hand. During the 19th century they were slowly mechanized; modern printing presses perform all four operations automatically. Hand presses have become a rarity and are used only by private presses that print limited editions. (See also PRINTING PRESS.)

All letterpress printing requires many steps. Some of these are executed by the pressman (called the machine minder in Great Britain), some by his assistant and some in the shop's planning department. The first decision is to select the right press for the job at hand. Sometimes the kind of press to be used for a job is self evident. But often detailed analysis and calculation are necessary to determine the right press. The time factor also must be considered; the ideal press may not be available at the proper time and the job may therefore have to be put on another, less appropriate one.

Imposition. — Once the press is selected. the imposition is decided upon. The imposition is the layout for the printed sheet indicating the place of each page on both the front and back of the sheet. (Imposing is the act of executing this plan and must not be confused with making the imposition or deciding on its plan.) There are four styles of imposition, differing mainly in the manner in which the front and back of the sheet are printed. The detail of the job as well as its finishing or binding have a great bearing on selecting the manner of imposition as well as arranging the detail within the selected style.

Preparation for the Press. — Once the imposition is decided. the printing-image carrier is prepared for the press. This operation aims not only at the proper positioning of all printing matter but also at its correct printing qualities, which depend on the correct height of the printing surface. (The standardized height of type is 0.9186 of an inch.) Foundry type, Linotype slugs and Monotypes are all cast type high and therefore merely need leveling. Photoengravings are made of 16-gauge metal, which is the equivalent of 0.065 of an inch. They must be mounted on blocks to become type high and suitable for printing with type matter. Stereotypes are either cast type high or 11 point (0.152 in.); electrotypes are all made 11 point high.

If only duplicate plates are used as printing-image carriers in flat-bed cylinder press printing, the bed of the press is equipped with a metal plate base, often called patent base. The standard height of plate bases is 0.759 in.; when to this is added the height of the electro, 0.152 in., the height becomes 0.911 in., leaving 0.0076 in. for make-ready. Some plate bases are honeycombed, others have a diagonal or rectangular pattern; all come in combination sections. The printing plates are beveled and attached to the base with hooks that grip the edge of the plate and are anchored in the base.

Lockup. — The locking up of forms consisting of type matter and blocked (mounted) photoengravings is done at the stone, as the printer calls the stone- or metal-topped table used for imposing. The many elements of which such a form consists are held in place by a device called the chase. It is a rigid metal frame, reinforced with movable crossbars for large-size flat-bed presses. The printing matter is placed in the chase according to the imposition, an operation called imposing in the printer's language. Empty spaces are filled out with wooden or metal blocks called furniture. Quoins (pronounced "coins"), expandable lockup devices, are used to tighten the form. When the lockup man imposes a form, he is concerned not only with the alignment of its elements but also with its height. All parts of the form are inspected and adjusted, if necessary, so that they are type high. The imposed form is then placed on the bed of the press and made ready for printing.

Make-Ready. — In make-ready the form is further leveled and prepared so that it may yield the best possible print. Three techniques are used: (1) underlaying; (2) interlaying; and (3) overlaying. Underlaying consists in placing paper in various thickness under the printing element; in interlaying paper is placed either between the photoengraving and its mounting or between plate base and stereotypes or electrotypes. In overlaying adjustment is made on the platen or impression cylinder and results in application of the right printing pressure on the various elements of the form: the technique consists in taking an impression and building up the impression cylinder where more pressure is needed by gluing paper of different thicknesses at the corresponding places on the overlay sheet, or by reducing its thickness where the pressure is too heavy. The overlay sheet is covered by the packing and tympan of the impression cylinder. Make-ready, which requires great experience and can be time consuming for big forms, can be reduced by premake-ready operations that help to prepare the form for proper printing before it is put on the press.

On the Press. — Once the press is running, the pressman and sometimes one or two assistants keep constant watch to maintain efficient production and the right quality. They check colour and register often and watch for work-ups or press batters (elements of the form that somehow become loosened). New paper must be put in feeding position and the printed sheets removed. Offsetting (unintentional transfer of wet ink from one sheet of paper to another) is controlled by using drying devices on the press, fast-drying inks or "smut sheets" that are laid between the printed sheets.

See BOOKBINDING; INK; PRINTING TYPE; PUBLISHING; TYPOGRAPHY; see also references under "Printing" in the Index volume.

BIBLIOGRAPHY.—E. C. Bigmore and C. W. H. Wyman, *A Bibliography of Printing,* 3 vol. (1884–86, reprinted 1945); Glen U. Cleeton and Charles W. Pitkin, *General Printing* (1953); Ronald B. McKerrow, *An Introduction to Bibliography* (1951). *History:* Thomas Francis Carter, *The Invention of Printing in China and Its Spread Westward,* 2nd ed. rev. by L. Carrington Goodrich (1955); Theodore L. De Vinne, *The Invention of Printing,* 2nd ed. (1878); H. Barge, *Geschichte der Buchdruckerkunst* (1940); S. H. Steinberg, *Five Hundred Years of Printing* (1959). *United States:* George J. Mills, *Sources of Information in the American Graphic Arts,* Occasional Papers No. 2 (March 1951); Lawrence C. Wroth, *The Colonial Printer,* 2nd ed. (1938); Isaiah Thomas, *The History of Printing in America,* 2 vol., 2nd ed. (1874); H. Lehmann-Haupt (ed.), *The Book in Anzerica* (1951). *Plates:* William Blum and George B. Hogaboom, *Principles of Electro-plating and Electroforming (Electrotyping),* 3rd ed. (1949); George A. Kubler, *A New History of Stereotyping* (1941). *Presses:* Lucien Neipp, *Les Machines à Imprimer depuis Gutenberg* (1951); Robert March Hoe, *A Short History of the Printing Press* (1902). *Practice:* Harry A. Groesbeck, *A Primer of Engraving and Printing, Including Composition, Electrotyping, Paper, Presses and Ink* (1950); R. Randolph Karch, *Printing and the Allied Trades,* 3rd ed. (1954); Robert H. Roy, *Management of Printing Production* (1953); S. Morison, *The Typographic Arts* (1949). (V. Ss.; X.)

PRINTING PRESS, the machine in which type and illustration images are transferred to paper by means of printing ink. Printing presses can be classified into two major groups — flat-bed and rotary — according to whether the form (spelled forme in Great Britain) used for printing has a flat or curved surface. Flat-bed presses can be further subdivided as platen or cylinder according to whether a platen (flat plate) or a cylinder is used for impressing the paper against the printing surface. Presses also can be classified in several other ways; *e.g.,* according to the nature of the printing surface: (1) letterpress, in which the image is printed direct from type or other relief surfaces; (2) planographic (*e.g.,* offset lithography), in which the image is printed from a chemically treated surface; (3) intaglio (*e.g.,* gravure), in which the ink is transferred from wells etched or engraved in the printing surface; and (4) silk screen, in which ink is forced through a silk screen to print an image. Presses also can be described by various other features; *e.g.,* according to whether the paper is fed into them in sheets or as a web from a roll; whether the sheets are fed by hand or by automatic devices; and whether one colour, two colours or more than two colours can be printed. In addition, flat-bed presses often are described by the number of revolutions made by the cylinder for each impression or according to whether the type bed is horizontal or vertical. Presses also are sometimes classified according to the size of the impression area or the number of pages, expressed in various standard sizes, that can be printed in one cycle, impression or cylinder revolution. Modern letterpress and offset machines also are classified as oil ink presses if no drying methods are used to set the ink and as heat-set ink presses if drying means are used. Heat-set presses usually print on both sides of a web of paper; this process is known as perfecting, or backing up. (See also PRINTING; PRINTING TYPE; LITHOGRAPHY; GRAVURE; SILK SCREEN PRINTING.)

Developments Before 1900.—*Early* Hand-Operated Presses.—There is no exact knowledge of the earliest presses although there is no doubt that Johann Gutenberg (c. 1398–*c.* 1468) must have used one. The earliest mention of a printing press is in the evidence given at a lawsuit against Gutenberg in Strasbourg in 1439 by Conrad Sahspach. a wood turner who had constructed a press for one of Gutenberg's partners.

A model for the first printing press was available in the heavy wooden presses used in the paper mills of that time; these presses operated on a principle that can be traced to the Roman wine and olive presses described by Pliny the Elder. They consisted of

FROM "ARCHIV FÜR BUCHGEWERBE," 1909

FIG. 1.— ENGRAVING BY ABRAHAM VON WERDT, 1640–80, SHOWING ANCIENT PRINTING SHOP WITH LIGHTLY CONSTRUCTED WOODEN PRESS

two stout upright pieces of wood joined by two horizontal beams. A screw. working in the upper beam and turned by a long bar, exerted pressure downward upon a wooden plank placed on the paper. Certain modifications had to be made to obtain a quick, precise impression from the type. The pitch of the screw was made steeper than in the paper press so that the necessary rise and fall was gained within the quarter turn obtainable with a fixed bar. The twisting motion of the turning screw was counteracted by suspending the platen (the wooden plank) from a hollow wooden box (the hose) that slid inside closely fitting guides while the screw turned freely within. The upright beams were frequently braced to the ceiling to keep the press steady. To make the type more accessible for inking, it was drawn on rails from under the platen by a windlass. To the back of the "carriage" which bore the type, a frame tightly covered with parchment (and therefore called the tympan) was hinged. This frame bore the paper, which was attached to it by projecting points and by a light folding frame (the frisket).

Most of these features can be seen in the first-known representation of a printing office. a wood engraving of about 1499, and in the many illustrations of presses used as marks by printers during the 16th century. Many of them are very massive, with thick wooden screws. The introduction of a metal screw is credited to Leonhard Danner (d. 1585). a screw maker of Nürnberg; this innovation greatly reduced friction, making the press easier to operate.

In the first of all printers' manuals. *Mechanick* Exercises (1683), Joseph Moxon recommends an improved Dutch press devised by Willem Janszoon Blaeu. Its only improvement appears to have been the substitution of an iron framework for the hose; it may also have been provided with a brass or iron platen, which seems to have been a common feature of presses in Holland, France, Italy and Germany from the end of the 16th century.

Further improvements were attempted during the 18th century. Printers who prided themselves on "fine" printing, such as J. Baskerville, the Didot family and G. Bodoni, took particular care with the construction of their presses.

The radical defects of the wooden hand press were the lack of stability caused by loosening of the joints and the slowness of operation. The output of a hand press, worked by two pressmen, does not appear to have varied greatly and payment was generally calculated on a rate of 250 sheets an hour printed on one side Newspapers might have been printed somewhat faster, but careful work required a much slower rate. The stability of hand presses was improved by the substitution of iron for timber. In 1772. Wilhelm Haas. a typefounder at Basel, completed a press with a framework of cast iron and with an iron platen that covered the whole form at once. Local difficulties prevented its development so that it did not gain the immediate recognition and praise accorded the iron press built to the designs of Charles. 3rd Earl Stanhope (1753–1816), by his engineer, Robert Walker. In this press a system of compound levers added to the power of the screw at the moment of impression.

Shortly after the beginning of the 19th century, many iighter and more powerful iron presses that dispensed with the screw were devised. The Columbian press, invented about 1813 by George Clymer of Philadelphia, used a system of compound levers and became popular in Great Britain, France and Germany. Most other iron hand presses incorporated a kind of knuckle joint. The pioneer among these was the press of John I. Wells of Hartford (Connecticut), patented in 1819, which was superseded by the Washington press of Samuel Rust of New York (1821). In Great Britain, the Albion press, devised about 1822 by R. W. Cope, shared, with Clymer's Columbian, the supreme position among iron hand presses throughout the rest of the 19th century. Its robustness and simplicity gave the iron hand press an almost unlimited working life.

The Cylinder Press and *the* Use of Power.—In 1790 William Nicholson of London patented a printing machine in which the sheet of paper passed between an impression cylinder and a cylindrical printing surface which was inked by a system of rollers. Although this machine was never built because of the difficulty of preparing a cylindrical printing surface, the most important advances of the next century were to be based on it.

The first power-driven printing machine was the work of Friedrich Konig, born at Eisleben in Saxony, who came to England in 1806. Encouraged by some of the London printers, he patented a machine in 1810 that was, in effect, a steam-driven hand press with automatic inking rollers. The first of these machines was built at the expense of Thomas Bensley, for whom it printed sheet H of the *Annual* Register in 1811 at a speed of 800 copies an hour. Konig's subsequent experiments, with an impression cylinder in place of the flat platen, led to an order for two machines from the *Times* (London). These were first used to print the edition of Nov. 29. 1814. which proclaimed itself "the first ne spaper printed by steam." They printed 1,100 sheets an hour on one side; the speed was later raised to 1.800. Konig also built a double cylinder machine that produced 750 sheets an hour printed on both sides. In 1817 he returned to Germany, where he set up his own printing machine works. Important improvements to his machines were made by Augustus Applegath and Edward Cowper, appointed engineers to the *Times* in 1818, who in 1827 supplied new machines capable of 4,000 to 5.000 impressions an hour. Among other early cylinder machines, the one built by David Napier in the early 1820s is notable for the introduction of grippers in the cylinder to hold the sheet of paper.

The mechanical advantage of the cylinder made it possible to print larger sheets. but the weight of the heavy type bed and the necessity for reversing directions as it moved rapidly backward and forward under the roller were severe limits on speed.

A machine following Nicholson's design, but with the type attached to the four sides of a revolving prism! was built by Brian Donkin (patented 1813), and in 1816 Cowper patented a means of forcibly curving stereotype plates, which could then be attached to a cylinder.

The Rotary Press.—The first rotary press employed a number of cylinders that rotated in contact with a central cylindrical printing surface. This obviated the need to move the flat beds of type. The first manufacturer to produce a successful rotary machine was Richard M. Hoe (*q.v.*) of New York, whose "type revolving machine" (patented 1845) was installed by the Philadelphia *Public* Ledger in 1847. The type was locked on a large central cylinder

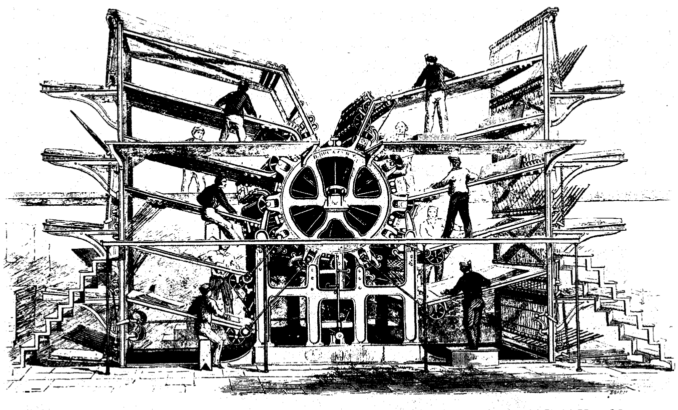


FIG. 2.—TEN-FEEDER "TYPE REVOLVING MACHINE" PATENTED 1845 BY RICHARD M. HOE

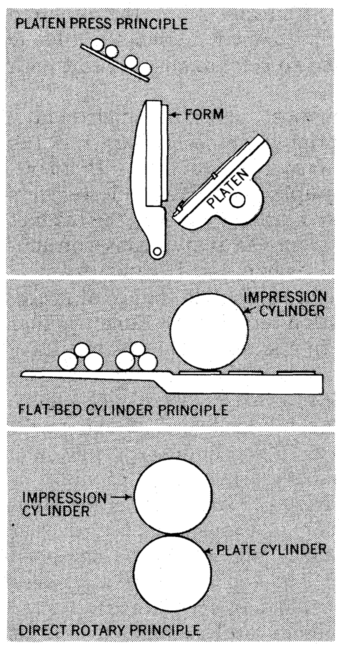
by means of wedge-shaped rules, and four impression cylinders were spaced around it, separated by four inking systems. Each impression cylinder was individually fed, so that the 2,000 revolutions an hour of the central cylinder (whose printing surface was in fact polygonal) produced 8,000 sheets printed on one side. Applegath produced a machine incorporating the same principles for the *Times* (patented 1846, erected 1848), with the difference that the axes of the type cylinder and eight impression cylinders were vertical. The Hoe rotary, with an increased number of impression cylinders, was imported into England to print Lloyd's Weekly Newspaper and in 1858 was adopted for the *Times*.

Two further developments were required before the rotary machine could be used efficiently: a new method of casting stereotype plates, and a mechanical device for feeding the paper. Following Cowper's experiment with forcibly curving stereotype plates, several attempts were made to cast curved plates. The substitution of papier mâché for the earlier clay or plaster mold (a French patent of 1829) enabled Charles Craske to cast curved plates for the New York Herald in 1854, and in 1861 Hoe presses were adapted to take such plates. In the early 1860s paper was still being fed to rotary machines by hand in individual sheets, although papermaking machines had been producing it in continuous webs since the first years of the century. In 1835, Rowland Hill produced an experimental type-revolving machine using a web or reel of paper, but the first application to a large rotary machine was made by William Bullock of Philadelphia. His machine (1865) cut the web automatically before it entered the impression cylinders. The *Times*'s engineers had been working on a rotary web press since 1862 and the result. their Walter press (named for J. Walter, then owner of the *Times*), was put into operation in 1866. When automatic folding devices were added to these rotary machines and a printing cylinder was added for each impression cylinder, the full benefits of the rotary principle were obtained. In the United States, the Hoe firm developed the multiple-unit press for the production of large newspapers.

Book and Job Presses.—The rapid pace of development in printing presses during the 19th century was mainly attributable to the demands of newspaper and periodical publishers, but press manufacturers also produced two important types of book-printing machines. In the stop-cylinder machine, the cylinder rotated in gear with the bed of type on its forward journey and remained stationary on the return of the bed. The best known of these was the Wharfedale, which was the outcome of the experiments of William Dawson and David Payne during the 1850s in the Yorkshire town of Otley. In the two-revolution machine, the cylinder turned continuously, making one complete revolution for each traverse of the bed. The impression was made on the bed's forward traverse and the cylinder was lifted clear for the backward traverse. At the same time the principle of the platen was not wholly abandoned; the Napier double-platen machine of 1830, in which two forms moved alternately beneath a central platen worked by a knuckle joint, was valued for the high quality of its output.

The machine that revolutionized job printing (the printing of small posters and handbills, cards and letterheads) was the treadle platen, produced in Boston (Mass.) by Stephen P. Ruggles in 1851 for printing cards. The vertical bed, holding the type, was hinged to the bottom of the platen, on which the paper was placed. This machine was developed by George Phineas Gordon, who used the same principles and the same source of power (a flywheel driven by a treadle) for his Franklin press of 1858; this press was widely known under the name of the inventor and, from that of its first English manufacturer, as the "Cropper." Gordon introduced more powerful machines, known as art platens, capable of printing wood engravings and halftone blocks. (Js. M.)

20th Century.—The 19th century saw a complete revolution in the mechanical principles of printing; before it was over the foundations of all modern techniques had been firmly established. By contrast, the improvements made in printing in the first six decades of the 20th century, in which so many major advances were made in almost all other branches of technology, were, in the main, relatively insignificant mechanical modifications. In 1900 the standard jobbing letterpress machines were the platen, the stop-cylinder and the two-revolution cylinder press; the rotary principle was employed on a large scale only in the web-fed newspaper field. The rotary offset was already in course of development, and both sheet-fed and web-fed rotary gravure presses were in operation. By 1950 the general situation had altered to the extent that offset lithography had usurped an important part of the letterpress field, but machines were scarcely more advanced technically: letterpress printing was carried out on flat-bed machines very similar to those in operation at the beginning of the century, and, indeed, many presses 50 to 60 years old were still operating and competing successfully with newer machines. Offset lithography presses were substantially identical in design to the first operational models introduced about 1905; and gravure printing had advanced little either in machine construction or in methods for preparing the printing surface. The only major printing process to have developed in the 20th century from the stage of an individual (and very ancient) art to that of a technology was screen printing.



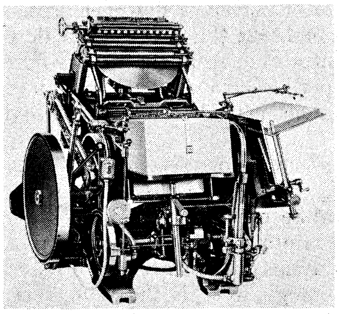
FROM J. S. MERTLE AND G. L. MONSEN, "PHOTOMECHANICS AND PRINTING"

FIG. 3.—PRINCIPAL METHODS OF PRINTING

Flat-bed Letterpress Machines.—In the early 1960s the letterpress machine was still, mechanically, the least refined of all printing presses. The flat-bed principle on which the majority of letterpress machines operates is extremely inefficient since it involves reciprocation, either of the type bed or. in the case of some platen presses, of both platen and bed. The reversal of direction creates two problems, one mechanical and one economic: first, considerable energy of momentum must be absorbed rapidly at the end of each movement without causing excessive vibration or heat; second, because the machine does not print on the return stroke. half of the total running time (on most presses) is unproductive.

In cylinder machines efforts have been directed to designing reciprocation systems in which the stopping and reversing part of the movement is speeded up so that it represents only a fraction of the complete printing cycle; as the form on the bed is not under impression during the return stroke it is possible to introduce special gear segments that take over the drive for this part of the cycle only. A letterpress cylinder machine known as the Printopress and introduced in Ireland in 1960 worked on an entirely different principle, developed from one of the many ideas born but then abandoned during the 19th century. In this press the bed remains stationary while a train of impression cylinders and an inking system moves around it on a planetary track.

Modern platen presses are available in a variety of ranges of size and speed; they are usually especially suited for a particular type of printing job. Most platen presses are used in small print shops for printing letterheads, handbills and similar matter. Their maximum printing areas range from about 7×11 in. to $14\frac{1}{2} \times 22$ in. and their speed ranges from about 2,000 to 5,000 impressions per hour. Most platens are operated by electric motors, are fed sheets automatically and print one colour at a time. Web-fed platens that print up to 6,000 impressions per hour have been developed.



BY COURTESY OF CHANDLER AND PRICE CO.

FIG. 4.— MODERN SHEET-FED AUTOMATIC PLATEN PRESS

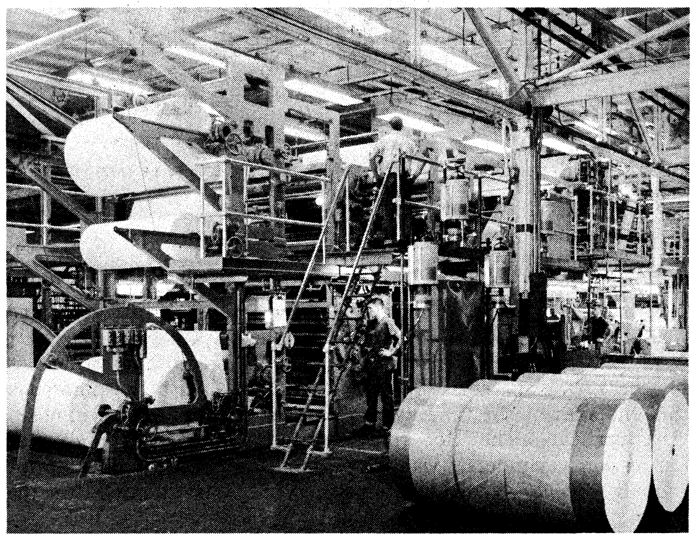
Most modern cylinder presses are designed to print sheets; their printing areas range from about $8\frac{1}{2} \times 11$ in. to $45 \times 68\frac{1}{2}$ in. Hand-fed cylinder presses produce about 2,500 impressions per hour; those with automatic feeding devices can produce up to about 6,500 impressions per hour. Cylinder presses, either sheet- or web-fed, are used to print books, magazines and other matter when good quality of reproduction is desired and when the required quantities call for press runs of up to medium length. These presses are also constructed to print two colours and to print both sides of the sheet.

Offset Lithography. — Possibly the most important single contribution of the 19th century to printing-press technology was the development of offset lithography (see LITHOGRAPHY: History). The great advantage of offset lithography over flat-bed letterpress is the rotary principle. In offset, the printing cylinder (the blanket cylinder carrying the image offset from the plate) runs continuously in one direction while the paper is impressed against it by an impression cylinder. There is no reciprocation, no change of speed, and the fundamental mode of operation remains the same whether the machine is sheet- or web-fed. In addition: offset plates, since they are thin sheets of metal, can be wrapped around the plate cylinder with ease. There is no need to cast or bend thick plates.

Offset presses are built in sizes ranging from that of the smallest platen to that of a medium-size rotary letterpress machine. For web-fed newspaper work, they have a maximum capacity of about 64 standard (or 128 tabloid) pages. These presses are built, as are letterpress rotary units, in four- or eight-page sections that can be arranged to suit the user. Such presses can be equipped for printing two or more colours. The top speed of a modern offset newspaper press is about 30,000 64-page (standard size) copies per hour. Sheet-fed offset presses can be equipped to print up to six colours in one run on one side of the sheet.

Rotary Letterpress. — Many difficulties are involved in printing letterpress by rotary means. The most common example of a rotary letterpress machine is the newspaper press, which has a number of inherent disadvantages: the curved or tubular printing plates, cast in stereo metal, require skill, experience and expensive equipment to produce and may crack under stress; the weight of the heavy plates (which can lead to damaging vibration in the axles of the plate cylinders) and unavoidable inaccuracies in their thickness make it necessary to print on a soft stock and against a soft rubber blanket if high press speeds are to be attained. This means that the quality of printing, particularly that of halftones, is not high.

Many nonmetallic materials have been investigated for molding letterpress plates in an attempt to find a surface combining sharpness with sufficient elasticity to give good halftone reproduction:

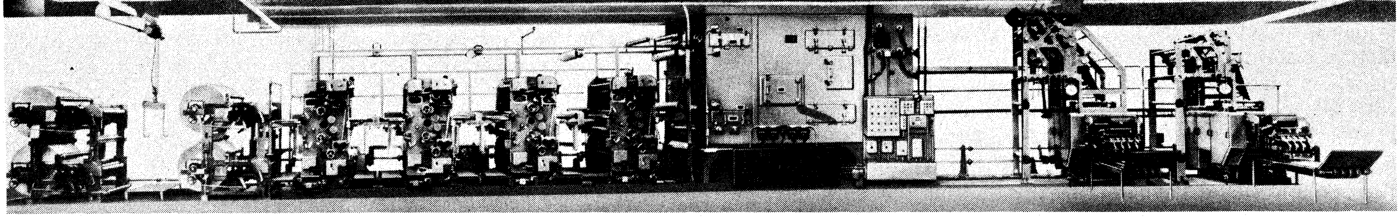


BY COURTESY OF R. R. DONNELLEY AND SONS COMPANY

FIG. 6.— MODERN ROTARY PRESS

these include rubber, Bakelite, polyvinyl chloride (PVC) and nylon. Apart from molding, letterpress relief plates can also be produced by embossing or etching. A small German press, the Printo. intended for use in offices, makes use of the embossing principle. A thin alloy sheet is placed in a standard typewriter, without ribbon, and the matter to be printed is typed onto it, giving a raised reversed image on the underside of the metal. The sheet can then be wrapped around the cylinder of the press and inked as a normal relief letterpress surface.

During the 1950s, following the introduction of new techniques for etching letterpress plates, there was a growing interest in the development of etched plates that could be wrapped around the cylinder of a rotary press and in the modifications necessary for this type of press. Within ten years, more than a dozen different models were in production! covering a wide range of sizes. A press using an etched metal plate differs from one using cast stereos in that the increased accuracy of the plate thickness makes great pressure between the impression cylinder and the plate unnecessary, only a "kiss" impression being required. For this reason modified offset machines were found eminently satisfactory in ex-



BY COURTESY OF THE AMERICAN TYPE FOUNDERS COMPANY, INC.

FIG. 5.—MODERN WEB-FED OFFSET LITHOGRAPHIC PRESS

periments. Modern production models of rotary letterpress machines closely resemble their offset lithography counterparts—indeed, machines adaptable to either process are available. Offset letterpress is also used in a number of applications, mostly of a specialized nature.

Modern sheet-fed rotary letterpress machines are used mainly for producing catalogues, magazines and similar long-run matter. Sheets ranging from about 21 × 15 in. to 52 × 76 in. can be handled, depending on the press. The number of impressions per hour ranges between 3.000 and 6,500. Up to six colours can be printed in one run. For long runs such machines usually can be adapted to print from a roll.

Modern rotary letterpress machines used in newspaper production are fed by web and are made up of basic 4- or 8-page units arranged to suit special needs. The speed of the newspaper press is limited by several factors; *e.g.*, the resistance of the paper web to breaking, the rate at which the paper absorbs ink, and the speed of the mechanisms that collect and fold the printed paper. The units of the press can be arranged in a straight line on one level or can be stacked in several decks. The total capacity of a press varies according to the size of the paper; for example, in the U.S. the capacity of dailies with 10,000 or less circulation averages about 16 pages, those with 10,000 to 50.000 circulation usually have a capacity of between 24 and 48 pages and those with more than 50,000 circulation may be able to print as many as 128 pages in a run. Extra pages can be inserted into an issue by hand or with special folding machines. Web-fed rotary letterpress newspaper machines can print up to about 60,000 copies of 128 standard-size pages per hour; in the interest of reproduction quality and wear and tear on the press, however, newspaper presses usually are operated at about only three-fourths of their rated top speed. Large daily ne spapers may operate as many as ten 128-page press units at one time in order to produce an edition quickly.

Advances in the Printing of Sheets.—Since 1900 the bulk of development in sheet-fed presses, whether printing by letterpress. planographic or intaglio process, has comprised a series of minor mechanical modifications designed to improve the speed of the machines. Stops in sheet-fed presses have been designed that do not cause the sheet to bounce back as it is being fed to the cylinder, and complex mechanical feeders have been devised to work at very high speeds. Swinging grippers take the sheet and accelerate it to the peripheral speed of the cylinder; after the sheet is printed it is taken by other grippers on a continuous chain and delivered printed side up onto a pile; special airblow devices can be employed to slow up the sheet as it is released. To prevent the transfer of wet ink from one printed sheet to the next, a powder or liquid is sprayed on each sheet as it is delivered or the sheet is passed quickly over a small flame to speed drying.

Advances in Web Printing.—In the early 1930s the need for printing mass-circulation magazines at high speed became urgent. To increase the speed of printing on web with the rotary letterpress, methods for drying the printed image to set the ink were introduced. Better plates and paper quickly followed. By 1950 the web-fed rotary letterpress became an immense machine; some models weighed up to 200 tons and produced four- and five-colour folded signatures on smooth, coated paper at the rate of 20,000 per hour. Automatic paper reels also were introduced; these allowed new rolls of paper to be spliced to old ones without slowing the press.

Advances in Rotogravure.—Until the 1950s, rotogravure in the C.S. was used primarily to print newspaper supplements. The quality of this work was generally unsatisfactory because of poor colour register and variations in ink and colour. The introduction of photoelectric means of controlling colour register and of instrumentation for controlling ink density made high-quality rotogravure work possible by the late 1950s. After that time, complex 10- and 12-unit multicolour rotogravure presses with automatic paper reels were used to print magazines and catalogues at speeds up to 25,000 revolutions per hour. (B. I.)

BIBLIOGRAPHY.—*Belore 1900:* Joseph Moxon, *Mechanick Exercises* (1683), ed. *H.* Davis and H. Carter (1958); F. J. F. Wilson and D. Grey, *A Practical Treatise on Modern Printing Machinery and Letterpress Printing* (1888); R. Green, *The Iron Hand Press in America* (1948), *A History of the Platen Jobber* (1953); L. Neipp, *Les Machines à Imprimer depuis Gutenberg* (1951); *The Times Printing Number* (1912); G. A. Isaacs, *The Story of the Newspaper Printing Press* (1931); A. L. Monet, *Les Machines et Appareils Typographiques* (1878); R. Hoe, *A Short History of the Printing Press,* (1902); Karl Dietrichs, *Die Buchdruckpresse von Johannes Gutenberg bis Friedrich König* (1930). (Js. M.)

20th Century: E. Kollecker and W. Matuschke, *Der Moderne Druck,* 2nd ed. (1958); J. Bass, *Das Buchdruckerbuch* (1953); *BP Specification Manual of Printing Machinery* (1961). (B. I.)

PRINTING TYPE. This article discusses the design and designing of printing type from its earliest times down to the present. Related material will be found in TYPESETTING; TYPOGRAPHY; PRINTING; PRINTING PRESS.

The Beginnings.—The invention in Europe of printing with movable metal types, in the middle of the 15th century, introduced the principle of mechanical mass production to a world in which nearly all man-made objects were made one at a time by hand. The earliest designers of printing types were the goldsmiths and other skilled metal workers whose experience with coinage and medal cutting for replica casting enabled them to attack the far more complex task of carving and filing in steel the sets of male dies called *patrones,* or punches; *i.e.,* model letters to be reproduced in quantity as characters on the faces (flat printing surfaces) of a font of type. The cutting of letters on so minute a scale, with strict consistency in the treatment of straight lines and curves throughout an entire alphabet, demanded a degree of manual skill which seems all the more spectacular in contrast with modern methods of cutting punches pantographically by power-driven tools from large mechanical drawings. But in admiring the virtuosity of the early punch cutters it is too easy to overlook their greater role in history; *i.e.,* that of the first practising industrial designers. What they were making by hand was only a means toward what they were actually designing for batch production, namely the appearance of printed words on paper: specifically the ink prints of type in some particular size and style of a face (design) which would indicate, to a predicted class or group of readers, the general nature and purpose of the book at hand.

FIG. 1.—ALTERATION OF LETTERS IN SAME BODY SIZE BY CHANGING LET- ’’’ WIDTHS ’’’ LENGTHS •’ ’’ CENDERS AND DESCENDERS

The pioneer punch cutter, like any other designer for industry, had to take into account successive mechanical processes which might affect the appearance of the multiple end product. Thus the different letters of the alphabet had not only to be consistent in the treatment of stems, curves and serifs (fig. 2) but also had to appear on the printed page in accurate alignment, a matter which would partly depend upon the successful processing of the brass matrices (female dies) that were to be struck from the punches. The types that were to be cast in molten metal from the matrices would have to fit together snugly into whole word shapes with no distracting gaps between the individual letters. Further allowance had to be made for the effect of the printing: the primitive wooden press would be driving an inked form. or forme, of composed type with heavy pressure into damped sheets of handmade paper and the resulting "squash" of viscous ink would leave the printed images of the characters looking considerably thicker and somewhat less sharp in detail than their steel prototypes. The modern type designer faces similar problems, made more complex by the variety of paper surfaces and reproduction processes in use today.

FIG. 2.—TYPE SAMPLES SHOWING DIFFERENT TREATMENTS OF THICKS. THINS AND SERIFS (TERMINAL STROKES)

Above all, the early punch cutter knew that the printed pages would come as bound books into the hands of readers who were accustomed not simply to deciphering the code symbols of the roman alphabet as such but to distinguishing between different kinds of books at first glance by their conventional styles of lettering. What links the modern type draftsman to the Renaissance punch cutter. and labels them both as type designers, is the need to look ahead through a long chain of production stages toward the ultimate object of all typographic design—the conveyance to the reader of meaningful texts through letter images which that reader will accept as appropriate to that particular kind of printed matter.

Printing created its own, entirely new kinds of "matter" (notably the periodical), which in turn had to be envisaged by the type designer as functional problems in legibility. From the early 19th century onward, competitive advertising opened up the distinct field of "display" type design ("jobbing") in which the ruling intention is the very opposite of that which disciplines the designer of type for continuous reading. Letters for a handbill may legitimately imitate any fantasy or distortion of sign writing, for the aim is to arrest and focus attention on a few words. The bold type which appears in various modern works of reference (such as dictionaries and timetables) has the similar purpose of attracting the searching eye quickly to the relevant entry by its abnormal thickness. Type for continuous reading has the contrary aim; it must carry the reader forward through line after line by its self-effacing conformity to whatever norm of legibility the reader counts upon for that particular kind of text. Thus the deliberate exploitation of abnormality in type design is a relatively new development and the inventors of eye-catching advertising types, represented by thousands of different designs since the beginning of the 19th century, seem far closer to sign writers than to the metal cutters of the days when books and booklets constituted almost the whole output of the printing press. Even in the earliest years the designers of type were accepting the principle, already fixed by the medieval scribes, that different sorts of book—liturgical, legal, revived-classical, popular-vernacular—should have different styles of letter.

Fortunately for Johann Gutenberg (*q.v.*) and the goldsmith whose services he used while he was at work on his invention, the northern scribes had evolved a formal script for use in short double-column lines, in which high legibility-for-size was gained by the use of a broad stiff pen that gave maximum thickness to the down strokes. To achieve this blackness with least waste of space, curves were condensed by being broken into angles and straight segments. The resulting textura script offered the metal engraver a model peculiarly suited to his file and burin. The readers of a folio bible in double column expected it to be set forth in this strong angular style of letter; hence the 42-line Bible (Mainz, *c.* 1456) gave them no jar of novelty (fig. 3). The round gothic associated with theological and legal texts in Latin, then the international language of the professional literates of Europe, was also relatively easy to reproduce in metal. It too had been evolved


Quod cũ audisset david: descendit in

FIG. 3.—LINE OF TYPE FROM 42-LINE BIBLE, ISSUED AT MAINZ; 1456. ACTUAL SIZE

for use mainly in narrow columns, where the amount of white space between the lines can safely be reduced by shortening the descenders and ascenders and thus increasing the apparent size of the letters. The stubby descenders of the prevailing black letter styles were well adapted to the type cutters' need to strike matrices by hammering the hardened letter punch into a slab of brass. The more informal and free-swinging bastarda style, mainly used for books in the mother tongue, again required little more than simple imitation (fig. 4).

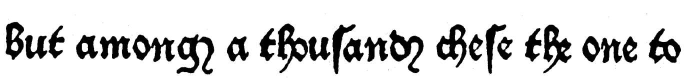

But among a thousand these the one to

FIG. 4.—CAXTON. TYPE NUMBER TWO, FROM DICTES OR SAYENGIS OF PHILOSOPHRES, WESTMINSTER: 1477. ACTUAL SIZE

But as printing spread from Germany to the Italian cities, the pioneer punch cutters faced their first insuperable problem: that of reproducing in separate metal letters, and eventually in type prints, the delicate, open-curved, long-descender style of calligraphy with which the humanist scholars and their scribes were optically distinguishing texts in the Latin of classical antiquity—or their own sedulously "Ciceronian" Latin—from those in the modernized Latin of the schoolmen and lawyers. To the humanists, the "language of divine antiquity" was not only to be studied and imitated, it had even to be equipped with its own style of script in which subtlety and elegance, lightness and amplitude would replace the bold simplicities of the styles which were given the contemptuous sobriquet of "gothic." The script revived by the humanists for this purpose was the minuscule standardized by Alcuin under Charlemagne at the beginning of the 9th century. The type cutters never succeeded in producing a plausible imitation of it in metal; but as crude attempts at copying gave way to deliberate paraphrase in terms of metal casting, what emerged was the first new contribution of type design as a creative art; *i.e.*, the kind of letter which is now called roman, or in French *romain*. Today the word is used broadly for "ordinary print" as distinct from anything exotic or attention-catching. But in Germany, where black letter survived as a language-linked style (Fraktur, Schwabacher), roman still bears its historical name of Antiqua.

Nicolas Jenson, formerly master of the royal mint at Tours,

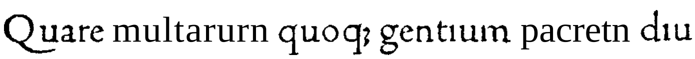
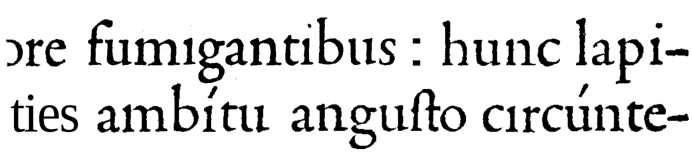

Quare multarum quoq; gentium pacem diu

FIG. 5.—ROMAN TYPE USED BY N. JENSON. USED IN PRAEPARATIO EVANGELICA BY EUSEBIUS OF CAESAREA, PRINTED IN VENICE; 1470. ACTUAL SIZE

cut an admirable roman for the Praeparatio evangelica of Eusebius which he printed in Venice in 1470. But it was the famous Venetian printer-publisher Aldus Manutius, directing the skill of the goldsmith Francesco Griffo, who launched the Antiqua


ore fumigantibus : hunc lapi-
ties ambítu anguſto circúnte-

BY COURTESY OF THE MONOTYPE CORP. LTD.

FIG. 6.—ROMAN TYPE USED BY ALDUS IN DE AETNA BY P. BEMBO: 1495. TWICE ACTUAL SIZE

lower case and its inscriptional style capitals on the rising tide of humanist scholarship by perfecting a type which became the model for the great French type cutters of the next generation, notably Claude Garamond, and so the direct ancestor of a long line of roman fonts, many of which have been revived for present-day use.

Aldus' roman of 1495 appeared in a literary exercise by Pietro Bembo, the humanist poet, later cardinal, who probably took a personal interest in its typography: successive copies show many variants made while the work was on the press.

Aldus' "pocket editions," dating from 1501, made the first use of the kind of type now known as italic; it originated with him as an imitation of the cursive minuscule in chancery style in which scholars had been swiftly copying out coveted texts. Italic was later equipped with its own sloped-roman capitals and adopted as an auxiliary to roman by being cast in alignment with it.

The subsequent history of roman type design falls into four distinct periods. Through the 16th and 17th centuries its treatment by successive engravers varied only in subtle detail, scarcely perceptible to the layman's reading eye, and its debt to the calligrapher remained evident in the angle of thickening or "stress" of the curves and serifs of the lower case. Type founders began, however, to offer alternative fonts of the same body size: one series (of sizes from small to large) for normal bookwork, with the longer descenders that help to create a channel of white space between the lines, and a larger-looking version with short descenders and condensed curves, suitable for narrow columns such as those of the periodical.

Transition and Revival.—The first effort to rethink and rationalize type design came in 1692–93 when Louis XIV commissioned his academicians to devise, and Philippe Grandjean to produce, a new series of roman and italic for the royal printing office.

e, 25 d'Aouſt, le Gouverneur ſe rendit à l

FIG. 7.—ROMAIN DU ROI, TYPE DESIGNED FOR KING LOUIS XIV BY P. GRANDJEAN. USED IN ROYAL PRINTING OFFICE. PARIS; 1702. ACTUAL SIZE

Type cutting entered its "transitional" phase in which sharp thick-thin contrasts brought a new look to the page. In Paris in the middle of the 18th century the learned printer-type founder P. S. Fournier developed the new style in one direction, with ingenious decorative use of *fleurons*, or border units, cast as type. At the same time John Baskerville in Birmingham, Eng., commissioned a rounder and still more sharply cut roman and italic, one which showed off the elegance of his hot-pressed paper and improved ink. Baskerville's chaste neoclassic style had a profound influence on European type cutters.

The transition was in effect from "this style" to "**this** style," used by G. Bodoni and introduced in France by the Didots shortly before the French Revolution. Here the graver declared its independence from the quill, italic forgot its current script ancestry and the abandonment of the "long s" (ſ) drew the only dividing line in the whole history of roman type that is immediately obvious to the uninstructed reader.

The new short-s style with strong vertical stress and hair-thin horizontals became the prevailing mode for books and periodicals for the first half of the 19th century and the long-s fonts were melted down as antiquities. But just as the humanists had turned from the rigidities of gothic to their "antique" roman, so the Romantic movement in England brought a new appreciation of the "old" (pre-Baskerville) type cut by William Caslon, the first meritorious English punch cutter and letter founder. in 1720. A font preserved by the Caslon type foundry as a museum piece was used as a pastiche type at the Chiswick press from 1840. It found favour among antiquarians and liturgical publishers. In France, the "old" types of the 17th-century Elzevir editions became the inspiration of tentative revivals. The Scottish type foundry of Miller and Richard, sensing a change of taste, brought out in 1860 their historic (to contemporary taste) modification in which for the first time the "old" style reappeared, without its long s, as an alternative to the "modern."

Present Era.—This opened the present era in type design, with the new notion of offering publishers or customers a choice of different styles of roman. At first it meant a costly duplication of the printer's type storage facilities; but the coming of the hot-metal composing machine reduced the problem to that of a simple change from one set of matrices to another. The term modern lost its meaning of "ruling mode of today" and became trade jargon for the sharper-cut style: "old style" and "old face" lost their antiquarian reference and took on a purely morphological meaning.

A present-day printer's type specimen book may offer an even wider variety of "composition faces" (for continuous reading) than is shown below (fig. 8). These examples, all of type faces in commercial use, are selected to indicate the different historical periods from which designs have been revived (with or without intelligent modifications) to meet the modern publisher's need for variety in taste and also for technical and economic reasons. Type (C), for example, is particularly suitable for printing on coated paper, which requires a very light impression; (E) is broad, (D) relatively condensed, and the difference can either save or bulk out 25 pages in a 248-page novel. (M) is effective in the long line of a book, where the space allowed for its deep descenders leaves a useful channel between the lines. but it is inefficient in narrow columns.

From 1885. Linn B. Benton's punch-cutting machine began to replace the hand craftsmen. New faces could thenceforth be drawn to any scale and cut with microscopic accuracy, in any type size from the same master pattern. The invention had little or no direct, immediate effect upon type design, for 19th-century punch cutters were not employed as creative designers; their pride was in their own manual skill, and there the machine surpassed them. The influence of the Benton machine was first shown in the emergence of the family of different versions (bold, condensed, etc.) of the same basic design—variants easily contrived by alterations to 10-in. drawings. Cheltenham, a roman designed by the U.S. architect B. G. Goodhue in 1905, failed as a book face but became the first runaway success in cotnmercial printing as a family of many variant weights and widths. But meanwhile Benton's invention had made possible the composing machine; this major innovation was indirectly responsible for the emergence of a new class of types—the first bridge ever thrown between the quiet

(A) Axabcdefghijklmnopqrstuvwxyz1234567MQ

(B) Axabcdefghijklmnopqrstuvwxyz1234MQ

(C) Axabcdefghijklmnopqrstuvwxyz12345MQ

(D) Axabcdefghijklmnopqrstuw1234MQ

(E) Axabcdefghijklmnopqrstuvwxy1234MQ

(F) Axabcdefghijklnopqrstuw 1234MQ

(G) **Axabcdefghiklmnopqrstuvwryz** 1234MQ

(H) Axabcdefghijknopqrstuw1234MQ

(I) *Chancery Italic revived from XVI century Italy. abc*

(J) *'Old style' italic, one of many versions pre-1700*

(K) *'Transitional' italic, English style abcd*

(L) *'Modern' italic, conforming closer to roman*

(M) Axabcdefghijklmnopqrstuvw1234MQ

(N) Axabcdefghijklmnopqrstuw1234MQ

(O) **Axabcdefghijklmnopqrstuvwx1234MQ**

(P) *Axabcdefghijklmnopqrstuvw1234.MQ*

(Q) Axabcdefghij**klmnopqrstuvw1234MQ**

FIG. 8.—MODERN REVIVALS OF EARLY TYPE FACES AND 20TH-CENTURY DESIGNS

(A) Centaur by B. Rogers, 1914, patterned after N. Jenson's roman, 1470; (B) roman by Aldus Manutius, 1495, prototype old face revived by Monotype Corp. Ltd., 1929; (C) roman by Aldus, 1499, recut in facsimile as Monotype Poliphilus, 1923; (D) roman by P. S. Fournier, revised as Monotype Fournier, 1925; (E) revival of roman by J. Baskerville, 1757; (F) roman by J. Bell, 1788, revived as Monotype Bell, 1930; (G) roman, revived from G. Bodoni, early 19th century; (H) Scotch Roman, 19th-century "modern" face; (I–L) four italic faces showing development of modern style; (M) Perpetua, E. Gill, 1929; (N) Times New Roman, S. Morison, 1931; (O) Gill Sans, E. Gill, 1928; (P) Palace Script, copperplate jobbing face; (Q) Egyptian, slab-serif jobbing face world of "book" faces (for continuous reading) and the restless, occasionally raucous and hitherto completely separate world in which the small jobbing printer's compositor had been confecting auction. theatrical and other "bills," trade cards, etc., from an ever-growing range of poster-like or otherwise attention-catching jobbing types.

Those faces, called in French *lettres de fantaisie,* had throughout the 19th century provided a not unprofitable sideline for the type founders. whose main income depended on the book and periodical printers' demand for ordinary text type in the tonnages required for hand composition. Since no one took advertising seriously to begin with. no self-consciousness inhibited the inventiveness of its type designers and their licence to impudence was exploited with honesty and gusto. Delicate pseudocalligraphic script types had appeared for commercial and society printing before the Industrial Revolution, but now "shock" types offered a new field. Capitals without serifs or thick-thin stress (sans-serif) were in use before 1825; fat black "Egyptians" (slab-serif) multiplied. The lithographic lettering artist's free fancies (*e.g.,* on music title pages) prompted the punch cutters to new feats of skill. Much of the most self-conscious avant-garde typography of the 20th century has drawn upon the early Victorian job printer's repertory; the crude sans-serif called "grotesque" ("grot") has been most often resuscitated for modern experimentalist display.

The new composing machines swept away the type founders' main market and left jobbing types as almost their sole remaining stock in trade. American type founders, banding together under the threat of extinction, began to give serious aesthetic attention to advertising faces. Under the new and respectable name of "publicity types." classic faces of the past were revived primarily for use in brochures and displayed press advertising, which the newly arriving advertising agencies were treating with a solemnity unknown to the old handbill printer. Thus book and display faces drew at least within sight of each other. Today, a fine book face is normally cut in sizes up to an inch high, where abnormality of size is alone enough to make it attention-catching; contrariwise, grotesques and sans-serifs have been used in small reading sizes by designers anxious to devise a "contemporary" style—for reasons more sentimental than rational, since no amount of respect for the machine age will reconcile book readers to alphabets which make it hard to distinguish I and l, or a from o.

Sans-serif and other monotone letters have, however, a functional justification in commercial printing, for they can retain their family characteristics through extremes of all-over thickening, condensing, expanding and so on. The sans-serif designed by the English sculptor Eric Gill is a widely used example of the serious treatment of monotone alphabets with care for legibility. Its adoption as a design family for railway printing caused it to proliferate into 25 design variations under the family name of Gill Sans.

The 20th century has seen eclecticism in type choice conquering the earlier' concept of one predominant taste in roman type design succeeding another and rendering it obsolete. In the disciplined book type field, where any queerness or romanticism is fatal, modern designers must compere with the greatest masters of past centuries. Very few new claimants to a place in the book printer's repertory have stood up to that rivalry. In 1932 the *Times* (London) commissioned a roman in the general style that the Dutch letter cutters had evolved for periodical work; *i.e.,* large-appearing, relatively narrow and gaining legibility by the tilted stress of the "old" style. Composing machine manufacturers were permitted to market the face commercially, and its world-wide popularity has made it the nearest approach that an eclectic century has to anything that could be called its own characteristic contribution to history. But modern multiplicity of processes, paper surfaces, different uses for print, to say nothing of the advertiser's constant demand for variety, prevent type design from settling back into the succession of ruling styles and fashions which characterized the centuries in which printing was in effect book printing and used one kind of paper (handmade rag) and one process of multiplication (direct letterpress).

The major languages of scholarship (Greek, Hebrew, Arabic) were exercising European punch cutters from the cradle years of printing. and missionary zeal quickly extended their range. Those nearest to the Latin alphabet, *e.g.,* Russian Cyrillic, have undergone parallel changes in style treatment; Arabic remains purely and stubbornly a calligraphic minuscule. No script among the hundreds which western type founders class as "exotics" has achieved the efficiency and adaptability of the roman font with its different member-alphabets—A, a, *A, a,* A and, where required. "related bold" **A, a.** It will not replace the other great scripts, but as a supranational vehicle of communication it has no rival.

The word "type" is broadly but legitimately used for the printed letters on the page, which are no longer necessarily the prints of metal types; they may be from metal. rubber or plastic plates which, today, need not have been taken from metal printing types; the images may have been photographically composed onto sensitized film. Hence the designers of new faces for filmsetting will still be type designers, subject to the same discipline where continuous reading is concerned and permitted the same licence in the display field, where film offers new possibilities; *e.g.,* novel alphabets can he quickly produced and distorted at will by the camera. Book faces, however, will require extra forethought. The old engravers, who had, of course, to cut a new set of punches for each successive size, subtly altered the proportions and colour value each time for optical consistency. In filmsetting, one set of master letters may have to serve for every size from footnote 6-point upward, and the best designs for filmsetting will be those which best survive arbitrary enlargement and reduction. But film imposes no other mechanical limitation upon the type designer —to his regret. for he would welcome any such technological challenge as stimulating as that which confronted the pioneer punch cutters.

See also biographical articles on outstanding type designers.

BIBLIOGRAPHY.—A F. Johnson, *Type Designs; their History and Development* (1959) ; D. B. Updike, *Printing Types: Their History, Forms and Use,* 2nd ed. *(1937);* W. T Berry and A. F. Johnson, *The Encyclopaedza of Type Faces,* 2nd ed. (1958) ; Cyril Burt. *A Psychological Study of Typography* (1959); Stanley Morison, *Type Designs of the Past aizd Present* (1926) ; Nicolette Gray, *Nineteenth Century Ornamented Types and Title Pages* (1938). (B L WA)

PRIOR, MATTHEW (1664–1721), English poet and diplomatist. was born in Wimborne, Dorset. July 21. 1664, the son of parents of modest station. His humble origin led to occasional difficulties in his diplomatic career, but did not prevent him from moving in distinguished company all his life. He was educated at Westminster school, where he made friends with Charles Montagu, later earl of Halifax. Both went on to Cambridge, and in 1687 collaborated in a piece of mockery directed at Dryden, *The Hind and the Panther Transvers'd to the Story of the Country Mouse and the Town Mouse.* In 1688 Prior's college. St. John's, elected him to a fellowship, which he retained until his death: but he soon entered diplomacy as secretary to the embassy at The Hague. Before long he was given responsible positions, and in 1697 was made secretary to the plenipotentiaries at the peace of Rijswijk. Next year he was transferred to Paris as secretary to the embassy.

He had already written a good deal of verse. both formal and occasional; and throughout his life he maintained his output of what he modestly described as "Public Panegyrics. Amorous Odes. Serious Reflections, and Idle Tales, the Product of his leisure Hours, who had Business enough upon his Hands—and was only a Poet by Accident." His lighter poems were marked by an ease, gaiety and grace unsurpassed in English literature. It is for his mastery in this field that he will always be most admired, although he could at times strike a more sombre note with telling effect. Perhaps his masterpiece is the poem known as "Jinny the Just," which remained in manuscript until the 20th century.

In 1699 he returned from France and sat in parliament in 1701 as member for East Grinstead, being also appointed a commissioner of trade and plantations. Soon after the accession of Queen Anne he transferred his support to the Tory party, and became the trusted confidant of Harley (later earl of Oxford) and St. John (later Viscount Bolingbroke). When the Tories came to power in 1710 his diplomatic talents were again employed. He was concerned in the negotiations which led to the peace of Utrecht; from

1712 until 1714 he resided at Paris as plenipotentiary.

After the death of Queen Anne he was recalled, and shared in the troubles which awaited the leading Tories; but despite rigorous examinations he refused to disclose the secrets of the fallen ministers who were his friends. During two years of mild confinement he wrote *Alma, or the Progress of the Mind,* a discursive and often subtle exercise in Hudibrastic metaphysics. In 1718 he published a stately folio of his collected poems, including *Alma* and his other long poem *Solomon on the Vanity of the World,* a didactic work completed at least a decade earlier. He passed his last years mainly with Lord Oxford, by whose family and household he was greatly beloved. Oxford bought for him a small property in Essex, Down Hall, to which he grew much attached. But his health had never been robust; and he died at Oxford's seat, Wimpole in Cambridgeshire, on Sept. 18, 1721.

As a diplomatist Prior proved himself an excellent negotiator, adroit, resourceful and clear headed. He was gifted with a personal charm and a sweet temper uncommon among the wits of his age. Most contemporary references to him are kindly, and he was fortunate in his friends in every walk of life. He never married, but maintained relations with various women from humbler circles than those in which he habitually moved. Little is known about them; but they included the much-loved Jinny, the subject of his most tender and moving poem.

BIBLIOGRAPHY.—Editions include *The Writings of Matthew Prior,* ed. by A. R. Waller, 2 vol. (1905–07); *The Literary Works of Matthew Prior,* ed by H. Bunker Wright and M. K. Spears, 2 vol. (1959). *See* also F. Bickley, *Life of Matthew Prior* (1914); L. G. Wickham Legg, *Matthew Prior: a Study of His Public Career and Correspondence* (1921); C. K. Eves, *Matthew Prior: Poet and Diplomatist* (1939).

(R. W. K.-C.)

PRIOR, a title applied generally to certain monastic superiors, but also in the middle ages to other persons in authority. Under the Roman Empire the word *prior* is found signifying "ancestor." In the early middle ages it was commonly applied to secular officials and magistrates, and it remained all through the middle ages as the title of certain officialsin the Italian city states.

In the Rule of St. Benedict and other early rules the titles *praepositus* and *praelatus* (*see* PRELATE) are generally used, but *prior* is also found signifying in a general way the superiors and elders in a monastery; afterwards the title prior (or *claustral* prior) was restricted to the abbot's vicegerent, who was generally charged with the details of the discipline of the monastery. With the foundation of the order of Cluny in the 10th century there appeared the conventual prior, who ruled as head of a monastery. The Regular Canons, and the Carthusians and Dominicans, later gave this title of prior to the heads of their houses

See Sir W. Smith and S Cheetham (eds.), *Dictionary of Christian Antiquities* (1875–80); "Prior" in the *Catholic Encyclopedia.*

PRISAGE AND BUTLERAGE, the names of ancient English customs duties which survived until the beginning of the 19th century. The oldest was a wine duty. Later it became customary to levy upon wool, woolfells and leather. This "customs" duty was known as "prisage." The earliest known prisage was levied in kind; one tun of wine being taken from every cargo of from 10 to 20 tuns, and two tuns from every cargo exceeding 20 tuns; a tun being 252 gal. The king's man took the liberty of sampling all the wine so that the king got his tun or tuns from the best on board. Later. importers were allowed to make a money composition instead of paying in kind. Prisage was payable both by British citizens and aliens.

In the reign of Edward I, by a charter known as *Carta Mercatoria,* aliens were given liberty of trading upon paying "to Us and to our Heirs, by the name of Custom, two shillings (for every hogshead of wine) over and above the antient customs due." This duty was made payable to the king's butler. and was consequently termed "butlerage." Later kings of England granted the produce of the duties of prisage and butlerage to certain of their subjects. In 1785 it was recommended that these duties should be revested in the crown. Thus, the duties of prisage and butlerage in Ireland had been granted to the dukes of Ormond, but parliament purchased those rights for nearly £200,000. In 1809 the duties were abolished by the Custotns Consolidation act of that year.

PRISCIAN (PRISCIANUS CAESARIENSIS) (*fl. c.* A.D. 500), the best-known of all the Latin grammarians, author of the *Institutiones grammaticae* which, together with the work of Aelius Donatus, had a profound influence on the teaching of Latin and indeed of grammar generally in Europe. He was born at Caesarea in Mauretania (the modern Cherchel in Algeria), but taught in &nstantinople. His minor works include *De nomine, pronomine et verbo* ("On Noun, Pronoun and Verb"), an abridgment of part of the *Institutiones guammaticae; Partitiones xii versuum Aeneidos principalium* ("The Parsing of the First 12 Verses of the *Aeneid"),* for the teaching of grammar in schools; a treatise on weights and measures; a treatise on the metres of Terence; *Praeexercitamina,* an adaptation for Latin readers of some Greek rhetorical exercises; a panegyric in verse on the emperor Anastasius I (*see* E. Bahrens, *Poetae Latini minores,* vol. v, 1883); and a verse translation of Dionysius' *Periegesis* (*see* the critical edition by P. van Woenstijne, 1953). Priscian's *Institutiones grammaticae* ("Grammatical Foundations") is a systematic exposition of Latin grammar. Of the 18 books into which it is divided, the first 16 deal mainly with sounds, word-formation and inflexions; the last 2 (which form nearly one-third of the whole work) with syntax. As far as possible Priscian takes the works of Apollonius Dyscolus on Greek grammar as his guide. He draws illustrative citations from many Latin authors and has thus preserved numerous fragments which would otherwise have been lost (for the text of the grammatical works *see* H. Keil, *Grammatici Latini,* vol. ii and iii, 1855–59).

Priscian's work was quoted by Aldhelm in the 7th century and by Bede and Alcuin in the 8th, and was much used by Rabanus Maurus and by Servatus Lupus of Ferrières in the 9th. Subsequently it became the standard work for the teaching of grammar in the medieval schools; and it provided the background for the rise of speculative grammar (the logic of language) in the 13th and 14th centuries. There are about 1,000 manuscripts extant. Of these, the greater part contain only books i–xvi (called *Priscianus major);* a few contain books xvii and xviii *(Priscianus minor)* and some of the minor works; and a few contain all 18 books of the *Institutiones.* Apart from fragments, the oldest manuscripts are of the 9th century. The first printed edition was that of 1470, at Venice.

BIBLIOGRAPHY.—J. E. Sandys, *History of Classical Scholarship,* vol. i, 3rd ed. (1921); A. Luscher, *De Prisciani studiis Graecis* (1912); R. W. Hunt, "Studies on Priscian in the Eleventh and Twelfth Centuries," *Mediaeval and Renaissance Studies,* vol. 1 and 2 (1943–50).

(R. H. Rs.)

PRISCILLIAN (d. 385), Spanish theologian and the founder of a party which, in spite of severe persecution for heresy, persisted in Spain and in Gaul until after the middle of the sixth century. He was a student of the occult sciences and of philosophy. He was a mystic, and regarded the Christian life as continual intercourse with God. He argued that to make himself a fit "temple of God," a man must, besides holding the Catholic faith and doing works of love, renounce marriage and earthly honour, and practise asceticism. On the question of continence in, if not renunciation of, marriage, he came into conflict with the authorities. Priscillian and his sympathizers, who were organized into bands of *spiritales* and *abstinentes,* like the Cathari of later days, refused the compromise which by this time the Church had established. (*See* MARRIAGE: *Canon Law*) This explains the charge of Manichaeism levelled against Priscillian and to this was added the accusation of magic and licentious orgies. Priscillian's friends included two bishops, Instantius and Salvianus, and Hyginus of Cordova; but, through the exertions of Idacius of Emerita, the leading Priscillianists, who had failed to appear before the synod of Spanish and Aquitanian bishops to which they had been summoned, were excommunicated at Saragossa in October 380.

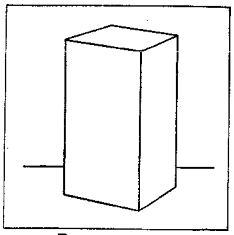
Meanwhile, however, Priscillian was made bishop of Avila, and the orthcdox party appealed to the emperor (Gratian), who issued an edict (afterwards withdrawn) threatening the sectarian leaders with banishment. On the murder of Gratian and accession of Maximus (383) Idacius fled to Treves, and secured the summoning of a synod (384) at Bordeaux, where Instantius was deposed. Priscillian appealed to the emperor, with the unexpected result that with six of his companions he was burned alive at Treves in 385.

The heresy, notwithstanding severe repressive measures, continued to spread in France as well as in Spain. As an openly professed creed it only disappeared after the second synod of Braga in j63.

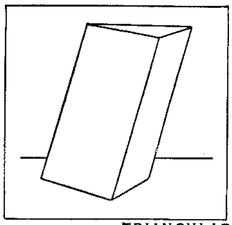
At the Council of Toledo in 400, 15 years after Priscillian's death, when his case was reviewed, the most serious charge that could be brought was the error of language involved in rendering ἀγένητος by *innascibilis.* It was long thought that all the writings of the "heretic" himself had perished, but in 1885 G. Schepss discovered at Würzburg 11 genuine tracts, since published in the Vienna *Corpus.* "They contain nothing that is not orthodox and commonplace, nothing that Jerome might not have written."

See *E. C.* Babut, *Priscillian et le Priscillianisme* (Paris, 1909).

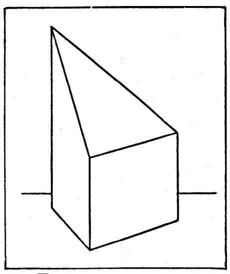
PRISM, in geometry, a polyhedron having two of its faces, known as *bases,* congruent (identical!:; equal) polygons in parallel planes, and the other faces parallelograms equal in number to the sides of the bases. The faces, excluding each base. are called the *lateral faces,* and the intersections of these faces are called the *lateral edges,* being all equal. The perpendicular distance between the planes of the bases is called the *height* or *altitude* of the prism. If the lateral edges are perpendicular to the planes of the bases, the prism is called a *right prism;* if they are oblique to these planes, it is called an *oblique prism.* Prisms are said to be *triangular, quadrangular, pentagonal* and so on according as their bases are triangles, quadrilaterals, pentagons and so on. A prism having parallelograms for its bases is called a *parallelepiped.* If the bases and lateral faces are all rectangles, it is called a *rectangular parallelepiped.* The part of a prism included between the base and a section made by a plane oblique to the base is called a *truncated prism.* A geometric solid which has for its bases two polygons in parallel planes, and for its lateral faces triangles or trapezia (U.S., trapezoids), with one side in one base and the opposite vertex or side in the other base, is called a *prismoid,* a prism being a special case. In optics the word denotes a triangular prism. The volume of a prism of base B and altitude a is aB; of a prismoid with bases B and B', altitude a and area of a mid-cross section M, is $\frac{1}{6}a\,(B+B'+4M)$. *See* CRYSTALLOGRAPHY; LIGHT; REFRACTION; and SOLIDS, GEOMETRIC.



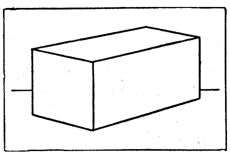
RIGHT PRISM



OBLIQUE TRIANGULAR PRISM



TRUNCATED PRISM



RECTANGULAR PARALLELEPIPED

PRISMOID, a solid bounded by any number of planes, two of which are parallel and contain all the vertices. The two parallel faces are called the *bases.* The volume V of such a solid was found by Thomas Simpson (1710–61) as follows: Let M be a section made by a plane parallel to the bases B and B' and midway between them, and let h be the distance between the bases. Then $V=\frac{1}{6}h(B+B'+4M)$, a formula frequently used in finding volumes and applicable to most of the elementary geometric solids, and in general to any solid bounded by a ruled surface and two parallel planes.

PRISON. In penal systems the function of the prison is threefold: custodial. coercive and corrective. In Roman law the *Digest* of Justinian established the custodial principle with the statement that "a prison is for confinement. not for punishment," and in countries that followed Roman law the principle that imprisonment was not a legal punishment was dominant for 1,000 years. In England also, the high court judges went out to "deliver the gaols"—to clear them, not to fill them. The prisons of the middle ages were therefore concerned only with holding prisoners awaiting trial.

The coercive function was added when, the punishment awarded being a forfeiture of property, the prisoner might be held until the fine or compensation was paid. This function is still active in England, since those committed for nonpayment of fines or debts or for contempt of court may secure release by paying what they owe or purging their contempt.

EUROPE

In England the earliest lawful prison was the common jail. which in legal theory was the king's jail, and in 1403 it was enacted that justices should commit offenders only to the common jails. Mediaeval jails were not specially provided buildings—castle tower, abbey gatehouse or inn cellar might serve. The keeping of jails was farmed out to private persons, whose only responsibility was the'safe-custody of the prisoners, their only interest to make the greatest profit from the fees they were permitted to charge them. To these forcing houses of contagious pestilence and moral corruption every type of prisoner was committed. with no adequate separation by age, character or even sex; and they so continued with little change and less disturbance of general public conscience until the latter part of the 18th century.

Sot less brutal and chaotic than the jails was the penal system they served. By the 16th century the mediaeval system of compensation was giving way to the capital penalty for major offenses, while for minor offenses fines and such punishments as whipping or the pillory were usual. But not all persons found guilty of capital offenses were executed. On the continent there was committal to the mines, galleys and fortifications. In England many escaped under "benefit of clergy" or under crown pardons on condition of agreeing to be "transported beyond the seas" to the American plantations. This practice received statutory sanction in 1679 and was regulated by a statute of 1717. In England the social and economic conditions of the Tudor period led to a poor-relief system enforced through the local justices. Houses of correction were set up for those of the unemployed who required compulsion to work and others who required "to be corrected in their habits by laborious discipline." The first was set up in London in 1553 in the former royal palace of Bridewell, from which they derived the popular name which lingers to this day, and in 1576 justices were required to provide one in every county.

On the continent a similar movement derived from the house of correction known as the Rasp Huis, established in Amsterdam, Neth.. in 1595. The purpose of houses of correction was not that of criminal lam, to cut offenders out of society by banishment or death. but the opposite—to bring them to good citizenship by the discipline of industry. education and religious instruction. Gradually, however, the penal implications predominated; industry as training gave way to hard labour as punishment, and during the 18th century houses of correction became instruments more of penal than of poor law. In England they became assimilated to the jails in all but name, and in 1865 the legal distinction was abolished.

Yet the idea of correction was to have continuing life, in England through the work of John Howard (*q.v.*) and on the continent through the influence of such historic houses of correction as that of Ghent, Belg., or of St. Michael in Rome, It.,—the first penal establishment to be set aside for reclaiming the young.

Beccaria, Howard and Reform.—The publication in 1764 of C. B. Beccaria's (*q.v.*) treatise *On Crimes and Punishments* laid the foundations of criminal science. His basic teaching was that the sole justification of legal punishment was the protection of society by prevention of crime and that the principle of uniform maximum severity, particularly by capital punishment, was not only wrong but ineffective. In England, under his influence, W. Eden, Sir William Blackstone, Sir Samuel Romilly and others fought for reform of the legal system and rationalization of the use of capital punishment; yet by the end of the century capital offenses had increased to more than 200.

Failure to reform the legal system was inevitable so long as there was no effective "secondary punishment," and the use of the prisons of the time to that end was inconceivable either in principle or in practice. Howard not only awakened world conscience to the scandal of the prisons; he showed. too, ho they might become an effective instrument of punishment. His publication in 1j77 of *The State of the Prisons in England and Wales, with Preliminary Observations, and an Account of Some Foreign Prisons* had the same world-wide influence on principles of prison management as had Beccaria's treatise on principles of legal punishment. Prisons, he argued, should be sanitary and secure; the keeper should be the paid servant of the justices who should exercise effective supervision; to break down the physical and moral corruption of the common wards and yards, there should be separate cells for sleeping; and prisoners should have useful work in proper workshops, with regular moral and religious instruction.

Statutes were enacted from 1774 to 1791 giving effect to Howard's views, but enforcement rested with the justices, and only a few progressive magistrates, such as Sir George Paul at Gloucester and Sir T. Beevor at Wymondham, persuaded their counties to build cellular prisons. An account of the work of Beevor was to start in Philadelphia, Pa., that movement for prison reform which later brought back to Europe the ideas for which Howard vainly fought in his own time.

Early 19th Century. — Necessity required many counties to provide larger jails for the growing number of prisoners, and better sanitation against jail fever, but 30 years after Howard's death another group of prison reformers found the prisons much as he had left them. The Society for the Reformation of Prison Discipline, founded in 1816, had as its most prominent members Thomas Foxwell Buxton and Samuel Hoare, leaders of a Quaker group among whom Elizabeth Fry (*q.v.*) was to live in history. Tirelessly and constructively working inside Newgate herself, and forming ladies' committees to do the same elsewhere, she showed that Howard's principles could be practically applied so as to restore criminals as useful members of society. But in parliament interest still centred on the penal system, and her work had no more immediate effect on the general state of prisons than that of Howard.

The question of secondary punishment might have been effectively faced when the loss of the American colonies had temporarily deprived the government of the resource of transportation for those felons whom it did not hang. Alternative arrangements were made in statutes of 1j7j and 1j78 and, though these fell through when in 1787 transportation was resumed. this time to Australia, certain novel provisions had a continuing effect on the 19th-century prison system. The first was the conception of punitive hard labour, defined as "labour of the hardest and most servile kind, in which drudgery is chiefly required. . . . such as treading in a mill or drawing in a capstern. . . . ." The second was to provide that. until they could be transported, convicts might be detained in "hulks" in harbours and river mouths. More important was the decision to build two "penitentiaries," and though nothing was then done. Jeremy Bentham (*q.v.*) here made a notable contribution. Under the influence of Beccaria, he fought for penal and prison reform?laying special emphasis on the provision for prisoners of useful work as against sterile hard labour. In 1794 parliament adopted his novel plan for a penitentiary, which he called a "panopticon." and a site was bought at Millbank, London. But when in 1816 the new building was started on the site, Bentham's plan had been abandoned.

The first effective steps to rationalize the penal system were those taken by Sir Robert Peel (*q.v.*). The capital statutes were reduced and consolidated. benefit of clergy was abolished (1827) and for many felonies which had been clergyable there was prescribed a penalty of up to two years' imprisonment. It was now essential to make the prisons an effective instrument of punishment, and Peel's Gaol act of 1823 was the foundation of the English prison system. The justices were required to organize their prisons on a prescribed plan, with the jailer as their paid servant, to inspect them and to make reports to the home secretary. The graver abuses of the 18th century a-ere swept away and the statute included a code of rules to be followed in every prison. Howard's principles were established; with one exception: the separate cell system was rejected in favour of classification into five groups which were to be associated in productive employment and maintained from the profits.

But the impulse which finally shaped the future of European prisons was to come from another direction. In 1776 the Quakers of Pennsylvania had taken in one stride the steps over which the old world was still to fumble for so long. Murder was made the sole capital offense, and imprisonment the primary legal punishment. The regime of imprisonment which became known as the separate. solitary or Pennsylvania system was based on Howard's cellular system, but went beyond his teaching in requiring the strict separation of the prisoners by day as well as by night. The reformative virtues of this system were held to lie in complete absence of contamination. in religious instruction and silent contemplation. But another school of thought, closer to Bentham and Howard, had greater influence on U.S. development: this required separate cells for sleeping but associated work by day. and in Auburn prison in the state of New York there was enforced, to prevent contamination, a strict rule of silence, from which this system became known as the silent or Auburn system (*see* below). As news of these developments spread in Europe there was a flow of visitors to inspect and report. and there began that battle of the systems of which the echoes have still not died away. But their common factor. the cellular prison: had come to stay. and all over western Europe, in the next 30 years, prisons were built on the new model.

In England this was a period of confusion. Some county jails of Howard's time were cellular; others had been rebuilt after 1823 for the classification plan. Some favoured hard labour and erected treadwheels, some the new silent system. Many were attracted by the profitable aspects of Bentham's useful employment; many more had changed little since Howard first saw them. The government still lacked power to create a coherent system by enforcing its enactments and the next steps were to remedy that constitutional defect and then, following the breakdown of the transportation system, to develop imprisonment as the primary legal punishment.

Central administration was strengthened by the appointment of inspectors of prisons in 183j and of a surveyor general of prisons in 1844; and the home office. after visits by two of the inspectors to the U.S., gave a decided lead in favour of the separate system. Meanwhile public criticism of transportation had come to a head in the report of a parliamentary committee of 1837. and one of the steps taken to reform the system was to institute an initial period of 18 months' separate confinement in a penitentiary for selected convicts believed to be capable of reform. To supplement Millbank, the government in 1842 built a second penitentiary at Pentonville, London, which was also intended as a model to local authorities for the operation of the separate system. Within a few years 54 cellular prisons, with 11,000 cells, were built on the Pentonville plan.

In 1850 home office administration mas further strengthened by the appointment of directors of convict prisons. to take charge of the hulks. Millbank. Pentonville and a prison built in 1839 at Parkhurst, Isle of Wight, for juvenile convicts; the first chairman of the directors was Sir Joshua Jebb. The transportation system was now crumbling under the revelations of its inhumanity and inefficiency: and the refusal of the colonies to accept any more convicts; in 1846 it was suspended and the home office had to develop a system to take its place in the prisons at home. New prisons were required to hold this new population and to replace the hulks: the old "war prison" at Dartmoor. Devonshire, was rebuilt and Portland. Dorset, and other convict prisons followed. The directors based the new system on the differentstages through which a convict passed under the transportation system, and notably on the pioneer work of Alexander Maconochie in the penal settlement of Norfolk Island. where he had sought to recover the self-respect of his convicts through a progressive stage system, based on the earning of marks for good conduct and industry. This system became one of the bases of 19th-century prison treatment; introduced by Jebb into Ireland. it was there further developed under Sir Walter Crofton and, as the "Irish system," much influenced the development of progressive reformatory discipline on the continent and later in the U.S.

To begin with in England there were three stages: (1) 12 months' separate confinement in a penitentiary; (2) associated labour on public works in a convict prison (Portland harbour was largely built by convict labour); (3) ticket of leave to be at large in the colonies. Finally. when it became necessary that the convicts should also be released in England, a new form of sentence called penal servitude was introduced, which in 1857 was legalized for any offense punishable by transportation: the minimum period was three years. Penal servitude. after 1857, was served in three parts: (1) nine months' separate confinement in Pentonville or a local jail; (2) associated labour in a convict prison, divided into three progressive stages carrying increasing privileges to be earned by marks. while marks were also earned to qualify for release before expiration of sentence; (3) after the necessary marks were earned. release on a conditional licence.

Meanwhile, in the local prisons, the classification provisions of 1823 had in 1839 been repealed and permission given for justices to adopt the separate system, to which most informed opinion was now converted; and in 1850 a parliamentary committee had again endorsed the separate system and recommended punitive hard labour rather than useful industry. The battle of the systems was nearing its end.

19th-Century System.— Capital offenses having been reduced in 1861 to treason, murder, piracy and the burning of dockyards, imprisonment was now established in England as the primary legal punishment; in 1863 a committee of the house of lords laid down the principles which were to govern the system for more than 30 years. Meeting under the influence of an increase of serious crime and a reaction against reformative methods, the lords laid down that the object of imprisonment was deterrence by severity of punishment; and the methods should be separate confinement with punitive hard labour—"hard labour. hard fare and a hard bed." They expressed disbelief in the possibility of reform as an aim of imprisonment. Statutory effect was given to these views by the Prison act, 1865, and in 1877 parliament took the final step to ensure that they should be enforced. By the Prison act of that year the ownership and control of all local prisons were transferred to the home secretary and a board of prison commissioners was set up to manage and inspect them. The first chairman of the commissioners was Sir Edmund Du Cane, who had succeeded Jebb, so that all prisons, convict and local. were now under one management.

For 20 years the principles of 1865 were uniformly, efficiently and rigidly applied. Darkness descended on the English prisons. and the "Du Cane regime" became the classic example of a punitive prison system.

But elsewhere were new lights. On the continent the theories of Cesare Lombroso (*q.v.*) stimulated scientific study of criminology, and the formation in 1869 of the Union Internationale de Droit Pénale revived interest in the prevention of crime and the principles and practice of legal punishment. Continental systems were experimenting with variations of the progressive system; but in general the separate system was still rigidly enforced, and in France progress was retarded by the institution of transportation to the penal settlements in Guiana. In the U.S. the first American national prison congress was held at Cincinnati. O.. in 1870, of which the "Declaration of Principles" is a foundation document of modern prison reform. In the same year Enoch C. Wines secured a joint resolution from the U.S. congress creating a special commissioner empowered to invite other nations to an international prison congress in London. This congress of 1873 approved the major principles of Cincinnati: that the moral regeneration of prisoners through hope, not fear, should be the primary aim of imprisonment and that any unnecessary pain or humiliation should be abolished. From this congress followed regular quinquennial congresses in the different capitals and later the International Penal and Penitentiary commission, an intergovernmental organization of official delegates. with a permanent office at Berne. Switz., whose discussions and resolutions have notably promoted knowledge and progress.

Light came again in England when, in 1895, a departmental committee. under the chairmanship of H. J. Gladstone, unsparingly condemned the system of 1865 as being ineffective for the prevention of crime. Prisoners, it was said. had been treated "too much as a hopeless and worthless element of the community . . . Prison discipline and treatment should be designed to maintain, stimulate, or awaken the higher susceptibilities of prisoners . . . and whenever possible to turn them out of prison better men and women than when they came in. . . . Prison treatment should have as its primary and concurrent objects deterrence and reformation." Separate confinement. and hard labour were condemned, and proposals made for the separate treatment of young offenders under 21 and of habitual criminals.

20th-Century System.—*Before* 1914.—By the Prison act, 1898, power was given to the home secretary to provide for detailed regulation of the prison system by statutory rules. and under this more elastic procedure the development of 50 years proceeded without further legislation. Before World War I, however, the most significant changes in English penal practice lay in the steps taken to keep as many people as possible out of prison altogether. The probation system was established by the Probation act. 1907, suitable treatment of young offenders under 17 by the Children act, 1908, and of mental defectives by the Mental Deficiency act, 1913.

The provision in the Criminal Justice act, 1914, requiring justices to allow time for the payment of fines caused a striking fall in the prison population. The Prevention of Crime act, 1908, provided the Borstal system of treating offenders aged 16 to 21 outside the prison system, and the system of preventive detention for the protection of society against the habitual criminal.

The Borstal system was the creation of Sir Evelyn Ruggles-Brise, who succeeded Du Cane in 1895 and served until 1921; it lies outside the prison system. Borstal training is carried out in Borstal institutions: which are wholly educational and reformatory in principle and in method. Borstal had a wide influence throughout Europe and the British commonwealth.

For preventive detention a regime was devised suited to long sentences (five to ten years) which in principle were preventive rather than punitive, the prisoner having already served a sentence of penal servitude for the offense of which he was convicted on the occasion of having been found to be an habitual criminal. This double-track system of punishment together with other procedural disadvantages resulted in very few habitual offenders being sentenced to preventive detention. and was reviewed in 1932 by the departmental committee on persistent offenders, though effect was not given to their recommendations until 1948.

The prison systems of Europe underwent no radical change in the early years of the 20th century. On the continent separate confinement for periods of years was still general. In England there was little change in the convict prisons, but in the local prisons penal hard labour ceased. workshops were built for industrial employment and separate confinement was abolished; in effect, the silent system had returned, the rule of silence being strictly enforced at all times. The progressive stage system was based mainly on additional letters. visits and library books. with increasing gratuities in convict prisons. A classification system was instituted for convicted prisoners: (1) young prisoners, under 21; (2) star class,, for those in prison for the first time and others suitable to associate with them; and (3) ordinary class, for all others. The earning of remission of sentence had by the act of 1898 been extended to persons sentenced to imprisonment, the amount being fixed at one-sixth; for penal servitude it was one-quarter. (During World War II remission for all sentences was increased to one-third.)

At this stage the doctrine that a prison regime must be punitive and humiliating, so as to exercise deterrence through fear both against those subjected to it and against potential offenders in general, was still too deeply ingrained in penal thought and prison tradition for prisons to become an instrument for making better men and women.

Post-World War I.—There was active in Europe a new school of penal thought whose aims were embodied in the phrase "individualization of punishment," in reaction against the mechanical infliction of imprisonment as a standardized punishment irrespective of the condition of the offender. England now moved toward individualization of punishment within the prison and the provision of a regime compatible with the moral and social rehabilitation of the prisoners.

Experience had shown that men and women would be made not better, but worse, by punitive treatment designed to hurt and humiliate them. It was therefore necessary to proceed from the hypotheses that general deterrence lies not in the fear of prison, but in the totality of the operation of the penal system; and that individual deterrence lies in the fact of imprisonment, with the absolute loss of personal liberty and the amenities of normal life, and subjection to labour and disciplinary control. The regime should then be directed primarily to the rehabilitation of every prisoner for whom it might be possible; for others, it should at least seek to avoid such deformative effects as would send them out of prison worse than when they came in, neither willing nor able to take a useful place in society.

The changes which were to follow, at first under the chairmanship of Sir Maurice Lyndham Waller (1922–28), were largely inspired by a remarkable personality, Sir Alexander Paterson, who served as a commissioner of prisons from 1922 to 1947. Deliberately humiliating features of prison life were now removed and the rule of silence disappeared. The system concentrated on training prisoners to take a useful place in society, with an organized system of assistance and aftercare on discharge. Special emphasis was laid on the personal influences of a carefully selected and well-trained staff. and also on those of men and women from the community outside. who were enlisted to provide. as a voluntary social service! both education and entertainment and to pay friendly evening visits to prisoners in their cells. The quality of industrial work was improved. the earning of small sums of money was introduced, and an adult education scheme established. Since this form of training could not be fully carried out in the unsuitable buildings of the 19th-century local prisons. with their mixed populations and diverse functions. special training prisons were set aside for prisoners eligible both by character and length of sentence; and to Wakefield, the first such prison, an open farm camp was attached.

Throughout Europe there was progress in the development of progressive reformatory systems: and many new penal codes were promulgated. The penal farm colony without walls at Witzwil, Switz., had long had a wide influence. and in Sweden, Italy and Greece prison farms were instituted as steps to complete liberty. In these developments the International Penal and Penitentiary commission continued to play a stimulating part, holding congresses in London (192 j), Prague (1930) and Berlin (1935). In 1933 it published standard minimum rules for the treatment of prisoners, which were adopted and recommended by the League of Nations.

Post-World War 11.—Once the initial difficulties of those penal systems directly affected by World War II had been overcome! the first postwar decade proved to be one of remarkable development; by its end, the outlines and direction of a matured zoth-century system were not only visible in practice in the more developed systems. but increasingly accepted in principle throughout the world.

The extent of this progress owed much to sustained international interest and co-operation. The International Penal and Penitentiary commission, resuming its meetings in 1946, undertook a revision of the standard minimum rules of 1933, and its work culminated in the 12th International congress at The Hague. Neth., in 1950. Thereafter its functions were assumed by the Cnited Nations, which through the social defense section of its secretariat, organization of regional groups of experts, holding of seminars in different countries. provision of technical assistance and organization of a world congress at Geneva, Switz., in 19j5, did much to promote and collate knowledge and experience.

Development was based on the acceptance of rehabilitation as the primary purpose of the prison, with individualization of treatment through correct classification based on a thorough study of the character and needs of the individual prisoner. In 1950 the United Nations held in Brussels a seminar to study the scientific examination of offenders on the basis of medical, psychiatric, psychological and social reports. The development of prison staffs into a branch of social service including many specialists—psychiatrists, psychologists, social workers. teachers. trade instructors—was also a subject of international study, emphasis being laid on the need for careful selection and training of all grades on a professional basis.

The open prison system, which had been developed especially in the United States. the United Kingdom and the British commonwealth, and the Scandinavian countries, was recognized as an important contribution to effective rehabilitation.

There was notable extension of the use of psychiatric and psychological science both in diagnostic reports for the courts and for internal use. and in the treatment of abnormal mental states.

Special interest was aroused by the Swedish prison code of 1944 and the English Criminal Justice act of 1948, which gave legislative expression to progressive thought on the treatment of offenders. the former providing particularly for the detention of as many prisoners as possible in open prisons. The Criminal Justice act abolished the outworn forms of sentence to hard labour and penal servitude, leaving the single sentence of imprisonment. New methods of dealing with persistent offenders were enacted: for those still apparently capable of reformation, sentences of two to four years' corrective training might be passed; for others, j to 14 pears' preventive detention in appropriate conditions under special rules. The act also sought to minimize the imprisonment of young persons under 21 years of age and provided additional methods of treatment for them outside the prison system. Similar acts followed in Scotland and Northern Ireland.

During this period there was a marked rise in serious crime in England, leading to a prison population more than double that of pre-World War II years. Serious overcrowding resulted in the local prisons. Nevertheless there were notable developments both in principle and practice. The new systems of treatment for persistent offenders were established. The open prison system was fully developed. Compulsory attendance centres and detention centres were established as alternatives to imprisonment for young offenders. The classification of prisons was pressed further and many new training prisons were opened. Vocational training in skilled trades was extended, leading to the taking of external examinations. A new educational scheme based on professional teachers provided by local education authorities was introduced. Libraries were overhauled and open access to the shelves provided. A central after-care association was established, and the work of local discharged prisoners' aid societies was reviewed. A new building program of seven institutions was started, one being a psychiatric hospital.

Although in some countries there was still adherence to initial periods of solitary confinement, throughout western Europe developments of prison treatment followed similar lines. In France, for example, a national observation centre for diagnosis and classification was established at Fresnes, two prisons were set aside as vocational training centres and central prisons with a progressive system replaced transportation. In Portugal modern prisons were built. notably the youth prison at Leiria, where novel methods of training young prisoners were introduced. There was increased interest in probation, but little positive progress. See also CRIMINOLOGY.

BIBLIOGRAPHY.—English: J. Howard, *The State of the Prisons, etc.* (London, 1777); S. and B. Webb, *English Prisons under Local Government* (London, 1922); S. Hobhouse and A. F. Brockway (eds.), *English Prisons To-day* (London, 1922); Sir Evelyn Ruggles-Brise, *Prison Reform at Home and Abroad* (New York, 1925); L. W. Fox, *The English Prison and Borstal Systems* (London, 1952); H. Mannheim, *The Dilemma of Penal Reform* (London, 1939); L. Radzinowicz and J. W. C. Turner (eds.), *Penal Reform in England* (London, 1946); *The Clarke Hall Lectures* (London, 1934 and annually); L. Radzinowicz, *History oj English Criminal Law* (London, 1948); Sir Leo Page. *Crime and the Community* (London, 1937); Norval Morris. *The Habitual Criminal* (London, Cambridge, Mass., 1951); M. Grunhut, *Penal Re-*

form (London, 1948); Home Office, *Prisons and Borstals* (London, 1956); see also *Annual Reports* of the prison commissioners and *Howard League Journal.*

European: M. Poll and P. Cornil, *Prisons et établissements pénitentiaires* (Brussels, 1939); P. Cannat, *La Réforme pénitentiaire* (Paris, 1949); J. Pinatel, *Traité élementaire de science pénitentiaire* (Paris, 1950); E. Bumke, *Deutsches Gefängniswesen* (Berlin, 1928); M. Grunhut, *The Development of the German Penal System, 1920–1932* (Cambridge and Toronto, 1944); G. A. Catopodis, *Phylake* (Athens, 1947); F. Siracusa, *Istituzioni di diritto penitenziario* (Milan, 1935); J. Beleza dos Santos, *Nova organização prisional portuguesa* (Coimbra, 1947); E. Cuello Calón, *Penologia (in: Derecho Penal)* (Barcelona, 1945); T. Sellin, *Recent Penal Legislation in Sweden* (Stockholm, 1947); K. Hafner and E. Zurcher, *Schweizerische Gefängniskunde* (Berne, 1925); International Penal and Penitentiary Foundation, *Modern Methods of Penal Treatment* (Paris, 1955).

(L. W. F.)

UNITED STATES

In the American colonial period, penological practice fell almost entirely within the first stage of handling convicts, who were punished outside of institutions by means of fines and cruel and brutal corporal punishments. The only exceptions occurred within the Quaker colonies of West Jersey and Pennsylvania, and there only briefly. The Quakers were repelled by the bloody methods of corporal punishment and sought another method of handling convicts, in imprisonment at hard labour in workhouses. The latter were the first true prisons established in human history. West Jersey set up such a system in 1681 and Pennsylvania in 1682. but the British government forced the abandonment of this humanitarian innovation; and in 1718 even the colony of Pennsylvania reverted to the usual practices of corporal punishment.

The second stage of penological practice in the United States: that of providing penal institutions to punish convicts within their walls: gradually emerged between 1776 and 1800. At the close of the American Revolution, the Quakers and other humanitarians, notably Benjamin Rush. quickly restored the Quaker practice of imprisonment. These Philadelphia reformers were also influenced by the recommendations of the great English penologist John Howard and by the cellular jail which had been erected at Wymondham, Eng.. in 1785 as a result of Howard's reform suggestions. Laws were passed by the state of Pennsylvania ordering imprisonment as the normal method of punishing criminals and, immediately after 1790, a small block of cells was erected in the yard of the Walnut Street jail in Philadelphia for the solitary confinement of convicts. This was the first true prison in the United States for confinement of adult felons. It was also the birthplace of the famous Pennsylvania system of prison discipline, which provided the model, with variations, for many prison systems of the world, especially the European, during the 19th century.

Pennsylvania's first state prison, opened at Allegheny near Pittsburgh in 1826, was the first institution to provide for the solitary confinement of all inmates. But the Eastern penitentiary, opened at Cherry Hill in Philadelphia in 1829, became the classic institution in which the Pennsylvania system of solitary confinement was fully developed. From this institution the Pennsylvania system spread over the world and took firm root in Europe during the remainder of the 19th century. Under the Pennsylvania system each convict was locked up by himself in a cell and kept there without any association with other convicts until he died or was released. Hence, the Pennsylvania system was known as the solitary or separate system. Its chief purpose was punishment, but it was hoped that the reflection of the convict upon this punishment for his crimes might lead to his reformation. The Pennsylvania system thus established the second period of penology—the idea and practice of using penal institutions to punish convicts.

The other famous U.S. system of prison discipline and administration was started in Xuburn, N.Y., in 1819, and was a variant of the Pennsylvania system. From 1821 to 1823 the institution was conducted according to the Pennsylvania system of constant solitary confinement. Because of the smallness of the cells ($3\frac{1}{2}$ by 7 by 7 ft.) and the total lack of exercise, many of the confined convicts went insane or died. As a result, the Xuburn authorities introduced in 1825 what became known as the Xuburn system, under which convicts were segregated individually in cells except during the periods of working and eating. They were allowed to leave their cells to work in prison shops and eat in a common dining room. But absolute silence was maintained at all times, and any type of communication between convicts was absolutely forbidden. Hence the Auburn system was known as the silent system.

From about 1825 to 1850 there was a vigorous conflict between the Pennsylvania and Auburn systems. The former was generally adopted by European countries. But, though the Pennsylvania system was experimented with briefly in Maryland. Massachusetts, Maine. New Jersey. Rhode Island and Virginia, the Auburn system had triumphed in every state except Pennsylvania before 1850. Two reasons for its popularity in the United States were that institutions on this plan were more economical to construct and administer, and they were also better adapted to the rising mechanical and shop industry than was the solitary cellular confinement of the Pennsylvania system. Perhaps even more important was the fact that Louis Dwight! secretary of the Prison Discipline Society of Boston. was an almost fanatical partisan of the Auburn system and carried on effective propaganda with state legislatures whenever the construction of a new prison was under consideration.

The third stage of penological theory and practice in the U.S. came into being through the Irish system of prison discipline introduced in the 1850s and 1860s by Sir Walter Crofton and Sir Joshua Jebb. This system aimed primarily to reform convicts rather than to punish them, and determined the duration of imprisonment on the basis of the conduct of the convict while confined. It aroused the interest of leading U.S. penologists such as Enoch C. Wines. Zebulon R. Brockway, Gideon Haynes. Gaylord Hubbell and Franklin B. Sanborn; at the Cincinnati prison congress of 1870 these reformers advocated that it should replace both the Pennsylvania and the Auburn systems. Opposition was so strong, however, that the reformers were able to apply it only to U.S. criminal youth. The result was the creation of the Elmira reformatory system, first set up at Elmira, N.Y., in 1876.

The reformatories usually confined convicted young men between the ages of 16 and 30, often limiting the age group to those between 18 and 2j. The system was based upon the idea of dividing inmates into graded classes, promoting them through these classes because of good conduct, providing adequate vocational education and speedily admitting worthy inmates to release under parole supervision. The reformatories were first to introduce parole into U.S. penological practice on a large scale.

By and large, the reformatory movement proved a disappointment because the high ideals of the reformers of the 1870s were not maintained. Moreover, the reformatory structures! differing little from conventional prisons, were not designed in harmony with the new treatment ideals. Actually, the program failed because it mas never given a fair trial. Most reformatories degenerated into ordinary prisons for young men. In the second quarter of the 20th century, however, there was a revival of interest in the reformatory conceptions and practices. Beginning with the opening of the New Jersey reformatory at Annandale in 1929, reformatories were designed more in harmony with the ideals of the system, and better rehabilitative programs were worked out.

In the interval between 1870 and 1930. the main beneficial influence of the Elmira system was its impact upon the conventional prisons for adult felons. Slowly and gradually, some of the Elinira ideals were introduced in the adult prison system. Among these were the increasing use of parole. speedier release upon the basis of good conduct. better provisions for inmate education and a gradual triumph, in theory at least, of the idea that the purpose of imprisonment should be the reformation rather than the punishment of the inmate. Beginning with the New Jersey prison system in 1918, the rational treatment program, generally known as the principle of classification, was developed. According to this program, the treatment of convicts was adapted not only to the needs of the major classes of convicts but also to those of each individual inmate. The conventional custodial staff was supplemented by a classification clinic or treatment staff, made up of physicians, psychiatrists, psychologists, social workers and sociologists. The "new penology" was exemplified in such state systems as those of New Jersey, Illinois and California and by the federal prison system after 1930 under the direction of Sanford Bates and James V. Bennett. The federal system made the most complete effort to apply the principle of classification in accordance with the types of inmates confined. Hence, the federal institutions became highly diversified. ranging from a supersecurity penitentiary for the more desperate type of criminals at Alcatraz. Calif., to a minimum-security correctional institution at Seagoville, Tex., at which there were no walls and in which the inmates were given relatively complete freedom of movement. An adequate classification clinic or treatment staff was provided for each institution.

Despite the advances represented by the new penology, the more realistic and progressive penologists came to recognize that the dominant ideal of reformation could never be effectively achieved within penal institutions. The public fear of escapes encourages the construction of prisons as a collection of escapeproof steel cages. Moreover, the attention of prison administrators tended to be concentrated primarily upon preventing escapes rather than reforming inmates, and the inmate attitudes produced by all these circumstances created a mental response unfriendly to the efforts of the treatment staff. The best prison community is no more than an extreme totalitarian society, and the most it can produce is a good convict, who is quite different from a good citizen. Penologists came to realize that reform of convicts must be achieved mainly by agencies operating outside prison walls, in the environment to which the convict must ultimately adjust himself if he is to becomea reformed man. The result was at least a preliminary entry into the fourth stage of penological theory and practice—the conviction that reformation of convicts must be attained chiefly outside any penal institution. The same philosophy came to be accepted in the treatment of juvenile delinquents.

Penologists estimate that 15% to 20% of all convicts are nonreformable and must be segregated in maximum-security institutions under humane conditions throughout their natural lives. All others, according to the fourth-stage theory, should be released from institutions as soon as possible and treated in the normal environment of social relationships. This means an ever greater use of probation, conditional release under close supervision, and parole. The penologist who most vigorously recommended transition to this penological practice was Howard B. Gill, who established the progressive Norfolk prison colony in Massachusetts in 1927. The first program designed to make extended application of this practice. at least among criminal youth, was the Youth Correction Authority program drafted by the American Law institute in 1940 under the leadership of John B. Waite. This was based on the principle that expert penologists should decide the treatment of all convicted youth, determining whether they should be treated in institutions or outside under probation, conditional release or parole. California adopted the program in 1941, Minnesota and Wisconsin in 1947, Massachusetts in 1948 and Texas in 1949. The federal government followed suit in 1950 In 1944 California also created an adult correction authority, envisaging application of the same principles to adult felons.

Prison Architecture. — From the time of the building of the Auburn and Sing Sing prisons and the Eastern penitentiary between 1819 and 1829, there was no fundamental change in prison architecture until well after 1900, except for the building of more secure and expensive Auburn-style prisons, with a greater array of forbidding tool-resisting steel cages. The Eastern penitentiary cost about $772,000 to construct. The Attica state prison, opened in New York state about a century later, cost nearly $11,000,000. The Eastern penitentiary was constructed according to the outside-cell layout, with radial wings; a central corridor ran through each wing. and the cells extended from the corridor to the outside wall of the wing. But, since the great majority of prisons built in the United States were erected on the Auburn pattern, it is the latter style of architecture which is chiefly of interest to students of U.S. prisons. The Auburn system discarded the radial wing layout and adopted in its place long rectangular cell houses, usually flanking the entrance to the institution. Within these cell houses, lighted by heavily barred windows in the walls, was the so-called inside-cell block made up of several tiers of heavily barred cells. These cells were located back to back. and were surrounded by a corridor extending all the way around the cell block. Because the cell house completed at Sing Sing prison in 1828 on the Auburn pattern was much larger and more impressive than the Auburn structure, the great majority of prisons erected in the United States after 1830 were based upon this Sing Sing model of long rectangular cell houses enclosing their sombre and ever more escapeproof inside-cell blocks. Hence, the prisons of the United States for more than a century were architecturally gloomy and oppressive and a constant frustration of reform efforts of both the custodial staff and the inmates.

The first revolutionary advance over the Sing Sing pattern of prison architecture came with the opening of the telephone-pole prison at Fresnes, near Paris, in 1898, designed by Francisque Henri Poussin. This split the long cell houses of the Auburn-Sing Sing pattern into two halves by means of a covered central corridor which extended throughout the length of the structure. The resulting external appearance roughly represented the arms on a telephone pole and thus gave rise to the name. This prison was a great improvement over previous structures in that it gave easy and protected access to all sections, reduced the possibility of escape, lessened the distance over which inmates had to move, made their supervision easier and facilitated the proper lighting of cell blocks.

The telephone-pole type of prison was introduced to a limited extent in the state prison at Stillwater, Minn.. in 1914. But the adaptation of the layout to effective prison designing in the United States was mainly the work of Alfred Hopkins, a professional architect who in his mature years gave more and more attention to prison architecture.

Hopkins began his work with a new county prison in Westchester county, N.Y., opened in 1916, but his first complete structures illustrating the telephone-pole layout were the federal penitentiary at Lewishurg, Pa, and the New York state medium-security prison at Wallkill. both opened in 1932 Other architects, notably Robert D. Barnes of the federal bureau of prisons, went further in perfection of the telephone-pole design, as best exemplified by the federal penitentiary at Terre Haute, Ind., and the federal correctional institution at Texarkana, Tex The most notable innovation, however, was the plan drawn for the federal prison to supplant Alcatraz. This provided for elimination of the heavily barred windows of the cell houses and substituted skylighting of the cell blocks.

In the 20th century there was a tendency to diversify prison construction according to the type of inmates confined From 1825, all prisons had been designed more or less exactly alike with the same form of cells for all offenders. Under the leadership of the federal bureau of prisons, institutions were progressively diversified to meet the needs of the very different types of convicts sent to them. In the federal system were the supersecurity penitentiary at Alcatraz, already mentioned, for the most desperate criminals; three maximum-security prisons for serious habitual criminals; two mixed-custody penitentiaries for less serious adult felons; eight medium-security correctional institutions for inmates not requiring excessive precautions for safe-custody; and one minimum-security correctional institution for inmates with good prospects of speedy reform. Housing facilities were also diversified within each institution. For example, in the federal penitentiaries at Lewisburg and Terre Haute, not more than 12% of the inmates were housed in maximum-security inside cells, with the rest detained in outside cells, dormitories and honour rooms This diversified construction enormously reduced building costs and enabled the planners to put more money into various educational and treatment facilities to promote reformation rather than discourage it. There was also a notable tendency to spend less money on expensive walls. The wall of the Attica state prison in New York state, opened in 1931, cost $1,275,000, whereas the federal penitentiary at Terre Haute was built without any wall whatever. A heavy wire fence was found to provide a sufficiently secure enclosure. Finally, later prison planning stressed the desirability of smaller buildings. Enormous prisons like those at Jackson, Mich., and Stateville, Ill., holding up to more than 5,000 inmates, were erected after World War I, but opinion at mid-century would limit prison capacity to not more than 1,200 inmates, approximately the number confined at Lewisburg and Terre Haute.

Prison Labour. — Prison labour has played an important part in US. prison history, because it is intimately tied up with both the prison economy and the health and reformation of inmates. During most of the 19th century labour was carried on under various types of contracting. Contractors usually supplied the raw materials and sold the finished product, paying only for the labour of inmates. The contract stage reached its greatest prosperity in the 1870s and the

1880s, after which it became progressively restricted. During the first third of the 20th century the public-account system dominated most U.S. prison industry. Under this system, the prison authorities manufactured and sold all prison-made products. After the 1920s state-use prison labour laws compelled prisons to manufacture solely for state use but did not make it obligatory for state institutions to buy from prison shops. Laws restricting prison industry did not apply to the federal prisons.

Education.—In a thorough study of prison education, Austin H. MacCormick pointed out that in 1927 not a single prison in the United States had a thoroughly satisfactory program of education. Ten years later there were still 12 prisons without any educational provisions. Probably the best U.S. prison school at mid-century was that of the Rockview penitentiary, near State College, Pa.

BIBLIOGRAPHY.—American Prison Association, *A Manual of Correctional Standards* (1954); Attorney General's Survey of Release Procedures, *Prisons*, vol. v (1940); H. E. Barnes, *History of the Penal, Reformatory and Correctional Institutions of New Jersey* (1918), *Evolution of Penology in Pennsylvania* (1927); H. E. Barnes, R. D. Barnes *et al.*, Federal Bureau of Prisons *Handbook of Correctional Design and Construction* (1950); H. E. Barnes and N. K. Teeters, *New Horizons in Criminology*, 2nd ed. (1951); Sanford Bates, *Prisons and Beyond* (1936); J. R. Ellingston, *Protecting Our Children From Criminal Careers* (1948); T. E. Gaddis, *The Birdman of Alcatraz* (1955); F. E. Haynes, *The American Prison System* (1939); Alfred Hopkins, *Prisons and Prison Building* (1930); Louis Hugueney *et al., Les grandes systèmes pénitentiaires actuels* (1950); George Ives, *A History of Penal Methods* (1914); O. F. Lewis, *The Development of Prisons and Prison Customs, 1776–1845* (1922); J. B. Martin, *Break Down the Walls* (1954); Peg and Walter McGraw, *Assignment: Prison Riots* (1954); Blake McKelvey, *American Prisons* (1936); T. M. Osborne, *Prisons and Common Sense* (1924); L. N. Robinson, *Penology in the United States* (1921); *Should Prisoners Work?* (1931); E. H. Sutherland, *Principles of Criminology*, 5th ed. (1955); P. W. Tappan (ed.), *Contemporary Correction* (1951); Frank Tannenbaum, *Wall Shadows* (1922); N. K. Teeters, *The Cradle of the Penitentiary* (1955); D. P. Wilson, *My Six Convicts* (1952); Margaret Wilson, *The Crime of Punishment* (1931); F. H. Wines, *Punishment and Reformation* (1919).
(H. E. BAR.)

PRISONERS OF WAR. The term prisoner of war, often abbreviated as PW or POW, is commonly used to mean any person captured or interned by a belligerent power during war. In the strictest sense it is applied only to members of regularly organized armed forces but by broader definition it has also included guerrillas, civilians who take up arms against an enemy openly, or noncombatants'associated with a military force.

Historical Background. — In the early history of warfare there was no recognition of a status of prisoner of war, for the defeated enemy was usually promptly destroyed on the battlefield. The women, children and elders of the defeated tribe or nation were frequently disposed of in similar fashion, although occasionally they were enslaved by the victor. The captive, whether or not an active belligerent, was completely at the mercy of his captor, and, if the prisoner survived the battlefield, his existence was dependent upon such factors as the availability of food and his usefulness to his captor. Slaughtering of prisoners was sometimes practised to terrify the enemy or to satisfy sadistic impulses of the conqueror. If permitted to live, the prisoner was considered by his captor to be merely a piece of movable property, a chattel. It is difficult to say which was less humane, immediate slaughter on the battlefield or lifetime enslavement.

Even before the dawn of the Christian era, prisoner exchange and ransom had become common, except when the enemies were barbaric tribes or infidels. Differences in war aims often determined the treatment of captives. During religious wars, for example, it was generally considered a virtue to put nonbelievers to death, but in the time of the Roman conquests of Julius Caesar a captive could, under certain circumstances, become a freedman within the Roman empire.

As warfare changed, so did the treatment afforded captives and members of defeated nations or tribes. Enslavement of enemy soldiers declined during the middle ages but ransoming was widely practised and continued even as late as the 17th century in Europe, A notable example was the ransoming of King Richard the Lion Hearted during the crusades. Civilians in the defeated community were only infrequently taken prisoner, for as captives they were sometimes a burden upon the victor. Further, as they were not combatants it was considered neither just nor necessary to take them prisoner. The development of the use of the mercenary soldier also tended to create a slightly more tolerant climate for a prisoner, for the victor in one battle knew that he might be the vanquished in the next.

In the 16th and early 17th centuries some political and legal philosophers expressed their thoughts about the laws of war generally, and, in an incidental fashion, the amelioration of the effects of capture upon war prisoners. The most famous of these; Hugo Grotius, stated in his *De jure belli et pacis* ("Law of War and Peace"; 1625) that victors had the right to enslave their enemies but he advocated exchange and ransom instead. The idea was generally taking hold that in war no destruction of life or property beyond that necessary to decide the conflict was sanctioned. The treaty of Westphalia (1648) which released prisoners without ransom is generally taken as marking the end of the era of widespread enslavement of prisoners of war.

In the 18th century a new attitude of morality in the law of nations! or international law had a profound effect upon the problem of prisoners of war. The French political philosopher Montesquieu in his famous *L'Esprit des Lois* (1748) ("Spirit of the Laws"), wrote that the only right in war that the captor had over a prisoner was to prevent him from doing harm. The captive was no longer to be treated as a piece of property to be disposed of at the whim of the victor but was merely to be removed from the fight. Other writers. such as Jean Jacques Rousseau and Emeric de Vattel expanded on the same theme and developed what might be called the quarantine theory for the disposition of prisoners. From this point on the treatment of prisoners generally improved.

During the American Revolution there was no strict observance of any set of rules for the treatment of POWs. The British sometimes applied the kind of harsh punishment customarily meted out during domestic disturbances. At one stage of the conflict Gen. George Washington warned Gen. Thomas Gage that the colonists would regulate their conduct toward British prisoners "exactly by the rule you shall observe toward those of ours now in your custody." This warning illustrated a basic principle that has influenced prisoner of war practice throughout history. Each belligerent tends to treat the prisoners it holds in the same way, be it good or bad. that its own men are treated by the enemy. Shortly after the end of the Revolution the United States entered into a treaty of friendship with Prussia (1785) wherein for the first time in U.S. history regulations for dealing with prisoners mere systematically set forth. Similar provisions appeared in U.S. agreements with Tripoli in 1805, Great Britain in 1813 and with Mexico in 1848.

By the middle of the 19th century it was clear that a definite body of principles for the treatment of war prisoners was being generally recognized in the civilized world. Most of these principles were summarized in the famous code prepared in 1863 for the U.S. army in the Civil War by Francis Lieber. But observance of the principles in the Civil War and in the Franco-Prussian War left much to be desired, and numerous attempts were made in the latter half of the century to improve the lot of both wounded soldiers and prisoners. whether wounded or not. In 1874 a conference at Brussels, Belg.. prepared a declaration relative to prisoners of war but it was not ratified. In 1899 and again in 1907 international conferences at The Hague. Neth., drew up rules of conduct that gained some recognition in international law. *(See* LAWS OF WAR). But during World War I when POWs were numbered in the millions, there were many charges on both sides that the rules were not being faithfully observed. Soon after the war the nations of the world gathered at Geneva, Switz., to devise the convention of 1929 which was ratified before the outbreak of World War II by France, Germany, Great Britain, the United States and many other nations, but not by Japan or the Soviet Union.

During World War II millions of persons were taken prisoner under widely varying circumstances and experienced treatment that ranged from excellent to barbaric. In the latter category was the notorious Bataan death march of American prisoners taken by the Japanese early in 1942 in the Philippines. As the Japanese code of military conduct did not condone surrender, the number of Japanese taken prisoner by United Nations forces was limited. On the other side of the world, in Europe and north Africa, treatment of prisoners was generally more nearly in accord with the Geneva convention, though there were some shocking instances of mistreatment. The Soviet Union shrouded its actions in mystery, and many difficult problems of exchange and repatriation developed as the war came to a close. In all theatres, efforts were made through the international Red Cross committee to deliver food parcels and medical supplies to prisoners from their families and friends. After the war, international war crimes trials were held in Germany and Japan, based on the concept that acts committed in violation of the fundamental principles of the laws of war were punishable as war crimes.

Geneva Convention of 1949.—Soon after the end of World War II the 1929 Geneva convention was revised and set forth in the Geneva convention of 1949. It continued the concept earlier expressed that prisoners were to be removed from the combat zone and be humanely treated without loss of citizenship or of legal identity. The 1949 convention broadened the term prisoner of war to include not only members of the regular armed forces who have fallen into the power of the enemy but also the militia, the volunteers, the irregulars and members of resistance movements if they form a part of the armed forces, and persons who accompany the armed forces without actually being members, such as war correspondents, civilian supply contractors and members of labour service units. Even civilian inhabitants of a country not occupied by the enemy may become prisoners of war if captured when they spontaneously take up arms to resist invasion at the approach of the enemy, provided that the arms are carried openly and the laws and customs of war are respected by them. The protections given prisoners of war under the Geneva convention remain with them throughout their captivity and cannot be taken from them by the captor or given up by the prisoners themselves.

The 1949 convention specifically charged the capturing nation, or detaining power, with responsibility for treatment given prisoners. Physical mutilation and exposure to medical or scientific experiments were expressly forbidden, and the prisoners were to be protected against acts of violence, intimidation, insults and public curiosity. Reprisals against prisoners were prohibited. A prisoner was required when captured to give only his name, date of birth. service number and rank.

During their internment, which was to be in camps or compounds with other prisoners of their own nationality, language and customs, the prisoners were to be quartered, fed and clothed by the captor nation. They were also to be paid a small amount depending in its size upon their grade. Medical inspections were to be held regularly and the prisoners were to have available to them adequate medical facilities. The prisoners were to be allowed to engage in certain religious. intellectual and physical activities. Enlisted prisoners, but not officers, could be required to work for the detaining power but the work was not to be directly connected with the war and the prisoners were to be paid for the work they performed.

Prisoners were made subject to the laws, regulations and orders of the detaining power. but a distinction was made between offenses which might be punished merely by disciplinary action and those punishable by judicial processes, although those judicial processes might be by a military court. As a general rule, a prisoner was not to be sentenced by military authorities to any penalty not provided for members of the armed forces of the detaining power who had committed the same acts. Collective punishments, torture and cruelty were forbidden and a prisoner might not be punished more than once for the same offense. Only disciplinary punishment. which is relatively mild. was permitted for a prisoner captured after an attempted escape, although the prisoner might be punished more severely if in the course of his escape attempt he committed offenses entailing violence against life or limb, or against public property. or involving theft for self-enrichment. If judicial proceedings were initiated the prisoner was entitled to counsel and was to be allowed to call witnesses and have a qualified interpreter. During the conflict prisoners might be repatriated or delivered to a neutral nation for custody. At the end of hostilities all prisoners were to be released and repatriated without delay, except those held for trial or serving sentences imposed by judicial processes.

The Korean War.—When the Korean war broke out in 1950 neither the United States, the largest contributor of armed forces on the side of the United Nations, nor Communist China and North Korea on the other side, had formally ratified the Geneva convention of 1949, but early in the conflict each side announced its adherence to the principles of the convention. The communists captured about 7,190 Americans in this war while the United Nations forces captured about 120,000 Chinese and North Koreans.

Treatment of prisoners by the communists was frequently barbaric. Movements from the front lines to prison camps turned into death marches for hundreds of POWs. In the prison camps food was meagre, consisting chiefly of rice. Chinese and North Korean spokesmen pointed out that this diet conformed to the Geneva convention in that it was the same as that eaten by the detaining forces, but for U.S. and British troops it amounted virtually to slow starvation, sickness and death. Many United Nations prisoners were subjected to physical abuse, threats and psychological pressures in an effort to extort information of military value or confessions that UN forces had resorted to germ warfare. When obtained, such confessions were widely used for propaganda purposes. The term brain washing was applied to the coercive methods and indoctrination techniques employed by the communists to induce UN captives to change their political outlook and embrace communism.

The truce agreement that ended the Korean war in 1953 included detailed provisions for repatriation of POWs. The prisoners were given an opportunity to choose to return to their homeland, to remain with their captors or to go to some other country. Under supervision of the Neutral Nations Repatriation commission "explanation sessions" were held during which representatives of the prisoner's own nation were permitted to talk with him and possibly persuade him to return home. Over 21,000 communist troops chose not to return home and 21 American soldiers remained with the communists when the final accounting was made. The entire problem of "forced repatriation" was given much attention at the time by international lawyers, and it became apparent that there still existed considerable disagreement as to whether a prisoner was permitted under the Geneva convention of 1949 the right to elect not to return to his homeland.

The Korean war also illuminated another facet of the problem of handling POWs—the effort to make use of prisoner status to further national war aims. In UN prison compounds POWs often rioted and committed acts of violence upon fellow prisoners and upon guards of the UN forces, apparently in an effort to develop propaganda material for use by the communist forces during the long truce negotiations. UN prisoners in communist compounds were subjected to extensive indoctrination programs designed to furnish the communists either with converts or propaganda statements. The prisoner became an important figure in the Korean war, the object of greater attention by the combatants than in either World War I or II. It appeared that a change in the status of the POW might be taking place with the prisoner being considered still a combatant and the prison compounds mere extensions of the fighting areas. If this apparent trend were to continue it would seriously threaten the improved conditions of prisoners afforded by the Geneva conventions.

U.S. POW Code of Conduct.—Upon return of the surviving U.S. prisoners from Korea—about 4,428 men—the U.S. government undertook a formal study of POW problems, appointing a special committee of military and civilian leaders to consider all aspects of the subject. Some of the specific problems considered were the causes of the apparent defections to the enemy by a few U.S. servicemen, the truth about the so-called brain washing, the propriety of punishing returned POWs for collaboration with the enemy under duress. and the existence or creation of a uniform standard of conduct for servicemen in battle and in captivity.

The report of the committee, made public in July 1955, found proper the action of U.S. authorities in bringing some 14 servicemen to trial by courts-martial for their acts of misconduct while in a prison camp. Brain washing was found to have had little lasting effect upon the prisoners in Korea. To guide U.S. servicemen who might be taken prisoner, the committee presented the following code of conduct which the president of the United States directed all servicemen to follow:

I

I am an American fighting man. I serve in the forces which guard my country and our way of life. I am prepared to give my life in their defense.

II

I will never surrender of my own free will. If in command I will never surrender my men while they still have the means to resist.

III

If I am captured I will continue to resist by all means available. I will make every effort to escape and aid others to escape. I will accept neither parole nor special favors from the enemy.

IV

If I become a prisoner of war, I will keep faith with my fellow prisoners. I will give no information or take part in any action which might be harmiul to my comrades. If I am senior, I will take command. If not, I will obey the lawful orders of those appointed over me and will back them up in every way.

V

When questioned, should I become a prisoner of war, I am hound to give only name, rank, service number and date of birth. I will evade answering further questions to the utmost of my ability. I will make no oral or written statements disloyal to my country and its allies or harmful to their cause.

VI

I will never forget that I am an American fighting man, responsible for my actions, and dedicated to the principles which made my country free. I will trust in my God and in the United States of America.

BIBLIOGRAPHY.—L. F. L. Oppenheim, *International Law*, vol. ii, 7th ed. (1952) ; W. E. S. Flory, *Prisoners of War: A Study in the Development of International Law* (1942) ; Herbert C. Fooks, *Prisoners of War* (1924) ; Julius Stone, *Legal Controls of International Conflicts* (1954) ; G. G. Lewis and J. Mewha, *History of Prisoner of War Utilization by the U.S. Army, 1776–1945,* Dept. of Army pamphlet, 20–213 (1955).
(G. S. PH.)

PRISTINA, a town in Serbia, Yugos. Pop. (1961) 40,071. Pristina was the seat of government of Stephen Nemanya, founder of the Serbian empire, and to the west lies the famous Field of Blackbirds where the empire was destroyed by the Turks in 1389.

PRITCHARD, CHARLES (1808–1893), British clergyman and astronomer who was among the first to apply photography to the determination of stellar parallax, was born at Alberbury, Shropshire, on Feb. 29, 1808. He was educated at St. John's college, Cambridge, elected a fellow of his college in 1832, was ordained in 1834 and became a schoolmaster. After his retirement in 1862, he was able to devote himself to his interest in astronomy, and was elected president of the Royal Astronomical society in 1866. In 1870 he was elected Savilian professor of astronomy at Oxford and founded the new university observatory. In 1881 he commenced a systematic study of stellar photometry and measured the relative brightness of 2,784 stars between the north celestial pole and about −10° declination; the results were published in 1885 in his Uranornetria *Nova Oxoniensis,* for which he was awarded, conjointly with E. C. Pickering, the Royal Astronomical society's gold medal (1886). Between 1888 and 1892 he made a systematic measurement of the parallax of second-magnitude stars. Throughout his life, Pritchard regretted being without a pastoral cure. Many of his frequent religious addresses to learned bodies, some of them concerning the harmony between science and Scripture, were published. Pritchard died on May 28. 1893. (O. J. E.)

PRIVAS, town of France, capital of *département* of Ardèche, 95 mi. S.W. of Lyons. Pop. (1954) 4,896.

Privas is first heard of in the 12th century, as a possession of the counts of Valentinois, and later as the seat of a separate barony. As a Protestant stronghold, it suffered during the Wars of Religion. It passed in 1619 to the vicomte de Lestrange, a Roman Catholic noble. A general rising followed, and in 1629 it was besieged and destroyed by Louis XIII, who decreed that it should not be again inhabited; but in 1632 the inhabitants returned.

PRIVATEER, an armed vessel belonging to a private owner, commissioned by a belligerent state to carry on operations of war. The commission is known as letters of marque. Acceptance of such a commission by a British subject is forbidden by the Foreign Enlistment act 1870. Privateers stand in a position between that of a public ship of war and a merchant vessel, and the raising of merchant vessels to the status of warships has given rise to so much difficulty in distinguishing between volunteer warships and privateers that the subject mas made one of those for settlement by the Second Hague conference (1907). By Convention vii a converted merchant ship cannot have the status of a warship unless it is placed under the direct authority, immediate control and responsibility of the power the flag of nhich it flies (art. 1) Conerted merchant ships must bear the external marks which distinguish the warships of their nationality (art. 2). The commander must be in the service of the state and duly commissioned, and his name must figure on the list of the officers of the fighting fleet (art. 3). The crew must be subject to military discipline (art. 4). A converted merchant ship must observe the laws and customs of war (art 5); and such conversion must be announced in the list of warships of the belligerent country. Privateering is now a matter of much less importance as the result of the Declaration of Paris, 1856 (*q.v.*), by which it was abolished.

PRIVET, any shrub of the genus *Ligustrum,* belonging to the olive family (Oleaceae), and containing about 50 species, natives of temperate and tropical regions of the old world; only the common privet (*Ligustrum* vulgare) is a native of Europe and northern Africa. Privets have evergreen or nearly evergreen opposite entire leaves, and dense clusters of small, white, tubular four-parted flowers, followed by small, globular, usually black fruits. The best-known species is the common European privet, which makes good hedges; there are numerous varieties with variegated leaves. The California privet (L. *ovalifolium*), half-evergreen and native to Japan. is the most planted hedge throughout the U.S. and thrives in Great Britain. *L. japonicum,* the wax privet, L. *lucidum* and L. *massalongianum* are fine evergreen species, hardy only in warm regions. Mock privet, *Phillyrea,* a member of the same family, is an ornamental evergreen shrub from the Mediterranean region, hardy only in warm places. (N. TR.)

PRIVILEGE, in law, an immunity or exemption conferred by special grant in derogation of common right. The term is derived from *privilegium,* a law specially passed in favour of or against a particular person. In Roman law the latter sense was the commoner; in modern law the word bears only the former sense. Privilege in English law is either personal or real — that is to say, it is granted to a person, as a peer, or to a place, as a university. The most important instances at present existing in England are the privilege of parliament (*see* PARLIAMENT), which protects certain communications irom being regarded as libellous (*see* LIBEL AND SLANDER), and the privilege of the client by which counsel and solicitor are protected from disclosing, in judicial proceedings, information which has come to them in that relation. This does not extend to clergymen or medical attendants (*see* Observations by Mr. Justice McCardie in *The Times,* July 19, 1927). Privileged copyholders were those held by the custom of the manor and not by the will of the lord. There are certain debts in most countries which are said to be privileged — that is, such debts as must first be deirayed by the executor out of the personal estate of the deceased, in payment, for example, of funeral expenses or servants' wages. There are certain deeds and summonses which are privileged in Scots law, the former because they require less solemnity than ordinary deeds, the latter because the ordinary *induciae* are shortened in their case (*see* Watson, *Law Dictionary, s.v.* "Privilege"). The priority formerly possessed by specialty debts was abolished in 1869. (*See* DEBTOR AND CREDITOR LAW.)

In the United States the term privilege is of considerable political importance. By art. iv, sec. 2 of the constitution, "the citizens of each State shall be entitled to all privileges and immunities of citizens in the several States." By art. xiv, sec. 1 of the amendments to the constitution (enacted July 28, 1868), "no State shall make or enforce any lam which shall abridge the privileges or immunities of citizens of the United States." It will be noticed that the former applies to citizens oi the states, the latter to citizens of the United States. "The intention of this clause (art. iv) was to confer on the citizens of each State, if one may so say, a general citizenship, and to communicate all the privileges and immunities which the citizens of the same State mould have been entitled to under the like circumstances" (Story, *Constitution of the United States,* 1806). The clauses have several times been the subject of judicial decision in the supreme court. With regard to art. iv it was held that a state licence tax discriminating against commodities the production of other states was void as abridging the privileges and immunities of the citizens of such other states (*Ward* v.

State of Maryland, 12 Wallace's Reports, 418). With regard to art. xiv, 1, it was held that its main purpose was to protect from the hostile legislation of the states the privileges and immunities of citizens of the United States, looking more especially to the then recent admission of Negroes to political rights. Accordingly it was held that a grant of exclusive right or privilege of maintaining slaughterhouses for 21 years, imposing at the same time the duty of providing ample conveniences, was not unconstitutional, as it was only a police regulation for the health of the people (*The Slaughter-House Cases,* 16 Wallace, 36). The same has been held of a refusal by a state to grant to a woman a licence to practise law (*Bradwell* v. *The State,* 16 Wallace, 130), of a state law confining the rights of suffrage to males (*Minor* v. *Happersett,* 21 Wallace, 162), and of a state law regulating the sale of intoxicating liquors (*Bartemeyer* v. *Iowa,* 18 Wallace, 129). Suits to redress the deprivations of privilege secured by the constitution of the United States must be brought in a United States court. It is a crime to conspire to prevent the free exercise and enjoyment of any privilege, or to conspire to deprive any person of equal privileges and immunities, or under colour of lam to subject any inhabitant of a state or territory to the deprivation of any privileges or immunities (*Revised Statutes of United States,* sec. 5507, 5510, 5519).

It is sometimes difficult to distinguish between "privileges" and "rights" in the United States, but privileges are more general and the act of suffrage is considered a "privilege" rather than a "right."

PRIVY **COUNCIL,** theoretically the British sovereign's private council, as distinct from the medieval great council, or council of magnates. and from council in parliament, now called parliament. It ceased to be an active body because (1) it lost most of its judicial functions; (2) the sovereign preferred to use informal meetings of ministers in cabinet; and (3) the sovereign ceased to take responsibility for political decisions. Meetings are held from time to time for the taking of formal decisions (*e.g.,* the making of orders in council), but usually only the quorum of three lords of the council are present and there is no discussion.

There is, however, a privy council office, with the lord president of the council as responsible minister. It is concerned with the making of orders in council and with a wide variety of functions deriving mainly from the power of the sovereign in council to issue royal charters, now used chiefly by municipal corporations and by charitable bodies engaged in education, research, the encouragement of literature, science, art, etc. Among the bodies with which it is concerned are the universities, various research councils (*e.g.,* the agricultural research council, the medical research council and the research council of the department of scientific and industrial research) and the bodies concerned with the maintenance of professional standards (*e.g.,* the general medical council). It bears the main responsibility for scientific research through the department of scientific and industrial research. Usually the privy council functions through committees, some standing and some *ad hoc.* The most famous of its committees is, however, statutory, the judicial committee of the privy council, which hears appeals from ecclesiastical courts, prize courts and courts from all colonies and some independent countries of the commonwealth (see PRIVY COUNCIL, JUDICIAL COMMITTEE OF).

History of the Privy Council.—The privy council, like all the British institutions of central government, is descended from the court of the Norman kings. This *curia regis,* composed of the king's tenants in chief, his household officials and anyone else whom the king chose to summon, performed all the functions of central government. According to feudal theory, tenants owed suit to their lord's court; but every great lord had also his household officials to transact his daily business. The *curia regis* expanded or contracted according to the nature of the business under consideration. The ordinary routine would be carried out by the officials, assisted by such barons as happened to be at court; for more important business the king would secure the attendance of a greater number of his tenants in chief; and on really vital matters the household officials would tend to become a numerically insignificant technical element in a large feudal assembly.

As time went by the larger and smaller gatherings came to be distinguished adjectivally; later, these adjectives developed a technical significance, until, although still remaining for a time merely different manifestations of a one and indivisible body, the larger assembly developed into the great council and the parliament. the smaller into the king's council. In early days the presence of many barons at conciliar meetings was the mark of a strong king; later, as the barons came to realize that attendance was not merely a tiresome incident of feudal tenure but a source of political power, that obligation became a privilege. Thus, in the later middle ages there developed a struggle between king and greater barons for the control of the king's council. In the end the barons failed to secure their greater demands—exclusive membership and the control of appointment and dismissal—because, though anxious to control and willing to be appointed, they could never be relied upon for constant attendance. Further, with the passing of the feudal organization of society, baronial counsel ceased to be expert advice on matters of government.

By the time of Henry VII this council had become the instrument of the crown. It was composed of an inner ring of counselors proper, who took an oath and sat at the council board, and of an outer ring of technical experts and dignitaries. Though they might occasionally be called upon for advice, the latter were not members of the board, did not take the conciliar oath, but merely that of their respective offices, and performed the technical and routine work of the central and provincial courts of the council. It was the policy of the Tudors to rule the country paternally by the prerogative exercised through the medium of the council.

This conception of government necessitated precision, subdivision and specialization, and thus the king's council and its functions were divided among the privy council, the courts of Star Chamber, of requests and of high commission (*qq.v.*), and such local offshoots as the courts and councils of the north, and of Wales and the Marches. A distinction between the council with the king and the council at Westminster had appeared from time to time during the middle ages. It now became "sharper and more permanent." The body following the king was commonly known as the council at court, while the other continued to be called the king's council in the Star Chamber. The former body became the privy council.

This conciliar government was admirably suited to a period of transition. But the need of this somewhat arbitrary, if paternal, government had passed with the Tudors. Moreover, this small but all-powerful bureaucracy depended for its efficiency on a resolute and discriminating sovereign, capable of choosing the right men and of superintending their labours. The Stuarts did not possess these qualifications. The house of commons, hitherto accustomed to follow the leadership of privy councilors, had now, with increased experience of partnership in government, developed a mind and policy of its own. Of the judicial aspect of the council's activities the common lawyers were coming to show an even more threatening jealousy, a jealousy justified by the misguided action of the Stuarts in checking the natural evolution of these courts toward independence of executive control and in using them to enforce, not justice, but policy. No wonder, then, that as religious and constitutional controversies developed between crown and parliament the attention of malcontents became focused on conciliar jurisdiction, nor that, when the parliamentary cause at last triumphed in 1641, the whole system of conciliar government was swept away. Only the privy council was spared. It was never legally abolished. It perished in the interregnum (though the name was resuscitated in 1657) and was restored with the return of Charles II in 1660.

Both in the middle ages and for several centuries later contemporary opinion favoured 20 as about the ideal total of conciliar membership. But seldom did practice conform with theory. When the privy council register begins, in 1540, we do, indeed, find 19 members, but by Henry VIII's death there were 29. In Edward VI's reign the record mas 40, in Mary's 44, and, although Elizabeth I reduced the numbers to between 12 and 20, the Stuarts, as usual, were less successful. By 1623 the total had increased to 35, and Charles I's council averaged about the same figure. At the Restoration the problem of numbers became even more acute. Charles II managed to begin with only 28, but the total had reached 47 by 1679. Sir William Temple's abortive attempt at conciliar reform temporarily reduced the figure to 33, but by 1688 it was back again at 48, by 1707 it had reached 60 and, by 1723, 67. In practice, however, Charles II and all later monarchs preferred to have matters of policy discussed privately by their principal advisers in cabinet.

The last serious attempt to restore the privy council to its former influence may be found in the clause of the Act of Settlement (1701), which enacted that, on the Hanoverian accession, "all matters and things relating to the well-governing of the kingdom, which are properly cognizable in the privy council by the laws and customs of this realm, shall be transacted there, and all resolutions taken thereupon shall be signed by such of the privy council as shall advise and consent to the same." But the proposal was by that date impracticable, and the clause was repealed in 1705 before it even came into force. The council board had been not merely short-circuited by the cabinet, it had even lost the power of debating such measures as came before it. In 1711 a debate on the subject in parliament elicited the remark that "the privy counsellors were such as were thought to know everything and knew nothing. Those of the cabinet council thought nobody knew anything but themselves." And the last occasion on which the council asserted its former rights was when, in 1714, as Queen Anne lay dying, certain Whig lords forced their way in at a meeting of the lords of the committee (see CABINET), claimed their right to be present as counselors of the crown, converted the meeting into a session of the privy council and, reinforced by their conciliar colleagues, ushered in the Hanoverian succession. From the accession of George I the privy council may be described as a purely formal body meeting on purely formal occasions to transact purely formal business. By 1960, there were more than 300 "right honourable lords and others of Her Majesty's Most Honourable Privy Council." They were mostly dignitaries who had held, or held, high political, judicial or ecclesiastical office, though the list occasionally included eminent persons in science or letters. Office lasts for the life of the sovereign and six months after, but a new sovereign may renew the appointment. See also references under "Privy Council" in the Index volume.

BIBLIOGRAPHY.—A. V. Dicey, *The Privy Council* (1860); Sir William Anson, *Law and Custom of the Constitution,* vol. ii, 4th ed. (1935); C. L. Scofield, *Court of Star Chamber* (1900); I. S. Leadam, *Select Cases Before the King's Council in the Star Chamber* (1903); Lord E. Percy, *The Privy Council Under the Tudors* (1907); J. F. Baldwin, *The King's Council in England During the Middle Ages* (1913); J. E. A. Jolliffe, *Constitutional History of Mediaeval England* (1937); D. L. Keir, *Constitutional History of Modern Britain* (1938).

(F. L. B.; W. I. J.)

PRIVY COUNCIL, JUDICIAL COMMITTEE OF.

From the abolition of the Star Chamber in 1641 until 1833, petitions from overseas to the crown, whether by way of appeal or otherwise, came before a general committee of the privy council which gave advice (as does the judicial committee) on what order should be made. In that year, while the approach by way of appeal to the king remained, the procedure was systematized and a judicial tribunal and, later, rules of procedure instituted. Certain matters, such as admiralty, were subsequently transferred to the high court of justice and so, by way of appeal, to the court of appeal and the house of lords.

The Statute of 1833.—This act provided in its first section for a new juridical composition for the council, to be headed by the president for the time being thereof, and the lord high chancellor and other learned dignitaries as there set forth. These, it was enacted, "shall form a committee of his majesty's said privy council and shall be styled the judicial committee of the privy council."

In later years the personnel of the committee was changed and enlarged. It now consists of the lord chancellor, the lord president of the council and the lords of appeal in ordinary, together with certain other members. To them are added such other members of the privy council as shall from time to time hold or have held "high judicial office," that is, membership of the court of appeal and high court or court of session in the United Kingdom, and certain judges of the dominions who are privy councillors.

By the third section of the 1833 act, it was provided: "That all appeals or complaints in the nature of appeals whatever, which, either by virtue of this Act, or of any law, statute, or custom, may be brought before his majesty or his majesty in council from or in respect of the determination, sentence, rule, or order of any court, judge, or judicial officer, and all such appeals as are now pending and unheard, shall from and after the passing of this Act be referred by his majesty to the said judicial committee of his privy council, and that such appeals, causes, and matters shall be heard by the said judicial committee, and a report or recommendation thereon shall be made to his majesty in council for his decision thereon as heretofore, in the same manner and form as has been heretofore the custom with respect to matters referred by his majesty to the whole of his privy council or a committee thereof (the nature of such report or recommendation being always stated in open court)."

Appeals are by petition, and the judgment is in the form of an opinion to the king, humbly advising what judgment should be given. The judicial committee, unlike the house of lords, is not bound by previous decisions, and minority opinions are not publicly expressed.

The Commonwealth.— In 1867 the principal British North America act was passed. By sections 91 and 92 the powers of the Canadian dominion parliament and functions of the provincial legislatures were distinguished. It became evident that the task of defining the respective jurisdictions not only interprovincially but between dominion and province would be a difficult task. The authority of the judicial committee of the privy council so to act was clear from the act of 1833, but the Canadian parliament thought fit to deal further with the matter in the 47th section of their Supreme and Exchequer Courts act (38 Victoria, chap. 11) in the following terms:

"The judgment of the Supreme Court shall in all cases be final and conclusive, and no appeal shall be brought from any judgment or order of the Supreme Court to any court of appeal established by the parliament of Great Britain and Ireland, by which appeal or petitions to her majesty may be ordered to be heard: saving any right which her majesty may be graciously pleased to exercise by virtue of her royal prerogative."

The Statute of Westminster.—Under the powers vested in it, the judicial committee formerly pronounced a series of several judgments on matters of imperial importance, but later, as regards the dominions, this field of judicial activity became very restricted. The effect of the passage of the Statute of Westminster in 1931 was that dominions which had adopted it were in a position to abolish the right of appeal from their courts to the judicial committee. Acting under this power Canada in 1935 abolished appeals to the judicial committee in criminal matters.

The Supreme Court act, 1949, came into force on Dec. 23, 1949. By Section 3 the right of appeal from Canadian courts was abolished, save that appeal was preserved in respect of litigation already in process at the time. By the British North America act, 1949, Newfoundland was incorporated into Canada.

The commonwealth of Australia, a federation of six states, had not yet adopted the Statute of Westminster, but the right of appeal was limited by Australian legislation to provisions specifically reserved in the constitution, and in any case leave of the Australian high court was needed before an appeal to the committee could be brought. This leave was, in practice, rarely given.

In the Union of South Africa, with a unitary and not a federal constitution, the right of appeal, with leave from the supreme court, to the judicial committee was ended in 1950. Previously this right had existed but actually leave to appeal was almost impossible to obtain. Such appeals had never been popular since it was felt that an English court must have an inadequate knowledge of the working of the system of Roman-Dutch law prevailing in the Union.

New Zealand also had not yet adopted the Statute of Westminster, and legal opinion there continued to be strongly opposed to the abolition of the right of appeal to the judicial committee, but in fact very few appeals came to the committee from that country.

The Republic of Ireland, while yet in law a dominion, took advantage of the power to abolish the right of appeal in all cases by the Irish Free State constitution (amendment act, 1943)—a course the validity of which was approved in the case of *Moore* v. *Attorney General for Eire* (1935) A.C. 484. Appeals from Northern Ireland were to the house of lords.

In India, appeals were abolished by the Indian Abolition of Jurisdiction of Privy Council act, 1949. Courts were established in 1726, by charter of George I, in the three settlements of Madras, Bombay and Bengal, and the right of appeal to his majesty in council was given. Subsequent charters constituted supreme courts and these in time were replaced by various high courts created under the charter, Acts 24 and 25 Victoria, chap. 104. These high courts were constituted by letters patent which contained rules providing for appeals to the privy council.

Other high courts were established later, and these were also constituted by letters patent containing similar provisions as to appeals. The Civil Procedure code also gave a right of appeal under prescribed conditions and there followed an order of council of Feb. 9, 1920, which replaced a much earlier one issued under the Judicial Committee Act of 1833. So great, at one time, was the growth of Indian judicial business before the committee, that the latter had to be divided into two sections, one of which was entirely. or almost entirely. occupied with Indian appeals. By sec. 30 of the Judicial Committee Act of 1833, Indian judges were made eligible as members of the committee; in 1928 provision was made for their remuneration.

Indian business was greatly affected by the passing of the Indian Independence act, 1947, which provided for the setting up, as from Aug. 15, 1947, of two separate independent dominions, India (now a republic) and Pakistan. By reason of the Federal Court (Enlargement of Jurisdiction) act, 1949, passed by the legislature of the dominion of India, civil appeals might come to the judicial committee from the federal courts of India, but not from the high courts, while the committee remained the supreme tribunal in criminal cases where broad principles of natural justice were concerned.

Pakistan followed India in terminating the right of appeal.

In the case of the crown colonies and protected and trust territories (not being dominions under the Statute of Westminster, but including the Channel Islands and the Isle of Man) the position remained virtually the same after 1833.

General Opinions.— This procedure has not often been employed in the privy council. By sec. 4 of the act the crown may refer any matter to the judicial committee for hearing or consideration. This enabled the committee to give general opinions otherwise than on immediate facts—a power rarely invoked in British jurisprudence. Such opinions had, however, been given in boundary disputes between Canada and Newfoundland and under the Irish treaty of 1921 and on some other matters.

Ecclesiastical Jurisdiction.— The ecclesiastical jurisdiction of the king in council is derived from the statute 25 Henry VIII, chap. 19, which followed the act of the previous year, 24 Henry VIII, chap. 12, abolishing appeals to Rome. By 25 Henry VIII, chap. 19, an appeal was given from the courts of the archbishop to the king in chancery and it was enacted that upon such appeal:

"A Commission shall be directed under the great seal to such persons as shall be named by the King's Highness his heirs or successors like as in case of appeal from the Admirall Court to hear and definitely determine such appeals and the causes concerning the same."

This commission, known as the High Court of Delegates, was abolished by 2 and 3 William IV, chap. 92; and, by 3 and 4 William IV, chap. 41, ecclesiastical appeals were transferred to the judicial committee. The result was that thereafter appeals irom the two courts of archbishops (*i.e.*, Arches court of Canterbury and provincial court of York) lay to the king in council.

With regard to appeals under the Clergy Discipline act, 1892 (dealing with morals). there was established an alternate right of appeal from the consistory court of bishops either to the court of the archbishop or to the king in council direct. If the appellant elected the former there was no further appeal to the king in council. On the hearing of ecclesiastical appeals under the rules made under the Appellate Jurisdiction act, 1876, five bishops were to be summoned as ecclesiastical accessors, of whom three at least had to be present. Cnder the Endowed Schools act, 36 and 37 Victoria, chap. 87, appeals lay to his majesty in council from schemes prepared by the board of education affecting schools subject to the Endowed Schools act. Under the Union of Benefices measure, 1923, of the national assembly of the Church of England, an appeal lay to the king in council against a scheme of the ecclesiastical commissions uniting two or more benefices.

Practice.— The following is a paraphrase of the privy council rules:

All appeals shall be brought either in pursuance of leave obtained from the court appealed from, or, in the absence of such leave, in pursuance of special leave to appeal granted by his majesty in council upon a petition in that behalf presented by the intending appellant.

A petition ior special leave to appeal shall state succinctly and clearly all such iacts as it may be necessary to state in order to enable the judicial committee to advise his majesty whether such leave ought to be granted. The petition shall deal with the merits of the case only so far as is necessary for the purpose of explaining and supporting the particular grounds upon which special leave to appeal is sought.

Whenever it shall be found that the decision of a matter on appeal is likely to turn exclusively on a question of law, the parties, with the sanction of the registrar of the privy council, may submit such question of law to the judicial committee in the form of a special case, and print such parts only of the record as may be necessary for the discussion oi the same.

The judicial committee may order a full discussion of the whole case, ii they shall so think fit, and, in erder to promote such arrangements and simplification of the matter in dispute, the registrar may call the parties before him, and having heard them, and examined the record, report to the judicial committee as to the nature of the proceedings.

All petitions for orders or directions as to matters of practice or procedure arising after the lodging of the petition of appeal and not involving any change in the parties to an appeal shall be addressed to the judicial committee. All other petitions shall be addressed to his majesty in council, but a petition which is properly addressed to his majesty in council may include, as incidental to the relief thereby sought, a prayer for orders or directions as to matters of practice or procedure.

As soon as the appealhas been admitted, whether by an order of the court appealed from or by an order of his majesty in council granting special leave to appeal, the Appellant shall without delay take all necessary steps to have the record transmitted to the registrar of the privy council, and the registrar shall, with all convenient speed, certify to the registrar of the privy council that the respondent has received notice, or is otherwise aware, of the order oi the court appealed from admitting the appeal, or of the order of his majesty in council giving the appellant special leave to appeal, and has also received notice, or is otherwise aware, of the dispatch of the record to England.

A petition not relating to any appeal of which the record has been registered in the registry of the privy council, and any other petition containing allegations of fact which cannot be verified by reference to the registered record or any certificate or duly authenticated statement of the court appealed irom, shall be supported by affidavit. Where the petitioner prosecutes his petition in person, the said affidavit shall be sworn by the petitioner himself and shall state that, to the best oi the deponent's knowledge, iniormation, and beliei, the allegations contained in the petition are true. Where the petitioner is represented by an agent, the said affidavit shall be sworn by such agent and shall, besides stating that, to the best oi the deponent's knowledge, information and belief, the allegations contained in the petition are true, show how the deponent obtained his instructions and the information enabling him to present the petition.

The registrar of the privy council may reiuse to receive a petition on the grounds that it discloses no reasonable cause of appeal, or is frivolous, or contains scandalous matter, but the petitioner may appeal, by way of motion, from such refusal to the judicial committee.

As soon as an appeal is set down, the appellant shall attend at the registry of the privy council and obtain ten copies of the record and cases to be bound for the use of the judicial committee at the hearing. The copies shall be hound in cloth or in half leather with paper sides, and six leaves of blank paper shall be inserted before the appellant's case. The iront cover shall bear a printed label stating the title and privy council number of the appeal, the contents of the volume, and the names and addresses of the London agents. The several documents, indicated by incuts, shall be arranged in the following order: (1) appellant's case; (2) respondent's case; (3) record (if in more than one part, showing the separate parts by incuts, all parts being paged at the top of the page); (4) supplemental record (if any); and the short title and privy council number of the appeal shall also be shown on the back.

The appellant shall lodge the bound copies not less than four clear days before the commencement of the sittings during which the appeal is to be heard.

The registrar of the privy council names a day on or before which appeals must be set down if they are to be entered in the list of business for the ensuing sittings. All appeals set down on or before the day named must, subject to any directions from the committee or to any agreement between the parties to the contrary, be entered in such list of business and shall, subject to any directions from the committee to the contrary, be heard in the order in which they are set down.

The registrar of the privy council shall, subject to the provisions of rule 42, notify the parties to each appeal by summons, at the earliest possible date, of the day appointed by the judicial committee for the hearing of the appeal, and the parties shall be in readiness to be heard on the day so appointed.

At the hearing of an appeal not more than two counsel may be admitted to be heard on a side.

In admiralty appeals the judicial committee may, if they think fit, require the attendance of two nautical assessors.

Where the judicial committee, after hearing an appeal, decides to reserve its judgment thereon, the registrar of the Privy Council shall in due course notify the parties by summons of the day appointed by the committee for the delivery of the judgment.

Conclusion.—A notable difference between British jurisprudence and the jurisprudence of Rome is that while Rome gave Roman law to its whole empire, the British empire sought to give to its component parts their own particular law. This imposed upon the judicial committee a task of great complexity. Systems of jurisprudence totally different in outward seeming, but respectively in entire accord with the historical and tribal traditions of the various populations and parts of the empire, had to be administered in such a fashion as, compatibly with British notions of natural justice, to accept and respect not only established local traditions, customs and laws but also rules of succession, rights of property and even of religion prevailing in various parts of the commonwealth.

It had been shown that the bonds of empire might be loosened without being broken, and that it was possible for countries within the commonwealth to evolve from a position of subordination to one of equality without thereby endangering the ties mutually binding the member states of the British Commonwealth of Nations. Nevertheless, the years after World War I saw a considerable reduction in the jurisdiction and business of the judicial committee, and in several instances the existence of the right of appeal to the king in council was felt to be incompatible with complete independence. The uniformity of common law principles, applicable in the past to many varying local conditions, may thus be partly lost.

In the case of ecclesiastical appeals, long a matter of religious dissension, the Church of England sought a new canon to establish its own final court of appeal.

BIBLIOGRAPHY.—J. F. Baldwin, *The King's Council in England during the Middle Ages* (1913); N. de M. Bentwich, *The Practice of the Privy Council in Judicial Matters*, 2nd ed. (1926); W. R. Anson, *The Law and Custom of the Constitution*, vol. 2, 4th ed. (1935); A. B. Keith, *The Dominions as Sovereign States* (1938); W. S. Holdsworth, *History of English Law*, vol. 1, 7th ed. (1938); D. H. J. Chalmers and O. H. Phillips, *Constitutional Laws of Great Britain, the British Empire and Commonwealth*, 6th ed. (1946); K. C. Wheare, *Statute of Westminster and Dominion Status*, 3rd ed. (1947). (H. SLE.)

PRIVY PURSE is the amount set apart in the civil list (*q.v.*) for the private and personal use of the sovereign in England. During the reign of Queen Victoria it was £60,000 a year, but on the accession of Edward VII the amount was fixed at £110,000 a year, which was the amount paid to the last sovereign (William IV) who had a queen consort. Under Queen Victoria the offices of keeper of the privy purse and private secretary were combined.

These officials, with their subordinates, are of the king's personal staff.

PRIZE, in law, may be defined as the vessels or goods of the enemy or of a neutral, or of a subject of the captor's own state or of a subject of an ally, captured *jure belli* by a belligerent captor on the high seas, or in rivers, ports and harbours and even in some circumstances on land (*see* the *Roumanian*, 1914, I.B. & C.P.C. 75). For England the term "vessels" includes merchantmen, lighters, rafts, tugs, boats and all other naval craft together with their appointments, such as signalling instruments (*see* the *Anickab*, 1919, 3 B. & C.P.C. 611; 1922, A.C. 235). The term "goods" includes "cargoes" which covers "choses in action" (the *Fredrick VIII*, p. 43, 1917); "bonds and securities" (the *Noordam* [No. 2], 1920, A.C. 904); and "moneys" (*Turkish moneys taken at Mudros*, 1916, 2 B. & C.P.C. 336). Not only goods shipped under a bill of lading (*Ten Bales of Silk at Port Said*, 1916, 2 B. & C.P.C. 13) but also goods dispatched by parcel post are carried by the term (*see* the *Tubantia*, 1916, L.R.P.C. 282). The property in prize does not pass to the captor until it has been brought within the jurisdiction and adjudicated upon. But the property in captured warships passes, on capture, to the captor, and they are only brought into the prize court in order that the prize money may be determined.

United States.—The term prize is "used as a technical term to express a legal capture." (*Miller* v. *The Resolution*, 1781, 2 Dallas Reports, 1.) The courts "assume that 'capture' and 'prize' are not convertible terms, and that for the subject of capture to be made prize for the benefit of the captors the taking must meet the conditions imposed by the statutes." (*The Manila Prize Cases*, 1903, 188 U.S. Reports, 254.)

Captures made on inland waters of the United States are not "liable to condemnation as maritime prize." (*The Cotton Plant*, 1870, 10 Wallace Reports, 577.) The act of congress of July 17, 1862, "excludes property on land from the category of prize for the benefit of the captors." (*United States* v. *Alexander*, 1864, 2 Wallace Reports, 404.) The word "ship," however, "embraces her boats, tackle, apparel and appurtenances because part of the ship as a going concern, and, for the same reason, ship or vessel of war includes her armament, search-lights, stores, everything, in short, attached to or on board the ship in aid of her operations." (*The Manila Prize Cases*, 1903, 188 U.S. Reports, 254.) Nonsea-going boats such as barges propelled by sweeps and by poling and boats having no means of propulsion are not regarded as maritime prize. (*Ibid.*) The United States long argued for the exemption from capture of private property at sea, but this doctrine was not accepted by other states or by the courts. The United States abolished prize money by an act of March 3, 1899. (30 U.S. Stat. 1007.)

Other Countries.—The French prize court will not adjudicate on the validity of captures of warships or on captures effected on lakes or other inland waters. Otherwise, prize covers the same property as in England. In Italy prize extends to captures on the high seas and inland waters which include captures in ports, quays, docks and other places in which maritime traffic is carried on. According to the German Prize code, 1909, prize includes enemy and neutral vessels and goods thereon, but not neutral public vessels. Enemy public vessels are confiscatable without other proceedings. German ships and cargoes and German goods on neutral or enemy vessels are excluded. During World War I the German prize courts declared themselves incompetent if the prize was destroyed without being first captured. Thus, claimants were deprived of their legal remedy for the sinking at sight of their vessels, contrary to the accepted customs of war.

PRIZE COURTS AND PRIZE LAW, in naval warfare, are instrumentalities by which the legality of captures of ships and goods at sea and incidental questions are determined. The establishment of such courts is both a right and duty of belligerents. Lord Parker observed that: "but for the existence of Prize Courts no one aggrieved by the acts of a belligerent power in times of war could obtain redress otherwise than through diplomatic channels and at the risk of disturbing international amity. An appropriate remedy is, however, provided by the fact that according to international law, every belligerent power must appoint and submit to the jurisdiction of a Prize Court to which any person aggrieved by its acts has access, and which administers international as opposed to municipal law—a law which is theoretically the same, whether the court which administers it is constituted under the municipal law of the belligerent power or of the sovereign of the person aggrieved, and is equally binding on both parties to the litigation" (*The Zamora*, 1916, 2 *A.C.* 77).

The judgment of a prize court is binding upon the parties to proceedings before it, that is, normally the captor and the individual or corporation, neutral or enemy, that challenges the validity of the capture. It is not necessarily binding. however, on the state whose national is involved, whether or not it is binding being dependent upon the conformity of the judgment with international law. In case of inconsistency the state of the captor becomes responsible to the state of the claimant, individual or corporation. As the U.S. commissioner William Pinkney pointed out before the Anglo-American mixed commission, established pursuant to the Jay treaty of Nov. 19, 1794, to determine the legality of the seizure of the American ship "Betsey" by the British captor:

> A belligerent has this jurisdiction for its own safety—because it is answerable to other nations for the conduct of its captors. It is allowed exclusive cognizance of the capture for the purpose of ascertaining whether it will confirm it and thus complete its own responsibility, or give to the claimant adequate redress against the captor and thus exonerate itself. . . . The judgment of its prize court in the last resort, in general, perfects or destroys that liability. If it grants adequate redress there is nothing to be answerable for, but if instead of doing so it completes the original injury by rendering it irreparable by any ordinary means, the national responsibility is obviously perfect. The injury becomes its own, and the neutral, from being compelled to ask redress against the captor is now authorized to ask it against his nation. . . .

Claims of belligerents against each other arising from capture are usually settled by the peace treaty. Claims of neutrals against belligerents are settled through diplomatic negotiations or, rarely, international arbitral tribunals. At the second Hague peace conference a proposal was adopted to establish an international prize court to settle disputes between neutrals and belligerents (*see* below).

As the objective of war at sea became increasingly the denial to the enemy of all trade, so prize courts and prize law and particularly the latter were gradually adapted to serve this end. Economic warfare became one of the most significant developments in World Wars I and II. This fact was shown in the expanding and eventually all-embracing concepts of contraband and blockade and the increasing severity of measures taken by belligerents, not merely against enemy, but also against neutral vessels, which came to be regarded by prize courts as permissible.

Prize Courts.—Prize courts are municipal (internal) courts and their character and organization are determined by national tradition and law. It is possible to distinguish two categories: judicial and administrative. English and United States prize courts are purely judicial but the prize courts of other nations are either purely administrative or of a mixed character.

In England, jurisdiction in matters of prize was vested from the 14th century by royal proclamations or commissions in the admiral's court along with instance jurisdiction comprising ordinary maritime cases such as collision or salvage. Statutory prize jurisdiction was conferred on the high court of admiralty by the Naval Prize act of 1864 which continued in the second half of the 20th century to be the basic law. It was amended in 1894, 1914, 1918 and 1939. By the High Court of Judicature act of 1891 and the Supreme Court of Judicature (Consolidation) act of 1925 jurisdiction in prize cases was transferred to the high court of justice and exercised by its probate, divorce and admiralty division. The practice continues, though not considered essential since 1864, to issue a royal commission at the beginning of war concerning exercise of jurisdiction in prize cases. Since 1864 appeals have been taken, in prize cases, to the judicial committee of the privy council, whose determinations are final, and in all other cases, to the court of appeal and ultimately the house of lords. The Prize act of 1939 was applicable in the United Kingdom, in the British dominions (but not in Canada and the Union of South Africa), in British protectorates, colonies and territories held under mandate from the League of Nations and in other territories in which the British crown had prize jurisdiction. In these territories prize jurisdiction was conferred upon the appropriate ordinary courts. The act of 1939 applied to ships as well as aircraft.

In the United States, the constitution (art. iii) provides that the jurisdiction of the United States shall extend "to all Cases of admiralty and maritime Jurisdiction." The judicial code (24, par. 3) provides that federal district courts shall have original jurisdiction "of all prizes brought into the United States; and of all proceedings for the condemnation of property taken as prize" (28 U.S.C.A. 41 [3]). Appeals from their decrees lie in prize cases, to the supreme court directly (Judicial Code 238, 28 U.S.C.A. 345). Bounty and prize moneys a-ere abolished by the act of March 3, 1899, which declared that "all provisions of the law authorizing the distribution among captors of the whole or any portion of the proceeds of, or providing for the payment of bounty for the sinking or destruction of vessels of enemy hereafter occurring in war, are hereby repealed" (30 Stat. 1044, sec. 13). In Britain, the Prize act of 1948 abolished prize money. In France, jurisdiction was exercised by an administrative tribunal composed of a member of the council of state *(conseil d'ktat)*, the highest administrative tribunal in France, six members chosen from the *maîtres des requêtes*, and officials of the ministries of foreign affairs and marine. The *conseil d'ktat* itself exercised appellate jurisdiction in prize cases. In Belgium prize courts were of a mixed character being composed partly of judges from the court of appeal of whom two were appointed, and four representatives of the navy and commerce. Appeals lie to the regular court of appeal. During World War II no prize court was established in Belgium. In Italy prize courts were partly judicial and partly administrative in composition; limited appeal was permitted to the court of cassation, the highest judicial authority. In Germany the prize courts of both original and appeals jurisdiction were of mixed character, and Chinese and Japanese prize courts followed the same pattern. No prize court was established in the U.S.S.R. during World War II. The difference in the character of prize courts in various countries does not necessarily mean that these countries do not administer justice, but in the fact that whereas in the United States and England prize jurisdiction is exercised by existing ordinary courts, in other countries it is the business of *ad hoc* tribunals.

Prize Law.—The law applied by prize courts is international law, customary and conventional. In England, the United States and other common-law countries the rule prevails that international law is part of the law of the land: "International law is part of our law, and must be ascertained and administered by the courts of justice of appropriate jurisdiction, as often as questions of right depending upon it are duly presented for their determination. For this purpose, where there is no treaty, and no controlling executive or legislative act or judicial decision, resort must be had to the customs and usages of civilized nations" (Justice Horace Gray, *The Paquete Habana*, 1900, 175 U.S. 677). Lord Parker said: ". . . the law which the Prize Court is to administer is not the national law or, as it sometimes is called, the municipal law, but the law of nations—in other words, international law" (*The Zamora*, 1916, 2 A.C. 77). Similarly Chief Justice John Marshall declared: "The law of nations is the great source from which we derive those rules, respecting belligerent and neutral rights, which are recognized by all civilized and commercial states throughout Europe and America" *(Thirty Hogsheads of Sugar* v. *Boyle*, 1815, 9 Cranch 191).

There is a practice of long standing for belligerents, at the outbreak of war, to enact prize law through statutory legislation dealing with both substantive and procedural rules. Thus England promulgated prize court rules in 1939; France the decrees of Sept. 2, 1939, amplified by numerous instructions; Germany the Prize Court law of Aug. 28, 1939, amended on Dec. 13, 1940; and Canada the Prize act of 1945. In the United States, congress enacted the Prize act of June 24, 1941 (55 Stat. 261), extending prize jurisdiction to aircraft. Such enactments are presumed to be declaratory of international law but they are in any event binding upon the courts. "It cannot, of course, be disputed that a prize court, like any other court, is bound by the legislative enactments of its own sovereign state. . . . But it is none the less true that if the . . . legislature passed an act the provisions of which were inconsistent with the law of nations, the prize court in giving effect to such provisions would no longer be administering international law" (Lord Parker, *The Zamora,* 1916, 2 X.C. 77). The same would be true in the United States as indicated by Justice Gray in the *Paquete Habana* (case 9), and in other countries. The difference between the Anglo-American and continental courts is that the latter do not feel free even to examine the consistency between international and municipal law since they are bound to apply the latter in any event. A difference arises in respect of British orders in council and equivalent decrees in other countries. Such orders in council are not binding upon the courts unless based upon statutes for the king in council cannot change the law administered by the courts in England any more than he can prescribe the law to be administered by prize courts. However, the prize court will apply orders in council when "they amount to a mitigation of the crown rights in favour of the enemy or neutral, as the case may be" (Lord Parker, *The Zamora,* 1916, 2 A.C. 77). Equivalent decrees would be given effect in other countries. No problem arises in connection with conventional law as this is applicable in most countries in accordance with national law. In the evolution of prize law in England and the United States precedents played a decisive role as they did in the formation of common law. Precedents do not have a comparable authority on the continent although a court would not easily depart from or overrule them.

With a view to ensuring greater uniformity in the application of law by prize courts, two methods were tried: on the one hand, the adoption of agreed rules by treaties or conventions and on the other the establishment of an international prize court. The most important among the former are: the declaration of Paris, 1856; some of the Hague conventions of 1899 and 1907 (namely the 6th convention relative to the status of enemy ships at outbreak of war, the 7th relative to the conversion of merchant ships into warships, the 11th relative to certain restrictions on the exercise of the right of capture in maritime war, and the 13th relative to the rights and duties of neutral powers in maritime war); the London declaration of 1909; and the London protocol of 1936 regarding action by submarines against merchant ships. The binding force of the Hague conventions was dubious because it depended to some extent on their having been ratified by all belligerents which was not usually the case. The conventions were, however, applied, in principle, by British prize courts in both World Wars I and II. The London declaration never entered into force but its rules were applied to the extent that they were deemed to be declaratory of customary international law. The London protocol of 1936 was largely disregarded in World War II by the major belligerents. This, at any rate, was the opinion of the Niirnberg International Military tribunal for the trial of major German war criminals:

In view of all the facts proved and in particular of an order of the British admiralty announced on May 8, 1940, according to which all vessels should be sunk at sight in the Skagerrak, and the answers to interrogatories by Adm. Chester W. Nimitz stating that unrestricted submarine warfare was carried on in the Pacific ocean by the United States from the first day that nation entered the war, the sentence on Adm. Karl Donitz is not assessed on the ground of his breaches of the international law of submarine warfare. (Judgment of Oct. 1, 1946. International Military Tribunal, *Trial of the Major War Criminals, Official Documents,* vol. i, p. 313 [1947].)

To ensure greater uniformity in the jurisprudence of prize courts the establishment of an international prize court with jurisdiction on appeals from national prize courts was envisaged at the second Hague conference in 1907. As noted above, judgments of national prize courts, in case of inconsistency with international law, engage the responsibility of the captor states. To provide a judicial method for settling disputes between states in such cases, an international tribunal would be obviously useful. It was also realized that in spite of their professions national prize courts apply international law as interpreted by their governments and they are bound by municipal statutes. However, the Hague convention of 1907 for an international prize court was never ratified.

Task of Prize Courts.—According to the principle "all prizes must be judged," the main question for prize courts is: "prize or no prize." In the past, prize courts, particularly in England and the United States, were also concerned with awarding prize and bounty moneys and allocation of shares between the crown and the admiralty, the so-called droits of the crown and the droits of admiralty. Judgments of prize courts condemning ships or cargoes or both provide a title for the captor which is "good against the world," without prejudice, of course, to the right of the injured state to seek a remedy in accordance with international law. As noted, prize courts were from a functional point of view instruments of economic warfare and continued so to function in World Wars I and II. However. new methods of depriving the enemy of supplies were developed, such as long-distance blockade and various forms of control at the ship's point of departure rather than in the course of its passage on the high seas. In spite of these innovations, which proved very effective, prize courts operated in England, France, Germany and many other countries. However, no prize courts operated in the United States during either World War I or II. In World War I, the president. authorized by the congressional joint resolution of May 12, 1917 (55 Stat. 261), took over about 100 German and Austrian ships lying in United States ports. In the Versailles treaty of June 28, 1919, Germany waived all claims arising from requisitioning, loss or damage of German ships. In World War II, the U.S. congress, proceeding in a similar fashion. enacted the Idle Foreign Vessels act (1941), which applied to all enemy and neutral vessels (55 Stat. 242). Some 80 ships, including the French liner "Normandie" were requisitioned pursuant to this act, which also provided for compensation.

The history of the matter shows that the policy of the United States has tended to avoid resort to capture and prize, and to substitute . . . gentler legal devices such as requisition for use or title upon promise or payment of just compensation. It is a fact that from 1899 to 1945, including six years of the two great wars, no prize ship or cargo was brought into a United States prize court for adjudication. Those who guide our policy . . . have employed other methods of bringing about the end result of getting foreign ships and cargoes into the war service of the United States. Thus our country has maintained its position of endeavoring to lead the world towards a general law or rule of immunity from capture or destruction of peaceful merchantmen and cargoes not contraband. (Arnold W. Knauth, "Prize Law Reconsidered," *Columbia Law Review,* p. 69 [1946].)

On the other hand, the policy against enemy merchant ships and cargoes was expressed in the official United States Navy dispatch of Dec. 7, 1941: "Execute unrestricted air and submarine warfare against Japan." It was estimated that more than 2,000 Japanese merchant ships were sunk, of which more than one half were destroyed by submarines (see SUBMARINE CAMPAIGNS [WORLD WARS I AND II]). Total war by air and on the sea against enemy shipping and stringent controls at the source of neutral shipping, reinforced by a comprehensive concept of contraband and of enemy destination, it was believed, might well reduce the scope and significance of both prize courts and prize law in a subsequent global conflict. In a limited conflict, however, prize courts and prize law continued to render the traditional service as was evidenced by the establishment of a prize court in Egypt in 1948 following the outbreak of hostilities in Palestine. On Sept. 25, 1955, the United States chief of naval operations promulgated the *Law of Naval Warfare* as the officialUnited States navy manual on the subject (NWIPIO-2, reproduced as an appendix in Tucker).

See also ADMIRALTY, HIGH COURT OF; LAWS OF WAR; VISIT AND SEARCH; ANGARY, RIGHT OF.

BIBLIOGRAPHY.—C. John Colombos, *A Treatise on the Law of Prize,* 3rd ed. (1949); A. P. Higgins and C. John Colombos, *The International Law of the Sea,* 2nd rev. ed. by C. John Colombos (1951); J. W. Garner, *Prize Law During the World War* (1927); Julius Stone, *Legal Controls of International Conflict* (1954); Robert W. Tucker, *The Law of War and Neutrality at Sea,* U.S. Naval War College *International Law Studies* (1955, 1957); S. W. D. Rowson, "Prize Law During the Second World War," *British Year Book of International Law,* pp. 160–216 (1947); Arnold W. Knauth, "Prize Law Reconsidered," *Colunzbia Law Review,* 46:69–93 (1946); H. A. Smith, *Law and Custom of the Sea,* 2nd ed. (1950); H. A. Smith, *The Crisis in the Law of Nations* (1947); Erik Castren, *The Present Law of War and Neutrality* (1954).
(L. Gs.)

PRIZREN, a town of Sarplaninski, Yugoslavia. Pop. (1953), 22,997, chiefly Albanians, with some Serbs, Greeks and Vlachs.

Prizren is 1,424 ft. above sea level among the Shar Planina mountains. Its chief buildings are the citadel and many mosques. Prizren has sometimes been identified with the ancient *Tharandus* or *Theranda*. In the 12th century it was the residence of the kings of Serbia. The town was taken by the Serbians in 1912, and assigned to them by the treaty of Bucharest (1913). Soon after the outbreak of World War I the government retired there.

PRJEVALSKY (PRZHEVALSKY), **NIKOLAI MIKHAILOVICH** (1839–1888). Russian traveler who by his explorations and route surveys contributed perhaps more than any other of his generation to the unveiling of central Asia, was born near Smolensk on March 31, 1839. He was educated at the Smolensk gymnasium and in 1855 joined an infantry regiment. In 1856 he became an officer and from 1864 to 1866 taught geography in the military school at Warsaw. The next year he was sent to Irkutsk, and in 1870 he set out from Kyakhta, southeast of Lake Baikal. traveled through Urga (Ulan Bator) and crossed the Gobi desert to Kalgan (Chang-chia-k'on), 100 mi. from Peking. Then he visited Mongolia and then returned to Urga. His second journey commenced from Kuldja in 1876 and took him southeastward across the Tien Shan and Taklamakan, for nearly 200 mi. along the foot of the Astin Tagh, and back by the same route. He set out from Zaisan on his third journey in 1879, crossed Dzungaria and continued southward over the Astin Tagh to within 170 mi. of Lhasa. which he was not allowed to visit. He then turned eastward, partly following the line of the upper Huang Ho, and crossed the Gobi to Kyakhta. The fourth journey began at Urga in 1883 and led across the Gobi. south of Koko Nor (Ch'ing Hai) and Tsaydam to the Astin Tagh and Kunlun mountains and then over the Tien Shan to Issyk-Kul. He had intended to lead another expedition. but died at its commencement at Issyk-Kul on Nov. 1, 1888. Prjevalsky made valuable collections of the flora and fauna of the regions he visited and his discoveries include the wild camel and the only known wild horse (*Equus przewalskii*). The accounts of his first two journeys have been translated into English: E. M. Morgan, *Mongolia, the Tangut Country, and the Solitudes of Northern Tibet* (1876), *From Kulja, Across the Tian-Shun to Lop-nor* (1879).

See N. M. Karataev, *Nikolai Mikhailovich Przheval'skii* (1948).
(A. M. F.)

PRO, MIGUEL (MIGUEL AGUSTÍN PRO-JUÁREZ) (1891–1927), Jesuit victim of the religious unrest in Mexico, was born on Jan. 13, 1891, at Concepcibn del Oro, Zacatecas. He had some Indian blood, and his father was a wealthy mining director. He entered the Society of Jesus in 1911; in Oct. 1914 the anticlerical measures under Pres. Venustiana Carranza obliged him. with other students for the Jesuit priesthood, to leave Mexico for California. He continued his studies in Spain, Nicaragua and at Enghien (Belgium), where he was ordained in 1925. He returned to Mexico, now under the religious persecution of Pres. P. Calles. in 1926 and for 15 months carried on his work as a priest among the people of Guadalupe with agents constantly searching for him. Every morning he offered mass secretly in the presence of many faithful. He preached in backyards, garages, factories, strengthening the faith of thousands. refusing no one who came to him for spiritual or material succour and supporting more than 100 poor families on the alms he could beg for them. In Nov. 1927 the police discovered his hiding place; he was falsely accused of complicity in a bomb plot against the life of Pres. Alvaro Obregón and on Kov. 23 was summarily shot. His connection with the international movement of the Jocistes, or Young Christian Workers, formed while he was in Belgium before ordination. helped to spread his fame rapidly.

BIBLIOGRAPHY—F. Royer, *Father Miguel Pro* (1955); Mrs. George Norman, *Cod's Jester* (1938); *see* also F. McCullagh, *Red Mexico* (1928), for eye-witness account of the execution, and Graham Greene, *The Lawless Roads* (1939). (M. DK.)

PROA, swift-sailing craft of Indian ocean pirates. The chief points which characterize these vessels are that while the weather side is rounded the lee side is flat and that there is a small similarly shaped hull swung out from the side of the main hull on poles, which acts as an outrigger. The main hull carries the mast rigging and a triangular sail.

PROBABILISM, in casuistry, is the view that, where one does not know whether an action would be sinful or permissible, one may rely on a probable opinion for its permissibility even though the more probable opinion is for its sinfulness. The word "probable" must here be understood to mean either "provable" (*i.e.,* logically sound). when opinions are said to have "intrinsic probability"; or "approvable" (*i.e.,* sponsored by some recognized authority). when they have "extrinsic probability." Formulated in 1577 by Bartolomé de Medina (c. 1527–80), a Dominican of Salamanca, probabilism was fast developed by the Jesuits. The Jansenists, who maintained that in doubtful cases of conscience one should take the safer view against permissibility (tutiorism, rigorism), attacked the benignity of the Jesuit confessors as leading to laxity of morals (*see* Pascal's *Lettres provinciales*). The excesses of probabilism were condemned by Pope Alexander VII (1666, 1667) and, more forcefully, by Pope Innocent XI (1679). Probabiliorism, which enjoins following the more probable opinion, was predominant in the 18th century before the formulation of equiprobabilism by Alfonso Maria dei Liguori (*q.v.*). *See* also CASUISTRY.

PROBABILITY. Of the precise meaning of probability there are conflicting views among experts (philosophers, mathematicians, statisticians). The reasons for this may be partly grasped from a survey of the various channels through which a scientific concept of probability has emerged.

Commercial insurance against risks was developed in the Italian cities of the early Renaissance. The theoretical foundations of life insurance were laid in the 17th century. John Graunt in 1662 drew attention to the stability of statistical series obtained from registers of deaths. Soon after, the astronomer Edmund Halley (1656–1742) showed how to calculate annuities from mortality tables (*see* ANNUITY).

Another early reason for interest in probability was in connection with the weight of evidence in legal procedure. The theory of judicial evidence occupies a prominent place in probability mathematics up to the mid-19th century. Today the results of earlier research are recognized as false or unsatisfactory.

Mathematical problems relating to games of chance had been considered, though with minor success, by Luca di Paciuolo, Girolamo Cardano (Jerome Cardan), Niccolb Tartaglia and other mathematicians of the Renaissance. The subject was developed into a "geometry of the die" (*aleae geometria*) by Blaise Pascal, Pierre de Fermat and Christiaan Huygens in the 17th century. Fermat treated the problems within a general theory of combinations, to become further developed by the Swiss mathematician Jacques Bernoulli. The latter can be regarded as the founder of probability theory as a branch of mathematics: his posthumously published *Ars conjectandi* (Basle, 1713) can be said to aim at a fusion of the a priori methods of combinatory probability and the a posteriori methods of early statistical theory. The research on probability done by 18th-century mathematicians culminated in the immense work of Pierre Simon de Laplace, the founder of a tradition that dominated the subject throughout the 19th century.

Laplace advocated a strictly deterministic view of the universe: an omniscient intelligence ("Laplace's demon") would be able to predict the course of nature in minutest detail with infallible accuracy. On this view, probability enters into a science of nature only as a theory of errors; *i.e.,* as a systematic study of the deviations from a mean which appear in repeated measurements of a quantity. This study was developed by Laplace, by A. M. Legendre and by K. F. Gauss (the *normal law of error* and the *method of least squares*). The mathematical calculus of probability soon provided tools for handling statistical material in connection with public finance, health administration, the conduct of elections and other social matters beside insurance. The marquis de Condorcet and later the astronomer L. A. J. Quetelet were champions of a social science on a statistico-probabilistic basis.

From the middle of the 19th century, probability gradually gained ground as a part of physical theory. It first appeared in the theory of heat. J. C. Maxwell in 1860 deduced the familiar gas laws from underlying probabilities for the distribution of positions and velocities over the molecules. Ludwig Boltzmann (1877) interpreted the irreversibility of thermal processes as a tendency toward a most probable distribution of the energies of the molecules. The rise of quantum mechanics saw the theory of radiation put on a probability basis by Max Planck (1900). With the further development of quantum physics, probability invaded atomic theory. By the middle of the 20th century the deterministic view of nature was thought in some quarters to be in process of being replaced by a probabilistic view. The concept of probability had become one of the fundamental notions of a modern science and philosophy of nature. This gave a new urgency to the need for clarifying the structure and meaning of the idea.

The Abstract Calculus of Probability. — In the course of the development already outlined, several definitions of probability were suggested. Accordingly, alternative methods were devised for basing the edifice of probability mathematics on those definitions. These alternative calculi take different views of the meaning of their fundamental notion, but they agree, by and large, in having a common logical structure.

These observations offer a starting point for attempts to create an abstract calculus of probability. It abstracts from the various interpreted calculi their common structure, the formal properties of which it studies independently of any definition of probability.

In the abstract calculus developed by the Russian mathematician A. Kolmogorov (1933), probability figures as a function of sets. This theory. which has found much favour among mathematicians, incorporates probability mathematics within the general theory of measurable sets of points.

Abstract calculi of a type that might be called logistic were constructed by J. M. Keynes (1921), Hans Reichenbach (1932), Harold Jeffreys (1939) and other authors. In these systems probability figures as an undefined logical relation betneen propositions or attributes (propositional functions, classes, sets).

Let us introduce, following Keynes, the symbol a/h, which can be read as "the probability of a given h." It is often convenient to speak of a as an "event" and of h as some "conditions" or "evidence." We need not assume that any pair of propositions (or attributes) determines a numerical value of the functor. But if there is a numerical probability, it should satisfy the following four postulates: (1) $a/h \geqq 0$; (2) $h/h=1$; (3) $a/h+$(not -$a)/h=1$, the principal of complementarity; and (4) (a and $b)/h=a/h\times b/(h$ and a), the general multiplication principle. These four postulates suffice, with the aid of a few principles of a subordinate character, for the erection of the whole fabric of probability mathematics.

From the first, second and third postulates it follows that all probability-values are in the interval from 0 to 1 inclusive.

From the third with the aid of the fourth, we can prove the general addition principle: (a or $b)/h=a/h+$ blh $-$ (a and $b)/h$.

If a and b are mutually exclusive alternatives, the probability of their joint occurrence is 0. Thus for exclusive a and b we have the equality: (a or $b)/h=a/h+b/h$. This is called the special addition principle.

If $a/h=a/(h$ and b). we say that a is independent (for probability) of b (in h). The notion of independence is of great importance to the further development of the calculus. It follows from the fourth postulate and the definition of independence that for independent a and b we have the equality: (a and $b)/h=a/h\times b/h$. This is called the special multiplication principle.

The Frequency Theory of Probability. — This is the view that, popularly speaking, the probability of a given h means the relative frequency with which the event a takes place when the conditions h are fulfilled. The probability of a given h, in other words, is the proportion of h's which are a's.

The frequency view of probability has a long history. Aristotle defines "a probability" as being "what men know to happen or not to happen, to be or not to be, for the most part thus and thus." A similar opinion was entertained by writers of the 17th and 18th centuries, who were interested in statistics or in a "theory of evidence."

The history of probability mathematics from Jacques Bernoulli to Laplace and his folloners is allied to a different view of the meaning of probability. The rebirth of the frequency theory followed a criticism of the foundations of the Laplacean calculus, particularly of the use of the so-called principle of indifference for the determination of probability values (see below). The attack was launched by R. Leslie Ellis, J. Stuart Mill and A. A. Cournot in publications of the same year 1843. The frequency conception of probability was first worked out into a mathematical theory by John Venn (1866).

Early proponents of the frequency theory spoke of probability as a relative frequency "in the long run." This loose way of speaking is not very satisfactory. Venn was the first to define an event's probability as the limiting value which its relative frequency approaches as the number of occasions is indefinitely increased. An improved version of this frequency-limit theory was presented by Richard von Mises in 1919; another later well-known adherent of the theory is H. Reichenbach.

Von Mises also thought that a probability cannot be simply (the limiting value of) a relative frequency and added the qualification that the event ought to be irregularly or randomly distributed in the series of occasions, relative to which its probability is measured. This demand of randomness he called the principle of excluded gambling systems.

It is a great merit of Von Mises' to have stressed the importance of the idea of random distribution to a frequency theory of probability. But with this idea he introduced a considerable difficulty into the theory. How is random distribution to be defined? The definition originally proposed by Von Mises has been accused of inconsistency, but it is doubtful whether any of the alternative definitions proposed by other writers (H. Reichenbach, K. Popper, A. Copeland, A. Wald) can be regarded as satisfactory.

The demand of randomness is relevant to the question of the adequacy of the frequency view as a proposed analysis of the meaning of probability. But it is not relevant to the question of the mathematical correctness of the interpretation of abstract probability in terms of frequencies (either in finite or infinite series). It may easily be verified that a frequency definition satisfies the postulates of the abstract calculus.

Even if we disregard difficulties caused by the notion of randomness, many more objections can be raised against the frequency view. Nevertheless, some form of a frequency theory is thought by many writers to offer the best account (at least for a large category of cases) of the relation between abstract probability and empirical reality.

The Range Theory of Probability. — This theory can, in its simplest form, be explained as follows: We analyze h into a number n of alternative conditions. That h is fulfilled means that either h_1 or . . . or h_n is fulfilled. Some of these alternatives, say m, entail the occurrence of a, the remaining ones entail the occurrence of not-a. Using a traditional terminology, we call the first group of alternatives *favourable* to a and the second *unfavourable* to a. The probability of a given h is the ratio $m:n$ of the number of favourable alternatives and the number of all alternatives.

This, if we omit an important qualification to be discussed presently, is substantially the definition of probability that emerged from the mathematical treatment of games of chance and was canonized in the theory of Laplace. We may refer to it as the classical form of the range definition.

It is natural to call the (mutually exclusive) alternatives covered by a proposition (or an attribute) its range. The classical definition given above can be generalized as follows: The probability of a given h is the ratio of the measure of the range of h-and-a and the measure of the range of h alone: $a/h =_{Df} \frac{\text{mr (h and a)}}{mr(h)}$

The notion of a range (in German, Spielraum) was introduced into probability theory by Johannes von Kries (1886). It was used to define probability as a logical relation between propositions by Ludwig Wittgenstein (1922). Substantially the same definition had been given by Bernard Bolzano as early as 1837. A generalized form (answering to the formula given above) of the Bolzano-Wittgenstein definition was suggested by F. Waismann (1929) and was further developed and extensively studied by Rudolf Carnap (1950). The Waismann-Carnap definition is independent of any specific way of measuring the ranges.

The range definition, both in its classical and in its generalized form. satisfies the postulates of absrract probability. The definition, no doubt, is mathematically correct. But does it give an adequate account of the meaning of probability?

The Principle of Indifference. — The main difficultyconfronting a range theory of probability concerns the measurement of the ranges. This difficulty is allied to the question of how to analyze propositions (or attributes) into alternatives. Usually there are several possibilities open for the choice of a measure and the analysis of the data into alternatives.

The classics of probability theory were aware of these difficulties and the first one to discuss the matter fully was Jacques Bernoulli. He stressed that the alternatives into which h (of the probability-functor) is analyzed ought to be equally possible; *i.e.*, "each case ought to have the same facility as any other case of coming about." This condition of equipossibility in the cases was usually added to the classical range definition of probability. The condition, it will be noted. is tantamount to a principle of measuring ranges.

But what does equipossibility mean and on what conditions may we rightly pronounce cases equally possible? In answer to the latter question Jacques Bernoulli laid down a rule which has become knonn under the names of the *principle of insufficient reason*, the *principle of equal distribution of ignorance* or the *principle of indifference* (Keynes). In its classical version this principle states that tao cases are equally possible if no reason is known why the one case rather than the other should come about.

Reliance on a principle of indifference for measuring ranges (probabilities) has a certain *prima jacie* plausibility in games of chance, where there usually is complete agreement among experts as regards the right analysis of the situations into alternatives of equal possibility. In cases which present no obvious analogy to games of chance, reliance on the principle becomes dubious. It was the use of it made by Laplace and his followers, particularly for the notorious doctrine of inverse probability *(see* below and also INDUCTION), that, in the middle of the 19th century. provoked criticism of the foundations of the entire classical fabric of probability theory. Among the earlier critics of the principle of indifference mention should be made of R. Leslie Ellis. G. Boole, C. S. Peirce and J. von Kries.

In modern times J. M. Keynes discussed the principle acutely and in detail. Severely criticizing its unguarded uses. he also attempted to refashion the principle and to make clear its relevance to any philosophy of probability. Warranted use of the principle is tied to the question of symmetry in the unit alternatives under consideration; and the problem of symmetry in its turn is tied to the problem of an ultimate analysis of propositions (attributes) into alternatives. Any judgment of symmetry or ultimacy, as it presupposes that all relevant information about the cases has been taken into account, is, negatively. a judgment of irrelevance or independence for probability among propositions (attributes). Any pronouncement on irrelevance involves, so Keynes thought, an "element of direct judgment or intuition."

The principle of indifference has usually been discussed in connection with the classical range definition, to which ·it was traditionally regarded as a necessary supplementation. It should, however. be observed that the problems connected with this principle recur, *mutatis mutandis*, within any theory which defines probability in terms of the relative magnitudes of ranges.

Is Probability Subjective or Objective? — Bernoulli and Laplace were both of the opinion that anything which happens has a sufficient cause, of which, however, we may be ignorant: man's ignorance, not nature's indeterminateness. is the mainspring of probability. This is why Bernoulli called probability a degree of certainty.

Many authors have spoken of probability as a degree of belief. This has a psychologistic or subjectivist implication which has brought a great deal of confusion into the subject. It carries nith it the suggestion that the principles of probability were mathematical laws concerning psychological facts; viz.. the ways in which people "distribute" their beliefs in conjectured events. It would seem that not even the most advanced attempts to work out a belief theory of probability (F. P. Ramsey, B. De Finetti) have taken this suggestion seriously. Some authors (*e.g.*, Keynes and Jeffreys) avoid psychologism by calling probability, not a degree of belief, but a rational or reasonable degree of belief.

It has been customary to contrast subjectivist or psychologistic views on probability with objectivist conceptions. The terms are unfortunate and obscure the point at issue. The contrast really is between an epistemic view, according to which probability is an attribute (or mode) of our knowledge of things, and an ontological view, according to which probability is an objective feature of the world. The issue between these two views, moreover, is not necessarily tied to the problem of determinism.

The definition of probability as a relative frequency is clearly objectivist. So is also the definition of probability as a relative measure of ranges, provided that the method of measurement does not—like the classical principle of indifference—make reference to a state of knowledge (or ignorance).

We have seen, however, that supporters of the definitions in question have found it necessary, in order to reach an adequate analysis of probability, to add to them ingredients which are not needed from the point of view, of pure mathematical theory. In the case of the frequency vien, this addition was a demand for random distribution of events on a series of occasions. In the case of the range theory, it was a demand for equipossibility in certain unit-alternatives. These additions, with which the notorious difficulties of the two views are intimately connected, easily lend themselves to an epistemic interpretation: of equipossibility in terms of insufficient reasons; and of randomness in terms of ignorance of the manner in which events alternate in a sequence.

Can randomness and equipossibility be satisfactorily accounted for in objectivist terms; *i.e.*, independently of reference to a state of knowledge or ignorance? This can be regarded as the fundamental question in the philosophy of probability. Authors of the classical period openly avowed an epistemic view of probability. Their often uncritical use of the principle of indifference and the dangers of subjectivism to which the epistemic view is exposed provoked a reaction in favour of an ontological conception of probability. By the middle of the 20th century the conflict of views had still not been settled, even provisionally.

Bernoulli's Theorem. — Let us assume that the probability for the occurrence of an event a on a certain occasion of h is not affected by its occurrence or nonoccurrence on previous occasions of h. The occurrences of a, in other words, are independent for probability of one another. And let us assume that this probability is p. A simple use of the special multiplication and addition principles can now be made for calculating the probability that the event a will, on n occasions of h, be realized with a relative frequency in the interval $p \pm \epsilon$. From considerations about this second-order probability we can prove that:

1. The most probable value of the event's relative frequency on n occasions is that value which comes nearest to its probability p.

2. The probability that the event's relative frequency on n occasions will deviate from its probability p by less than a given amount ϵ, however small, approaches 1 as a limit when n is indefinitely increased. Thus, popularly speaking, in the long run the event will almost certainly be realized with a relative frequency corresponding to its probability.

An example will illustrate this asymptotic character of the increasing probability. The probability of head and tail in tossing with a normal coin is $\frac{1}{2}$. The results are independent for probability: no combination of head and tail in previous tosses will influence the probability of getting head or of getting tail in the next toss. A simple calculation shows that the probability of getting 49, 50, or 51 heads in 100 tosses is approximately 0.16; the probability of getting between 490 and 510 heads in 1,000 tosses is 0.47; and the probability of getting between 4,900 and 5,100 heads in 10,000 tosses is 0.95. In other words: in 10,000 tosses it is already almost certain that the proportion of heads will deviate by less than 0.01 from its probability $\frac{1}{2}$.

This remarkable theorem is known as Bernoulli's theorem. It is chronologically the first member of a class of propositions which are called the laws of great numbers. The name was introduced by Siméon Denis Poisson (1837).

Inverse Probability. — In 1763 Thomas Bayes proved that, if m:n is the relative frequency of an event on n independent occasions, then m n is also the most probable value of the event's probability,, provided that any value of this probability is initially (a priori) as probable as any other value. The same theorem was proved independently by Laplace in 1774. Laplace also proved that, on the assumptions mentioned. it will in the long run become almost certain that the probability of the event coincides with its relative frequency.

The Bayes-Laplace theorem is the inversion of Bernoulli's theorem and the cornerstone of the classical doctrine of inverse probability for the estimation of probabilities on the basis of frequencies. The doctrine was developed and put to extensive use by Laplace and his followers. It was thought to be of great relevance to the problem of induction (*q.v.*).

The Achilles' heel of inverse probability is its dependence on initial or a priori probabilities. These were in the classical doctrine often established by deplorably uncritical use of the principle of indifference. The doctrine was challenged in the 19th century, particularly by early proponents of the frequency view. The use of inverse probability is still a matter of debate. Some researchers, among them R. A. Fisher, have altogether rejected it.

Asymptotic **Probabilities** and the Principle of Moral **Certitude.**—It was often thought in the past that, by virtue of Bernoulli's theorem, *events will, in the long run, happen in numbers proportional to the probabilities* (A. De Morgan, 1838). But this is a serious mistake. The theorem only says that it becomes increasingly probable that the frequency coincides with the probability. And this, by itself, does not warrant any conclusion about actual frequencies, not even in the long run.

The error latent in the idea that Bernoulli's theorem provides a bridge from a subjectivist conception of probability as a degree of certainty to an objectivist conception in terms of frequencies was first clearly seen and conclusively criticized by R. Leslie Ellis (1843). There were many relapses into the error afterward, but today the correctness of the criticism is universally admitted.

There is, however, another way of using Bernoulli's theorem and other asymptotic principles of probability (laws of great numbers) as a bridge from (uninterpreted) probabilities to statistical frequencies without committing a logical error. It may be briefly indicated as follows:

Let us assume that, either from observations about frequencies or from considerations about ranges or from some other source, we frame a hypothesis about the probability of a given h. From this hypothesis we calculate that it is "almost" or, as Bernoulli would have said it, "morally" certain (say probable to degree 0.95) that in a series of n trials the relative frequency of the event will deviate from its probability by less than a small iraction (say 0.01). In other words, it is "most unlikely" (morally impossible) that the frequency will fall short of the hypothetical probability by more than this fraction. Now we may adopt a maxim that very improbable events are "practically excluded" or that "moral certainty!' should be treated as equal to full certainty. Consequently, if the event's frequency nevertheless deviates irom the hypothetical value by more than the fraction in question, we say, not that something very improbable has happened, but that our probability hypothesis has to be rejected.

The proposed maxim mas in fact suggested already by Bernoulli. It might be called Bernoulli's principle of moral certitude. Its adoption seems to be in good accord with actual use of probability calculations for scientific and applied purposes. And it partially explains why it is possible, without detriment to the applications of probability, to suspend judgment as regards the meaning of this controversial notion. The calculus is a vehicle which takes us from hypothetical probabilities to predicted irequencies. If the observed frequencies conflict with the principle of moral certitude, the hypotheses are modified or rejected. The boundaries of moral certitude are, of course, elastic; and whether we wish provisionally to fix them at one value rather than at another will depend upon a multitude of circumstances peculiar to each case. Such circumstances are the amount of statistical evidence at hand, the possibilities of repeated trials and the facility with which dependencies between occurrences can be controlled. Among them are also considerations of an ethical nature relating to the gains and losses which we may incur by choosing one probability hypothesis rather than another as a basis of our actions. To analyze and to evaluate these circumstances is a major task of statistical theory.

Has "Probability" One or Many Meanings?— Compare the following uses of probability: (1) "the probability of a normal six-sided'die turning up 'six' is $\frac{1}{6}$"; (2) "the probability that Shakespeare wrote the plays commonly attributed to him is overwhelming"; (3) "Fresnel's experiment increased the probability of the undulatory theory of light." Does "probability" mean the same in all the three statements?

According to Hans Reichenbach, one of the chief proponents of the frequency theory in modern times, there is only one (scientific) meaning of probability. A statement of the second type exemplified above, which concerns the probability of an individual event, is literally meaningless, but may be reinterpreted as a statement about that *which usually is the case under similar circumstances.* Statements of the third type, again, which attribute probability to general propositions (laws of nature, theories, hypotheses) may, according to Keichenhach, be given a frequency interpretation as referring either to a proportion of successiul predictions, or to a proportion of true theories within a class.

A unitary view of probability was also taken by J. M. Keynes, though on quite different grounds. According to Keynes, the difficulties presented by cases such as the second and third types exemplified above mould indicate that probability is a wider notion than the concept which figures in a frequency theory or even in any theory which requires probability to be a measurable quantity. In its wide sense, probability is a (not necessarily measurable) degree of rational beliei (*see* above).

Those who have advocated a dualistic view of probability have usually wished to contrast cases of the third type, or the probability of laws of nature. with other types of probability. Jacob Friedrich Fries (*System der Logik*, 1811; *Versuch einer Kritik der Principien der Wahrscheinlichkeitsrechnung*, 1842) called the probability of laws "philosophical probability" and contrasted it with "mathematical probability." This distinction was adopted by many logicians and philosophers of the 19th century (E. F. Apelt, A. A. Cournot, M. W. Drobisch). Philosophical probability was thought to be nonnumerical in principle. A similar position found favour with many 20th-century authors: B. Russell (1948) contrasts "credibility" and "mathematical probability"; W. Kneale (1949), "acceptability" and "chance"; R. B. Braithwaite (1953), "reasonableness" and "probability."

A dualistic view of a somewhat different nature mas developed by Rudolf Carnap (*Logical Foundations of Probability*). Of the two concepts of probability that he distinguishes, the first (which he also calls "degree of confirmation") is probability in the sense of a range theory; the second is probability in the sense of a frequency theory. Both concepts are mathematical and may be regarded as alternative interpretations of an abstract calculus. Carnap tries to reconcile the rival claims of the two theories by assigning to each concept of probability its proper field of application. In view of the difficulties, however, which both theories encounter as proposed analyses of probability, it cannot he taken for granted that this reconciliation is altogether satisfactory.

Bibliography.—For a good introduction to the general and philosophical aspects, *see* E. Nagel, *Principles of the Theory of Probability* (London, Chicago, 1939). For the classical view: Jacques Bernoulli, *Ars conjectandi* (Basle, 1713), especially book iv; and P. S. de Laplace, *Essai philosophique sur les probabilite's* (Paris, 1814). For modern range theory: W. Kneale, *Probability and Induction* (Oxford, 1949), a good introduction to the whole subject; and R. Carnap, *Logical Foundations of Probability* (Chicago, 1950; London, 1952). For the frequency view: R. von Mises, *Probability, Statistics and Truth* (London, New York, 1939), Eng. trans. of *Wahrscheinlichkeit, Statistik und Wahrheit* (Vienna, 1928; 2nd ed. 1936); and H. Reichenbach, *The Theory of Probability* (Berkeley, 1949), Eng, trans. of *Wahrscheinlichkeitslehre* (Leyden, 1935). For abstract probability and general questions: H. Reichenbach, *op.cit.;* J. M. Keynes, *A Treatise on Probability* (London, 1921); A. N. Kolmogorov, *Foundations of the Theory of Probability*, trans. ed. by Nathan Morrison (New York, 1950); and G. H. von Wright, *A Treatise on Induction and Probability* (London, 1951; New York, 1952). For questions of probability mathematics: E. Borel (ed.), *Traite' du calcul des probabilite's et de ses applications, 4* vol. (Paris, 1925 ff.). For questions of theoretical statistics: H. Cramér, *Mathematical Methods of Statistics* (London, Princeton, N.J., 1946). (G. H. v. W.)

PROBABILITY AND STATISTICAL THEORY. The theory of probability is that branch of applied mathematics which deals with a priori numerical evaluation of the relative frequencies with which events or combinations of events are predicted to occur under repetition of a set of conditions. Statistical theory deals with the application of probability theory to the collection, analysis and interpretation of numerical observational data.

The branch of applied mathematics which deals with probability and its application to the theory of statistics is called mathematical statistics.

THEORY OF PROBABILITY

The a priori evaluation of relative frequencies is often easy to make. For example: consider an ordinary six-sided die. If, upon preliminary analysis, it appears reasonable to assutne that the die is "true," then an a priori evaluation of the relative frequency with which an ace will turn up when the die is thrown is $\frac{1}{6}$. We predict that if the die is rolled a large number of times, about one-sixth of the trials mill result in an ace; we say that the probability of getting an ace in a single trial is $\frac{1}{6}$. All of these statements about the die are made independently of whether the die is actually thrown. In order to determine whether the statement that the probability of getting an ace with the particular die is $ has validity, a number of experiments would have to be performed, each of which would consist of rolling the die a large number of times and counting the proportions of aces and comparing these proportions with the prediction that "one-sixth of the trials mill result in an ace." This comparison in turn involves probability considerations in order to determine whether the discrepancies between the proportion of aces resulting from the various experiments and the proportion predicted by probability theory are large enough to invalidate the prediction.

Another idea involved is that in the sequence of trials in each experiment the aces and "nonaces" are mixed up in a random fashion in the ratio of about one to five. The notion of randomness is an extremely elusive one to define precisely. The idea of randomness in a finite sequence of events produced in an experiment depends on the consideration of a set consisting of a large number of such sequences and the evaluation of the proportion of the sequences of a given composition (e.g., configuration of aces and nonaces). But even this approach does not completely define the concept of randomness. It is not unreasonable to leave it as an undefined intuitive concept. It turns out that there are "practical" ways of statistically testing the randomness of a sequence, which will be discussed under Statistical Tests, below.

At this juncture we begin to get into statistical theory—the application of probability theory in the interpretation of observational data. It is to be noted, therefore, that the concept of probability involves the notion of the prediction of the proportion of trials in repeated experiments which will have a given property, and also the notion of the randomness with which trials with the given property occur in a sequence of trials. Thus, if we consider two "perfect" dice, we note that there are 36 different ways the two dice can fall, all ways assumed to be "equally likely," and of this number, there is only one way in which the two dice will both turn up aces. The statement would then be made that the probability of getting two aces in a single throw of two dice is $\frac{1}{36}$, which is a prediction that if the two dice are thrown a large number of times, pairs of aces will occur "at random" in the sequence with such frequency that one thirty-sixth of the trials will result in a pair of aces. Similarly, we can evaluate the probability that the total number of dots turning up in a throw of a pair of dice will be four, or the probability that the number of dots will be larger than nine, and so on.

Definition of Probability for Discrete Events.—If an event can occur in exactly one of n different or discrete ways, all "equally likely," in which m have property A, we say that the probability of an A is m/n. The usual notation is to write:

$$Pr(A)=\frac{m}{n}. \tag{1}$$

The term "equally likely" is left as an undefined term, except to remark that if several alternative outcomes of an event are regarded as equally likely, they are given equal weight in evaluating probabilities. To attempt to pursue the term "equally likely" much further will essentially result in tautology, and will lead to confusion in the application of probability theory to statistical theory. It is unnecessary, so far as the theory of probability is concerned, to worry about the statistical meaning of the term "equally likely" as many authors have done. It is an idea involved only in the probability theory and not in its application to a set of observations. Thus, it can be rigorously handled as far as mathematical operations are concerned, even though left as an undefined concept. Various other definitions of probability have been proposed but space does not permit a discussion of them here.

Addition of Probabilities for Events with Mutually Exclusive Properties.—Suppose an event can happen in exactly one of n different ways, all equally likely. Furthermore, suppose that in m' of them the event has property B, and that no event can have property A and also property B. Then the number of ways in which the event will have property A or property B is $m+m'$, and hence the probability of properties A or B occurring is $(m+m')/n$, which is the same as $m/n+m'/n$. But m/n is the probability of property A, and m'/n is the probability of property B. This fact may be summarized as the law of addition of probabilities: *If A and B are mutually exclusive properties which an event can have (i.e., the event cannot have both properties A and B), then the probability of an A or a B is equal to the probability of an A plus the probability of a B.* Stated more briefly: *If A and B are mutually exclusive properties which an event can have, then*

$$Pr(A \text{ or } B)=Pr(A)+Pr(B). \tag{2}$$

More generally: *If A, B, . . . , K are all mutually exclusive properties which an event can have, then*

$$Pr(A \text{ or } B \text{ or } \cdots \text{ or } K)=Pr(A)+Pr(B)+\cdots+Pr(K). \tag{3}$$

As an example of how the law of addition works, consider the probability of getting a total of less than four dots in a throw of two dice. The probability of getting less than four dots is the same as the probability of getting two dots, or three dots. The probability of getting two dots is $\frac{1}{36}$. The probability of getting three dots is $\frac{2}{36}$ (since there are two ways in which three dots can occur). Therefore, since getting two dots and getting three dots are mutually exclusive events, we have, by the law of addition, the probability of getting less than four dots is equal to the probability of getting two dots plus the probability of getting three dots; i.e., $\frac{1}{36}+\frac{2}{36}=\frac{3}{36}$. More briefly:

$$Pr(\text{less than } 4)=Pr(2 \text{ or } 3)=Pr(2)+Pr(3).$$

Conditional Probability.—Suppose an event can result in an A or an $\bar{A}$, and also in a B or a $\bar{B}$. Then the event will always result in one of four mutually exclusive categories characterized as follows: (1) A and B, (2) $\bar{A}$ and B, (3) A and $\bar{B}$, and (4) $\bar{A}$ and $\bar{B}$. If n_{11}, n_{12}, n_{21}, n_{22} are the numbers of ways the event can result in these four categories, respectively, then the situation can be represented by the following table:

	B	$\bar{B}$	
A	n_{11}	n_{12}	$n_{1\cdot}$
$\bar{A}$	n_{21}	n_{22}	$n_{2\cdot}$
	$n_{\cdot 1}$	$n_{\cdot 2}$	n

where $n_{1\cdot}=n_{11}+n_{12}$, the total number of ways A can occur, $n_{\cdot 1}=n_{11}+n_{21}$, the total number of ways B can occur, with similar meanings for $n_{2\cdot}$ and $n_{\cdot 2}$. $n=n_{11}+n_{21}+n_{12}+n_{22}=n_{1\cdot}+n_{2\cdot}$. $n_{\cdot 2}$ is the total number of ways the event can occur.

Now suppose an event (which can actually happen; i.e., $n_{\cdot 1}\neq 0$) is known to have property B. Then the probability that it will also have property A is $n_{11}/n_{\cdot 1}$. But $n_{11}/n_{\cdot 1}=(n_{11}/n)/(n_{\cdot 1}/n)=Pr(A \text{ and } B)/Pr(B)$. We have, therefore, an important law in probability theory known as the *law of conditional probability* which can be stated as follows: *The probability that an event will be an A, given that it is a B, is equal to the probability that it is both an A and a B divided by the probability that it is a B.* This law is usually stated briefly as follows:

$$Pr(A|B)=Pr(A \text{ and } B)/Pr(B). \tag{4}$$

As a simple example, to show how this law operates, suppose we have four kinds of wooden beads all of the same size in the following quantities:

6 beads painted with luminous red paint,
12 beads painted with plain red paint,
10 beads painted with luminous green paint,
14 beads painted with plain green paint.

The situation can be represented in the following table:

	Luminous	Plain	Total
Red			
Green			
Total	16	26	42

Now suppose the 42 beads are put in a bowl and thoroughly mixed. Assume that the colour (red or green) of the beads is exactly the same for luminous as for plain paint, and similarly that the visibility in the dark is exactly the same for red luminous paint as for green luminous paint. A bead is drawn from the bowl in the dark, and observed to be luminous. What is the probability that it is red? The answer is:

$$Pr(\text{red}|\text{luminous})=Pr(\text{red and luminous})/Pr(\text{luminous})$$
$$=\left(\frac{6}{42}\right)\Big/\left(\frac{16}{42}\right)=\frac{3}{8}.$$

If a bead is simply drawn from the bowl the probability of its *being red is* $\frac{18}{42}=\frac{3}{7}$. *If a bead is* drawn *from the bowl in daylight and is* observed *to be red, the probability of its being luminous*= Pr(red *and luminous*): $Pr(\text{red})=\left(\frac{6}{42}\right)/\left(\frac{18}{42}\right)=\frac{1}{3}$.

Multiplication of Probabilities.— It will be seen in the example given above that the probability of getting a red bead knowing that the bead is luminous *is different from the probability of getting a red bead,* when *no use is made of* its *property of being luminous or plain. However, if the ratio of red to green beads with luminous paint mere exactly the same as that for beads with plain paint, no such difference in probabilities mould exist. For example, if the number 14 were replaced by* 20 *in the table we would have such a condition; in this case we would have*

$$Pr(\text{red}\,|\,\textit{luminous})=Pr(\text{red}),$$

or

$$Pr(\text{red } \textit{and luminous})/Pr(\text{luminous})=Pr(\text{red}).$$

This may be rewritten as:

$$Pr(\text{red } \textit{and luminous})=Pr(\text{red})\times Pr(\text{luminous}).$$

Thus, when the ratio of red to green beads is the same for luminous paint as for plain paint (or, what amounts to the same thing, when the ratio of luminous to plain painted beads is the same for red as for green) it follows that if a bead is drawn from the bowl, the probability of its being both red and luminous is equal to the probability of its being red multiplied by the *probability of its being luminous. Under the same conditions it would also follow that:*

$$Pr(\text{red}\,|\,\textit{plain})=Pr(\text{red})\times Pr(\text{plain}),$$

with similar results holding for the values of Pr (green|luminous) and Pr(green| *plain*).

In the more general case it follows that if $n_{11}/n_{12}=n_{21}/n_{22}$ *then* $Pr(A\,|\,B)=Pr(A)$ *and hence formula* (4) *reduces to* $Pr(A)=Pr(A \text{ and } B)/Pr(B)$, which *may be written as:*

$$Pr(A \text{ and } B)=Pr(A)\times Pr(B). \tag{5}$$

If the condition $n_{11}/n_{12}=n_{21}/n_{22}$ *holds, then properties A and* $\bar{A}$ *are said to bc independent of properties B and* $\bar{B}$. *Formula* (5) *is known as the multiplication* law *of probabilities, and it can be stated in words as follows: If A and* $\bar{A}$ *are independent of B and* $\bar{B}$ *then the probability of an event having both properties A and B* is *equal to the product of the Probability of A and the probability of B. Similar results hold, in the case of independence, for* $Pr(A \text{ and } \bar{B})$, $Pr(\bar{A} \text{ and } B)$ *and* $Pr(\bar{A} \text{ and } \bar{B})$.

The notion of independence extends rather readily to the case in which each event may have one of several mutually exclusive properties $A_1, A_2, \ldots, A$, *and also one of several mutually exclusive properties* $B_1, B_2, \ldots, B_q$. *If* n_{11} is *the number of events having both properties* A_1 *and* B_1 *with similar meanings of* n_{12}, $n_{21}, \ldots, n_{pq}$ *then if the numbers* $n_{11}, n_{12}, \ldots, n_{1q}$ *are proportional to* $n_{21}, n_{22}, \ldots, n_{2q}$ *and to* $n_{31}, n_{32}, \ldots, n_{3q}$ *and so on, then* $Pr(A_i \text{ and } B,)=Pr(A_i)\times Pr(B_j)$ *where A, is any given one of the A categories and B, any given one of the B categories.*

As an example, consider a throw *of two dice, A and B. Let* A_1, $A_2, \ldots, A_6$ *denote the faces* 1, 2, . . . , 6 *of die A,* with *similar meanings of* $B_1, B_2, \ldots, B_6$ *for die B. In this example,* $n_{11}=n_{12}=n_{21}=\ldots=n_{66}=1$, *and* we *have independence. The probability of getting a 3 on die A and 4 on die B is*

$$Pr(A_3 \text{ and } B_4)=Pr(A_3)\times Pr(B_4)=\frac{1}{6}\times\frac{1}{6}=\frac{1}{36}.$$

Addition of Probabilities for Events Having Properties Which Are Not Mutually Exclusive.— Under the section Addition of Probabilities for Events with Mutually Exclusive Properties, above, it was shown that if an event can have either property A or property B (not both) then the probability of getting A or B is given by $Pr(A \text{ or } B)=Pr(A)+Pr(B)$ *— the law of addition of probabilities for events with mutually exclusive properties. Now suppose A and B are not mutually exclusive properties, as is the case under Conditional Probability, above. What is the probability of an event yielding property A or property B? Looking at the first table in the above-mentioned section it will be seen that the number of ways in which an event can result in an A or a B is* $n_{11}+n_{12}+n_{21}$, *which may be written as* $(n_{11}+n_{12})+(n_{11}+n_{21})-n_{11}=n_{1\cdot}+n_{\cdot 1}-n_{11}$. *Hence the probability of an A or B is*

$$Pr(A \text{ or } B)=\frac{n_{1\cdot}+n_{\cdot 1}-n_{11}}{n}=\frac{n_{1\cdot}}{n}+\frac{n_{\cdot 1}}{n}-\frac{n_{11}}{n}.$$

But

$$\frac{n_{1\cdot}}{n}=Pr(A),\ \frac{n_{\cdot 1}}{n}=Pr(B), \text{ and } \frac{n_{11}}{n}=Pr(A \text{ and } B).$$

Therefore,

$$Pr(A \text{ or } B)=Pr(A)+Pr(B)-Pr(A \text{ and } B). \tag{6}$$

This is the la of addition of probabilities for events having properties which are not mutually exclusive. Stated in words: If A and B are properties which an event cart have, then the probability of being an A or a B is equal to the probability of being an A plus the probability of being a B minus the probability of being both an A and a B. It will be noted that (6) will hold also when *A and B are mutually exclusive, for in this case,* $Pr(A \text{ and } B)=0$.

In the example of Conditional Probability, the probability of getting either a red bead or a luminous bead is:

$$\begin{aligned}&Pr(\text{red or luminous})\\&=Pr(\text{red})+Pr(\text{luminous})-Pr(\text{red and luminous})\\&=\frac{18}{42}+\frac{16}{42}-\frac{6}{42}=\frac{28}{42}=\frac{2}{3}.\end{aligned}$$

Permutations and Combinations.— The definition of probability expressed in (1) together with the laws expressed in (2), (3), (4), (5) and (6) will *enable one to solve the majority of common probability problems that arise in games of chance and other situations involving a finite number of discrete events. In actually applying these* laws *the main technical problem is that of enumerating the total possible number of events n, and the number of these events m having a given property A. Many of the problems of enumeration reduce to the computation of permutations and combinations.*

Consider the word "and." How many arrangements of two letters can be made from these three letters? The answer is six which are readily seen to be: an, na, ad, da, nd and dn. We *say there are six two-permutations which can be formed from the letters in "and." Or more briefly,* ${}_3P_2=6$. Now, *this number of arrangements can be arrived at more briefly. Consider* two *spaces—to be filled from the letters in "and." The first can be filled by a letter in three ways, and after the choice of a letter has been made for the first place, there are two ways of filling the second place. Therefore, for each of the three* ways *of filling* thr *first place there are two* ways *of filling the second, and hence* the *total number of* ways *of filling both places is* $3\times 2=6$.

To examine a little more complicated case, how *many* three-*permutations are there in the word "problem?"* W*e* would write *down three spaces———. There are seven* ways *of filling the first place, after which there are six* ways *of filling the second, after which there are five* ways *of filling the third. Each choice in the first place can be combined with each choice in the second place, and each pair of these choices can be combined with each choice in the third place. The total number of ways of filling the three places is* $7\times 6\times 5=210$. *That is,* ${}_7P_3=210$.

In general, the number of r-permutations ${}_nP_r$ (*i.e., the number of arrangements of r objects which can be made from n different objects) is given by:*

$${}_nP_r=n(n-1)(n-2)\text{ ------ }(n-r+1)=\frac{n!}{(n-r)!}, \tag{7}$$

where $n!$ (*read n factorial*)$=n(n-1)(n-2)\ldots 2.1$, with *a similar meaning for* $(n-r)!$ *In particular, if* $r=n$, we have ${}_nP_n=n!$

Thus far, we have treated only the case in which all letters are different. Consider what form the formula for ${}_nP_n$ *takes when some of the letters in the original set are repeated. As an example let us take the word "bobbin" and determine how many different six-permutations there are of these three letters. Putting two dashes on the first b and one dash on the second b, it* will *be noted that the six-permutations of the six letters occur in* *sets of six which differ only in the way in which b, b′ and b″ are arranged. For example, one such set of six is boinb′b″, boinb″b, b′oinbb″, b′oinb″b, b″oinbb′, b″oinbb, which is simply the number of ways (i.e., 3!) three objects can be permuted. If the dashes are dropped, these permutations will be indistinguishable. Since there are 6! six-permutations when dashes are retained, and since these occur in sets of six which become identical when the dashes are removed, the number of distinct six-permutations of the letters in "bobbin" is 6!/3!.*

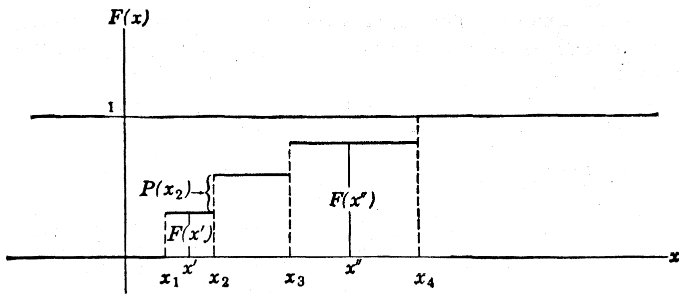


FIG. I.—DISCRETE CUMULATIVE DISTRIBUTION FUNCTION

In general, if a set of n letters (or objects) consists of n_1 letters of one kind, n_2 of a second kind, . . . , n_k of a kth kind, where $n_1+n_2+\ldots+n_k=n$, then the number of distinct n-permutations $_nP(n_1n_2\ldots n_k)$ of these letters is given by

$$_nP(n_1n_2\ldots n_k)=\frac{n!}{n_1!n_2!\ldots n_k!} \qquad (8)$$

It should be noted that if $n_1=n_2=\ldots=n_k=1$, then $_nP(11\ldots 1)={}_nP_n=n!$

For example, the number of distinguishable arrangements of the letters in "banana" is:

$$_6P(321)=\frac{6!}{3!2!1!}=60,$$

since there are three a's, two n's and one b in "banana."

As seen in the foregoing discussion, permutations are defined as arrangements of objects. In many probability problems, the arrangement of the objects is irrelevant, and the important thing is the set of objects. For example, let us return to the word "and" and inquire how many sets or combinations of two letters can be formed from these three letters. The answer is three: an, ad and nd. In considering permutations of two letters the answer is six, because the letters in each of these three sets of two letters can be arranged in two (i.e., 2!) ways. In other words, for each combination of two letters there are two permutations of the two letters. If we denote by $_3C_2$ the number of two-combinations of letters which can be made from the three letters in "and" we have $2\times{}_3C_2={}_3P_2$. In general, the number of different r-combinations $_nC_r$ which can be made from n different letters or objects is given by:

$$_nC_r=\frac{_nP_r}{r!}=\frac{n!}{r!(n-r)!}. \qquad (9)$$

Formulas (7), (8) and (9) can be used for solving many of the probability problems that arise in games of chance and other situations where discrete events are involved. As an example, consider the problem of determining the probability of getting four aces in dealing a hand of 13 cards from an ordinary deck of playing cards. The total number of possible hands of 13 cards out of a deck of 52 cards is $_{52}C_{13}$. The total number of hands each containing four aces is equal to the number of ways of getting 9 nonaces out of 48 nonaces multiplied by the number of ways of getting four aces out of four aces; i.e., $_{48}C_9\times{}_4C_4$. Hence, the probability of getting a hand with four aces is

$$\frac{_{48}C_9\times{}_4C_4}{_{52}C_{13}}=\frac{48!}{9!39!}\div\frac{52!}{13!39!}=\frac{13.12.11.10}{52.51.50.49}=.0028.$$

Treatment of arrangements and combinational problems of a more complex character than can be handled by formulas (7), (8) and (9) will be found, for example, in W. A. Whitworth's Choice and Chance and H. Levy and L. Roth, Elements of Probability.

Random Variables and Distribution **Functions.**—*The Discrete Case.—In dealing with probability problems, it is usually convenient to describe the events under examination by means of values of one or more variables. For example, we can describe the probability theory of a single die by writing down the probability $p(x)$ that x dots will turn up in a throw of the die, which in the case of a true die is given by $p(x)=\frac{1}{6}$, for $x=1, 2, 3, 4, 5, 6$. In other words, the probability is $\frac{1}{6}$ for each value of x. In the case of throwing two dice, the probability $p(x)$ of getting a total of x dots is defined by writing:*

$$p(2)=\frac{1}{36},\ p(3)=\frac{2}{36},\ p(4)=\frac{3}{36},\ \ldots,\ p(12)=\frac{1}{36}.$$

In many cases, one can write down an explicit formula for $p(x)$ in terms of x. For example, the probability of getting x aces in a hand of 13 cards from an ordinary deck is

$$p(x)=\frac{_{48}C_{13-x}\times{}_4C_x}{_{52}C_{13}}$$

which holds for all possible values of x; namely 0, 1, 2, 3, 4. Furthermore, in this example, it can be readily verified that $p(0)+p(1)+p(2)+p(3)+p(4)=1$.

When an event can be described by one of several values of a variable x, say $x_1, x_2, \ldots, x_k$, such that the probability is $p(x_i)$ that x takes on a given value x_i when a trial is made, then we say that x is a random oariable, with discrete probability law (or distribution function) p(x), where $p(x)\geqq 0$. In such a situation we usually abbreviate and say that x is a discrete random variable. The numbers $x_1, x_2, \ldots, x_k$ are sometimes called the event points or sample points of the random variable x. The collection of all of these numbers is called the event space or sample space of x. If rue sum $p(x)$ for all values of i for which $x_i\leqq x'$ and denote this sum by F(x); i.e.,

$$F(x')=\sum_{x\leqq x'}p(x), \qquad (10)$$

then $F(x')$ is the probability that x$x. If x can take on only four values, say x_1, x_2, x_3, x_4 and if $F(x)$ is graphed as a function of x it would look something like the heavy graph in fig. 1. $F(x)$ as defined by (10) is called a discrete cumulative distribution function.

The graph takes a jump at each possible value of x (e.g., x_1, x_2, x_3, x_4 in fig. 1), the jump being equal to the probability that x has that particular value of x. The ordinate F(x) at any particular value of x, say x', is the probability that x will not exceed x' when a trial is made. $F(x)$ remains constant or increases as X takes on increasing values and is such that the value of $F(x)$ ranges from 0 to 1 as x ranges from $-\infty$ to $+\infty$. If we take any two values of x, say x' and x", where $x'<x''$, then it follows, from the law of addition of probabilities, that the probability that $x'<x\leqq x''$ will be given by the difference $F(x'')-F(x')$; more briefly, $Pr(x'<x\leqq x'')=F(x'')-F(x)$. In the case of a die (a "true" die) where x denotes the number of dots, which would appear when the die is thrown, there would be six possible values of X, which are 1, 2, 3, 4, 5, 6, and $F(x)$ would have six jumps, each equal to 1/6, and occurring at each of these values of x. Although the above discussion has been carried out assuming k finite, the same ideas can be extended to the case in which k is infinite. The possible values of x would be $x_1, x_2, x_3, \ldots$ and the probabilities $p(x_1), p(x_2), p(x_3), \ldots$, would form an infinite sequence whose sum would be 1.

The Continuous Case.—Not all events can be described by a discrete random variable x. Some events require a continuum of possible values for description. For example, consider the breaking strength of a piece of a given type of steel wire. If we denote the breaking strength by x, then x may have any value whatever (within certain limits) depending on the fineness of measurement *of the testing machine. If we imagine testing a large number of pieces of such wire, we would get a large number of values of x. If $F_N(x')$ denotes the fraction of these values of x which do not exceed x′, then $F_N(x)$ is the cumulative distribution function of this set of values of x, and for large values of N it would look something like fig. 1, except there would be many more and smaller jumps. If sufficiently small measuring units were available on the testing machine and if a sufficiently large number N of tests*

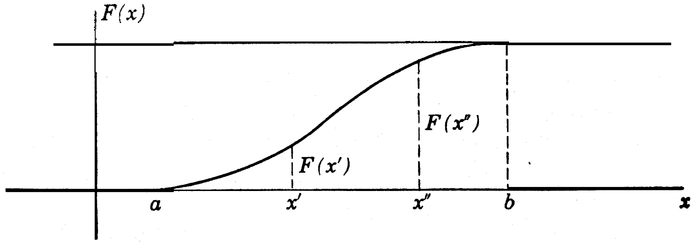


FIG. 2.— CONTINUOUS CUMULATIVE DISTRIBUTION FUNCTION

were made, it is clear that it would be possible to have an $F_N(x)$ which would be as nearly continuous (having no jumps) as we please. A similar situation often arises when a given quantity is measured a large number of times. The measurements will tend to be distributed rather than identical because of errors of measurement. It turns out in many probability problems that one can conveniently associate with the possible events a random variable x which can take on any value in an interval (which may be finite or infinite) and which has a continuous cumulative distribution function $F(x)$. Such random variables are called continuous random variables. In this case the graph of $F(x)$ would look something like that in fig. 2, where $F(a)=0$, $F(b)=1$ and $F(x)$ increases continuously as x increases from a to b, and where a might be $-\infty$ and (or) b might be $+\infty$. If a and b are finite (as shown in fig. 2) it is customary arbitrarily to define $F(x)$ to be 0 for values of x between $-\infty$ and a, and 1 for values of x between b and $+\infty$. For a given value of x, say x′, $F(x')$ is the probability that $x \leqq x'$ in a given trial. The probability that a trial will result in a value of x falling in the interval $(x, x+h)$ is $F(x+h)-F(x)$. Dividing this difference by the length of the interval, h, and taking the limit as $h\to 0$ (assuming it exists) we have the derivative of $F(x)$, with respect to x. Denoting this derivative by $f(x)$, we have:

$$\frac{dF(x)}{dx}=f(x). \tag{11}$$

$f(x)$ is called the probability density function of the continuous random variable x, and since $F(x)$ is constant for values of x outside the interval (a, b), $f(x)=0$ outside of (a,b)—hence, $F(x)$ can be expressed in terms of $f(x)$ by writing

$$F(x')=\int_{-\infty}^{x'} f(x)dx, \tag{12}$$

which is the analogue to (10) for the continuous cumulative distribution function. The interpretation of $F(x')$ in (10) and (12) is exactly the same; namely, the probability that $x\leqq x'$. The interpretations of $p(x)$ and $f(x)$ from which $F(x')$ is obtained in the discrete and continuous cases, respectively, are different. $p(x)$ is probability, but $f(x)$ is probability density and has to be integrated over an interval, however short, before it becomes probability. To get the probability that $x'<x\leqq x''$ in the continuous case we would have, by the law of addition of probabilities:

$$Pr(x'<x\leqq x'')=F(x'')-F(x')$$

$$=\int_{-\infty}^{x''} f(x)dx-\int_{-\mathrm{m}}^{x'} f(x)dx=\int_{x'}^{x''} f(x)dx. \tag{13}$$

The graph of $f(x)$, in general, looks something like the curve in fig. 3. It is called the frequency curve or distribution curve for x. The shaded area in fig. 3 is the graphical representation of the integral

$$\int_{x'}^{x''} f(x)dx;$$

i.e., the probability that $x'<x\leqq x''$. Numerically, the shaded area in fig. 3 is equal to the difference between the two ordinates in x′ and x″ in fig. 2.

Mean Value, Moments, Variance and Other Properties **of Distributions.**—The *mean value* $E(x)$ of a random variable *x is defined as follows for the discrete and continuous cases, respectively,*

$$E(x)=\sum_{i=1}^{k} x_i\, p(x_i)$$

$$E(x)=\int_{-\infty}^{\mathrm{m}} x\, f(x)dx. \tag{14}$$

$E(x)$ is sometimes referred to as the expected value of x, or the mathematical expectation of x. $E(x)$ may be interpreted as the centroid or centre of gravity of the distribution in each case.

Mean value is an extremely important concept in the calculation of expectation of loss or gain, particularly in insurance and gambling. To take a simple example, suppose a person receives $1 for each dot that appears uppermost in the throw of a die. What is his expected winning per throw? To evaluate this, we simply multiply the winning in each possible outcome of the throw of the die, by the probability of that event. This results in

$$1\cdot\tfrac{1}{6}+2\cdot\tfrac{1}{6}+3\cdot\tfrac{1}{6}+4\cdot\tfrac{1}{6}+5\cdot\tfrac{1}{6}+6\cdot\tfrac{1}{6}=\$3.50,$$

which is the expected winning per throw or average winning per throw assuming a perfect die. The fair price to pay for the privilege of playing such a game is $3.50 per throw. A player who would pay more would lose in the long run. More complicated games can be similarly analyzed and fair prices for playing them can be established.

If $u(x)$ is any function of x, the mean value of $u(x)$ is defined in the two cases as follows:

$$E[u(x)]=\sum_{i=1}^{k} u(x_i)\, p(x_i)$$

$$E[u(x)]=\int_{-\infty}^{\infty} u(x)\, f(x)dt. \tag{15}$$

In probability theory it has been found convenient to use what

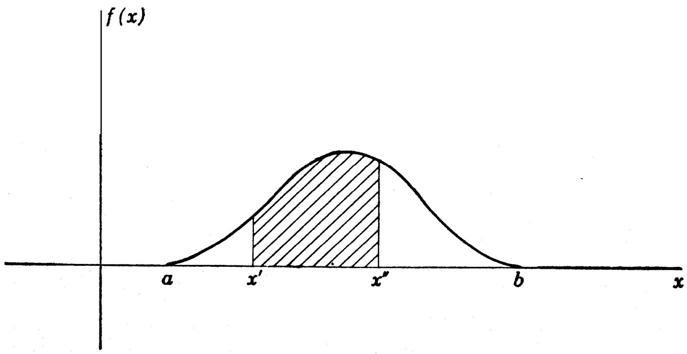


FIG. 3.— FREQUENCY OR DISTRIBUTION CURVE (*see* TEXT FOR FURTHER INFORMATION)

is called the Stieltjes integral, which enables us to write either of the equations in (15) as

$$E[u(x)]=\int_{-\mathrm{m}}^{\infty} u(x)d\,F(x).$$

This integral is simply the sum

$$\sum_{i=1}^{k} u(x_i)p(x_i)$$

in the discrete case and the ordinary integral (Riemann),

$$\int_{-\infty}^{\infty} u(x)f(x)dx,$$

in the continuous case. In particular, expressions (15) define the h*th moment* μ'_h *of* x *if* $u(x)=x^h$.

If we set $u(x)=e^{tx}$, *we have the moment-generating function of* x, *denoted by* $\varphi(t)$; *i.e., using Stieltjes integral notation to cover both the discrete and continuous cases,*

$$\varphi(t)=\int_{-\infty}^{\infty} e^{tx}dF(x). \tag{16}$$

The reason for the term "moment-generating function" is clear when we note that by differentiating (16) h times with respect to t, then setting $t=0$, *we get the hth moment of X.* Briefly:

$$\left[\frac{d^h\varphi(t)}{dt^h}\right]_{t=0}=\left[\int_{-\infty}^{\infty} x^h e^{tx}dF(x)\right]_{t=0}=\int_{-\infty}^{\infty} x^h dF(x)=\mu_h'.$$

The median $\tilde{x}$ *of a random variable x is a value such that*

$$Pr(x<\tilde{x})=Pr(x>\tilde{x}). \tag{17}$$

The mode $\breve{x}$ *of a random variable x, when the mode exists, is that value of x to which corresponds the greatest probability in the discrete case or greatest probability density in the continuous case.*

If $u(x)$ *is made equal to* $[x-E(x)]^2$, *then (15) defines the variance* σ^2 *of x; i.e.,*

$$\sigma^2=E[x-E(x)]^2, \tag{18}$$

which may be written as

$$E(x^2)-[E(x)]^2=\mu'_2-(\mu'_1)^2.$$

The variance σ^2 *is seen to be the mean of the squares of the deviations of x from its mean value. It gives an indication of how much the probability function is spread out along the x axis; the greater the spread, the larger the variance. The quantity* σ, *the square root of the variance, is called the standard deviation of x.*

An important property of any distribution function, discrete or continuous, is expressible in a form known as Tchebycheff's inequality, which states that the probability does not exceed $1/\lambda^2$ *that a random variable x deviates from its mean value by more than* λ *times its standard deviation.* More *briefly:* $Pr(|x-a|>\lambda\sigma)\leqq 1/\lambda^2$.

Some Important Special Distribution Functions.—There are several distribution functions of fundamental importance in the theory of probability and its application to statistics.

The Binomial Distribution.—Suppose that an event or trial can result in either an A or an $\bar{A}$. *Let the probability of A be* p *and that of* $\bar{A}$ *be* q *where* $q=1-p$. Now *if the trial is repeated* n *times, and the trials are independent, we ask, what is the probability that A will occur x times and* $\bar{A}$ $n-x$ *times? Since the trials are independent, the probability of getting x A's and* $n-x$ $\bar{A}$'s *in n trials in a particular order, say* $AA\bar{A}A\bar{A}\bar{A}\ldots A\bar{A}A$ [*x A's and* $(n-x)$ *A's*], *is* $ppqpqq\ldots pqp=p^xq^{n-x}$. *But from (8) it is seen that there are* ${}_nP_{(x,\,n-x)}=\frac{n!}{x!(n-x)!}$ (*also*$={}_nC_x$) *different orders (permutations) in which x A's and* $n-x$ $\bar{A}$'s *can occur. These different sequences of trials are mutually exclusive, and therefore, by the law of addition of probabilities* (3), *the probability of x A's and* $n-x$ B's *is* p^xq^{n-x} *added* $\frac{n!}{x!(n-x)!}$ *times; i.e.,*

$$b(x)=\frac{n!}{x!(n-x)!}p^xq^{n-x}. \tag{19}$$

$b(x)$ *is called the binomial distribution. It will be noted that x is a discrete random variable whose event points are* $0, 1, 2, \ldots, n$. *Furthermore, it should be observed that* $b(x)$ *is the* $(x+1)$th *term of the expansion of the binomial* $(q+p)^n$. *If the terms* $b(x)$ *are summed for all values of x from 0 to n, we get* $(q+p)^n=1$, *since* $q+p=1$.

As a simple application of the binomial law, let us derive the probability that, in tossing two coins five times, both coins will turn up heads three times. The probability of getting two heads in tossing the coins is $\frac{1}{4}$, *and the probability of failing to get two heads is* $\frac{3}{4}$. *Thus, if the act of tossing two coins is performed five times, the probability of getting two heads three times is*

$$\frac{5!}{3!\,2!}\left(\frac{1}{4}\right)^3\left(\frac{3}{4}\right)^2=\frac{45}{512}.$$

The mean and variance of x distributed according to the binomial law can be readily found to be np *and* npq *respectively, by setting up the moment-generating function of x.*

Another useful distribution is the negative binomial distribution

$$\bar{b}(x)=\frac{(x-1)!}{(k-1)!(x-k)!}p^xq^{x-k}, \tag{20}$$

where the event points of x are $k, k+1, \ldots$ *ad infinitum.*

Expression (20) *is simply the probability that x trials mill have to be performed before getting k A's. The mean value of x is* k/p. *The negative binomial distribution arises in such problems as repeated testing of a piece of equipment until a given result occurs as, for example, one failure, or some given number of failures.*

The Poisson Distribution.—Another important discrete distribution function is the Poisson distribution defined by:

$$p(x)=\frac{\mu^x}{x!}e^{-\mu}, \tag{21}$$

where the event points of x are $0, 1, 2, 3, \ldots$ *ad infinitum.*

By putting $pn=\mu$ *in the binomial distribution* (19), *one finds that, when* p *is "small" and* n *"large," the binomial distribution is closely approximated by the Poisson distribution.*

The Poisson distribution law provides a good description of the distribution of events for a fairly wide range *of phenomena. For example, if the number of alpha-rays emitted by radium which strike a given small area (as recorded by a Geiger counter, for example) in a given time, say ten seconds, is called x, and if the values of x for a large number of such time intervals are obtained, the distribution of these values of x will be closely approximated by a Poisson law in which* μ *is set equal to the average number of alpha-rays per time interval. If a* screw *machine is turning out a small percentage* (*e.g.,* 1%) *of defective screws, the numbers of defective screws in boxes of* 100 *will be approximately distributed according to a Poisson law with* $\mu=1$. *The Poisson law also arises in estimating density of bacteria or bacterial colonies in liquids.*

The Normal Distribution.—The most important continuous distribution is the normal or Gaussian law, having probability density function,

$$f(x)=\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(x-\mu)^2}{2\sigma^2}}. \tag{22}$$

The mean and variance of x in this distribution are μ *and* σ^2 *respectively.*

The graph of $f(x)$ *is an inverted symmetrical bell-shaped curve, as shown in fig. 4, where* μ *(the mean) is the value of x at the centre of the curve, and* σ *(the standard deviation) is the distance from the centre of the curve out to the inflection point on either side.*

Half the area under the curve lies between the ordinates $\mu\pm.6745\sigma$; *the quantity* $.6745\sigma$ *is called the probable ewor. About* 95% *of the area lies between the ordinates at* $\mu\pm1.9600\sigma$, *and approximately* 99% *of it lies between the ordinates at* $\mu\pm2.57586$.

The cumulative distribution or probability integral of the normalized form of the Gaussian distribution function defined by

$$F(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x} e^{-\frac{1}{2}t^2}dt \tag{23}$$

and the farm

$$\Phi(x)=\frac{1}{\sqrt{2\pi}}\int_{0}^{X} e^{-\frac{1}{2}t^2}dt \tag{24}$$

have been tabulated in various books for values of x between -6 and $+6$. The form

$$\psi(x)=\frac{1}{\sqrt{\pi}}\int_0^x e^{-t^2}dt \qquad (25)$$

has also been tabulated and is used extensively by physical scientists, although it is not as convenient as the form (24) for most statistical purposes. Expression (24) is the cumulative form of

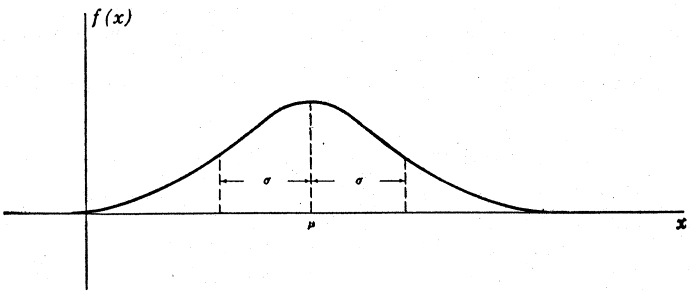


FIG. 4.— NORMAL DISTRIBUTION CURVE SHOWING STANDARD DEVIATION σ FROM THE MEAN μ

the Gaussian lam in which a is taken as the unit of measurement, whereas (25) is the cumulative form when $\sigma\sqrt{2}$ is taken as the unit of measurement.

The normal distribution function arises in many places in probability theory particularly as the limiting distribution function of certain functions of large numbers of independent random variables. One important case occurs in connection with the binomial distribution. It can be shown that the probability

$$Pr\left(\frac{x-np}{\sqrt{npq}}<y\right),$$

where x is distributed according to the binomial distribution (19), has as its limit, as n approaches ∞, the Expression $F(y)$ for any given value of y where $F(y)$ is obtained by replacing x by y in (23). This means that for large values of n, the value of x will be approximately normally distributed with mean np and standard deviation $\sqrt{npq}$, which in turn means that the normal probability tables can be used for approximating the probability that a binomially distributed variable x will lie between any two given values. For example, suppose 400 coins are thoroughly mixed in a sack and are poured out on a table. What is the probability that between 190 and 210 heads will turn up? We have $p=\frac{1}{2}$, $n=400$ and $\frac{x-np}{\sqrt{npq}}$ becomes $\frac{x-200}{10}$. The probability that x lies between 190 and 210 is the same as the probability that $\frac{x-200}{10}$ lies between -1 and $+1$, and this probability is approximately $F(+1)-F(-1)=.6827$, where $F(x)$ is given by (23).

Distribution Functions of Two or More Random Variables.—The Discrete Case.—Thus far we have discussed probability theory in which the significant feature of an event can be characterized by some value of a single random variable. In the extension of probability theory and its application to statistical theory, several random variables are usually required to describe the event under consideration. For example, suppose two dice are thrown, a green one and a red one, and that we wish to keep track of what happens to each die when the pair is thrown. Two random variables are needed, say x and y, where x gives the number of dots appearing on the green die when it is thrown and y the number appearing on the red die. Thus, the event of throwing the two dice can be described by a value of x and one of y. If 2 appears on the green die and 4 appears on the red one, we can briefly state that the values of x and y for this particular event are (2, 4). If the dice are "true," the probability of each of the 36 combinations of x and y: (1, 1), (1, 2), ... , (6, 6), is $\frac{1}{36}$. We can represent the distribution of probabilities in the xy plane by "attaching" a probability of $\frac{1}{36}$ at each of the 36 event points (1, 1), ... , (6, 6). More briefly, we write $p(x, y)=\frac{1}{36}$ for each combination of values of x and y. Now from $p(x, y)$ (that is, the probabilities at these 36 points spread out in the xy plane) we can calculate various other probabilities, such as the probability of getting a total of 4 dots on the two dice [which would be the sum of the probabilities at (1, 3), (2, 2), (3, 1), namely $\frac{3}{36}$], or the probability that neither die turns up more than a 3 [which would be the sum of the probabilities at (1, 1), (1, 2), (1, 3), (2, 1), (2, 2), (3, 2), (3, 1), (3, 2), (3, 3) or $\frac{9}{36}$], etc. In particular, if we add all of the probabilities for which x has a given value, say 2, we get $\frac{1}{36}+\frac{1}{36}+\frac{1}{36}+\frac{1}{36}+\frac{1}{36}+\frac{1}{36}=\frac{1}{6}$, which is the sum of the probabilities at (2, 1), (2, 2), (2, 3), (2, 4), (2, 5), (2, 6). This is the probability that the green die turns up 2 regardless of how the red one turns up. We can abbreviate by saying that

$$\sum_{y=1}^{6} p(2, y)=\tfrac{1}{6}=$$

the probability that $x=2$, regardless of what y is equal to. More generally, we can write

$$p(x')=\sum_{y=1}^{6} p(x', y)=$$

probability that $x=x'$, $p(x)$ (dropping the prime) calculated in this way from $p(x, y)$ is called the marginal distribution of x.

If we have three dice (say a red, a green and a blue one), three random variables x, y and z, each taking on values 1 to 6, would be required to describe completely the results of a throw of the three dice. Two hundred and sixteen combinations of values of x, y and z would, therefore, be required to describe all possible results. These event points (1, 1, 1), . . . , (6, 6, 6) can be visualized as 216 points arranged 6 by 6 by 6 in a cubical lattice in three-dimensional space at each of which the probability to be "attached" is $\frac{1}{216}$. More briefly, $p(x, y, z)=\frac{1}{216}$. From $p(x, y, z)$ one can calculate probabilities of occurrences of all kinds of events in a throw of three dice, such as the probability that the total number of dots is eight, the probability that at least one die turns up a number less than three, and so on. Note that if $p(x, y, z)$ is summed for all values of z from 1 to 6 for any fixed values of x and y, say x' and y', we simply get the probability of getting $x=x'$ and y=y', regardless of what value z may have. More briefly,

$$p(x', y')=\sum_{z=1}^{6} p(x', y', z)$$

is the probability that $x=x'$ and $y=y'$. $p(x, y)$ (dropping the primes) calculated in this way from $p(x, y, z)$, is called the marginal distribution of x and y. If $p(x', y, z)$ is summed with respect to both y and z, we obtain $p(x')$, the probability that $x=x'$, no matter what values y and z may have. $p(x)$ (dropping the prime) determined in this way is called the marginal 'distribution of x.

By further extension one can see how to set up a k-dimensional space for the k discrete random variables required for characterizing a throw of k dice. In general, one can see that if there are k discrete random variables $x_1, x_2, x_3, \ldots, x_k$ characterizing an event such that only certain values of each x can be taken on, then there would be certain event points in the k-dimensional random variable space, among which the probability would be allocated or distributed. We would denote the probability at any point $(x_1', x_2', \ldots, x_k')$ by $p(x_1', x_2', \ldots, x_k')$. Thus, $x_1, x_2, \ldots, x_k$ would be a set of k random variables having a discrete *probability law* or probability *distribution*,

$$p(x_1, x_2, \ldots, x_k). \qquad (26)$$

From $p(x_1, x_2, \ldots, x_k)$ we can find various probabilities concerning the x's by summing $p(x_1, x_2, \ldots, x_k)$ over the appropriate event points in the event space. For example, to find the probability that $x_1+x_2+\ldots+x_k<y$ where y is any given number, we would sum $p(x_1, x_2, \ldots, x_k)$ over all event points whose co-ordinates satisfied the above inequality. By summing $p(x_1, x_2, \ldots, x_k)$ with respect to one of the x's, say x_k, we obtain the marginal distribution of $x_1, x_2, \ldots, x_{k-1}$, which is merely the distribution law for these k−1 variables, ignoring the last one. Mean values and moments are defined for $p(x_1, x_2, \ldots, x_k)$ just as in the case of a probability law of one variable. For example, the mean value of x_1, $E(x_1)$, is defined by multiplying x_1 and $p(x_1, x_2, \ldots, x_k)$ and summing over all event points in the event space. Similarly, the mean value of any function of the x's, say $u(x_1, x_2, \ldots, x_k)$, is defined by multiplying $u(x_1, x_2, \ldots, x_k)$ and $p(x_1, x_2, \ldots, x_k)$ and summing over all event points in the event space. In particular, the mean value of $(x_1-\mu_1)(x_2-\mu_2)$, where $\mu_1=E(x_1)$ and $\mu_2=E(x_2)$, is the covariance between x_1, and x_2. The ratio of the covariance between x_1 and x_2 to the product of the standard deviations of x_1 and x_2 is called the correlation *coefficient* between x_1 and x_2, and is denoted by the ρ_{12}. It can be shown that $-1\leqq\rho_{12}\leqq+1$. The covariance and correlation coefficient can be similarly defined for any other two x's.

Applying the ideas of the section Conditional Probability, above, one can define conditional probability distributions. For example, for k=2, one may write $p(x_2|x_1=x_1')=p(x_1', x_2)/p(x_1')$ which states that the probability law of x_2, given $x_1=x_1'$, is equal to $p(x_1, x_2)$ evaluated for $x_1=x_1'$, divided by the marginal distribution of x_1 evaluated at $x_1=x_1'$.

The Continuous Case.—In case the event which is characterized by $x_1, x_2, \ldots, x_k$ is such that the event points do not form a discrete set, but rather a continuum of values, so that the event points in the k-dimensional space "fill up" a whole region in that space, then we have the case of continuous variables $x_1, x_2, \ldots, x_k$, whose probability law is expressed by a probability density *function* $f(x_1, x_2, \ldots, x_k)$. From this function one can determine various probabilities concerning the x's by integration. For example, the probability that $x_1x_2\ldots x_k<y$, where y is any given number, is obtained by integrating the Probability element,

$$f(x_1, x_2, \ldots, x_k)dx_1dx_2\ldots dx_k, \tag{27}$$

over the k-dimensional space of x's for which the above inequality holds. Similarly, one can find the probability that $x_1+x_2+\ldots+x_k<y$, where y is any given number, or one can find the probability that the largest of the x's in the set $x_1, x_2, \ldots, x_k$ is less than any given value y, and so on. If one integrates (27) with respect to x_k one obtains the marginal probability element of $x_1, x_2, \ldots, x_{k-1}$, which is simply the probability element for the variables $x_1, x_2, \ldots, x_{k-1}$, ignoring x_k. Marginal probability elements for other sets are similarly defined. The mean value of any x, say x_1, is obtained by integrating the product of x_1 and the probability element (27) over the entire space of the x's. More generally, the mean value of any function of the x's, say $u(x_1, x_2, \ldots, x_k)$, is defined as the integral of the product of $u(x_1, x_2, \cdots, x_k)$ and (27) over the space of the x's. The definitions of the covariance and correlation coefficient ρ_{ij} between any two of the x's, say x_i and x_j, are similar to those for the discrete case. The definition of a conditional probability element; *e.g.*, $f(x_2|x_1=x_1')dx_2$, follows at once from the ideas of the section on Conditional Probability together with those expressed in the last paragraph of the Discrete Case.

Some Important Probability Laws of Two or More Variables.—Perhaps the most important application of probability theory of two or more random variables is to statistical theory, to which the remainder of this article will be devoted. However, it is worthwhile to mention two joint or multivariate probability laws which are interesting and important in their own right: the multinomial law and the multivariate normal law.

The *Multinomial* Probability Law.—The multinomial law—a discrete probability law—states that if the probabilities are p_1, $p_2, \ldots, p_k$ that *an* event will result in *the mutually* exclusive *categories* $A_1, A_2, \ldots, A_k$, respectively, then the probability that in n trials x_1 will result in A_1, x_2 in A_2, $\ldots, x_k$ *in* A_k *is*

$$m(x_1, x_2, \cdots, x_k)=\frac{n!}{x_1!x_2!\ldots x_k!}p_1^{x_1}p_2^{x_2}\ldots p_k^{x_k}, \tag{28}$$

where $x_1+x_2+\ldots+x_k=n$ and $p_1+p_2+\ldots+p_k=1$. Since the sum of the x's must be equal to n, (28) is really a probability law of only k−1 random variables. The derivation of this law is similar to the derivation of the binomial law (19), the essential difference being that one deals with permutations of x_1 p_1's, x_2 p_2's, $\ldots, x_k$ p_k's (of which there are

$$\left.\frac{n!}{x_1!x_2!\ldots x_k!}\right)$$

rather than xp's and (n−x) q's. It will be noted that (28) is the general term in the expansion of the multinomial $(p_1+p_2+\ldots+p_k)^n$.

As a simple example of the application of the multinomial law, suppose two coins are tossed 20 times. What is the probability of getting two heads five times, two tails five times and one head and one tail ten times? The event of tossing two coins can result in one of three mutually exclusive events: two heads, two tails, one head and one tail with probabilities $\frac{1}{4}$, $\frac{1}{4}$ and $\frac{1}{2}$ respectively. The required probability is therefore

$$m(5, 5, 10)=\frac{20!}{5!5!10!}(\tfrac{1}{4})^5(\tfrac{1}{4})^5(\tfrac{1}{2})^{10}.$$

The Multivariate *Normal* Probability Law.—The second important probability law in several variables is the multivariate normal probability law of $x_1, x_2, \ldots, x_k$—a continuous probability law. The probability density function of this law is

$$\frac{1}{(2\pi)^{k/2}\sigma_1\sigma_2\ldots\sigma_k\sqrt{\Delta}}e^{-\frac{1}{2}Q_k} \tag{29}$$

where Q_k is a quadratic form in $x_1, x_2, \cdots, x_k$ given by

$$\sum_{j=1}^{k}\sum_{i=1}^{k}(-1)^{i+j}\frac{\Delta_{ij}}{\sigma_i\sigma_j\Delta}(x_i-\mu_i)(x_j-\mu_j)$$

where μ_i and σ_i are the mean and variance of xi, A is the determinant of correlation coefficients ρ_{ij}, (ρ_{ii} being defined as 1) and Δ_{ij} is the determinant obtained by deleting the ith row and jth column in A.

Term (29) is a generalization of the normal or Gaussian law (22) to k random variables. In particular, if $k=2$, we have the bivariate or two-dimensional normal law,

$$f(x_1, x_2)=\frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho_{12}^2}}e^{-\frac{1}{2}Q_2} \tag{30}$$

where

$$Q_2=\frac{1}{1-\rho_{12}^2}\left[\frac{(x_1-\mu_1)^2}{\sigma_1^2}+\frac{(x_2-\mu_2)^2}{\sigma_2^2}-2\rho_{12}\frac{(x_1-\mu_1)(x_2-\mu_2)}{\sigma_1\sigma_2}\right].$$

The probability density represented (30) is greatest at (μ_1, μ_2), since at this point $Q_2=0$. The density diminishes as one moves out in any direction from (μ_1, μ_2) in the x_1x_2 plane in such a way that this density is constant on each of the ellipses in the family $Q_2=c$, where c is any number greater than or equal to zero. If we hold x_1 fixed, say at x_1', and find the mean value of x_2; *i.e.*, evaluate the integral,

$$\int_{-\infty}^{\infty}x_2f(x_1', x_2)dx_2,$$

we obtain

$$\mu_2+\rho_{12}\frac{\sigma_2}{\sigma_1}(x_1'-\mu_1).$$

In other words, the mean value of x_2 for any given value of x_1, say x_1', lies on the straight line in the x_1x_2 plane whose equation is

$$x_2-\mu_2=\rho_{12}\frac{\sigma_2}{\sigma_1}(x_1'-\mu_1), \tag{31}$$

which is called the *regression* line *of* x_2 *on* x_1. It can be shown that the probability density which lies along any line $x_1=x_1'$ is a one dimensional normal probability law of the form (22) with a replaced by

$$\sigma_2\sqrt{1-\rho_{12}^2}$$

and μ replaced by

$$\mu_2+\rho_{12}\frac{\sigma_2}{\sigma_1}(x_1'-\mu_1).$$

Similarly, there is a regression line of x_1 on x_2. The correlation coefficient between x_1 and x_2 is ρ_{12} and measures the degree of statistical relationship that exists between x_1 and x_2. If $\rho_{12}=0$, x_1 and x_2 are statistically independent and the regression lines are perpendicular. If $\rho_{12}=1$ (or -1) the regression lines coincide and have slope

$$\frac{\sigma_1}{\sigma_2}\left(\text{or} -\frac{\sigma_1}{\sigma_2}\right).$$

In each of these extreme cases, x_1 and x_2 are functionally related, and all probability is concentrated along the lines

$$x_1-\mu_1=\pm\frac{\sigma_1}{\sigma_2}(x_2-\mu_2),$$

respectively.

The bivariate law is an extremely useful function in many statistical problems, providing a satisfactory model for describing the joint distribution of two statistically related variables such as range and deflection errors in repeated artillery fire or precision bombing, scores of two examinations taken by a large number of students, two anthropometric measurements on a large number of individuals, etc.

STATISTICAL THEORY

Some of the most important applications of probability theory, particularly of several variables, are in the theory of statistics. In the remainder of this article some of these applications will be discussed.

Sampling Theory. — Sampling From an *Infinite Population.*— Under Distribution *Functions* of Two or More Random Variables, above, we have seen how to set up a probability law for describing the results of throwing two or more dice. It is only a short step from that discussion to see how to set up a probability law for describing the results of making n independent trials where each trial is described by a value of a random variable having, of course, some distribution law. Thus, if x is the random variable having distribution law $dF(x_1)$, [$p(x_1)$ for the discrete case, and $f(x_1)dx_1$ for the continuous case], describing the first trial, x_2 the random variable having distribution law $dF(x_2)$ describing the second trial, and so on, then the probability law for describing the results of n independent trials (as measured by $x_1, x_2, \ldots, x_n$) is the product

$$dF(x_1)dF(x_2)\ldots dF(x_n). \tag{32}$$

In statistical terminology we say that $x_1, x_2, \ldots, x_n$ are the *values of* x *in a sample of* n *items drawn independently from a population having distribution law* dF(x), *where* dF(x) = p(x) *in* the discrete case and dF(x) = f(x)dx in the *continuous case.* Term (32) is called the probability law *of* the entire *sample.* This type of sampling is often called *sampling from an infinite population* (as contrasted with *sampling from a finite population* discussed below); the x's in the sample are independent in the probability sense. We thus have a basis for setting up a mathematical theory of sampling in the case of independent trials. The usual kinds of questions which are considered in sampling theory are these: What is the probability law of the means of the sample $x=(x_1+x_2+\ldots+x_n)/n$? Or the probability law of the sample variance

$$s^2=\sum_{i=1}^{n}(x_i-\bar{x})^2/n-1?$$

Or, the probability law of any other given function of the sample values, say $u=u(x_1, x_2, \ldots, x_n)$? Or the joint probability law of two or more functions $u_1=u_1(x_1, x_2, \ldots, x_n)$, $u_2=u_2(x_1, x_2, \ldots, x_n)$, .. ?

The problem of finding the probability law of any function of the x's in the sample, say $u(x_1, x_2, \ldots, x_n)$, is solved by finding $Pr[u(x_1, x_2, \ldots, x_n)\leqq u']$ the cumulative distribution of $u(x_1, x_2, \ldots$, x,); that is, by integrating (32) (in the Stieltjes sense; *i.e.,* summing in the discrete case and integrating in the continuous case) for all values of the x's for which $u(x_1, x_2, \ldots, x_n)\leqq u'$, where u' is any given number (real). Such an integration will produce a value $G(u')$. Dropping the prime, $G(u)$ is called the *cumulative sampling distribution* of $u(x_1, x_2, \ldots, u_n)$.

To find the joint cumulative sampling distribution $G(u_1, u_2)$ of two sample functions $u_1(x_1, x_2, \ldots, x_n)$ and $u_2(x_1, x_2, \ldots, x_n)$ one integrates (32) over all values of the x's such that both the inequalities $u_1(x_1, x_2, \ldots, x_n)\leqq u_1$ and $u_2(x_1, x_2, \ldots, x_n)\leqq u_2$ hold, where u_1 and u_2 are any two given numbers.

The meaning of $G(u)$ may perhaps be clarified in the following way: Suppose that when a certain trial or experiment is made the outcome is measured by a value of a random variable x, which has a cumulative distribution law $F(x)$. Now if the experiment is performed n times we will get n values of x, say $x_1, x_2, \ldots, x_n$, from which we will calculate the value of $u(x_1, x_2, \ldots$, x,), which might be a mean, sum of squares or any other function of statistical interest. Let this set of n trials be carried out a large number of times. The proportion of times when the computed values of $u(x_1, x_2, \ldots, x_n)$ will be $\leqq u'$ is a number which, under "ideal" conditions is predicted by $G(u')$. For example, if a sample of n items is drawn from a population having the normal distribution (22), then the mean $\bar{x}=(x_1+x_2+\ldots+x_n)/n$ will have as its cumulative probability law; *i.e.,*

$$Pr\left(\frac{1}{n}(x_1+x_2+\ldots+x_n)\leqq u\right),$$

the expression

$$G(u)=\frac{\sqrt{n}}{\sqrt{2\pi}\sigma}\int_{-\infty}^{u}e^{-\frac{n(t-\mu)^2}{2\sigma^2}}dt, \tag{33}$$

from which the probability element of the mean is

$$dG(\bar{x})=\frac{\sqrt{n}}{\sqrt{2\pi}\sigma}e^{-\frac{n(\bar{x}-\mu)^2}{2\sigma^2}}d\bar{x}. \tag{34}$$

This states that if a population has a normal probability law with mean μ and variance σ^2, then the probability law of the mean of n items from this population is normal with mean μ and variance σ^2/n. In general the functional form of $G(u)$ is a simple known function for only a very few specific sample functions $u(x_1, x_2, \ldots, x_n)$ and population cumulative distribution laws $F(x)$. The sampling theory of means, sums of squares and correlation coefficients of x's in samples from normal univariate and multivariate populations was developed thoroughly after 1925 by M. S. Bartlett, R. A. Fisher, H. Hotelling, P. L. Hsu, W. G. Madow, J. Neyman, E. S. Pearson, A. Wald, J. Wishart, S. S. Wilks and others, and published in *Biometrika,* the *Annals of* Mathematical Statistics, the Annals *of* Eugenics, Sankhyii and other journals. Results were also published from time to time dealing with sampling theory for samples from other kinds of populations; *e.g.,* those having binomial, Poisson and multinomial distribution laws. Many technical mathematical devices such as Fourier transforms, n-dimensional Euclidean geometry, combinatorial theory, etc., have been used in solving these sampling problems.

Results for samples from populations having arbitrary distributions are rather meagre. Mean values of means, variances and higher moments in samples from such populations are well known. It might be mentioned that if $x_1, x_2, \ldots$, x, are items in a sample from a population having any given distribution law with mean μ and variance σ^2, then the mean values of the sample mean $\bar{x}$ and sample variance s^2 are μ and σ^2 respectively, where the sample variance is defined as

$$s^2=\frac{1}{n-1}\sum^{n}(x_i-\bar{x})^2.$$

Another general sampling result of importance is the following: *If* $x_1, x_2, \ldots, x_n$ are *items* in a sample from a population whose distribution law has mean μ and variance a², then the limit, as

$n \to \infty$, *of* $\Pr\left(\frac{\sqrt{n}(x-\mu)}{\sigma} < u\right)$ is given *by*

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{u} e^{-\frac{1}{2}t^2} dt.$$

This means that large samples of n items from any population whose distribution law has mean μ and variance u^2 are such that their means are approximately distributed in accordance with a normal distribution law having mean μ and variance σ^2/n. A somewhat more general theorem can be stated, which is known as the central *limit theorem*, but the special case stated above is sufficient to give here, and is very useful in statistical theory.

As a simple application of this theorem suppose a die is thrown 100 times. What can we say about the average number of dots per throw appearing in the n throws; *i.e.*, the total number of dots divided by 100? In this case the population distribution law is $p(x) = 1/6$ for $x = 1, 2, 3, 4, 5, 6$. The mean of this distribution is

$$p = \sum_{x=1}^{6} x p(x) = 3.5,$$

and the variance is

$$\sigma^2 = \sum_{x=1}^{6} (x - 3.5)^2 p(x) = \frac{35}{12}, \text{ from which } \sigma = 1.708.$$

If the total number of dots divided by 100 is denoted by $\bar{x}$, then it follows by our theorem that the cumulative distribution law of

$$\frac{(\bar{x} - 3.5)\sqrt{100}}{1.708}$$

is approximately

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty} e^{-\frac{1}{2}t^2} dt$$

which means that $\bar{x}$ is approximately normally distributed with mean 3.5 and variance $\sigma/\sqrt{100}$; *i.e.*, 0.1708. Referring to the normal distribution in the section *Some Important Special Distribution Functions*, above, it will be seen, for example, that we can state that the probability is approximately 0.95 that $\bar{x}$, the total number of dots in 100 throws divided by 100, will not deviate from 3.5 by more than 1.96(0.1708); *i.e.*, 0.3348.

The Theory of Sampling from Finite Populations.—There is a special class of problems commonly referred to as problems of *sampling from* finite populations in which there is a population with a finite number N of elements or items, each of which is characterized by a value of a variable x, or by values of several variables. It is sufficient here to consider only one variable. Drawing a sample of n elements from such a population corresponds to taking out n of the original N elements. The successive drawings (or trials) of the n elements are not independent and hence the multivariate probability law for the x's in the sample is not given as a product of the form (32). It is more complicated, but essentially consists of considering all possible ways [there are $N(N-1)(N-2)\cdots(N-n+1)$ of them] in which a succession (*i.e.*, permutation) of n items can be drawn from the population of N items and assuming these to be "equally likely" to be drawn; *i.e.*, they are assigned equal probabilities. An alternative approach is to ignore the order in which elements appear and to consider the ${}_NC_n$ possible combinations of n elements which can be formed from the N elements in the population, assigning equal probabilities to all these combinations. In fact this approach can be used when the first one cannot, notably in situations where the n elements are drawn as a set or simultaneously. In either case, each sample consists of a set of n x's, say $x_1, x_2, \ldots, x_n$ from which can be calculated the sample mean, the sample variance or any other function of the x's. The sampling problem in either of these approaches simply amounts to the consideration of how the values of any given function of the sample x's are distributed when calculated for all possible samples of n items from the population of N items. Perhaps the most important results are that the mean and variance of the distribution of sample means for either of the two approaches are μ, and

$$\frac{\sigma^2}{n}\left(\frac{N-n}{N-1}\right),$$

respectively, where μ and u^2 are the mean and variance of x in the population of N elements. Means and variances of the distribution of sample variances, and certain higher sample moments have been worked out.

It can be shown as one would expect, that as N increases indefinitely, the theory of sampling from a finite population reduces to the theory of sampling from an infinite population discussed previously. Although we have considered the sampling theory of single functions of the x's in samples from populations in which each element or trial is characterized by a single random variable x, the whole set of ideas and concepts extend to sampling theory of one or more functions considered jointly, where samples are drawn from multivariate populations.

The theory of sampling from finite populations has been extensively used in *stratified* sampling and acceptance *sampling.* The principal idea involved in stratified sampling is that a population is composed of a number of subpopulations, each having a finite number of elements and having its own distribution. A subsample of a given size is drawn from each subpopulation, depending on certain characteristics of that subpopulation and then the subsamples are combined into a single master sample which is thus a sample of the original over-all population. This type of sampling has been widely applied to the sampling of human populations for social, political and economic purposes. Government surveys, market surveys, etc., are often conducted on samples of households or individuals determined by principles of stratified sampling. The mathematical theory of this type of sampling was worked out by J. Neyman (1934), Hansen and W. A. Hurwitz (1943) and others.

The second important field of application of the theory of sampling from finite populations is that of acceptance sampling of manufactured products. In the simplest application in this field, lots of articles (each article of which is acceptable or not acceptable), varying from several dozen to several thousand or several hundred thousand items, are submitted to an inspector who drams a sample of items, inspects them and on the basis of the results of this inspection decides to accept or reject the lot. Such a sampling plan specifies a number n of items to be drawn from a lot of N articles and an allowable number of defectives c, such that if there are not more than c defective items among the n items of the sample, then the lot is accepted; otherwise it is rejected or subjected to 100% inspection. If the fraction of defectives in the lot is p, then there is a definite probability P that the lot will be accepted on the basis of the sample for the particular sampling plan used. For a given sampling plan, P is a function of p that decreases from 1 to 0, as p increases from 0 to 1, and the curve of P as a function of p is known as the operating characteristic *curve* of the sampling plan. This curve provides both the producer and purchaser information as to what risks each will take in agreeing to use the given sampling plan. For each value of p and a given sampling plan there is an average number, A, of items inspected per lot before a decision is made to accept or reject. A is a function of p and is the *average* inspection number curve. There are many sampling plans which could be devised for deciding whether to accept a lot or not. The type of plan described above is known as single sampling and was originally devised by H. F. Dodge and H. G. Romig (1929). Another type known as *double* sampling, also introduced by Dodge and Romig (1941), provides for the possibility of (1) accepting, (2) rejecting or (3) reserving judgment until a further sample is drawn, in which case either acceptance or rejection of the lot will be decided upon. These ideas were further extended to multiple *sampling* by W. Bartky (1944). Another type of sampling known as sequential sampling, which is essentially a generalization of multiple sampling, was devised by A. Wald (1947) and applied to inspection problems by H. A. Freeman, M. Friedman, F. Mosteller and W. A, Wallis (1948). This plan provides for the possibility of deciding whether to accept, reject or reserve judgment at the end of the drawing of each item or each group of several items. These sampling plans all have operating characteristic curves and average inspection number curves. In general, the sequential methods have been shown to require a smaller amount of inspection, although the usefulness of the various methods of sampling depend to a considerable extent on practical considerations. These sampling methods have been widely used, particularly in connection with the procurement of military matériel.

Importance of Order *Information* in Sampling.—It should be remarked that in the theory of sampling thus far considered we have been concerned with distribution laws of sample means, variances and other functions of sample x's, and not with the distribution law of any quantity which depends on the order in which x's appear as a sample is "drawn." There are many situations in which a sample is drawn one item at a time until there are n items. In such cases a consideration of the ordering of the x's becomes important, to see whether or not the property of "randomness" is being exhibited as the sample is being drawn. W. A. Shewhart (1939) discussed and demonstrated the practical importance of investigating the randomness of sequences which occur in sampling as a source of clues for detecting why an alleged random variable is not behaving like a random variable. He developed criteria for testing randomness of sequences. These criteria proved useful in connection with quality control problems in mass production and industrial research. As a simple example, suppose a sample of seven items is drawn in a sequential manner from a population in which a random variable x has a continuous distribution. Let the order in which the x's are drawn in the sample be $x_1, x_2, \ldots, x_7$, which correspond to seven points in time. One of the x's will be the median; *i.e.*, it will exceed three of the x's in size and will be exceeded by the remaining three. Let $x_1, x_2, \ldots, x_7$ be plotted as ordinates corresponding to $t = 1, 2, \ldots, 7$. We therefore have seven points. Let a horizontal line be drawn through the point whose ordinate represents the median. There will be three points above this horizontal line and three below. If a point lies above the median let this fact be denoted by $+$, and if below by $-$. We would therefore have a sequence of three $+$'s and three $-$'s. For example, the sequence might look like this: $+--++-$. Note that there are two runs of $+$'s, in which therei s a t least one $+$, and two runs of $-$'s, a total of four runs. What is the probability of getting four runs in a "random" ordering? To answer this question, we would consider all possible permutations of the $+$'s and $-$'s, of which there are $6!/(3!)^2 = 20$, and assign equal probabilities to them, and find .out what proportion of possible sequences have four runs. The answer is $\frac{8}{20}$, which is the probability of four runs. One can do this for any possible number of runs from two to six, and hence get a probability law for the total number of runs. In fact, the probabilities of 2, 3, 4, j, 6 runs are $\frac{2}{20}, \frac{4}{20}, \frac{8}{20}, \frac{4}{20}, \frac{2}{20}$, respectively. A small number of runs corresponds to heavy bunching of $+$'s and of $-$'s and hence to a strong indication of nonrandomness as might be caused by some gradual changes being introduced into the x's. The probability law states probabilities for any degree of bunching as measured by total number of runs from two to six under the hypothesis that nothing is causing the sequences to be other than equally likely. If, in a given case, we should get only a small total number of runs, say two, me can claim that something has crept in to cause heavy bunching with a risk of 0.1 of getting two runs if nothing has entered to cause excessive bunching, although we claim that it has.

The probability theory of runs under various conditions was worked out by A. M. Mood (1940), J. Wolfowitz (1945) and others.

It should be pointed out that in statistical practice samples of at least 2j or 30 items are considered in making analyses of runs and trends. The most common graphical method of presenting the sample sequence is the control chart introduced by W. A. Shewhart (1931), in which the sample values are plotted as ordinates in the order in which they are drawn. A horizontal line is drawn through the mean of the ordinates and "control" lines are drawn on each side of this horizontal line and are usually spaced at such a distance that the probability is between .01 and .05 oi a point falling outside the band between the control lines when nothing has entered to upset the randomness of the sequence. This chart is widely used in mass production problems. An exposition of it and its various applications has been given by the American Standards association (1941).

Statistical Tests.—Type-I *and Type-II* Errors *in* a Statistical Test.—In an example at the end of the last section we defined a certain type of run for a sample and described how the distribution law of the total qumber of runs in a sample could be determined. It was pointed out how the total number of runs could be taken as an indication of how thoroughly the $+$'s and $-$'s are mixed or randomized in a sample—the smaller the number of runs the greater the amount of bunching and hence of nonrandomness. In fact, on the basis of the total number of runs, we can make a rule for deciding whether or not to claim that there is significant bunching in a given sample; *i.e.*, more bunching than can be accounted for by the hypothesis of randomness. In fact, suppose we say that there is significant bunching if there are as few as two runs. The probability that we will erroneously claim there is significant bunching, when in fact there is none, is 0.1, which is the probability of as few as two runs under the hypothesis of pure randomness; *i.e.*, that all 20 possible sequences of $+$'s and $-$'s are equally likely. What we have stated above is a simple example of a statistical significance test. or simply a statistical test:

A statistical test is a procedure for testing a given hypothesis about the distribution lam of a population from which a sample is assumed to have been drawn. The hypothesis in its simplest form is whether the cumulative distribution function of the population is some specific function $F_1(x)$ alternative to a specified function $F_0(x)$. It is assumed that the sample comes from one of these populations. To test the hypothesis, a function $u(x_1, x_2, \ldots, x_n)$ of the sample x's isconstructed, and a range R of critical *values* of this function is found so that the probability is a given value 6 (usually .01 or .05) of $u(x_1, x_2, \ldots, x_n)$ lying in R if the population cumulative distribution function is $F_0(x)$, and also such that the probability of $u(x_1, x_2, \ldots, x_n)$ falling in R when the population distribution $F_1(x)$ is made as large as possible—certainly larger than δ. Then the claim can be made that the sample has been drawn from the population having distribution $F_1(x)$ with a risk of probability δ of *making* a type-I error. By a type-I error we mean the error committed by saying that the sample is not from the population having distribution $F_0(x)$, when, in fact, it is. In other words, when the value of $u(x_1, x_2, \ldots, x_n)$ falls in R we run a risk of erroneously claiming the sample not to have come from the population with distribution $F_0(x)$ when it actually does come from such a population. If the value of $u(x_1, x_2, \ldots, x_n)$ does not fall in range R the test calls for the assertion that the sample comes from the population having distribution $F_0(x)$, which is considered as the only alternative to $F_1(x)$ at present. There is a risk of being in error in this assertion, too, because the sample could have come from the population with distribution $F_1(x)$. The probability ϵ of this error is obtained by finding the probability of $u(x_1, x_2, \ldots, x_n)$ not falling in range R, when the sample has actually been drawn from the population having distribution $F_1(x)$. This error is called a *type-II* error. The probability of $u(x_1, x_2, \ldots, x_n)$ falling in R when the sample is from the population having distribution $F_1(x)$ is $1-\epsilon$ and is called the power of *the* test based on $u(x_1, x_2, \ldots, x_n)$. When $u(x_1, x_2, \ldots, x_n)$ falls in R we often say that it is statistically *significant* at the 6 probability level. Usually, $F_1(x)$ is a member of a family of functions $F(x, \theta)$, when θ is a parameter, which would be a specific member of the family, say $F(x, \theta_0)$. In this case the power $1-\epsilon$ for the various alternatives corresponding to all values of θ (except θ_0) would depend on θ and is called the *power* function of the test based on $u(x_1, x_2, \ldots, x_n)$. The essential idea underlying type-I and type-I1 errors was originally introduced by Bell Telephone laboratories' quality control engineers (Dodge and Romig, 1929), who first referred to them in their own applications as producer's risk and consumer's risk, respectively. The producer's risk is the probability that a given lot of products of satisfactory quality offered by a producer will be rejected on basis of the results of an inspected sample from the lot, whereas the consumer's risk is the probability of the consumer's accepting a lot of products of unsatisfactory quality on basis of the results of the inspected sample. J. Neyman and E. S. Pearson (1928) developed the idea which underlies these two risks into the present theory of testing statistical hypotheses described above for a specified sample size. Contributions to this theory and its application to various problems are numerous. Two important examples will be briefly discussed.

A. Wald (1950) further generalized the ideas by developing a theory of statistical decision functions in which decisions regarding a statistical hypothesis may be more numerous than simply acceptance or rejection and where the risks associated with such decisions are measured.

The "Student" Test.—First, consider a sample to have been drawn from some normal population and that we wish to test, on the basis of a sample of n items, whether this population has a given mean μ_0. The criterion for this test is

$$\frac{\sqrt{n}\,(\bar{x}-\mu_0)}{s}=t,$$

say, where s^2 is the sample variance

$$\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2.$$

The sampling distribution of t when the sample has been drawn from a normal population with mean μ_0 is:

$$dF(t)=\frac{\Gamma\left(\frac{n}{2}\right)}{\Gamma\left(\frac{n-1}{2}\right)\sqrt{\pi(n-1)}}\left(1+\frac{t^2}{n-1}\right)^{-\frac{n}{2}}dt, \qquad (35)$$

where $\Gamma(m)$ is the gamma function which equals $(m-1)!$, if m is a positive integer and provides a good interpolation function for $(m-1)!$ if m is real but not a positive integer. In either case, $\Gamma(m)$ can be expressed as a definite integral. The distribution law expressed by (3j) is known as the "*Student*" (1908) *distribution* law *with* n—I degrees offreedom. The range R of critical values of the function t is taken as the set of values of t outside the interval $(-t_\delta, t_\delta)$ where t_δ is given by the relation

$$\int_{-t_\delta}^{+t_\delta} dF(t)=1-\delta.$$

This means that the probability is $1-\delta$ that the sample will be such that

$$-t_\delta<\frac{\sqrt{n}(\bar{x}-\mu_0)}{s}<+t_\delta, \qquad (36)$$

when the sample is actually from a normal population with mean μ_0. If the sample yields values of $\bar{x}$ and s so that the inequality (36) is not satisfied we reject the hypothesis that the sample is from a normal population with mean μ_0. The risk of rejecting this hypothesis falsely is measured by the fact that the type-I error is δ. Tabulations of values of t_δ have been presented in various statistics books for $\delta = .01$, .05 and other values and for values of n—I from 1 to 30. There are many applications of the Student t test.

The Chi-Squared *Test*.—As a second example, consider an infinite population in which each element belongs to one and only one of the mutually exclusive classes $A_1, A_2, \ldots, A_k$ having probabilities $p_1, p_2, \ldots, p_k$, where

$$\sum_{i=1}^{k} p_i = 1.$$

In a sample of n elements from this population, the probability of getting x_1 A_1's, x_2 A_2's, $\ldots$, x_k A_k's is given by the multinomial law (28). It is important in many statistical problems to test whether the observed frequencies $x_1, x_2, \ldots, x_k$ could have reasonably come from a population in which $p_1, p_2, \ldots, p_k$ have specified values $p'_1, p'_2, \ldots, p'_k$; *i.e.*, whether the x's depart significantly from their expected values $np'_1, np'_2, \ldots, np'_k$ under the hypothesis that the sample came from a population with these specified values of the p's. The criteria for testing this hypothesis which was originally proposed by K. Pearson (1900) is:

$$\chi^2 = \sum^{k} \frac{(x_i - np'_i)^2}{np'_i}, \tag{37}$$

known as the chi-squared test criterion. It will be seen that it satisfies our intuitive requirement that it should somehow measure the discrepancy between each xi and its expected value. The more the x's depart from their mean or expected values, the larger the value of x^2. Thus, the range R of critical values which suggests itself consists of all values of χ^2 greater than a suitable chosen value χ_δ^2. For larger values of n, and assuming that none of the p's are very small, the sampling distribution of χ^2, if the hypothesis is true that the sample came from a population in which the p's have the values specified, is approximately

$$dF(\chi^2) = \frac{\left(\frac{\chi^2}{2}\right)^{\frac{k-3}{2}}}{2\Gamma\left(\frac{k-1}{2}\right)} e^{-\frac{1}{2}\chi^2} d(\chi^2). \tag{38}$$

This is an important sampling distribution, known as the *chi-squared* distribution with k−1 degrees *of* freedom. Values of χ_δ^2 have been tabulated for which

$$\int_{\chi_\delta^2}^{\infty} dF(\chi^2) = \delta$$

has various values from .01 to .99 and for values of k from 2 to 30. There are many statistical functions having sampling distributions which are of the form (38).

As a simple example of the application of the criterion (37), suppose a bridge player has kept a record of the number of aces which he has obtained in each of 500 bridge hands which he has played over a period of time. Suppose that he received no aces in 165 hands, one ace in 210 hands and more than one ace in 125 hands. Is this distribution of aces consistent with the hypothesis of thorough shuffling and fair dealing? Under the hypothesis of thorough shuffling and fair dealing one finds by applying the theory of combinations that the probabilities of no aces, one ace and more than one ace are approximately 0.30, 0.44 and 0.26 respectively. The numbers of hands containing no ace, one ace and no aces in 500 hands are, therefore, 150, 220, 130 respectively. The value of χ^2 computed from (37) is

$$\chi^2 = \frac{(165-150)^2}{150} + \frac{(210-220)^2}{220} + \frac{(125-130)^2}{130} = 2.147.$$

This is not a significantly large value of χ^2. For example, in a large number of sets of 500 bridge hands more than 30% of the sets would yield hands deviating more widely from the expected distribution of aces than in the present case. In order to have significant discrepancies at the 0.05 probability level the observed distribution of aces would have to yield a value of χ^2 equal to about 6 or larger.

The Method of Likelihood Ratios.—In the theory of testing statistical hypotheses, one of the major problems is that of devising a test criterion from the sample. For a wide class of situations which covers many of the practical statistical problems, a procedure is available for constructing the tests, known as the *method of likelihood* ratios. In applying this method we assume that the sample is drawn from a population having a cumulative distribution function of the functional form $F(x, \theta)$, where θ is a parameter. We wish to test the hypothesis that θ has a specified value θ'. The probability law of the x's in a sample of n items is

$$dF(x_1, \theta)\, dF(x_2, \theta) \ldots dF(x_n, \theta). \tag{39}$$

We maximize (39) with respect to θ and denote the maximum of (39) by $P(x_1, x_2, \ldots, x_n, \hat{\theta})$ and then take the ratio

$$\lambda = \frac{P(x_1, x_2, \ldots, x_n, \theta')}{P(x_1, x_2, \ldots, x_n, \hat{\theta})}, \tag{40}$$

where the numerator is obtained by replacing θ by θ' in (39). The ratio λ is known as the likelihood *ratio*, and is a test criterion which has, under certain conditions, optimum properties for large samples. The value of λ varies between 0 to 1, and the critical range R for risk δ of type-I error of values of λ would be those between 0 and λ_δ where λ_δ is chosen so that $Pr(\lambda < \lambda_\delta) = \delta$ when the hypothesis is true that $\theta = \theta'$. The distribution of $-2\log_e\lambda$ in large samples actually drawn from a population having distribution $F(x, \theta')$ is approximately the chi-squared distribution law (38) with one degree of freedom (*i.e.*, when the hypothesis that $\theta = \theta'$ is true). For type-I error of probability δ the critical range R of $-2\log_e\lambda$ are those values greater than χ_δ^2 where $Pr(\chi^2 > \chi_\delta^2) = \delta$, where χ^2 has the distribution law (38) with $k = 1$. This method extends readily to the case of several parameters in which the population cumulative distribution is $F(x, \theta_1, \theta_2, \ldots, \theta_h)$, the hypothesis being that these θ's have specified values $\theta'_1, \theta'_2, \ldots, \theta'_h$.

A. Wald (1941) showed that in large samples the likelihood ratio is the best statistical test that can be devised in a certain reasonable (but technical) sense. The method is applicable to many statistical hypotheses that arise in connection with populations having normal, Poisson, binomial, multinomial and many other types of distribution laws. Wald (1947) also devised a theory of statistical tests based on the likelihood ratio for sequential sampling.

Statistical Estimation.— Under the section Statistical Tests, above, me have discussed the problem of testing whether or not a sample could "reasonably" have arisen from a population with a given distribution or a given type of distribution. More precisely we have discussed the problem of testing the hypothesis that one or more parameters in a population distribution law have certain specified values, regardless of what values certain other parameters in the distribution law may have.

Closely related to this problem is that of estimating, on the basis of a sample, the value of a parameter in a population distribution law. There are two approaches to this problem: point estimatiou and interval estimation.

Point Estimation.—By point estimation in the simplest case, we mean the computation of a function, say $\breve{\theta}$, of a sample of x's drawn from a population having a distribution law involving a parameter θ whose value is unknown, such that in repeated samples $\breve{\theta}$ will "cluster" around θ. Thus, in any given sample the value assigned to θ is $\breve{\theta}$. This value is subject, of course, to an error described, in repeated samples, by the probability law of $\breve{\theta}$. A fundamental problem in point estimation is to devise an *efficient* estimate; *i.e.*, a function so that in repeated samples it will cluster as closely around the true value of θ "as possible." R. A. Fisher (1921) proposed a method by which such a function can be formed which is valid in many of the statistical situations that arise. If $F(x, \theta)$ is the population distribution, in which θ is to be estimated, then, under fairly general conditions, the most efficient point estimate $\hat{\theta}$ of θ for large samples is provided by the value of θ which maximizes the probability (39) at the given sample point $x_1, x_2, \ldots, x_n$—most efficient in the sense that no other function of the sample x's can be devised which has a smaller variance in repeated samples than that of $\hat{\theta}$. The variance of $\hat{\theta}$ is given by $\frac{1}{nV^2}$, where

$$V^2 = \left[E\left(\frac{d\{\log dF(x, \theta)\}}{d\theta}\right)^2\right].$$

As defined in this manner θ is called the *maximum* likelihood estimate of θ. As examples: the sample mean $\bar{x}$ is the maximum likelihood estimate of the mean μ of a normal population having distribution law (22); the sample mean $\bar{x}$ is the maximum likelihood estimate of μ in the Poisson law (21); the maximum likelihood estimate of the probability p of an A in a binomial population is x/n, where x is the number of A's obtained in the sample of n items. The method of maximum likelihood estimation extends to the case in which the population distribution function is characterized by several parameters, say $\theta_1, \theta_2, \ldots, \theta_h$.

Interval Estimation.—By interval estimation we mean the computation of two functions of the x's in a sample say $\underline{\theta}$ and $\bar{\theta}$ such that if the sample is drawn from a population having cumulative distribution law $F(x, \theta)$ then $\underline{\theta}$ and θ will include the unknown value of θ for the population between them with a given probability 1−δ. In practice, 1−δ is usually taken to be a number between 0.90 and 0.99. $\underline{\theta}$ and θ are called *upper* and *lower confidence* limits; the interval $(\underline{\theta}, \bar{\theta})$ is called the confidence interval, 1−δ the *confidence coefficient*. $\underline{\theta}$ and $\bar{\theta}$ are often referred to as $100(1-\delta)\%$ confidence limits. It should be noted that $\underline{\theta}$ and $\bar{\theta}$ are constructed from the x's of the sample and hence are random variables whose values fluctuate from sample to sample. An example of confidence limits can be obtaincd by examining inequality (36). This inequality asserts that if a sample having mean $\bar{x}$ and standard deviation s is drawn from a population having a normal distribution law with mean μ_0, then the probability is 1−δ that the value of $\bar{x}$ and s will be such as to satisfy the inequality (36), which is equivalent to the statement that the probability is 1−δ that the two quantities

$$\bar{x} \pm t_\delta \frac{s}{\sqrt{n}}$$

will include the value of μ_0 between them. These two quantities are confidence limits for μ_0 with confidence coefficient 1−δ. There are usually many ways of constructing $\underline{\theta}$ and $\bar{\theta}$ from a sample but the fundamental problem of interval estimation is to devise $\underline{\theta}$ and $\bar{\theta}$ in such a way that they are as close together as possible in some average sense. Fortunately, there is a method for doing this which is applicable to the case of large samples for a wide class of population distribution laws. The method is based on the fact that in large samples the cumulative distribution function of the quantity

$$\left[\frac{1}{\sqrt{n}V} \cdot \frac{\partial}{\partial\theta} P(x_1, x_2, \ldots, x_n, \theta)\right] = \psi,$$

say (where V is defined in the discussion of maximum likelihood estimation, and $P(x_1, x_2, \ldots, x_n, \theta)$ is the probability given by expression (39)) is approximately given by the cumulative normal distribution $F(\psi)$, where $F(\psi)$ is obtained by replacing x by ψ in (23). To obtain confidence limits for θ for any given confidence coefficient 1−δ one finds x_δ from (23) so that $F(x_\delta) = 1 - \frac{1}{2}\delta$. The probability is approximately 1−δ that in a large sample the value of ψ defined above will be such that $-x_\delta<\psi<x_\delta$. ψ, it will be noted, involves the sample x's and θ, and, when the method is valid, ψ is an increasing or decreasing function of 8. Hence, solving the inequality $-x_\delta<\psi<x_\delta$, one obtains two values of 8, say $\underline{\theta}$ and $\bar{\theta}$, which are the desired confidence limits. For example, if a sample is drawn irom a binomial population in which the probability of getting an A in a single drawing is p, the expression for ψ is $(x-np)/\sqrt{npq}$, which x, n, p and q are defined in (19). To get 95% confidence limits of p, one would solve the following inequalities for p

$$-1.96<(x-np)/\sqrt{npq}<+1.96.$$

The idea embodied in the concept of confidence limits was first pointed out by E. B. Wilson (1927), using the example just given. But the theory of confidence limits was rather fully developed by Neyman (1937). R. A. Fisher (1933) used the term *fiducial* limits instead of confidence limits.

Method of *Moments*.—Another procedure of point estimation extensively used in many statistical problems is the method of moments. In using the method of moments a sample of n x's is available, and it is assumed that the sample is irom a population having a cumulative distribution function of the form, or closely approximated by the iorm, $F(x, \theta_1, \theta_2, \ldots, \theta_h)$, whose functional form is known, but the values of the θ's for the specific problem at hand are unknown. The problem is to estimate the values of the θ's. The principle of estimation by the method of moments provides that the first h moments of the x's in the sample, *i.e.*,

$$\frac{1}{n}\sum_{i=1}^{n} x_i,\ \frac{1}{n}\sum_{i=1}^{n} x_i^2,\ \ldots,\ \frac{1}{n}\sum_{i=1}^{n} x_i^h,$$

be equated, respectively, to the first h moments of x computed from the distribution iunction $F(x, \theta_1, 82, \ldots, \theta_h)$. Since the h moments of this distribution function will be functions of the θ's we have a set oi h equations in h unknowns, $\theta_1, \theta_2, \ldots, \theta_h$ to be solved. The values of the 8's yielded are the point estimates of $\theta_1, \theta_2, \ldots, \theta_h$ by the method of moments. In general, the method of estimation by moments is not as efficient as the method of maximum likelihood. There are cases in which the two methods give identically the same estimates. This is true, for example, in estimating the mean μ and variance σ^2 in the normal distribution (22) iunction on the basis of a sample.

Karl Pearson (1895) gave a general functional form of the distribution function $dF(x, \theta_1, \theta_2, \ldots, \theta_h)$ for the continuous case and for the case h=4, so that the method of moments can be used on the basis of the first four moments. The probability density function is given as the solution of the differential equation

$$\frac{df}{dx}=\frac{(x+\theta_1)f}{\theta_2+\theta_3x+\theta_4x^2},$$

which will involve four unknown parameters. For various combinations of values of the constants $\theta_1, \theta_2, \theta_3, \theta_4$, probability density curves $y=f(x, \theta_1, \theta_2, \theta_3, \theta_4)$ of many different shapes can be obtained which are flexible enough to cover many practical problems.

The Method *of* Least Squares.—Another well-known procedure of point estimation of population parameters is known as the method oi least squares. In this method it is assumed that under "ideal" conditions a variable y can be expressed as some iunction of x, say $g(x, \theta_1, \theta_2, \ldots, \theta_h)$ involving certain parameters $\theta_1, \theta_2, \ldots, \theta_h$. A set of "observational" pairs $(x_1, y_1), (x_2, y_2) \ldots (x_n, y_n)$ are obtained. Often these observational pairs are obtained by picking a value of x, then performing an experiment to get a value of y corresponding to that value of x. Thus by picking $x_1, x_2, \ldots, x_n$ as the values of x, one gets a corresponding set oi values of y; *i.e.*, $y_1, y_2, \ldots, y_n$. The "theoretical" values of the y's corresponding to these values of x are $g(x_1, \theta_1, \theta_2, \ldots, \theta_h)$, $g(x_2, \theta_1, \theta_2, \ldots, \theta_h) \ldots$, $g(x_n, \theta_1, \theta_2, \ldots, \theta_h)$. The least squares estimates of the θ's are defined as the values of the θ's which will minimize the sum of squares

$$S=\sum_{i=1}^{n}[y_i-g(x_i, \theta_1, \theta_2, \ldots, \theta_h)]^2.$$

The idea of least squares can be extended in various directions, and many applications were, for example, treated by W. E. Deming (1943). It turns out that the method of least squares and the method of maximum likelihood yield identically the same result if one assumes that y and $g(x_1, \theta_1, \theta_2, \ldots, \theta_h)$ are such that the "error" $[y-g(x, \theta_1, \theta_2, \ldots, \theta_h)]$ is normally distributed nith mean zero. The distribution function (32) of the entire sample is such that the sum of squares S appears in the exponent, and the problem of maximizing the likelihood (32) with respect to the θ's becomes equivalent to minimizing S.

Tolerance Interval Estimation.—Another important concept in the theory of estimation is *tolerance interval* estimation introduced by W. A. Shewhart. The problem here may be stated as follows Suppose a random variable in a population has a continuous probability law and that the probability element is $f(x)dx$, but where $f(x)$ is unknown. A sample is drawn from the population, and from the sample x's two quantities, say L_1 and L_2, are computed such that we can state that the probability is γ (usually .go to .99), that the proportion of the x's in the population included between L_1 and L_2 is at least p (also usually .90 to .99), no matter what form $f(x)$ may have. More briefly, L_1 and L_2 are such that

$$Pr[\int_{L_1}^{L_2} f(x)dx \geqq \beta]=\gamma,$$

and they are called $100\beta\%$ tolerance limits at tolerance level γ. Order statistics can be used as tolerance limits; *i.e.*, L_1 and L_2 may be taken as the least and greatest x in the sample, respectively, or next to the least and next to the greatest, etc. If the functional form of $f(x)$ is known, other methods of obtaining L_1 and L_2 can be used. For example, if $f(x)$ is known to be normal, $100\beta\%$ tolerance limits of the form

$$\bar{x}\pm t_\beta\sqrt{\frac{n+1}{n}}s,$$

$\bar{x}$ and s^2 being the sample mean and variance, can be used where t_β is such that $Pr(-t_\beta<t<t_\beta)=\beta$, where t is distributed according to the Student law (35).

Design of Experiments.—With the rapid development of statistical theory, an increasing amount of attention is being paid to the original design or setting up oi any type of an experiment or an investigation which depends heavily upon statistical analysis of the results for interpretation. consideration of experimental design led to the development of theory and procedures for determining what combinations of iactors important to the entire experiment should be introduced to simpliiy statistical analysis of the data and its interpretation, and also to determine how many repetitions or replications of the experiment should be performed in order to detect important differences in experimental results attributable to the various factors or combinations of factors. R. A. Fisher was the leading exponent on the importance of carefully designed experiments. Fisher and his school developed experimental designs together mith an appropriate statistical procedure known as the analysis of variance for analyzing the data from such experiments. The principal idea in this work is to arrange the entire experiment in an orderly manner as a set of subexperiments (which may consist of as iew as one trial each), these subexperiments differing from each other by varying one or more iactors, so as to permit the effect of the variation of the factor (or iactors) on the outcome of the experiment to assert itself in case there is such an effect. A statistical test iunction is designed: (1) to detect whether the outcome of the experiment is such that the differences in results irom one subexperiment to another are real, and attributable to the variation of the factors being tested, or whether they are simply chance differences; and (2) to measure such differences ii they are real. Frequently such differences are known to be real in advance and the statistical functions are used to measure the differences.

Experimental Designs by W. G. Cochran and Gertrude M. Cox (1950) should be consulted by the reader interested in details of these developments.

Suppose samples are drawn from each of two populations, and that we can safely assume these two populations to have normal distribution laws with equal variances. The question is this: could the two samples have reasonably come from normal populations with the same mean? If the numbers of items, means and variances oi the two samples are n', n''; x', x''; s'^2, s''^2, respectively, a suitable criterion for making the test is $\sqrt{n}(\bar{x}'-\bar{x}'')/s$ where n$=n'+n''$, and

$$s^2=(n'-1)s''^2+n(n''-2-1)s''^2.$$

Thus, the greater the difference between the sample means in relation to s, the greater the value of the criterion and the more uniavourable it is to the hypothesis of equality of population means. This criterion computed from pairs of samples from normal populations having the same means has a distribution law given by (3j) with $n'+n''-2$ degrees of freedom; *i.e.*, with n−1 replaced by $n'+n''-2$. Therefore, ii the absolute value of the criterion exceeds t_δ, lve say that the samples' means are significantly different at the δ probability level, which means that we can say that the samples are actually irom normal populations mith the same means with a risk of probability δ of making a type-I error. This test is useful in testing whether the effects of two treatments A and B on a given measurable characteristic are significantly different; *e.g.*, whether two rations A and B are different in their effects in increasing the weight of pigs. The experiment might be set up with 30 pigs of a given age to receive ration A and 30 more pigs matched with those in the first group on age and weight to receive ration B. Thus, there are two subexperiments. Aiter a given time interval, say 60 days, each of the 30 pigs in each sample would be weighed, and these t o sets of weights would be the two samples of x's to be used in the criterion.

Note that in using the two-sample criterion described above it has been assumed that the variances oi the populations are equal. Actually, we may wish to test this assumption, assuming only that the two population distributions are normal. A criterion is available for making this test, namely

$$\mathcal{J}=s'^2/s''^2$$

which has the following distribution law when the hypothesis of equal population variances is true:

$$dF(\mathcal{J})=\frac{\Gamma\left(\frac{n'+n''-2}{2}\right)}{\Gamma\left(\frac{n'-1}{2}\right)\Gamma\left(\frac{n''-1}{2}\right)}\left(\frac{n'-1}{n''-1}\right)^{\frac{n'-1}{2}}\mathcal{J}^{\frac{n'-3}{2}} \tag{41}$$

$$\left(1+\frac{n'-1}{n''-1}\mathcal{J}\right)^{-\frac{n'+n''-2}{2}}d\mathcal{J}$$

which is known as Snedecor's $\mathcal{J}$ distribution and defined on the interval $(0, \infty)$. The $\mathcal{J}$ criterion is an intuitively reasonable one since small or large values of it are values unfavourable to the hypothesis of equal population variances. The critical range R of values of $\mathcal{J}$, for a given level of significance δ are found by cutting off the lower tail of the distribution at $1/\mathcal{J}_\delta$ and the upper tail at $\mathcal{J}_\delta$ so that the probability of F falling between $1/\mathcal{J}_\delta$ and $\mathcal{J}_\delta$ is $1-\delta$. The distribution (41) is the basic probability law involved in making statistical tests in the analysis of variance.

Next, let us consider a slightly more elaborate experiment. Suppose it is desired to test whether the quality of screws of a given type as measured by number of defectives per 1,000 varies significantly from machine to machine or from operator to operator. An experiment might be designed along the following lines: consider eight machines and eight operators; let each operator make 1,000 screws on each machine, and let x_{ij} be the number of defectives in the 1,000 screws produced by the ith operator on the jth machine. We assume that x_{ij} is made up of the sum of four parts: m which is the same for all combinations of operators and machines, r_i an "effect" which is due to the ith operator, c_j an "effect" which is due to the jth machine, and a "pure" random error e_i, which is normally and independently distributed for all combinations of i and j with mean zero and variance σ^2. Then $x_{ij}=m+r_i+c_j+e_{ij}$. The r_i and c_j may be thought of as corrections to m, which may be positive or negative; r_i a correction to be made for the ith operator; and c_j a correction for the jth machine. They are such that

$$\sum_{i=1}^{8} r_i=\sum_{j=1}^{8} c_j=0.$$

Now the x_{ij} are sample values and what we wish to do is to set up a criterion for testing whether the operator corrections r_i are all zero (*i.e.*, no average change from operator to operator), and similarly whether the machine corrections c_j are all zero. The likelihood ratio or least squares criterion for testing for no significant variation from operator to operator is

$$7\sum_{i=1}^{8}(\bar{x}_{i\cdot}-\bar{x})^2\Big/\sum_{i,j=1}^{8}(x_{ij}-\bar{x}_{i\cdot}-\bar{x}_{\cdot j}+\bar{x})^2,$$

where $\bar{x}_{i\cdot}$ is the average of $x_{i1}, x_{i2}, \ldots, x_{i8}$, with a similar meaning for $\bar{x}_{j\cdot}$; $\bar{x}$ is the average of all x's. The denominator of this expression is rather insensitive to variations due to operators or machines although the numerator tends to be sensitive to operator variations, and the ratio tends to have large values if there is significant variation from operator to operator. The criterion has as its sampling distribution the $\mathcal{J}$ distribution (41) with $n'-1=7$, and $n''-1=49$ if there is no significant operator to operator variation, which provides a method of obtaining a critical value of the ratio beyond which we would declare that operator variation is significant. A similar analysis would be made for testing significance of machine to machine variation.

Bibliography.—W. A. Whitworth, *Choice and Chance,* 5th ed. (New York, 1925); E. T. Whittaker and G. Robinson, *The Calculus of Observations* (New York, 1924); H. L. Rietz and others, *Handbook of Mathematical Statistics* (Boston, 1927); T. C. Fry, *Probability and Its Engineering Uses* (Boston, 1928); W. A. Shewhart, *Economic Control of Quality of Manufactured Product* (Boston, 1931; New York, 1932); G. W. Snedecor, *Calculation and Interpretation of the Analysis of Variance and Covariance* (Ames, Ia., 1934); H. Levy and L. Roth, *Elements of Probability* (London, 1936); J. V. Uspensky, *Introduction to Mathematical Probability* (New York, 1937); G. Udny Yule and M. G. Kendall, *An Introduction to the Theory of Statistics* (London, 1937); A. C. Aitken, *Statistical Mathematics* (New York, Edinburgh, 1942); R. A. Fisher, *Statistical Methods for Research Workers,* 10th ed. (Edinburgh, 1948), and *The Design of Experiments,* 4th ed. (Edinburgh, 1947); W. E. Deming, *Statistical Adjustment of Data* (New York, 1943); S. S. Wilks, *Mathematical Statistics* (Princeton, N.J., 1943); Harald Cramér, *Mathematical Methods of Statistics* (Princeton, N. J., and London, 1946); Abraham Wald, *Sequential Analysis* (New York, London, 1947), and *Statistical Decision Functions* (New York, London, 1950); H. A. Freeman and others (eds.), *Sampling Inspection* (New York, 1948); William G. Cochran and Gertrude M. Cox, *Experimental Designs* (New York. London, 1950); M. G. Kendall, *The Advanced Theory of Statistics,* 2 vol. (London, 1943, 1946); I. J. Good, *Probability and the Weighing of Evidence* (London, New York, 1950); A. M. Mood, *An Introduction to the Theory of Statistics* (New York, Toronto, London, 1950); J. Neyman, *First Course in Probability and Statistics* (New York, 1950, London, 1951); W. Feller, *An Introduction to Pvobability Theory and its Applications* (New York, London, 1951); A. Hald, *Statistical Theory with Engineering Applications,* Eng. trans. by G. Seidelin (New York, London, 1952); S. S. Wilks, *Elementary Statistical Analysis* (Princeton, N.J., 1952); Oscar Kempthorne, *The Design and Analysis of Experiments* (New York, London, 1952); C. R. Rao, *Advanced Statistical Methods in Biometric Research* (New York, London, 1952); W. G. Cochran, *Sampling Techniques* (New York, London, 1953); J. L. Doob, *Stochastic Processes* (New York, London, 1953); M. H. Hansen, W. U. Hurwitz and W. G. Madow, *Sample Survey Methods and Theory* (New York, London, 1953); D. H. Blackwell and M. A Girshick, *Theory of Games and Statistical Decisions* (New York, London, 1954); C. A Bennett and N. L. Franklin, *Statistical Analysis in Chemistry and the Chemical Industry* (New York, London, 1954); O. L. Davies, *Design and Analysis of Industrial Experiments* (New York, London, 1954); P. G. Hoel, *Introduction to Mathematical Statistics* (New York, London, 1954); L. J. Savage, *The Foundations of Statistics* (New York, London, 1954).

Journals: *Annals of Eugenics; Annals of Mathematical Statistics; Biometrics; Journal of the American Statistical Association; Journal of the Royal Statistical Society; Sankhyā.*

(S. S W.)

PROBATE

PROBATE refers to the formal proof of a will, which in England has to take place at Somerset House, London, or at a district registry. The early jurisdiction of the English ecclesiastical courts over the probate of wills of personalty is discussed under Will. The Court of Probate Act 1857 transferred the jurisdiction both voluntary and contentious of all ecclesiastical, royal peculiar, peculiar and manorial courts to the court of probate thereby constituted, created a judge and registrars of that court, abolished the old exclusive rights in testamentary matters of the advocates of Doctors' Commons, and laid down rules of procedure. Contentious jurisdiction was given to county courts when the personal estate of the deceased was under £200 in value.

The Judicature Act 1873 merged the old court of probate in the probate divorce and admiralty division of the High Court of Justice. Probate may be taken out either in common or *solemn* form. In the former case. which is adopted when there is no dispute as to the validity of the will, the court simply recognizes the will propounded as the last will of the deceased. This formality is necessary to enable the executor to administer the estate of his testator.

Probate in this form is granted simply as a ministerial act if the attestation clause declares that the formalities of the Wills Act have been complied with, or if other evidence to that effect is produced. Such grant is liable to revocation, but it is provided that any person dealing with an executor on the faith of a grant of probate in common form. shall not be prejudiced by its revocation. The executor may within 30 years be called upon to prove in solemn form. A person who doubts the validity of the will propounded may enter a caveat which while in force prevents any probate other than in solemn form. Separate representation may be granted in respect of real estate since the administration of Estates Act 1925, and of a trust estate only, but except or regards trust estates a separate representation may be granted of a known insolvent estate. Under the Law of Property Act, 1925, S. 11, probate and letters of administration convey the legal estate to the personal representative, and this makes the real estate directly available for payment of debt. Probate in solemn form is a judgment of the court in favour of the will propounded, and is only revocable by the discovery of a later will. In order, therefore, to obtain such grant proceedings have to be taken by action, and witnesses produced in support of the will, and the action proceeds in the usual way.

The principal rules now obtaining as to probate are these. Probate, which since the Land Transfer Act 1897 (see New Administration of Estates Act, 192j, ss 79, 80) must be taken out for wills of realty as well as wills of personalty, may be granted either in the principal or in a district registry, and should be obtained within six months after the testator's death. When no executor is named the will is not now invalid, as was once the case, but administration cum testamento annexo is granted. The same course is pursued where the executor renounces or dies intestate before administering the estate of the deceased. After probate, the probate itself (as the official copy of the will is called) becomes evidence, the original will being deposited in the principal registry at Somerset House, London. On grant of probate, estate duty is payable on the gross value of the personal estate and the English real estate (see Estate and Inheritance Taxes). The act of 1881 enables any officer of inland revenue to grant probate where the personal estate does not exceed £300.

In 1867 an act on lines similar to the English act was passed for Ireland and under the Irish Judicature Act of 1877 the then existing court of probate was merged in the High Court of Justice.

In Scots law *Confirmation* includes both the probate and letters of administration of English procedure. It forms the executor's legal title to ingather the estate. Originally confirmation of testaments of movables fell, as in England, under the cognizance of the Church courts. It is now part of the jurisdiction of the sheriff courts and is regulated by statutes, the principal of which are, the Confirmation and Probate Act 1858, the Sheriff Courts Act 1876. and Executors Act 1900. When the will is attested and probation alluding to sects, forms for the execution of deeds, it proves itself, and the onus is on the person challenging it. In other cases the executor may be required to prove the validity of the will in the proceedings for confirmation.

UNITED STATES

Special Courts. — Probate is granted in some States by the ordinary chancery or common law courts, but more frequently by courts of special jurisdiction, such as the prerogative court in New Jersey, the surrogates' court in New York, the orphans' court in Pennsylvania.

"In a great majority of the States the original equitable jurisdiction over administrations is in all ordinary cases — without any special circumstances such as iraud, or without any other equitable feature such as trust — either expressly or practically abrogated. The courts of equity, in the absence of such special circumstances or distinctively equitable features, either do not possess or will not exercise the jurisdiction, but leave the whole matter of administrations to the special probate tribunals" . . . so that "unless the case involves some special feature or exceptional circumstances of themselves warranting the interierence of equity, such as iraud, waste, and the like, or unless it is of such an essential nature that a probate court is incompetent to give adequate relief, or is one of which the probate court having taken cognizance has completely miscarried and failed to do justice by its decree, the courts of equity will refuse to interpose and to exercise whatever dormant powers they may possess, but will leave the subject matter and the parties to the statutory forum which the legislature plainly regarded as sufficient and intended to be practically exclusive" (Rice's ***Probate Law,*** pp. 4 and 5). For the old law on probate, see G. W. Marshall, Ancient Courts of ***Probate* (1895).**

Jurisdiction as to wills and their probate as such is neither included in nor excepted out of the grant of judicial power to the courts of the United States (*i.e.*, the *Federal* as distinguished from the State courts). So far as it is *ex parte* and merely administrative it is not conferred, and it cannot be exercised by them at all until in a case at law or in equity its exercise becomes necessary to settle a controversy by reason of the (diverse) citizenship of the parties. An action to set aside the probate of a will of real estate may be maintained in a Federal court when the parties on one side are citizens of a different State from the parties on the other side *(Ellis* v. *Davis,* 109 US. Reports, 485). Probate in solemn form, *i e.,* after due notice to all parties in interest is the almost universal form in use in the United States. One reason for this no doubt is that all documents affecting title to real estate must be recorded and probate in solemn form concludes all parties to the proceeding and thus tends to establish the title to all real estate passing under the will.

In the United States wills of real property must be separately proven in the proper probate court in each State in which the real property is situated, unless statute dispenses with separate probate (each State being "foreign" to every other for this purpose). Copies of such will and probate should be filed also in the office of the register of deeds of each county in the State in which any real property belonging to the testator is situated.

In the State of *New Jersey* it has been held that an unprobated will is capable of conveying an interest in the property devised, and when a conveyance is made under a power in the will before probate, a subsequent probate validates the conveyance (1906, *Mackey* v. *Mackey,* 63 Atl. Rep. 984).

In Illinois a court of equity has no *inherent* power to entertain a bill to contest a will (1906, *O'Brien* v. *Bonfield,* 220 Ill. Rep. 219).

In *Missouri* a foreign (New York) will of real estate in Missouri, probate of which was duly recorded in Missouri, cannot be *collaterally* attacked, and cannot be set aside by direct proceeding after being filed for record more than five years in Missouri (1907; *Cohen* v. *Herbert,* 104 So. W. Rep. 84)

PROBATION. When a person has been found guilty of an offense, the court may exercise its right to give the offender a chance not to do it again, by putting him or her on probation for a period, in Great Britain, of not less than one, or more than three. years. During this period, a probation officer is authorized to supervise and befriend the offender. Probation officers also act as advisers in matrimonial cases and similar problems involving mediation or advice to the courts.

It appears that the first probation officers were appointed in the United States in about 1878. The principle was recognized in England for first offenders in 1887 when the First Offenders act became law. This was followed by the Probation of Offenders act in 1907 which permitted the use of probation in cases where there were previous convictions if such a course appeared justifiable or desirable. Credit must be given to the London Police Court mission for at once placing its missionaries at the disposal of the court to act as probation officers The mission may thus be regarded as the father of the probation service in England. Through its hostel for students in training for the probation service the mission continues to strive to preserve the vocational approach to the work. Training facilities are provided by the national advisory and training board, appointed by the home secretary. The National Association of Probation Officers exists to improve and strengthen the service as a whole.

Under the act of 1907 the appointment of probation officers was not compulsory and it was in many cases ignored, but this defect was remedied by the Criminal Justice act of 1925 which made obligatory the appointment of a probation committee for every probation area. This area may be either that within the jurisdiction of a single petty sessional court or a combined area including several such courts (approved by the secretary of state).

Probation work among children *(see* also JUVENILE DELINQUENCY*)* differs materially from that among adults and is of even greater importance. It is essential that a child offender should. at first, be under very careful supervision; that his mental, physical and psychological characteristics should receive the closest study; that friendly relations should be established between the parents and the probation officer; that the child should be brought in touch with outside agencies such as boy scouts, clubs, etc.; and that he should feel that in his own officer he has a real friend to whom he can always look for advice, sympathy and help. It will be seen that the essential character of probation is not mere supervision. nor must the popular fallacy be encouraged that probation means that the offender is, in fact. "let off" Not only is the offender expected to report at regular intervals to the probation officer but the officer is in close personal touch with his home and family and is as much concerned with free time activity as with work and home conditions. A U S. writer on juvenile courts has made the point that "Probation is damned if the court, the offender and the public regards it as something amounting to a form of leniency or acquittal." (H. S. Lou. *Juvenile Courts in the United States,* Chapel Hill, 1927). Probation does, in fact, involve considerable discipline and some sacrifice of freedom and spare time.

When the probationer fails for any reason he or she may be brought back to court again and the court may then decide on an alternative punishment of a more serious nature. It is in that sense that probation may be likened to a suspended sentence or judgment which is subject to the behaviour of the person concerned. The probation service depends largely on the sustained and genuine interest of the courts and probation officers, and on their mutual concern in the future of those with whom they deal

By the middle of the 20th century it was possible to judge the probation system on its results. which were generally satisfactory especially with children. Over half the number of children who appeared before juvenile courts were placed on probation and returns from 15 large towns showed that 65% of the children placed on probation did not get into further trouble for at least three years after their probation order was completed. (C. A. JE.)

United States.—As in England, probation grew out of certain practices of the criminal courts under common law, such as the release of offenders on their own recognizance with sureties, or their release on bail. Such procedure involves a conditional suspension of the imposition of sentence, and the abandonment of punitive action if the conditions (primarily good behaviour) are complied with. The origin of probation in the United States took place in Massachusetts during the first half of the 19th century. In Boston in 1841 a cobbler, John Augustus, appeared before the police court and offered to stand bail for a drunkard, and to assist in his rehabilitation. The court permitted him to do so. The experiment was so successful that Augustus then proceeded to stand bail for many more offenders. These were first adult males, charged with drunkenness; but gradually persons committed to him included women and children, and the offenses were not confined to drunkenness. In time the work was extended to the municipal court. Beiore his death in 1859 Augustus had "bailed on probation" nearly 2,000 persons with a large measure of success.

In 1878 Massachusetts passed the first adult probation statute in the United States. This provided for the appointment of a paid probation officer ior the courts of criminal jurisdiction in the city of Boston. The statute directed that those who could be reformed without punishment should be placed on probation. Subsequent laws extended probation throughout the cities and towns of Massachusetts and to all criminal courts. By the turn of the century six other states had given statutory authorization for probation. Great impetus was given to the growth of probation by the juvenile court movement, beginning in Chicago (Cook county) in 1899.

The possibility of probationary treatment is an integral part of juvenile court laws which have been adopted in all states except Maine. That state provides otherwise ior juvenile probation. Statutory provisions ior adult probation exist in all but four states.

Essential to the proper administration of adult probation are the following steps: (1) careiul selection of cases which give promise oi improvement under supervision. Theoretically, this should be made not with exclusive consideration for the degree of gravity of the offense committed, but on the basis of the likelihood of the offender's improvement under probationary treatment. This principle is violated by the laws of those states which deny probation to all those convicted of certain grave crimes; (2) suspension oi sentence for persons selected for probation; (3) supervision of probationers by trained personnel. This means at best the establishment of friendly relations between the probation officer and his client. Probation has been termed "casework in an authoritative setting." Good casework is of the essence of probation. In relatively few areas of the United States is this principle maintained, either because of the lack of trained, efficient probation officers,or because oi case loads so large that individual attention cannot be given; (4) release of the probationer at the end of the period of supervision set by the court, provided that his behaviour has been satisfactory, or revocation of probation and the remanding of the offender to court for sentence on the original charge if he has violated the conditions of his probation either by the commission of a new crime or by iailure to comply with the restrictive rules imposed during the period of supervision.

Careiul studies' of the outcome of probation indicate that approximately 75% of probationers successfully complete their period of probation, that is, without violations of any sort. How large a proportion oi them remain permanently law-abiding in subsequent years is a question concerning which there is little evidence.

It is not too much to say that probation, properly administered. is the most promising innovation in modern penology. It affords a chance for the rehabilitation of offenders apart irom the degrading environment of a prison where it costs ten times as much to keep a man as it would were he on probation. In the United States the National Probation and Parole Association carries on educational work and renders valuable services oi advice to states and communities in relation to their systems of probation. (A. E. WD.)

PROBOSCIDEA, the scientific name of an order of Eutherian mammals represented at the present day by the African and Indian elephants. These animals (see ELEPHANT) differ very widely in their structure from all other living mammals but fossil remains of similar structure have long been known. Only during the 20th century, however, have primitive Proboscidea been discovered capable of comparison with other mammalian forms. The leading characteristics of the living elephants are as follows.

The animal is of large size with pillar-like limbs. The neck is short and the large head is provided with a proboscis, a long flexible muscular organ capable of' being turned freely in all directions, and provided with one or two finger-like processes at its tip which can be used to handle articles as small as a penny. The trunk can also be employed as a prehensile organ by being wrapped as a whole round a large object. It is capable of very considerable accuracy of movement and is used in feeding. The trunk represents the whole anterior part of the face, that is the nose and also the upper lips, the strip of skin along its ventral surface being essentially a part of the palate. The two nostrils lie at the extremity of the trunk and lead into great canals which perforate the whole of that organ opening into olfactory chambers at its base. The mouth is short, placed below the trunk and provided with thick fleshy lower lips meeting anteriorly so as to form a short spout. The eye is small, laterally directed and provided with a pair of eyelids often bearing stiff eyelashes. The pinna of the external ear is large, becoming enormous in certain races of the African elephants. It is usually carried close to the side of the neck but can be erected so as to stand out perhaps a yard from the side of the head. The female bears two teats placed on the pectoral surface just between and behind the forelegs. Most living adult elephants possess very few hairs; there are normally a certain number on the forehead and cheek and always a tuft of long extremely thick hairs at the end of the short tail.

The skeleton of an elephant is as peculiar and characteristic as his external appearance. The skull is very short from back to front, deep, and built up of spongy bone full of air-spaces. Within the great mass of bone there lies a relatively small, though actually large brain cavity, and the olfactory chambers form great perforations which with the naso-pharyngeal ducts penetrate obliquely through the skull uniting only quite posteriorly. The skull of the new-born elephant differs from that of the adult in that whilst the head increases greatly and disproportionately in size, the brain undergoes much less expansion. Thus during the period of growth of the animal the external surface of the skull, by the development of the great air-spaces in its middle layer, becomes more and more widely separated from the layer of hard bone which surrounds the brain. The bony lamellae which separate these air-spaces run radially so as to buttress the external surface. The great size of the adult skull is necessary in order to give adequate areas for the attachment of the immense neck-muscles which support and move the very heavy trunk and tusks, and take the great strains which are produced when these structures are used in digging up and tearing down trees.

The jaw-bones of the elephant and the whole structure of its palate are modified so as to receive and afford adequate support to the tusks and cheek teeth. The bony nostrils lie very high up and are overhung by very small nasal bones to which some of the muscles of the base of the trunk are attached. This attachment is brought as far back as possible in order to increase the range of action of the proboscis.

The dentition of an adult elephant consists of a single pair of exaggerated incisors, the tusks, and either one or two molars on each side of the upper and lower jaws. These molars are built up of a series of plates each composed of a core of dentine surrounded by a layer of enamel; the individual plates, continuous with one another at their base, are held together and supported by an infilling of cement. In the elephant the milk incisors, little teeth about two inches in length, are shed and replaced by the permanent tusks, but the milk molars instead of being pushed out by a permanent pre-molar which develops underneath them, replace one another from behind as follows. The new tooth is developed deep down in the posterior part of the jaw and travels obliquely forwards and towards the mouth, so that more and more of it cuts the gum as the preceding tooth is worn down to its root, until finally the latter is shed and its successor is well in wear. A living elephant in this way works through six teeth in each side of each jaw during its lifetime, wearing down a total thickness of nearly a yard of tooth over an area which increases from about half a square inch to nearly 30 sq. id. on each side of its mouth. This extraordinary dentition is unparalleled, but the process by which it came into existence is fortunately completely known from fossil material.

The elephant's backbone possesses a neck of seven very short vertebrae, the number of dorsals varies from 19 to 21, the anterior having exceedingly long neural spines for the attachment of the nuchal ligament which passes forwards to the back of the skull. There is a short lumbar region of three or four vertebrae and the sacrum is a compact bone built up by the fusion of four vertebrae: there are about 30 caudals. The ribs are of enormous length surrounding the very capacious thorax. The shoulder girdle consists of a very large triangular scapula placed vertically on the side of the thorax. The humerus is longer than the forearm so that the elbow of an elephant lies at a point relatively only a little higher than the wrist of a horse. The radius and ulna are peculiar in that their surfaces of articulation with the carpus are nearly equal, whilst the upper end of the radius is relatively small and lies in front of the ulna, the two bones crossing one another as they are traced downwards. The carpus of an elephant is unusual in that the bones of the two rows of which it is composed do not alternate but are superimposed on one another. In this feature the elephants resemble the Hyraxes. The elephant walks on the extreme tips of his fingers and toes, but the palm of the hand and the sole of the foot are swollen out into great pads of connective tissue which transmit the weight of the animal to the ground directly and so reduce the load carried by the phalanges. The elephant's pelvis is remarkable for its extraordinary width, the ilia being expanded into transversely placed sheets of bone from whose posterior surface muscles pass down to the hind-leg, whilst their margins give attachment to the muscles of the body-wall which support the weight of the viscera within the abdominal cavity. As in the fore-limb the upper segment of the leg is considerably longer than the lower one, and in the tarsus the astragalus is flattened, as a weight carrying adaptation, whilst the calcaneum is produced into a short heel directed backwards and downwards.

The anatomy of the soft parts of the elephant has been repeatedly described but presents few features of special interest except those which result from the modification of the nose and upper lips into the trunk. The animal is peculiar in that there is no pleural cavity. The fact that the testes are abdominal, the uterus bicornuate, and the placenta zonary and deciduate are of importance because similar conditions occur in the Sirenia which may have sprung from an early Proboscidean stock.

The most primitive and earliest known ancestors of the elephant belong to the genus *Moeritherium* and are found in Upper Eocene deposits in the Fayûm of Egypt. *Moeritherium* was an animal resembling in its external appearance and size the living tapir. The eye was placed far forward and the head was low and elongated, probably the end of the snout was slightly flexible and it may have been produced into a short proboscis. The legs were considerably more bent than those of the modern elephants but are still rather incompletely known. *Moeritherium* possesses three upper and two lower incisors of which the second pair are enlarged, those in the upper jaw projecting straight downwards, whilst the lower teeth are directed forwards so that their tips bite against those of the upper incisors. There is a small and very reduced canine tooth; three pre-molars are present in each jaw and there is evidence that each of these vertically replaced a milk predecessor. Three permanent molars occur in both upper and lower jaws, each consisting of two transverse ridges.

The next stage, represented by *Palaeomastodon* from the Lower Oligocene of Egypt, presents a great advance on *Moeritherium.* There are several species of which the largest is not very much smaller than a small elephant, whilst the smallest is little bigger than the largest *Moeritherium.* The back of the skull begins to show the separation of the outer surface from the brain-cavity by air-spaces, which is carried to an extreme in the living elephants. The bony nostril has shifted backwards to a point in the middle of the cheek-teeth, and in front of it the pre-maxillae form an open channel in which lay the base of the trunk. The second incisor is very much enlarged and directed forwards and downwards. The lower jaw is so much longer than the skull that the incisors, which lie horizontally, project forwards several inches in front of the upper jaw, and even extend beyond the tips of the upper incisors. The single "second" lower incisor is enlarged, and with its fellow forms a shovel-shaped termination to the lower jaw. The shape of this tooth is such as to show that its upper surface was worn by contact with some part of the animal and the only explanation of its structure is that the nose, upper lip and palate projected so far forward as to overhang the front of the lower jaw and form there a movable proboscis. The lower incisors are, however, worn all round in a way which suggests that the creature used them for grubbing about in the ground to secure food. There are three upper pre-molars each of which replace a milk tooth, whilst in the lower jaw the three milk molars are replaced only by two pre-molars. Both upper and lower molar teeth' have three transverse ridges, thus differing from those of *Moeritherium.* The body of the animal was much like that of a small elephant but the neck was longer.

In the next stage, which is represented by *Gomphotherium angustidens* from the Miocene and Pliocene of Europe, North America, Africa and Baluchistan, we have an animal somewhat larger than the largest *Palaeomastodon,* with a completely elephant-like body, though with a somewhat longer and more flexible neck. The skull is much more elephant-like than that of *Palaeomastodon* because of the increased bulk of the air-cavities in its bones. It supports a pair of immense incisors, which, unlike the tusks of living elephants, are still down-turned and are provided with a belt of enamel lying on the outer surface of the ivory of which they are composed. The lower jaw is even longer than in *Palaeomastodon,* nearly half its length projecting in front of the bony skull. The lower tusks are directed forwards and bear a wear facet on their upper surfaces made by friction against a pad on the flexible and unsupported anterior part of the face, soon to be, if it had not already become, a true trunk. *Gomphotherium* still possesses milk molars which are replaced vertically by pre-molars, but these latter are comparatively small teeth soon displaced by the cutting of the second and third molars, which push their way forward from the cavity in the hinder part of the jaw in which they are formed. This process is carried so far that the adult has only two molars, the second and third, in position in each jaw. The individual teeth though larger than those of *Palaeomastodon* have still only three ridges, except in the case of the third, which has five. It seems evident that the enormously elongated jaws of *Gomphotherium* developed as an adaptation to allow the animal to reach the ground, when as a whole it was increasing in height while its neck was becoming shorter.

In the next stage represented by such forms as *Gomphotherium longirostris,* the elephants gave up the attempt to reach the ground and came to depend on their trunks both for eating and drinking. As the elongated lower jaw is thus no longer necessary, and must have interfered with the free use of the trunk, its anterior extension becomes very rapidly reduced in size so that it no longer extends in front of the bony upper jaw. In these animals only one milk molar is replaced by a pre-molar and the first two molar teeth have each four or five transverse ridges. The lower tusks are short and rounded whilst the upper tusks become still larger and outwardly directed. In these forms the shortening of the lower jaw allowed the trunk to fall down vertically, as it does in modern elephants and in external appearance they must have been entirely elephantine.

The later mastodons pass gradually into the elephants by a still further reduction of the lower jaw, the lower tusks becoming quite small and eventually disappearing altogether, finally the front of the lower jaw becomes reduced to a very small down-turned spout which is retained in the living elephants. In the later forms the milk teeth are no longer replaced vertically by pre-molars, whilst such teeth when they do occur must have been pushed out almost immediately by the forward movement of the molar teeth. At the beginning of the series, the second molar tooth in either jaw has four or five ridges, separated from one another by deep valleys in which there is no cement. In an intermediate stage, *Stegodon,* the number of ridges varies from 6 to 12 in different forms and the valleys between these ridges become filled up with cement. In the true elephants the ridges are not only more numerous but much higher and the cement forms a plate lying between them Continuation of this process leads to the most highly specialized of all elephants, the mammoth, in which the number of ridges in the second molar may be as high as 16, and the whole tooth was extraordinarily deep.

The history of the evolution of the elephant set forth above is a mere outline. It is really greatly complicated by the existence of a large number of side branches, many of which migrated into North and some even into South America. Of these side branches much the most striking is that represented by *Deinotherium,* an animal with an elephant-like body, apparently with exceptionally long limbs and a trunk. This animal is remarkable because its molar teeth throughout the whole history of the genus have had only two transverse ridges and are very low crowned. The upper tusks are completely absent while the large lower tusks are directed downwards at right angles to the lower jaw. This animal is probably of African origin and is found only in that continent and in Europe and India. See ELEPHANT; MAMMOTH; MASTODON.

(D. M. S. W.; X.)

PROBOSCIS MONKEY, a large, long-tailed, red Bornean species (*Nasalis larvatus*) characterized by the prolongation of the nose of the adult male, which hangs down in front of the upper lip. In the females and young the nose is less developed. This monkey is a leaf eater, nearly allied to the langurs.

See PRIMATES.

PROBUS, MARCUS AURELIUS, Roman emperor A.D. 276–282, was a native of Sirmium, in Pannonia. At an early age he entered the army, where he distinguished himself under the emperors Valerian, Claudius and Aurelian. He was appointed governor of the east by the emperor Tacitus, at whose death he was proclaimed his successor by the soldiers. Florianus, who had claimed to succeed his brother, mas put to death by his own troops, and the senate ratified the choice of the army. The reign of Probus was mainly spent in successful wars, by which he re-established the security of all the frontiers, the most important of these operations being directed to clearing Gaul of the Germans. Probus had also put down three usurpers, Saturninus, Proculus and Bonosus. In time of peace he kept the soldiers at work, which made him unpopular, and while superintending draining operations at his native town he was killed by his own soldiers. Scarcely any emperor has left behind him so good a reputation; his death was mourned alike by senate and people, and even the soldiers repented and raised a monument in his honour.

PROBUS, MARCUS VALERIUS (fl. second half of the 1st century A.D.), Latin grammarian and literary critic, of Berytus (Beirut) in Syria. The title of his lost treatise De *inaequalitate* consuetudinis suggests that he was of the Anomalist school. His critical editions of Plautus, Terence, Lucretius, Horace and Persius and of Vergil's Aeneid are also lost; but there is extant a commentary on Vergil's Eclogues and Georgics under his name. The extant part of De *notis* (probably an excerpt from a larger work), which deals with abbreviations, is printed by H. Keil, Grammatici Latini, vol. iv (1864); but other works ascribed to Probus in that volume are not his.

See J. Steup, *De Probis grammaticis (1871)*; J. Aistermann, *De M. Valerio Probo Berytio* (1910). (R. H. Rs.)

PROCACCINI, a family of Italian painters of the Bolognese school. ERCOLE THE ELDER (1520?–1591?) was born in Bologna but moved to Milan, where he began a school of painting known as the Academy of the Procaccini, in which many fine painters were trained. He himself was a student of Annibale Carracci, a founder of the eclectic school of painting. His best works are in the churches of Bologna.

CAMILLO (1546–1629?), GIULIO CESARE (1548?–1626) and CARLO ANTONIO (1555–1605?), his three sons, studied with their father; Camillo also studied in Rome. The two elder sons painted principally religious subjects in the tradition of Correggio. Camillo was a more successful colourist than his father, and Giulio Cesare followed the style of Correggio most perfectly of the three. Their paintings are found in the churches of Milan, Bologna. Genoa and other Italian cities and hang in the galleries of most European capitals. They died in Milan. The youngest and least talented son painted still life and landscapes.

ERCOLE THE YOUNGER (1596–1676) was born and died in Milan. He studied with his uncle Giulio Cesare and was best known for his still-life pictures. On the death of Giulio Cesare, he became director of the academy.

PROCELLARIIDAE: see SHEARWATER; FULMAR.

PROCESSION, in general, an organized body of people advancing in formal or ceremonial manner. This definition covers a wide variety of such progresses: the medieval pageants, of which the lord mayor's show in London is the most conspicuous survival; the processions connected with court ceremonies; those organized to demonstrate political or other opinions; processions forming part of the ceremonies of public worship. In a narrower sense of "going forth, proceeding," the term is used in the technical language of theology in the phrase "Procession of the Holy Ghost," expressing the relation of the Third Person in the Triune Godhead to the Father and the Son.

Greek and Roman Processions.—Processions are included in the ritual of many religions, and in many countries they accompany such events as weddings and funerals.

Religious and triumphal processions are abundantly illustrated by ancient monuments.

Processions played a prominent part in the great festivals of Greece, where they were always religious in character. The games were either opened or accompanied by more or less elaborate processions and sacrifices, while processions from the earliest times formed part of the worship of the old nature gods and later formed an essential part of the celebration of the great religious festivals and of the mysteries.

Of the Roman processions the most prominent was that of the triumph, which had its origin in the return of the victorious army headed by the general, who proceeded in great pomp from the Campus Martius to the Capitol to offer sacrifice. accompanied by the army, captives, spoils, the magistrate and priests bearing the images of the gods, amidst strewing of flowers, burning of incense and the like. Connected with the triumph was the *pompa circensis,* or solemn procession, which preceded the games in the circus; it first came into use at the ludi *romani,* when the games were preceded by a great procession from the Capitol to the Circus. The praetor or consul who appeared in the *pompa circensis* wore the robes of a triumphant general. Thus, when it became customary for the consul to celebrate games at the opening of the consular year, he came, under the empire, to appear in triumphal robes in the processus *consularis,* or procession of the consul to the Capitol to sacrifice to Jupiter. After the establishment of Christianity, the consular processions in Constantinople retained their religious character, proceeding to Hagia Sophia, where prayers and offerings were made; but in Rome, where Christianity was not so widely spread among the upper classes, the tendency was to convert the procession into a purely civil function. Besides these public processions, there were others connected with the primitive worship of the country people, which remained unchanged, and were later to influence the worship of the Christian Church. Such were those of the Ambarvalia, *Robigalia,* etc., which were essentially rustic festivals, lustrations of the fields, consisting in a procession round the spot to be purified, leading the sacrificial victims with prayers, hymns and ceremonies, in order to protect the young crops from evil influences.

Processions in the Christian Church.—As to the antiquity of processions as part of the ritual of the Christian Church, there is no absolute proof of their existence before the 4th century, but as we know that in the catacombs stations were held at the tombs of the martyrs on the anniversary of their death, for the celebration of the eucharist, it is quite probable that the faithful proceeded to the appointed spot in some kind of procession. There are, indeed. early instances of the use of the word processio by Christian writers, but it does not in any case appear to have the modern meaning "procession." Tertullian (2nd century) uses processio and procedere in the sense of "to go out. appear in public." and, as applied to a church function, processio was first used in the same way as *collecta,* as the equivalent of the Greek *συνάξις, i.e.,* for the assembly of the people in the church.

For the processions that formed part of the ritual of the eucharist. those of the introit, the gospel and the oblation, the earliest records date from the 6th century and even later (see Duchesne, *Origines,* and ed.. pp. 77, 154, 181; 78. 194), but they evidently were established at a much earlier date. As to public processions, these seem to have come into rapid vogue after the recognition of Christianity as the religion of the empire. Those at Jerusalem would seem to have been long established when described by the authoress of the *Peregrinatio Silviae* towards the end of the 4th century (see PALM SUNDAY, for the procession of palms).

Litanies or Rogations. — Very early were the processions accompanied by hymns and prayers, known as litaniae (Gr. λιτανεῖα from λιτή, prayer), rogationes or *supplicationes* (see **LITANY**). It is to such a procession that reference appears to be made in a letter of St. Basil (c. 375), which would thus be the first recorded mention of a public Christian procession. The first mention for the Western Church occurs in St. Ambrose (c. 388, Ep. 40 § 16, Ad Theodos.: "monachos . . . qui . . . psalmos canentes ex consuetudine usuque veteri pergebant ad celebritatem Machabaeorum martyrum"). In both these cases the litanies are stated to have been long in use. There is also mention of a procession accompanied by hymns, organized at Constantinople by St. John Chrysostom (c. 390–400) in opposition to a procession of Arians, in Sozomen, *Hist.* eccl. viii. 8. In times of calamity litanies were held, in which the people walked in robes of penitence, fasting, barefooted, and, in later times, frequently dressed in black (*litaniae nigrae*). The cross was carried at the head of the procession and often the gospel and the relics of the saint were carried. Gregory of Tours gives numerous instances of such litanies in time of calamity; thus he describes (Vita S. Remig. I.) a procession of the clergy and people round the city, in which relics of St. Remigius were carried and litanies chanted in order to avert the plague. So, too, Gregory the Great (*Ep.* xi. 57) writes to the Sicilian bishops to hold processions in order to prevent a threatened invasion of Sicily. A famous instance of these penitential litanies is the *litania septiformis* ordered by Gregory the Great in the year 590, when Rome had been inundated and pestilence had followed. In this litany seven processions, of clergy, laymen, monks, nuns, matrons, the poor and children respectively, started from seven different churches, proceeded to hear mass at Sta. Maria Maggiore (see Greg. of Tours, *Hist.* Fr. x. 1, and Johann. Diac. *Vita* Greg. Magn. i. 42). This litany has often been confused with the *litania* major, introduced at Rome in 598 (vide supra), but is quite distinct from it.

Funeral processions, accompanied with singing and the carrying of lighted tapers, were from very early times customary and in some ways similar to these; also very early, were the processions connected with the translation of the relics of martyrs from their original burying place to the church where they were to be enshrined (see, *e.g.*, St. Ambrose, *Ep.* 29 and St. Augustine, De *civitate* Dei, xxii. 8 and *Conf.* viii. 7, for the finding and translation of the relics of Saints Gervasius and Protasius). From the time of the emperor Constantine I. these processions were of great magnificence.

Origin of Christian Processions. — Some liturgists maintain that the early Church in its processions followed Old Testament precedents, quoting such cases as the procession of the ark round the walls of Jericho (Josh. vi.), the procession of David with the ark (2 Sam. vi.), the processions of thanksgiving on the return from captivity, etc. The liturgy of the early Church as Duchesne shows (*Origines,* ch. i.) was influenced by that of the Jewish synagogue, but the theory that the Church adopted the Old Testament ritual is of quite late growth. What is certain is that certain festivals involving processions were adopted by the Christian Church from the pagan calendar of Rome. Here we need only mention the litaniae majores et minores, which are stated by Usener ("Alte Bittgange," in Zeller, Philosophische Aufsatze, p. 278 seq.) to have been first instituted by Pope Liberius (352–366). It is generally acknowledged that they are the equivalent of the Christian Church of the Roman lustrations of the crops in spring, the *Ambarvalia,* etc. The litania major, or great procession on St. Mark's day (April 25) is shown to coincide both in date and ritual with the Roman *Robigalia,* which took place *a.d. vii.* Kal. *Mai.,* and consisted in a procession leaving Rome by the Flaminian gate, and proceeding by way of the Milvian bridge to a sanctuary at the 5th milestone of the Via Claudia, where the *flamen quirinalis* sacrificed a dog and a sheep to avert blight (robigo) from the crops (*Fasti praenestini,* C.T.L.T., p. 317). The litania major followed the same route as far as the Milvian bridge, when it turned off and returned to St. Peter's, where mass was celebrated. This was already established as an annual festival by 598, as is shown by a document of Gregory the Great (*Regist.* ii.) which inculcates the duty of celebrating *litaniam,* quae major ab omnibus *appellatur.* The *litaniae* minores or rogations, held on the three days preceding Ascension Day, were first introduced into Gaul by Bishop Mamertus of Vienne (c. 470), and made binding for all Gaul by the 1st Council of Orleans (511). The litaniae minores were also adopted for these three days in Rome by Leo III. (c. 800). A description of the institution and character of the Ascensiontide rogations is given by Sidonius Apollinaris (*Ep.* v. 14). "The solemnity of these," he says, "was first established by Mamertus. Hitherto they had been erratic, lukewarm and poorly attended (vague, tepentes, infrequentesque); those which he instituted were characterized by fasting, prayers, psalms and tears." In the Ambrosian rite the rogations take place after Ascensiontide, and in the Spanish on the Thursday to Saturday after Whitsuntide, and in November (Synod of Girona, 517).

Processions in the Modern Roman Catholic **Church.—It** is impossible to describe in detail the vast development of processions during the middle ages. The most important and characteristic of these still have a place in the ritual of the Roman Catholic Church. The rules governing them are laid down in the Rituale *Romanum* (Tit. ix.), and they are classified in the following way:—

(1) Processiones generales, in which the whole body of the clergy takes part. (2) Processiones ordinariae, on yearly festivals, such as the feast of the Purification of the Virgin (Candlemas, *q.v.*), the procession on Palm Sunday (*q.v.*), the *Litaniae* majores and minores, the feast of Corpus Christi (*q.v.*), and on other days, according to the custom of the churches. (3) Processiones *extraordinariae,* or processions ordered on special occasions, *e.g.,* to pray for rain or fine weather, in time of storm, famine, plague, war, or, in quacunque tribulatione, processions of thanksgiving, translation of relics, the dedication of a church or cemetery. There are also processions of honour, for instance to meet a royal personage, or the bishop on his first entry into his diocese (*Pontif.* rom. iii.).

Reformed Churches. — The Reformation abolished in all Protestant countries those processions associated with the doctrine of transubstantiation (Corpus Christi); "the Sacrament of the Lord's Supper," according to the 28th Article of Religion of the Church of England, "was not by Christ's ordinance reserved, carried about, lifted up, or worshipped." It also abolished those associated with the cult of the Blessed Virgin and the saints. The stern simplicity of Calvinism, indeed, would not tolerate religious processions of any kind, and from the "Reformed" Churches they vanished altogether. The more conservative temper of the Anglican and Lutheran communions, however, suffered the retention of such processions as did not conflict with the reformed doctrines, though even in these churches they met with opposition and tended after a while to fall into disuse.

Lutheran Church. — The Lutheran practice has varied at different times and in different countries. Thus, according to the Wiirttemberg *Kirchenordnung* of 1553, a funeral procession was prescribed, the bier being followed by the congregation singing hymns; the Brandenburg Kirchenordnung (1540) directed a cross-bearer to precede the procession and lighted candles to be carried, and this was prescribed also by the Waldeck *Kirchenordnung* of 1556. At present funeral processions survive in general only in the country districts; the processional cross or crucifix is still carried. In some provinces also the Lutheran Church has retained the ancient rogation processions in the week before Whitsuntide and, in some cases, in the month of May or on special occasions (*e.g.,* days of humiliation, *Busstage*), processions about the fields to ask a blessing on the crops. On these occasions the ancient litanies are still used.

Church of England. — In England "the perambulations of the circuits of the parishes . . . used heretofore in the days of rogations" were ordered to be observed by the Injunctions of Queen Elizabeth in 1559; and for these processions certain "psalms, prayers and homilies" were prescribed. The Puritans, who aimed at setting up the Genevan model, objected; and the visitation articles of the bishops in Charles I's time make frequent inquisition into the neglect of the clergy to obey the law in this matter. With the multitude, however, these processions appear to have been very popular. The Commonnealth formally put an end to them, and they only survived in some remote country parishes.

Among the processions that survived the Reformation in the English Church was that of the sovereign and the Knights of the Garter on St. George's day. This was until Charles II's time a regular rogation: the choristers in surplices; the gentlemen of the royal chapel in copes; and the canons and other clergy in copes preceding the knights and singing the litany. In 1661, after the Restoration, "that supplicational procession" was "converted into a hymn of thanksgiving." Akin to this procession also are the others connected with royal functions, which retain many pre-Reformation features.

The only procession formally prescribed in the Book of Common Prayer is that in the order of the burial of the dead. Tapers seem to have been carried in processions, not only at royal funerals, until well into the 18th century. Processions, with the singing of the litany or of hymns, appear also to have been always usual on such occasions as the consecration of churches and churchyards and the solemn reception of a visiting bishop. Examples of processions in use in the English Church are the processional litanies, and the solemn entry and exit of clergy and choir. The use of the processional cross, banners and lights has been largely revived.

PROCESSIONARY CATERPILLAR: *see* ARMY WORM.

PROCÈS-VERBAL, in French law, a detailed authenticated account drawn up by a magistrate, police officer or other person having authority of acts or proceedings done in the exercise of his duty. In a criminal charge, a procès-verbal is a statement of the facts of the case. The term is also applied to the written minutes of a meeting or assembly.

PROCIDA, an island off the coast of Campania, Italy. on the west side of the Gulf of Naples, 12 mi. S.W. of Naples. Pop. (1951) 10,156. It is about 2 mi. in length, and, reckoning in the adjacent island of Vivara, is made up of four extinct craters. It is very fertile. Procida, the only town, lies on the east side; its castle is a prison. It also contains a royal palace.

PROCLAMATION, a historic form of executive action in England and the United States. In England, while the powers of parliament were evolving, the king in council still asserted and exercised a power to legislate, in the 14th century by ordinance and in the 16th and 17th centuries by proclamation. In 1539 the Statute of Proclamations (31 Henry VIII, c. 8) made a general authorization of legislation by proclamation which should "not be prejudicial to any person's inheritance, offices, liberties, goods, chattels or life" and of its enforcement by forfeitures and imprisonment. This statute was repealed, however, in 1547 by 1 Edward VI, c. 12, s. 5. In 1610 the opinion in the *Case of Proclamations* (12 Coke's Reports 74) declared that the king by his proclamation could not create an offense which was not one before; and this became unquestioned after adoption of the English Bill of Rights (1689). Royal proclamations are still employed in the second half of the 20th century, however, to give uide publicity to actions taken by the king in council. such as dissolving one parliament and summoning the next.

In the U.S. proclamations are issued by governors of states and mayors of cities; but of especial importance are those issued by the president, proclamations and executive orders being, aside from messages to congress, the chief kinds of formal presidential action. In U.S. presidential proclamations the body of the proclamation ("Now, therefore, I . . . ,") is preceded by a preamble ("Whereas . . .") and followed by the formula of attestation, the presidential signature. the seal of the U.S. and the countersignature of the secretary of state. The date is stated, by a tradition going back to President Washington, in terms of the independence of the U.S. as well as the Gregorian calendar.

Some proclamations of the president are merely informative or hortatory, while others are exercises of quasi-legislative authority delegated by statute or inferred from powers vested in the president by the constitution. Two of the most famous are Washington's proclamation of neutrality of April 22, 1793, and Pres. Abraham Lincoln's proclamation of emancipation of Jan. 1, 1863. Careful provision is made by law and executive order for the preparation, clearance and numbering of presidential proclamations and for their publication in the Federal Register. Proclamation of treaties is separately handled. (J. HT.)

PROCLUS (PROCULUS) (A.D. 410–485), the most important representative of the later Neoplatonism inaugurated by Iamblichus (*q.v.*), was born at Constantinople of Lycian parents and brought up at Xanthus in Lycia. He studied philosophy under Olympiodorus the elder at Alexandria and then under Plutarch and Syrianus, the Platonic *diadochi* ("successors"), at Athens. He eventually became himself *diadochus* (i e., successor of Plato in the headship of the Platonic Academy at Athens) and held that position until his death in 485. An enthusiastic biography of him by his successor Marinus is preserved.

Proclus is the most notable figure of the Athenian school of Neoplatonism, which was distinguished by its passionate paganism and by its taste for elaborate metaphysical speculation. He was probably not a very original thinker (we have too little detailed information about the works of his predecessors to be quite sure about the extent of his own contribution). But he was a great systematizer. expositor and commentator. The type of Neoplatonism which began with Iamblichus reaches its fullest development in the thought of Proclus, and it is through his works that we know it best. His chief importance in the history of philosophy is as one of the principal sources from which Neoplatonic ideas were diffused through the Byzantine and Islamic worlds and the medieval Latin west. He greatly influenced the Pseudo-Dionysius (Dionysius the Areopagite; *q.v.*), whose influence on the Christian thought of both east and west was immense.

Of the Arabic works nhich transmitted his ideas the most important was the so-called *Liber de causis*, which passed in medieval times as a work of Aristotle. though it is in fact based upon Proclus' *Elements of Theology* (as St. Thomas Aquinas, who knew both works in Latin translations. recognized). The *Liber de causis* and Proclus' own *Elements of Physics* were translated into Latin in the 12th century. Other Latin translations of important works of Proclus, including the *Elements of Theology*, mere made in the next century by William of Moerbeke. the translator of Aristotle and friend of St. Thomas Aquinas. These translations, appearing at a time when very little of Plato and nothing of Plotinus was known in the Latin west, became for the later middle ages the principal source of their knowledge of Platonism.

The philosophical works of Proclus can be classified as follows: (1) his commentaries on Plato, of which those on the *Republic*, on the *Parmenides*, on the *Timaeus* and on *Alcibiades* I are extant nith excerpts from that on the *Cratylus;* (2) his major exegetical work on Plato, the *Platonic Theology;* (3) two systematic manuals, the *Elements of Physics* and the *Elements of Theology*, the former being based on Aristotle's physical works, the latter, which is considerably more important, being a concise exposition of Neoplatonic metaphysics in 211 propositions; and (4) three occasional essays, the *De decem dubitationibus circa providentiam*, the *De providentia et fato* and the *De malorum subsistentia*, which survive only in the Latin translation of William of Moerbeke. Of his nonphilosophical writings there survive some astronomical and mathematical works, including the *Hypotyposis* on astronomical positions and a commentary on the first book of Euclid's *Elements;* some grammatical works (the identity of the author of the *Chrestomathia grammatica* with Proclus the philosopher is disputed); seven hymns and two epigrams, one of which *(Greek Anthology*, vii, 341) is an inscription for the common tomb of himself and his master Syrianus; and some fragments on religious-magical themes. *See* also NEOPLATONISM.

BIBLIOGRAPHY.—The best introduction to the thought of Proclus is to be found in *The Elements of Theology*, ed. with Eng. trans. by E. R. Dodds (1933). For the *Platonic Theology* recourse must still be had to the edition of Aemilius Portus (1618). The Teubner series includes the commentaries on the *Republic*, ed. by G. Kroll, 2 vol (1899–1900), on the *Timaeus*, ed. by E. Diehl, 3 vol. (1903–06), on the *Cratylus*, ed. by G. Pasquali (1908), and on Euclid, ed. by G. Friedlein (1873);

the *Elements of Physics,* ed. with Ger. trans. by A. Ritzenfeld (1912); the *Hypotyposis,* ed. with Ger. trans. by C. Manitius (1909); and the *Hymns,* ed. by A Ludwich with the poems of the empress Eudocia (1897). The part of the commentary on the *Parmenides* that survives in Greek, the commentary on *Alcibiades I* and the three essays *De decem dubitatioizibus, De providentia et fato* and *De malorum subsistentia* are printed in V. Cousin, *Procli opera inedita* (1864); for the important final section of the commentary on the *Parmenides,* extant only in the medieval Latin trans., *see* R. Klibansky and C. Labowsky (eds.), *Plato latinus,* vol. iii (1953). The commentary on the *Parmenides* is also ed. by G. Stallbaum (1840) and that on *Alcibiades* I by L. Westerink (1954).

Thomas Taylor's English translation of the works of Proclus comprises *Philosophical and Mathematical Commentaries of Proclus,* 2 vol. (1788–89; reissue 1792), including the commentary on Euclid and the *Life of Proclus* by Marinus together with the *Elements of Theology; The Six Books of Proclus . . . on the Theology of Pluto,* 2 vol. (1816), with the three philosophical essays; the commentary on the *Timaeus* (1820); *The Fragments* (1825); and a separate edition of the *Two Treatises . . . of the Ten Doubts Concerning Providence and . . . of the Nature of Evil* (1833).

The text of the *Life* by Marinus, ed. by J. Boissonade, is appended to C. G. Cobet's edition of Diogenes Laertius (1850). For a detailed account of Proclus' thought, with a survey of the literature and an English version of Marinus, *see* L. J. Rosán, *The Philosophy of Proclus* (1949). *See* also T. Whittaker, *The Neo-Platonists,* 2nd ed. (1918). (A. H. AG.)

PROCONSUL AFRICANUS. A few fragmentary remains of jams found in Miocene epoch deposits in Kenya in 1931 gave evidence of a new type of fossil ape which was given the generic name *Proconsul.* The British-Kenya expedition of 1947 discovered more remains of this creature. including many jaws and teeth, a few limb bones, and the greater part of a skull—the first example known of a fossil ape's skull of such antiquity. The expedition's collections also showed that east Africa during the Miocene was inhabited by a remarkable variety of anthropoid apes, including three species of *Proconsul* ranging in size from that of a small chimpanzee to a gorilla. A study of the limb bones led to the interesting conclusion that these fossil apes were far more generalized in limb structure and proportions than modern apes. While evidently beginning to assume the arboreal habits of the modern apes, they still possessed features found only in the more primitive monkeys of today. *Proconsul* thus provides concrete evidence of a stage in the evolutionary transition from tailed monkeys to true anthropoid apes—a transition long postulated on the indirect evidence of comparative anatomy. *Proconsul's* nonspecialized morphology provides some reason for supposing that it may have been closely allied with the extinct group from which both man and the modern anthropoid apes were derived.

See W. E. Le Gros Clark and L. S. B. Leakey, *The Miocene Hominoidea of East Africa,* "Fossil Mammals of Africa Series" no. 1 (1951); J. R. Napier and P. R. Davis, *The Fore-limb Skeleton and Associated Remains of Proconsul africanus,* "Fossil Mammals of Africa Series" no. 16, British Museum of Natural History (1959). (W. E. L. G. C.)

PROCOPIUS, Byzantine historian, mas born at Caesarea in Palestine toward the end of the 5th century A.D. He became a lawyer, probably at Constantinople, and was in 527 appointed private secretary to Belisarius, whom he accompanied on his Persian, African and Italian campaigns. After the capture of Ravenna in 540 Procopius seems to have returned to Constantinople, since he minutely describes the great plague of 542 (*op. cit.* ii, 22). It does not appear whether he was with the Roman armies in the later stages of the Gothic War, when Belisarius and afterward Narses foughtagainst Totila in Italy; his narrative of these years is much less full and minute than that of the earlier warfare. Of his subsequent fortunes nothing is known, except that he was living in 559. Whether he was the Procopius who was prefect of Constantinople in 562 (Theophanes, *Chronographia,* 201,202) and was removed from office in the year following cannot be determined, though it is not improbable.

Procopius' writings fall into three divisions: the *Histories* (Persian, Vandal and Gothic wars), in eight books; the treatise on the *Buildings of Justinian (De aedificiis),* in six books; and the *Unpublished Memoirs (Historia arcana),* so called because they were not published during the lifetime of the author.

The *Histories* are called by the author himself the *Books About the Wars.* They consist of: (1) the Persian Wars, in two books, giving a narrative of the long struggle of the emperors Justin and Justinian against the Persian kings Kavadh and Chosroes Anushirvan down to 550; (2) the Vandal War, in two books, describing the conquest of the Vandal kingdom in Africa and the subsequent events there from 532 down to 546 (with a few words on later occurrences); (3) the Gothic War, in three books, narrating the war against the Ostrogoths in Sicily and Italy from 536 till 552. The eighth book contains a further summary of events down to 554. These books contain notices of some of the important domestic events: the Nika insurrection at Constantinople in 532 and the plague in 542. Honever, they tell little about the civil administration of the empire and nothing about legislation.

The *De aedificiis* contains an account of the chief public works executed during the reign of Justinian down to 560 which are of course ascribed to the personal action of the monarch. If not written at the command of Justinian (as some have supposed), it is evidently grounded on official information and is full of gross flattery of the emperor and of the (then deceased) empress. In point of style it is greatly inferior to the *Histories*—florid, pompous and affected. and at the same time tedious. Its chief value lies in the geographical notices which it contains.

The *Anecdota* (date probably 550) purports to be a supplement to the *Histories,* containing explanations and additions which the author could not insert in the latter work for fear of Justinian and Theodora. It is a furious invective against these sovereigns. with attacks on Belisarius and his wife Antonina and on other noted officials. Owing to the ferocity and brutality of the attacks upon Justinian, the authenticity of the *Anecdota* has often been called in question, but the claims of Procopius to the authorship are generally recognized. In point of style, the *Anecdota* is inferior to the *Histories* and has the air of being unfinished or at least unrevised. The history of Philip of Macedon by Theopompus probably furnished the author with a model.

The best complete edition of Procopius is by J. Haury (Teubner Series, 1905–13). There are English translations of the *History of the Wars,* by H. Holcroft (1653), of the *Anecdota* (1674, anonymous), of the *Buildings,* by Aubrey Stewart (Palestine Pilgrims' Text Society, 1888) and by H. B. Dewing (Loeb Classical Library, 1914, etc.).

See as chief authorities: F. Dahn, *Procopius von Cäsarea* (1865); J. Haury, *Procopiana* (1891–93). On the genuineness of the *Anecdota, see* J. B Bury, *A History of the Later Roman Empire* (1889), vol. i and introd. to vol. ii (p. 57) and appendix to vol. iv of his edition of E. Gibbon, *Decline and Fall* (1925).

PROCRUSTES, also called POLYPEMON or DAMASTES, in Greek legend, a robber dwelling in the neighbourhood of Eleusis, who was slain by Theseus (*q.v.*). He had an iron bed (or according to some accounts, two beds) on which he compelled his victims to lie, stretching or cutting off their legs to make them fit the bed's length. The "bed of Procrustes" has become proverbial for inflexibility.

PRQCTER, WILLIAM COOPER (1862–1934), U.S. manufacturer, was born in Glendale, O., Aug. 25, 1862. His grandfather's candle-manufacturing firm had been merged with James Gamble's soapmaking firm to form Procter & Gamble Co.. and after being graduated from Princeton university in 1883 Procter immediately entered the firm. In 1890 he became general manager and in 1907 succeeded his father as president. Procter was active in civic and philanthropic endeavours and entered national politics in 1920 uhen he managed the unsuccessful campaign of Gen. Leonard Wood for the Republican presidential nomination. Procter died on May 2, 1934. (H. J. SG.)

PROCTOR, ALEXANDER PHIMISTER (1862–1950), U.S. sculptor and painter best known for his representations of animals, was born in Ontario, Canada, on Sept. 27, 1862. As a youth he lived at Denver. Colo., spending much of his time in the Rocky mountains; and his familiarity with the ways and habits of wild animals was supplemented later by study in the Jardin des Plantes, Paris. He was a pupil at the National Academy of Design and later in the Art Students' league, in New York and first attracted attention by his statues of wild animals at the Columbian exposition, Chicago. In 1896 he won the Rinehart scholarship, which enabled him to spend five years in Paris, where he studied under Denys Puech and J. A. Injalbert. Among his works of sculpture are: "Quadriga." for the U.S. pavilion, Paris exhibition (1900); the Princeton Tigers, for Princeton university; the equestrian statue of Col. Theodore Roosevelt as rough rider, Portland, Ore.. and groups in the City park, Denver, Colo., and Zoological park, New York city. He died on Sept. 4, 1950. at Palo Alto. Calif.

PROCTOR, a variant of the word procurator, nearly equivalent in meaning to agent; it is now obsolete in English except for certain technical meanings. In law, it was formerly applied to a practitioner in ecclesiastical and admiralty courts, licensed by the archbishop of Canterbury to perform such duties as were performed by solicitors in ordinary courts. With the passing of the Judicature act, 1873, proctor in this sense became obsolete, the term solicitor being extended to include proctors. (See LEGAL PROFESSION: England and Wales.) However, the word is still sometimes used both in Great Britain and in the United States to denote any practitioner in probate and admiralty courts; another trace of it remains in the office of queen's proctor, who represents the crown in British divorce courts and has a duty to expose collusion. In the Church of England a proctor is a representative of the clergy in convocation; at certain universities—notably Oxford and Cambridge—a proctor is an important university official charged primarily with the enforcement of discipline among undergraduates.

PROCUREMENT, MILITARY. This term denotes the acquisition by a military establishment of goods and services, other than military personnel, whether by purchase, rent, lease. manufacture or requisition. It includes determination of requirements, drafting of specifications, selection of sources of supply, determination of contractual terms, expediting, inspection and the payment and audit of accounts.

The importance of military procurement arises from its effects on the nation's economy. Poor procurement practices may promote social tensions and economic instability, and low civilian standards of living. As the art of warfare has become more complicated in the 20th century, procurement has taken on increased importance. In the United States at the peak of World War II, military requirements absorbed about 44% of the gross national product; in Great Britain and Germany about 50%; in Japan 41%. Even in the peacetime years of the late 1950s military requirements absorbed about 12% of the gross national product in the United States and 10% in Britain, and about 15% in the Soviet Union.

Making accurate estimates of requirements in the light of a nation's strategic plans is of major importance to effective procurement. This process involves two steps: (1) determination of the requirements for various end products; (2) the conversion of requirements for end products into requirements for labour, material and productive facilities, and their comparison with available resources in order to determine whether or not strategic plans are feasible. In determining its requirements a country inevitably takes calculated risks and chooses between alternative strategic plans in the light of their costs. Since the impact of procurement on the economy depends upon its timing as well as its magnitude, it is important that requirements be properly phased. Unnecessary strain may be placed on the economy if, for example, contracts for the delivery of ammunition in six months are placed while the weapons that are to use the ammunition will not be ready for two years.

Once the requirements are set up, the objectives of procurement policy are several: (1) fulfillment of requirements in the volume and quantities and at the time and place needed; (2) efficient utilization of resources so that requirements may be fulfilled with minimum impact upon civilian standards of living; (3) budgetary economy; (4) economic stabilization; and (5) sociopolitical objectives, such as elimination of excessive profits, fostering of small business and elimination of discrimination in employment practices.

Most governments have reserved the power to requisition goods and services in times of emergency, but in recent times this power has been used cautiously. Countries vary in the extent to which the government itself undertakes the manufacture of military equipment. In the United States, Great Britain and Germany the military establishments have relied heavily upon purchases from private enterprise.

Two principal purchasing techniques are used in military procurement: the system of public advertising for sealed bids; and the negotiated contract. Under the sealed-bid system the contract is normally awarded, after public opening of the bids, to the lowest responsible bidder who meets the advertised specifications. Consequently, once specifications are determined, the purchase function becomes routine and opportunities for favouritism in selecting suppliers are minimized. Moreover, where there is genuine competition the system protects the financial interest of the government.

Often the sealed-bid system is not a useful device and is replaced by the negotiated contract. Since the procurement officer will frequently negotiate with several sources of supply, negotiation does not preclude competition. Frequently it is desirable to award an unpriced "letter of intent" before specifications can be put in final form and bids sought so that the supplier may have a head start in tooling up, placing orders for materials and recruiting a labour force. In other cases national security makes it inadvisable to publicize specifications. In some industries strategic planning requires the maintenance in readiness of several geographically dispersed sources of supply. Often it is desirable to place contracts in the light of the availability of manpower or other scarce resources rather than on the basis of price alone. In the case of research and development contracts, where confidence in a particular supplier is paramount. selection of a supplier on the basis of a low bid is not practicable. Likewise, where suppliers are few or where costs are uncertain because of rapid change in design or in the rate of output, the sealed-bid system may not be the most efficient way to develop a competitive price. Finally, in situations where military needs can be fulfilled by several products of similar but slightly different specifications, the interest of the government may lie in negotiating on specifications as well as price.

When an economy operates under a general system of price control, the question arises whether such controls should apply to military contracts. In Britain and the United States during World War II, responsibility for the prices of specialized military equipment mas generally placed on the procurement agencies while prices on contracts for standard commercial items were subject to the general controls. This practice facilitates the diversion of economic resources to military needs by leaving the military establishment free to attract suppliers by price incentives and relieves price control authorities from possible charges of interfering with the military program.

The system of negotiation permits the tailoring of contract terms to the circumstances of the particular procurement. There are several basic types of contracts in common use. The type selected in a particular case will depend in part on the relative emphasis on providing incentives to efficient production in contrast to controlling profits. The simplest type of contract is the fixed price contract. It is the easiest to administer and provides the supplier maximum incentives to control costs. The central problem in the use of this type of contract is arriving at a reasonable price; where there is previous experience in producing similar items under similar conditions or where there are alternative suppliers, it may not be difficult. However, in the absence of good cost estimates. unexpectedly large profits may develop, not because of the effectiveness of the supplier in controlling costs but because of ignorance in estimating costs when the contract is negotiated.

Cost plus contracts are nidely used where there are difficulties in estimating costs. Under such contracts the supplier receives a fee for his services as well as reimbursement for his allowable costs. The earlier practice of calculating the fee as a percentage of actual costs left the supplier with a positive incentive to increase his costs. The cost plus-fixed fee contract (CPFF), in which the absolute amount of the fee is predetermined, eliminates the incentives to cost inflation and minimizes the possibilities of excessive profits but provides no financial incentives to cost control. The administrative disadvantages of cost contracts are great, since they require careful audit of the supplier's accounts to verify his costs and frequent inspection of his operations to insure efficient use of resources.

There are many variations of these two basic types of contracts. Incentive features may be added to cost contracts by providing that the fee shall not be fixed but shall depend upon the extent to which the contractor exceeds or falls short of some target cost. Nonprofit organizations often operate under cost contracts without any fee. Fixed price contracts have been modified in many cases to provide for redetermination of price at some time during the life of the contract on the basis of actual cost experience. A fixed price contract may include an escalator clause providing for change in price in the event of some increase in labour or material costs. Such a clause, by relieving the contractor of risks over which he may have no control, makes it possible to eliminate from the contract price an allowance for contingencies.

In the United States, in particular, there has been considerable concern over the tendency to place military contracts with the larger suppliers, popularly known as "big business." This concern arises in part because of the fear that military procurement will accentuate monopolistic tendencies and in part because of the need during periods of mobilization to use all productive facilities. Consequently, various devices have been adopted for encouraging the dispersing of contracts among small businesses.

Control of profits often plays a large part in military procurement policy. Because of difficulties in negotiating close prices on many contracts, profits often turn out to be larger than anticipated. Various noncontractual devices have been tried for recouping excessive profits. Many countries at one time or another have enacted excess profits taxes, which usually take normal peacetime rates of profit as a basis for estimating allowable profits during periods of mobilization. Since 1942 the United States has experimented with a system of contract renegotiation designed to recapture excessive profits at the end of the year after review of the supplier's over-all profit-and-loss position on his government business. In determining whether or not a contractor has excessive profits the renegotiation authorities are required by statute to consider various factors, including the contractor's promptness in delivery; the quality of his product; his risk; and his efficiency. The renegotiation procedure establishes a pattern of allowable profits which serves as a guide to suppliers and procurement officers in their negotiations. It also serves to eliminate excessive profits arising from errors in judgment, deficiencies in contract negotiation or from the efforts of a willful minority to take advantage of the government. While the elimination of excessive profits serves important social purposes, some students believe that the renegotiation process as practised is to some extent in conflict with the objectives of controlling costs and prices. Moderate profits do not insure low prices and low costs.

Another important problem facing procurement officials is the control of prices on subcontracts. This may be achieved in part by direct price controls on many standard items, by renegotiation and by excess profits taxes. Other attempts to control subcontract prices directly have generally met with limited success.

There has been much public discussion in the United States of the relative merits of centralization of the procurement function in a single agency as against decentralization into various divisions of the armed services. During World War II, each of the armed services was responsible for most of its own procurement, and within each of the services procurement was further decentralized to the technical bureaus or services. Although the army, navy and air force have since been absorbed into the department of defense and the formulation of procurement policy and the purchase of some items common to the various services have been centralized, the responsibility for the procurement of most specialized military equipment is still decentralized to the component services.

BIBLIOGRAPHY.—John Perry Miller, *Pricing of Military Procurements* (1949); Thomas Blanchard Worsley, *Wartime Economic Stabilization and the Efficiency of Government Procurement* (1949); William Ashworth, *Contracts and Finance* (1953); Dickson Reck, *Government Purchasing and Competition* (1954); R. Elberton Smith, *The Army and Economic Mobilization* (1959). (J. P. MI.)

PROCYON, the brightest star in the constellation Canis Minor (*see* CANIS MAJOR), hence its Bayer equivalent, α Canis Minoris. It and Sirius (*q.v.*) in Canis Major were called the two dog stars, though Dog Star refers to Sirius, which is the brighter of the two. Procyon is a double star consisting of one bright and one very faint component. It is located at a distance of about 11 light-years from the sun and is therefore one of the nearest stars.

PRODICUS OF CEOS (c. 465–after 399 B.C.), Greek sophist, came to Athens from Ceos and became known as a lecturer, writer and teacher. He appears as a character in Plato's *Protagoras*. His *Horae* contained the famous story of the Choice of Hercules summarized in Xenophon, *Memorabilia*, ii, 1, 21 *seq.* He held that the gods were natural objects and forces, together with deified benefactors of mankind. He was also interested in morals and physical science. A lecture or course of lectures *On the Right Use of Words* distinguished between apparent synonyms and influenced Socrates, Plato and others. For fragments and testimonia *see* H. Diels and W. Kranz, *Fragmente der Vorsokratiker*, vol. ii, 7th ed. (1954).

See also T. Gomperz, *Greek Thinkers*, Eng. trans., vol. i (1901).

(G. B. KD.)

PRODIGY, an extraordinary, astonishing person, event or deed. The word has been particularly applied to children—*wunderkinder*—who show early signs of genius or exceptional ability along certain lines. Among these are the arithmetical prodigies; the chess prodigies; and the lightning calculators, who have a remarkable memory for figures and vivid visual or auditory imagery, but often do not excel in other ways. Best known are the musical prodigies—Mozart, Schubert and Mendelssohn, all of whom began to compose before the age of 12; Johann Hummel, Chopin and Yehudi Menuhin, who gave public concerts by 11 years of age; and Ruth Slenczynska, who astounded audiences at 6; Brahms, Dvořák and Richard Strauss, whose exceptional musical talents attracted attention from their earliest years.

Far less common is precocious ability in acting, writing, drawing and painting, such as that of the famous 19th century child actor William Betty, popularly known as "the young Roscius"; Minou Drouet, who in 1956 at the age of 8 won fame for poems and letters of doubtful authenticity; and Albrecht Diirer, who painted a self-portrait at 13.

In a somewhat different category are children whose intellectual development has been greatly accelerated, *e.g.*, Pascal who at 11 secretly constructed a geometry of his own; Norbert Wiener and Fred Safier, Jr., who read science and literature at five years and entered college by the age of 12.

How do children become prodigies? They are both born and made—born with retentive memories and a quality of mind that enables them to relate and organize experiences; made in the sense that they receive opportunities and rewards and special practice, instruction or training. The three prodigies last mentioned had radically different home environments. When Pascal was 11, his father deprived him of mathematical books. In marked contrast, Norbert Wiener was subjected to his father's insistent, severe and often painful demands for precise and ready knowledge. Fred Safier's parents, on the other hand, never pushed the boy but encouraged him to cultivate varied interests.

Do prodigies fulfill the promise of youth? Very few of the mental prodigies reported in history have met early expectations. However, musical prodigies seldom fade into oblivion. Original, creative geniuses who achieve the highest eminence could probably have been identified as extraordinary in early childhood.

(RU. S.)

PRODUCTION, CENSUS OF. Strictly speaking, "census of production" should refer to a count of the total production of a country. The term has been used traditionally in certain countries, notably the United Kingdom, to denote periodic censuses of the output and characteristics of industrial establishments. In the United States, the term used is "census of manufactures," indicating that the field concerned is only part of total production, the remainder being mainly covered by the census of agriculture and the census of distribution. Other countries use the term "census of industry" or "industrial production." Such censuses became increasingly important after the middle of the 19th century in connection with the planning and conduct of public and private policies as a consequence of rapid industrialization. The censuses originally had a twofold purpose: to aid the government in its assessment of the internal economy of the country and the formulation and negotiation of commercial treaties with other countries, and to inform the general public of the results of the governments' economic policies. By 1900 only a comparatively few countries had obtained statistics on industrial production, but the number grew rapidly during the early decades of the 20th century. During the first decade after World War II, more than 60 countries conducted censuses which accounted for about 75% of total world industrial production.

Production censuses generally contain detailed statistics on the quantity and value of goods produced. on employment and wages and on the use of materials and power equipment together with statistics on the number of establishments. their location, size and other characteristics. In the earliest censuses, interest tended to centre simply upon the quantity and value of output, but as industrialization increased, more and more countries investigated the structure of industry — the type, size, location, ownership and similar characteristics. All this information is required under modern conditions although the census inquiry itself need not contain all these questions if some of the information is available from other sources such as registers of establishments or social security records.

In addition to the detailed information on products, this census provides aggregates of considerable importance. The total value of industrial production is the aggregate value of all the products produced by industrial establishments. When deductions are made to take account of the materials and products consumed in the process of production, however, one obtains the "net output" of industry. This net output, both for industry as a whole and for individual industries, is an important series as it measures, with certain additions, the contribution of industry to the gross national product.

It is generally the practice that the unit enumerated is the establishment rather than the enterprise, an establishment being defined as an individual plant at a single location as distinguished irom an enterprise which may be composed of more than one plant each of which may manufacture different products. In the case of the establishment, it is possible to associate statistics on the product produced with the geographical location of the plant and with labour and other resources consumed in production. Unless it is a single-establishment enterprise, however, it becomes extremely difficult to associate statistics of plant operations with the financial data which would normally be available only for the enterprise as a whole.

The compilation of value aggregates of total production or of the production of specific subdivisions of industries also presents problems. It is true that most manufacturing plants produce goods for other plants and not for direct consumption. Thus if the gross sales of all plants were aggregated, a misleading total would be reached. It is therefore necessary to deduct the cost of materials and intermediate products used to arrive at "net output" or "value added in manufacture."

A further problem arises from the fact that to obtain true net output the value of capital consumed in the process of production must be deducted. This is done by means of allowances for depreciation and obsolescence. In addition, it is important to distinguish between those activities of the plant which are directed toward producing goods for current consumption and those resulting in the formation of new capital goods.

Production aggregates are indispensable for a correct understanding of modern economy.

It is important to know whether the industrial sector and its innumerable parts are being maintained and extended and in the economically correct proportions.

See also AGRICULTURE: *World Agriculture.* (W. R. LD.)

UNITED STATES

The first census in the United States. that for 1790, covered population only, and not until 1810 was any effort made to secure data on other subjects. Fragmentary data on minerals and manufactures were collected in the censuses of 1810 and 1820, and beginning in 1840 employment and production information for these activities was collected in every decennial census prior to 1949. Questions on agricultural production were included in the 1840 census. and additional inquiries on the acreage and value of farms and related matters were included in 1850. The year 1850 also witnessed the first decennial census of state and local government finances; this census was later placed on an annual basis for the larger governmental units.

During the 19th century the decennial censuses of population and production were conducted by temporary staffs recruited for that purpose. With the creation of a permanent census office in 1902, the quinquennial censuses of electrical industries were added to the program, and the census of manufactures was converted to a five-year basis. The country's need for production information became more generally recognized during World War I; after the war the census of manufactures was made biennial and the census of agriculture quinquennial.

Censuses of construction and distribution were included in the decennial censuses of 1930 and 1940 and a census of service establishments in 1940. Thus at the beginning of World War II the census bureau's program included in one census or another most of the country's economic activity with the major exception of financial institutions: transportation, the professions. domestic service, some business services and the activities of the federal government. While industries such as banking, rail and water transportation and electric and gas utilities are not included in the regular censuses, a large amount of information concerning them is compiled by regulatory agencies.

The biennial census of manufactures was replaced during World War II by an extensive current statistics program. However, the regular census of agriculture was taken in 1945, a census of manufactures in 1947 and a census of business (trade and service) in 1948. At mid-century legislation authorized the bureau to conduct censuses oi manuiactures, minerals and distributive trades and service establishments covering 1953 and every fifth year thereafter. These censuses were actually conducted for 1954.

Census **of** Manufactures. — At its inception in 1810, the census of manufactures covered only a few questions on employees and payrolls, production and selected materials. Beginning in 1849, which may be considered the first scientific survey of manufactures, every subsequent census included questions on the number of production workers and their wages, on total value of products and total cost of materials and the derived figure, value added by manufacture; irom' 1895, information on salaried employees and their earnings was also collected. In other respects there were considerable changes after 1849. The collection of data on capital invested. a feature of every census in the earlier years, was discontinued after 1919; on the other hand, inventory data for the beginning and end of each census year were introduced in 1937, and an inquiry on expenditures for new plant and equipment in 1939. During the earlier years. it was customary to collect information on such costs as rent and taxes, but subsequently the only cost items. other than labour costs: requested were "cost of materials and supplies." "cost of contract work" and "cost of fuels and electric energy." The 1954 census included for the first time an inquiry on the industrial use of water. Data on horsepower of prime movers were collected in all decennial and quinquennial censuses from 1899 and in several of the biennial censuses; this inquiry was not in the 1947 census but was covered in 1954. Data on man-hours of production workers were collected from an expanding list of industries starting in 1933, and since 1947 this information has been obtained regularly from all industries. From 1879, when establishments in a few selected industries were asked to supply data on the quantity and value of individual products made. these data increased steadily with the growing complexity of U.S. industry and the increasing demand on the part of manufacturers and trade associations for this type oi information. In 1954 value data and in most instances quantity data were published for about 7,000 individual manufactured products. For many decades the censuses have also included inquiries on the consumption of the more important types of industrial raw materials and, in some instances, semifinished manufactures. In 1947 and 1954 information was collected on employment in a specified list of metalworking operations.

Table I shows the growth in U.S. industry from 1849 as recorded by the principal census measures of manufacturing activity. So far as possible, the historical data were revised to exclude industries not covered in the later censuses. However, it was not possible to adjust the back figures for three major changes in the scope of the census of manufactures. The decennial censuses through that of 1899 attempted to include all manufactured products, wherever made, whereas after 1904 only factory production was included. Data on hand and neighbourhood industries for 1899 show that this change resulted in the exclusion for that year of about 300,000 establishments employing 600,000 production workers and accounting for about $800,000,000 in value added. The relative, if not the absolute: importance of such activities certainly declined after the turn of the century. In 1919 the minimum size limit for reporting establishments was raised from $500 to $5,000 in terms of value of products. For 1914 approximately 100,000 establishments employing 120,000 production workers and accounting for $150,000,000 of value added reported value of products between these two limits. Many of these smaller establishments mere, however, included in 1919 and subsequent years because of the sharp rise in the price level during World War I. Finally, in 1947, the $5,000 value of products cutoff was abandoned, but establishments with no employees were not covered in that census. This resulted in the addition of some establishments and the exclusion of others, but the effect on employment and value added was only a small fraction of 1%.

The addition of the value of products figures to derive aggregates for groups of industries or for states and other geographic units results in a considerable amount of duplication because of the use of products of some industries as materials by others. With some important exceptions, such as steel, refrigeration and motor-vehicle industries, this duplication is not significant within individual industries. It arises importantly, however, from the addition of industries representing successive stages in the production of a finished manufactured product. Because of the unknown and varying amounts of duplication contained in value of products, and also in cost of materials which is similarly affected, these two figures were not shown in the 1947 census or subsequent annual survey publications for groups of industries or states or local areas, and United States totals are not shown in Table I for any year. Except for 12 of the 453 industries covered in the census, individual industry totals are shown in the census publications both for the United States and for each producing state of significant size for which publication would not disclose the operations of individual companies.

Even where no serious amount of duplication is involved, "value of products" is frequently a very defective measure of the relative economic importance of individual manufacturing industries—principally because of the wide variation in the ratio of materials costs to processing costs. For this reason, the bureau of the census early urged the use of "value added by manufacture" as the most appropriate census measure of .the economic importance of individual manufacturing industries. Value added by manufacture is computed by subtracting from the value of products, the cost of materials and contract work used in making those products.

Value added. does have the advantage that, since it eliminates the type of duplication referred to above, the totals for individual industries may properly be combined to arrive at aggregates for groups of industries and geographic regions.

Value added by manufacture should not be confused with the net contribution of the manufacturing industry to the nation's income, as shown in various national income reports. The principal differences between these concepts are twofold: (1) value added by manufacture does not exclude depreciation, which in many respects should be considered ,as equivalent to a materials cost; and (2) value added also includes taxes (except excise taxes) and other costs such as insurance, rent and advertising which are properly the contribution of nonmanufacturing industries.

Figures for either value added by manufacture or value of products are affected by changes in the price level. In order to measure changes other than those deriving from price influences, indexes of the physical volume of manufacturing production for all manufacturing as well as for individual industries and industry groups have been compiled from census data. For an individual industry, an index of physical production is usually obtained by weighting the changes in the output of individual commodities by their value in a selected "weight period." Indexes for groups of industries and for all manufacturing are ordinarily obtained by weighting the indexes for individual industries by the value added by each industry in the weight period. Indexes of physical production are thus independent of changes in the general price level and so can be compared with physical measures of input such as employment or man-hours worked. The latter figure was collected on a comprehensive basis beginning in the 1947 census but is available in earlier years on a partial basis from the census and other sources. In 1928 the bureau of the census published a monograph of the physical volume of manufacturing output as disclosed by census figures covering the years 1899 to 1923. Since that time improved indexes for census years have been compiled by the National Bureau of Economic Research and by the census bureau in cooperation with the board of governors of the federal reserve system. These indexes are shown for selected years in Table I. Monthly and annual production indexes, of which the most widely used is that of the board of governors of the federal reserve system, are published by various other agencies.

The 1954 census of manufactures covered all establishments primarily engaged in manufacturing as defined in the "Standard Industrial Classification Manual," vol. i, *Manufacturing Industries*, prepared by the bureau of the budget. In accordance with this system of classification, each establishment reporting in the census was classified into one of the more than 450 manufacturing industries, generally on the basis of the principal products made. Individual industries were combined into 20 broad groups of industries, usually known as major industry groups.

Table II shows the distribution of manufacturing activity by major industry group for 1939, 1947 and 1954. Nearly every census had seen marked changes in the definition of a substantial number of individual industries. The 1954 census is unusual in that the classification system is only slightly changed from that of 1947. The major revisions since 1947 were the inclusion of data for establishments engaged in the processing and distribution of fluid milk and logging camps and

Table I.—General Statistics for Manufacturing Industries in the U.S., Selected Years, 1849–1954

Year	Number of establishments (000)	Production workers: Number (average for the year) (000)	Production workers: Wages total (000,000)	Value added by manufacture (000,000)	Index of physical production* (1939=100)
Factories and hand and neighbourhood industries:					
1849	123	957	$ 237	$ 464	†
1859	140	1,311	379	854	†
1869	252	2,054	620	1,395	†
1879	254	2,733	948	1,973	†
1889	354	4,129	1,821	4,102	†
Factories only:					
1899	205	4,502	1,893	4,647	27
1909	265	6,262	3,205	8,160	42
1919	270	8,465	9,664	23,842	60
1929	207	8,370	10,885	30,591	98
1939	174	7,808	8,998	24,487	100
1947	241	11,916	30,242	74,426	174
1954	288	12,373	44,595	116,912	†

*Indexes for 1899–1939 prepared by National Bureau of Economic Research index for 1947 prepared jointly by Bureau of the Census and Board of Governors of the Federal Reserve System. †Not available.'

TABLE 11.—Selected Statistics for Major Manufacturing Industry Groups, 1939, 1947 and 1954

Major industry group	Number of production workers (average for the year)			Value added by manufacture		
	1939 (000)	1947 (000)	1954 (000)	1939 (000,000)	1947 (000,000)	1954 (000,000)
All industries, total	7,808	11,916	12,373	$24,487	$74,426	$116,913
Food and kindred products	802	1,099	1,138	3,485	9,025	13,400
Tobacco manufactures	87	103	87	350	641	988
Textile-mill products	1,082	1,147	948	1,818	5,341	4,749
Apparel and related products	753	973	1,070	1,386	4,443	5,147
Lumber and wood products	423	596	582	731	2,497	3,188
Furniture and fixtures	189	283	287	418	1,378	1,966
Pulp, paper and products	270	389	436	888	2,875	4,581
Printing and publishing	324	438	500	1,765	4,269	6,265
Chemicals and allied products	276	466	501	1,697	5,365	9,444
Petroleum and coal products	108	170	136		2,015	2,209
Rubber products	121	215	196	406	1,303	1,904
Leather and leather products	327	349	321	583	1,533	1,637
Stone, clap and glass products	267	406	412	856	2,307	3,822
Primary metal industries	672	1,010	966	2,170	5,766	9,717
Fabricated metal products	451	822	821	1,401	4,922	7,596
Machinery (except electrical)	536	1,244	1,171	2,037	7,813	12,339
Electrical machinery	248	639	722	941	3,894	7,403
Transportation equipment	545	987	1,327	1,773	5,869	13,926
Instruments and related products	85	182	196	333	1,080	2,120
Miscellaneous products	242	398	556	630	2,090	4,473

contractors. Census practice is to be retabulated, insofar as possible, the reports submitted in the preceding census in terms of the revised industry classifications! but it was frequently impossible to go further back than one census. Consequently, of the 453 industries tabulated in 1947, comparable data for at least a few census measures were available for 443 industries in 1939, but only 217 could be carried back to 1929, and only 135 back to 1899. Since most of the changes in industry classification! however, occurred within a major industry group, comparable data for 14 of the 20 major groups were available back to 1899. Later changes in the definition of metal products industries affected the industry groups as well as the individual industries with the result that for four of these major groups census data could not be carried further back than 1937. Historical data for industries and industry groups were published in vol. ii, *Statistics by Industry,* of the census of manufactures. This volume also contains detailed statistics on employment, payrolls, value of shipments, cost of materials, inventories and capital expenditures for each industry as well as the quantity or value of the principal products of the industry and, in some cases, the quantity and value of the principal materials consumed.

In addition to industry data for the United States as a whole, the census of manufactures also provides information for states and local areas. In vol. iii, *Statisfics by States,* employment and payroll. value added by manufacture and capital expenditures data were shown for all counties and for all urban places having a population of more than 10,000 in the latest census of population. Industry data were shown for states and selected metropolitan areas and industrial counties. In vol. i, *General Summary,* the more significant information presented in vol. ii and iii was arranged by subject matter and both industry and state comparisons were presented. (M. R. C.)

Mineral **Industries.**—The censuses of 1810 and 1820 included only fragmentary data on the mineral industries and some discussion of their potential development. The law providing for the 1840 census made the first specific provision for a census of mining. Subsequent minerals censuses were conducted at approximately 10-year intervals, with the exception of a 1 j-year interval between the 1939 and 1954 censuses. Legislation provided for a minerals census every five years thereafter.

Prior to 1880, the same form was used for collecting data on manufactures, agriculture and mining, somewhat limiting the adequacy of the data collected for the mineral industries. Beginning in 1880 experts on mining were used to design special forms and to present appropriately the results of the minerals census. The basic types of information obtained, however! were always closely similar to those of the manufactures census described above. In addition special statistics were provided on mining, such as information permitting the classification of establishments by method of mining—open-pit, underground, etc.—and data on number of days and number of shifts worked.

For 1939 and 1954 statistics were developed on man-hours by department for all mineral industries, on loading equipment by type and kind of fuel, on drilling costs in oil and gas fields, on capital expenditures for development of mineral properties, and reports were obtained for contract services performed for mineral establishments. Figures on the value of inventories were generally excluded from the minerals census, although some quantity inventory figures have been obtained.

Computations of value added in mining were not published prior to 1954. The value of shipments figures for individual mineral industries or for all mining combined contain relatively little duplication, and the contribution of other industries to mining is less than such contribution for manufacturing industries. However. a concept of value added in mining was developed for the 1954 census which includes, besides the usual measure of value added in production during the year, a measure of value added in development of mining properties. Value added, thus computed, ranges for industry totals from 20% to 40% below value of shipments. This special concept for value added in mining mas needed because of the importance of development activities which may be carried on for several years without any resultant production, whereas during a period of peak demand, production may be obtained with relative ease by concentrating activities on developed ore bodies and postponing further development.

The 1954 census of mineral industries covered establishments primarily engaged in mining as defined in the "Standard Industrial Classification Manual," vol ii, *Nonmanufacturing Industries.* Mining operations were classified in five major groups representing metal mining; anthracite mining; bituminous coal and lignite mining; crude petroleum and natural gas extraction; and nonmetallic minerals, except fuels. These five major groups were subdivided into 72 industries. Special statistics are shown in the minerals census for each of these industries. wherever such publication would not approximately disclose the operations of individual companies. Statistics are also shown for certain subindustries, such as special figures for geophysical exploration contract services and for producers of glass sand and producers of asbestos.

The minerals census also includes tabulations, where possible, of the industry statistics by state. The minerals census does not include mining activities which are conducted as part of manufacturing establishments, such as stone quarrying at cement plants and clay mining at brick plants. However, data on such activities are collected in the manufactures census and statistics based on them are reproduced in the minerals census publications.

The minerals census for 1954 included about 36,000 establishments, corresponding to about 19,000 mines and about 500,000 producing oil and gas wells. Table III shows the number of employees, and value of shipments, for each of the five major industry groups for census years 1880–1954. This table also includes index of production figures, constructed by the bureau of the census, for the same industry groups and years, except that data for 1952 (the latest figures available for this index), rather than 1954, are shown.

The census of mineral industries final results are published in two volumes: vol. i, *General Summary and Industry Statistics,* and vol. ii, *Area Statistics.* The general summary includes, in addition to a chapter showing summary statistics, chapters on size of establishment; employment and related statistics; company characteristics; power equipment; energy, water, and selected supplies; and type of operation. Volume i includes summary statistics chapters for the four major mining areas: metal mining, coal mining, crude petroleum and natural gas extraction and nonmetallic minerals

Table 111.—Selected Statistics for Mineral Industries, by Industry Group, Selected Years: 1880–1954

Item and year	All mineral industries	Metal mining	Anthracite mining	Bituminous coal and lignite mining	Crude petroleum and natural gas extraction	Nonmetallic minerals (except fuels) mining
Number of employees (000):						
1880	298	66	71	109	11	41†
1889	543	109	124	175	29	106†
1902	622	134	73	295	27	93†
1909	1,010	179	173	507	46	105†
1919	1,063	146	155	580	112	70†
1929	*	125	151	483	*	96
1939	841	100	89	391	186	75
1954	785	100	37	219	316	113
Value of shipments ($000,000):						
1880	254	115	42	53	25	19†
1889	426	158	66	95	38	69†
1902	773	216	76	291	102	88†
1909	1,183	354	149	402	176	102†
1919	3,123	545	364	1,146	903	165†
1929	*	634	385	967	*	376
1939	3,407	540	201	731	1,660	275
1954	14,903	1,506	408	2,065	9,342	1,582
Index of production‡ (1900=100):						
1902	111	110	72	123	136	134
1909	164	150	141	160	275	182
1919	209	146	154	219	572	194
1929	321	183	129	252	1,591	420
1939	317	176	90	186	1,977	421
1952	525	223	70	219	3,863	949

*Not available. †Excludes sand and gravel operations The number of employees of such operations in 1929 was 22,000 and the value of shipments was $112,000,000 ‡Based on Bureau of the Census *Working* Paper S o. *1*.

(except fuels) mining. as well as separate chapters for individual industries or groups of industries. Volume ii includes separate chapters for individual states, which contain industry statistics for establishments within the state and also county statistics.

(V. E. S.)

Methods of Collection. — The agricultural censuses have been conducted by means of a field canvass. The report forms are delivered to the farm operator and collected by personal visit from enumerators charged with a complete canvass of all farms in preassigned districts. In the 1939 census of manufactures, the forms were similarly handled by field enumerators who were responsible for the collection and distribution of report forms for the census of business and for most firms in the manufactures census. The minerals census of 1939 was conducted largely by means of a mail canvass; however, in certain industries, where the establishments were typically small and widely scattered, a field canvass was used.

Unless the census of manufactures is taken in conjunction with that for business or population. the field canvass is inordinately expensive and has some technical limitations for the complex manufactures questionnaires. Consequently, in 1947, as in the earlier biennial censuses, the manufactures canvass was conducted largely by mail. Report forms were mailed to firms known or believed to be engaged in manufacturing activity and field enumeration was resorted to only in those instances in which satisfactory reports could not be obtained by mail or by telephone calls from the nearest district office of the bureau. The names and addresses of manufacturing establishments were derived from lists maintained at the bureau or made available by other government agencies or private organizations. In 1947 an important new source of manufacturers' names became available — the files of the bureau of old-age and survivors insurance of the Federal Security agency, to which all employers in manufacturing, as in most other industries, were required to report. In 1954 these records, together with the corresponding names and addresses from the internal revenue service, were used as the primary universe to be covered, not only by the census of manufactures, but for the larger trade. service and mining establishments as well. **All** of these censuses mere conducted by mail in 1954.

Despite the most careful handling of report forms, no census is ever 100% complete. In order to test the coverage of the 1947 census of manufactures, there was undertaken late in 1948 an intensive field canvass of selected areas throughout the country. Preliminary results of this coverage check showed that more than 98% of all employees properly classified as engaged in manufacturing activities were covered in that census. The bulk of the establishments not included in the census were small and engaged in marginal manufacturing activities closely related to construction. distribution or other nonmanufacturing activities. For this reason, these establishments either did not appear on the lists used or were classified as nonmanufacturing when their report forms were reviewed.

Tabulation. — When the returns are received in the Washington. D.C., office of the bureau, they are carefully edited to identify omissions and discrepancies. When such errors are significant, correspondence is undertaken with the manufacturer. In the 1947 census nearly half of all reporting firms were asked to complete or clarify their returns. In 1954 electronic computers were used to do much of the work of inspecting returns that had previously been done by clerks or technicians. Internal relationships for each report were tested on the basis of industry, size and regional standards. Failures in larger cases were "rejected" for correspondence. In the case of very small establishments, missing data and evident discrepancies mere corrected by reference to fairly stable relationships between the figures reported on various sections of the form.

Publication. — When a significant part of the tabulations are completed for a particular county (agriculture and business) or industry (manufactures and mineral industries). a preliminary statement, often restricted to the more significant types of information, is issued. Later, one or more printed bulletins containing final detailed figures for each state or industry are published. Finally, these separate pamphlets are collected into bound volumes which constitute the official report on the census. These are, however, frequently supplemented by a general report presenting the more significant data for each state and industry. The final census volumes are generally published two to three years after the close of the census year, though much of the information will have been in print for some time. For example. in the census of manufactures, preliminary industry releases usually begin to appear about a year after the close of the census year. In both the 1947 and 1954 censuses. the first industry report in manufacturing was released in December of the following year.

Current Production Statistics. — Much of the information collected in the production censuses was published in the 1950s on a monthly, quarterly or annual basis in part by the bureau of the census and in part by other government agencies and private organizations. In the agricultural and mineral fields current data were provided by the department of agriculture and the bureau of mines, respectively. In the manufactures field, employment and payroll data were published on a current basis by the bureau of labour statistics of the department of labour, and information on production of individual commodities from a wide variety of sources, principally the regulatory agencies of the federal government and a large number of trade associations.

Formerly, it was only in respect to commodity production information that the bureau of the census attempted to keep any of its census of manufactures on a current basis. The bureau's program was designed to cover the more important types of products not covered by other organizations. Among the products included were: wheat flour, confectionery, shoes, textiles, selected items of apparel, lumber, paper and pulp, household furniture. the major inorganic chemicals, fats and oils, ferrous and nonferrous castings, containers, heating and cooking apparatus, plumbing fixtures, tractors. machine tools and agricultural machinery. Current data on the quantity and value of the output of these and other manufactured products were published in the bureau's "Facts for Industry" series. After the inauguration of the annual survey of manufactures in 1949, annual figures were published on the value of shipments of classes of products for approximately 600 classes accounting for almost 90% of shipments by manufacturing establishments. These class of products data, together with individual product statistics excerpted from the "Facts for Industry" series, are shown in the publication *Annual Survey of Manufactures,* which also presents annual estimates of employment, payrolls, man-hours, value added by manufacture, inventories, expenditures and similar statistics by industry and by state. Many of these series are also incorporated in the monthly *Survey of Current Business* prepared by the office of business economics, a convenient source of production data also for other manufactured commodities as well as for general information on factory employment, payrolls, shipments. inventories and expenditures for new plant and equipment. On an annual basis, the more important production statistics are conveniently summarized in the *Statistical Abstract of the United States,* a publication of the bureau of the census. Selected production series are carried back as far as available in a companion publication, *Historical Statistics of the United States, 1789–1945.*

The statistical data published before mid-20th century on a current basis a-ere deficient on three important counts. First, much of the general information collected between censuses by agencies other than the bureau of the census was on a company rather than on an establishment basis. Consequently, it was difficult to carry forward data on an industry basis and, in particular, impossible to relate employment with the volume of production associated with it. Second, information on cost of materials was not collected and value added by manufacture could not, therefore, be derived from any of these sources. Finally, there were important gaps in the current coverage of manufactured commodities. To remedy these inadequacies, a survey of manufactures was taken in 1949, and similar surveys were conducted for each subsequent intercensal year through 1953. After the 1954 census, the annual series was resumed again, beginning with 1955. These surveys were to canvass all large establishments in each industry but in general only a sample of the smaller establishments. The tabulation plan is similar to but in considerably less detail than that followed in the census. Data are presented for over 300 of the country's industries, accounting for over 90% of total employment and value added, all major industry groups and all states. Data are also shown for the more important major industry groups within each state. (M. R. C.)

Census of Agriculture. — A nation-wide census collection of the vast store of essential facts about agricultural production was started in 1840. This first farm census provided data on the output of the principal crops and for the numbers of livestock and poultry on farms. The agricultural census of 1850 extended the coverage of farm census information to include the acreage of farmlands, value of farms and farm machinery and the value of animals slaughtered. By 1860 the number of inquiries in the farm census had grown to 48 and by 1870, to 52. The coverage of the censuses of 1880 and 1890 greatly exceeded that of prior censuses, and more than roo separate detailed inquiries were made for a large number of agricultural products such as cereals, fruits, tobacco, hogs and other livestock. During the 20th century, the questionnaire for the census of agriculture continued to expand, as the complexity of agriculture increased, until it contained, by 1950, more than zoo separate inquiries.

For more than a century, the periodic censuses of agriculture have furnished, decennially from 1840 to 1920 and quinquennially since 1920, the only available detailed data on agricultural production in each county and state. During recent decades the farm censuses provided detailed data on the output of each agricultural crop, and of major livestock products, the slaughter of livestock on farms, the use of farm products on farms together with detailed figures on agricultural resources, such as farmlands classified by use, principal power machines, livestock classified by age and sex, farm facilities, etc. The farm census statistics have furnished the bench marks for a large number of seasonal and annual state and national estimates of agricultural production made by the United States department of agriculture.

Recent censuses of agriculture supply detailed data indicating the kind of farm specialization in agricultural production, measures of scale of farm operation and indexes of the unfolding development in the power mechanization of agriculture during the last half century. The classification of farms by type, together with related data on resources. source of sales, production, etc., give data on the increasing high degree of specialization in agricultural production. The scale of operation for the central core of 3,000,000 competing independent commercial farms is indicated by the classification of farms by the total value of farm products sold. The 20th-century revolution in agriculture, resulting from the substitution of mobile tractor power for horses and mules, is indicated by the classification of farms by type of power.

Roughly half of all the money spent for all goods and services by consumers in the United States goes for food, clothing and other products of farm origin. However, farm products undergo many changes between the farm and consumer — they are transported, processed and incorporated with other products of nonfarm origin, etc. Large quantities of products of farm origin are processed in nonfarm factories and returned to the farm as food, clothing and other articles required by farmers and their families. During the 20th century, many activities once conducted on farms were transferred to the nonfarm sphere because they could be performed more efficiently there. Forces of modern agricultural technological changes — mechanical, chemical, genetic and social — have sprung from many nonfarm sources. Fertilizers, tractors, new farm machines, pesticides, etc., are some of the nonfarm products used by farmers in their factories to produce food and fibre for the rapidly growing nonfarm population.

Statistics from the census of agriculture on agricultural production and its organization are of interest and useful to those selling food, clothing, machinery, chemical and other products to farmers. Statistics on farm value, farms classified by type, farms classified by gross value of farm products sold, the production of several hundred agricultural products, the inventory of power equipment on farms, etc., not only indicate the potential farm market in each county and state, but also enable manufacturers and dealers to direct their sales efforts into counties or areas where the market possibilities are the greatest. Census figures show the location of areas of agricultural production, together with measures of output, and thus assist manufacturers and others to locate manufacturing plants — canneries, butter factories, fertilizer plants, etc., in the most advantageous location.

(See also AGRICULTURE.) (R. H.)

UNITED KINGDOM

Legislative Authority **and** Scope. — Censuses of production in Great Britain are taken in accordance with the provisions of the Statistics of Trade act, 1947, which lays down that the board of trade shall, for purposes of providing general surveys of the state of trade and business, take a census of production in respect of the year 1948 and of every subsequent year. The first census was taken in the United Kingdom in respect of 1907 under the provisions of the Census of Production act, 1906.

The necessity of annual censuses was recommended by the White Paper on employment policy (Cmd. 6527) presented to parliament by the coalition government in May 1944, and the 1947 act gave statutory effect to the recommendations of the *Report of the Census of Production Commzttee* (Cmd. 6687, 1945). This act gave compulsory powers to the government to ask questions on a wide range of subjects, among them the nature of the undertaking, including its association with other undertakings; the persons employed, the nature of their employment, their remuneration and the hours worked; the output, sales, deliveries and services provided; stocks and work in progress; the outgoings and costs and capital expenditure; the power used or generated; the fixed capital assets; the plant and the premises occupied. The scope of these questions is sufficient to permit an effective analysis of most of the important aspects of production. In 1954 the advisory committee on the censuses of production and distribution reported on the operation of censuses carried out under the 1947 act, and made representations for future policy.

The original 1906 act limited the scope of the census broadly to a summary of employment and output. It permitted questions to be asked mainly about the value for any product, together with the aggregate estimated value of materials used, the amount paid for work given out and such related data as employment, number of days worked and power used and generated. The quantitative data that could be asked for about output was limited, and none could be obtained compulsorily about materials, but power used covered coal and coke. Just as the original Census act arose out of the tariff reform controversy at the beginning of the century, an extension of compulsory powers to collect more information was given by the Import Duties act, 1932, in respect of the production of goods covered by the new tariff. This act enabled detailed information to be obtained about both output and materials. These powers were extended by the Finance act, 1933, to goods covered by the silk and McKenna duties and to all products by the Census of Production act, 1939. No census was taken. however, under this latter act (repealed in 1947) because of the outbreak of World War II. Wages were specifically excluded as a subject of inquiry by the original Census act. Voluntary sample inquiries by the ministry of labour, conducted at about the time of each census, made possible, however, an estimate of the wages bill in the various industries. By all these means, even the pre-World War II census reports became a rich source of data on British industry, covering a wide range of subjects in a systematic and consistent manner.

Details of Individual Censuses.—Before World War II censuses were taken in respect of the years 1907, 1912 (incomplete), 1924, 1930 and 1935. Inquiries undertaken in connection with the Import Duties act, covering a selection of industries protected by the tariff, were held for 1933, 1934, 1935 and 1937. The first postwar census taken was for 1946, but this covered selected industries only. After 1948 annual censuses were held but these varied considerably in coverage. The 1948 census covered nearly the whole range of questions permitted by the 1947 act. In addition to detailed information on sales? materials used and employment, such as had been obtained in earlier censuses, for the first time questions were asked regarding investment expenditures and payments for services and miscellaneous items. In 1949 and 1950 skeleton censuses were taken; a considerable volume of information was collected concerning the total receipts, payments. investment expenditures, etc., of the establishments, but no questions were asked about quantities and values of individual products and materials. The censuses in respect of 1951 and 1954 were more comprehensive, and included most of the items covered in 1948. In addition the census for 1951 included questions on the new topic of shift working, and data on power equipment available were collected for the first time since 1930.

For 1954 information on pension schemes was included. For 1952 and 1953, sample inquiries were made covering the same type of information as that collected for 1949 and 1950. It was intended that full inquiries should in future be held every three (or possibly five) years, with sample inquiries in the intervening years. (See the Report of *the Committee* on the Censuses of Production and Distribution, Cmd. 9276, H.M.S.O., London, 1954.)

The final reports of each census give comprehensive definitions as well as the full results. In addition a summary volume was published for the 1948, 1949 and 1950 censuses which also included information for 1935 reclassified on the same basis as the later inquiries. The results of the 1912 census, insofar as available, were published together with the results of the 1924 census and the final results of the 1937 inquiry with those of the 1948 census.

Industries and Area Covered.—The postwar censuses, like earlier ones, generally covered undertakings in manufacturing, mines and quarries, building and contracting, public utilities and a few distributive and service trades, accounting together for about half of the total labour force in civil employment. For other branches of the national economy no similar comprehensive range of information is available but for the distribution and service industries, the first census of distribution, taken in respect of 1950, provides much of this information. As a result a number of trades which overlap with the distribution and service industries were excluded from the 1950 census of production.

The postwar censuses covered productive operations carried out in Great Britain, but in all years except 1948 censuses in Northern Ireland were conducted at the same time and the results incorporated in the reports, which thus cover the whole of the United Kingdom. The censuses for 1907 and 1912 covered the whole of Ireland. No Northern Ireland census of production was taken for 1948, however, and the figures for that year relate to Great Britain only. Reports for later years again covered the whole of the United Kingdom.

Collection of Information. — Information for purposes of the censuses is collected on the basis of questionnaires sent out to each individual firm in the industries covered. For the purposes of the 1930 and all later censuses, however, firms employing ten or fewer persons were (with some exceptions) only required to furnish information about the number of persons employed and the nature of their business. The 1907 and 1924 censuses included production of all establishments irrespective of size. The final report of the 1951 census was based on data supplied by nearly 77,000 establishments with more than ten workers; in addition, simplified returns were made by 108,000 small firms with ten or fewer workers. The data relating to the firms and their plants are classified by industries according to the nature of their major products, as far as possible in conformity with the standard industrial classification. The 1951 census distinguished 157 individual industries such as cotton spinning and doubling, etc. These industries were grouped into the 14 manufacturing orders and j relevant nonmanufacturing orders of the standard industrial classification for purposes of the summary reports.

Main Census Results. — Table IV gives certain aggregate results for the United Kingdom in 1951, with comparative .figures for gross output, net output and employment in 1907 and 1935. Data on wages and salaries, stocks and investment were not collected in the earlier inquiries. The gross output of a trade is the total vaiue of goods made and other work done during the year. The net output of a trade represents the value added to materials by the process of production and constitutes the fund from which wages, salaries, rents, rates and taxes, advertising and other selling expenses and similar charges have to be met, and from which depreciation and profits are provided. It indicates broadly the contribution of industry to the total national output, whereas the aggregate of gross output includes duplication: as the end product of one industry — for example, steel — is the material used by another industry—*e.g.,* engineering.

TABLE IV.—*Summary Results of Census of Production in the United Kingdom*

Item	1907*	1935*	1951†	
			All industries	Of which manufacturing
Production (£000,000):				
1. Value of gross output (selling value of goods made and value of work done)	1,765	3,543	18,032	15,428
2. Cost of materials and fuel used anh amount paid for work given out	1,053	1,817	10,850	9,725
3. Value of net output (excess of (1) over (2) after deducting excise taxes)	.697	1,640	6,692	5,045
4. Wages and salaries			3,764	2,737
5. Stocks of materials and fuel, finished products and work in progress (at beginning of year)	...	...	...	2,502‡
6. Investment in new plant, machinery, vehicles and buildings	...	...	...	492
Employment (000):				
7. Operatives	6,493	6,462	8,426	6,188
8. Administrative, technical and clerical staff	492	835	1,593	1,305
9. Total	6,985	7,297	9,974	7,453
10. Total employment (including that in small firms)	...	8,130	10,669	7,827

*All firms. †Establishments employing more than ten persons. ‡Excludes stocks in three trades accounting for 3.8% of net output. §Including working proprietors.

Note: Results for the three years are not strictly romparahlr; 1907 is not comparable with 1935 because of (1) inclusion of firms in the territory which is now the republic of Ireland; (2) inclusion of small firms; (3) inclusion of trades subsequently omitted; (4) deficiency of returns. The over-all effectof (1–4) is that output has to be reduced by nearly 6% to make it comparable with 1935; 1951 includes some trades (accounting for about 2% of net output in that year) which were omitted in 1935.

Production and Productivity. — Changes in the value of output between the various censuses are the result of changes both in prices and in quantity. A measure of the quantitative changes can be arrived at by eliminating the effect of price changes and thus estimating changes in the volume of production. The estimates given in Table V were prepared on the basis of data contained in

TABLE V.—*Productivity in Manufacturing in the United Kingdom*

Year	Volume of production	Output per operative	Output per man-hour
1907	100	100	100
1924	133	121	142
1930	142	128	...
1935	177	152	171
1948	246	170	203

Source: A. Maddison, "Output, Employment and Productivity in British Manufacturing Industry in the Last Half Century," Bull. *Oxf. Univ. Inst. Statist.*

the censuses and of data on hours worked. They relate to the manufacturing industries only and are thus not comparable with the data in Table IV, which include also mining, building and public utilities. Between 1907 and 1948 the volume of production increased at the annual compound rate of 2.2%, output per operative increased by 1.3% and output per man-hour increased at the compound annual rate of 1.7%.

Mechanical Power.—One factor in the increase in output per worker shown in Table V is clearly the striking increase in mechanical power available to industry. Information on this subject is included in the censuses for some years. The estimated horsepower of prime movers and of electric motors in manufacturing driven by purchased electricity increased from about 1.5 h.p. per worker in 1907 to 2.0 in 1924, 2.4 in 1930 and 3.1 in 1951.

These figures exclude equipment returned as "idle or in reserve," except in 1907.

Employment.— Between 1907 and 1924 the number of persons employed by all firms; including small firms, covered by the two inquiries increased in Great Britain by about 14%. Later figures available for the whole United Kingdom indicated an increase of 2% between 1924 and 1935, both years of only moderately good employment. Between 1935 and 1954 employment in trades covered by the censuses of both years increased by about 34%. Over the whole period, therefore. employment in the census industries expanded by about 56%, but this figure is approximate only, as various small changes in coverage have not been allowed for.

The census results indicate that the number of administrative, technical and clerical staff expanded throughout the period. The total of the controlling and clerical staff amounted in 1907 to 7% of the total employed, in 1926 to 8.7%, in 1935 to 11.4% and in 1951 to 15.4%. One reason for this increase is the change in industrial structure. Industries growing in proportionate importance, *e.g.,* metals, employ more administrative and clerical staff than those which are diminishing in importance, *e.g.,* textiles.

TABLE VI.—*Industrial Distribution of Persons Employed in the United Kingdom in All Firms (Per Cent)*

Trade group*	1907†	1924	1935	1948‡	1954§
Iron and steel	8.6	7.8	8.3	10.0	9.2
Engineering, shipbuilding and vehicles	14.3	16.6	18.8	27.3	29.0
Nonferrous metals	1.9	1.9	2.0	2.5	2.1
Textiles	21.3	18.4	15.5	10.4	10.7
Leather	0.9	0.8	0.8	0.7	0.6
Clothing	10.6	9.0	9.3	6.7	6.5
Food, drink and tobacco	7.7	7.8	9.2	8.5	8.9
Chemicals	2.4	2.7	3.6	4.1	4.3
Paper and printing	5.5	5.4	6.4	5.3	5.6
Timber	3.1	2.7	3.8	3.2	2.9
Clay and building materials	3.5	3.1	3.9	3.5	3.4
Miscellaneous	1.6	2.6	2.9	3.6	3.6
Total manufacturing	81.4	78.8	83.9	85.8	86.8
Mining	16.4	18.5	12.4	10.2	9.1
Gas, water and electricity	2.2	2.7	3.7	4.0	4.1
Total, all above trades	100	100	100	100	100
(000)	5,888	6,950	6,899	8,158	9,118

*The classification is that used for pre-1939 censuses, but employment in government departments has been distributed among the other industries according to products, and only part of the utilities group is included. Trades covered only in some years are omitted throughout. Reclassification of data for 1948 and 1954 is approximate only. †Includes the republic of Ireland. ‡Excludes Northern Ireland. §Preliminary.

Some of the other reasons for increase are the greater attention given to production planning, designing, research, cost accounting and other similar work, and an extension of the preparation for sale and of the control of sales, carried out by the manufacturers' staffs.

Industrial Change.— Subsequent censuses reveal a considerable change in the distribution of productive energies and output among the different industries. The change in the distribution of employment among the manufacturing industries, mining and public utilities is shown in Table VI. Generally speaking, output per worker has increased faster in the expanding industries than in those which are stationary or contracting, so that the distribution of real output would show even greater changes.

Over the period of nearly 50 years covered by the census reports the share of total employment engaged in engineering, shipbuilding and vehicles more than doubled, and by 1956 this group accounted for nearly 30% of the total. A similar expansion occurred in the gas, water and electricity group, due primarily to the large expansion of electricity production; in chemicals; and in the miscellaneous industries, which include scientific instruments, rubber and plastic materials. This expansion was offset by a sharp decrease in textiles, whose share was halved; in mining, particularly coal mining; and in clothing and leather.

The position of the remaining groups, which include basic metals, building materials, timber and gaper, changed little and they accounted for about one-third of total employment both in 1907 and in 1954.

Concentration of Production.—The census throws light on the relative importance of different-sized firms operating in British

TABLE VII.—*Relative Importance of Different-Sized Manufacturing Firms in the United Kingdom in 1949*

Size of firms (average no. employed)	No. of firms	No. of firms (per cent)	Net output (per cent)	No. of persons employed (per cent)
11–99	43,514	75.68	21.49	22.49
100–499	11,673	20.30	34.15	34.29
500–999	1,418	2.47	13.93	13.76
1,000–7,499	860	1.50	25.92	24.65
7,500 and over	31	0.05	4.51	4.81
Total*	57,496	100.00	100.00	100.00

*Omits 598 unclassified firms.

industry. In 1949 there were in the census manufacturing industries 79,138 small firms employing not more than 10 persons which together employed about 368,000 persons or just over 5% of the total. Another 58,094 establishments with more than 10 employees employed 6,721,500 persons or 95% of the total. As the small firms are to a large extent engaged in such activities as repair work, it is more relevant to consider the degree of concentration among firms with more than 10 employees. In 1949, 76% of these establishments had fewer than 100 employees and they accounted together for 21% of the value of net output and 22% of the employment; 22% of the firms employing between 100 and 999 accounted for 48% of the net output and of employment; there mere 891 big firms with 1,000 employees or more accounting for 1.6% of all firms but producing 30% of the net output and employing 29% of all employees. (*See* Table VII.) Several firms may be owned or controlled by a single company, and on a company classification the degree of concentration would therefore be even greater. This is illustrated by a study by H. Leak and A. Maizels of concentration in the three largest companies in various industries in 1935, the latest year for which data are available. At that date the three largest companies in the chemical and allied trades accounted for 48% of all employment, in the miscellaneous industries for 47%, in engineering and vehicles for 43%, in iron and steel for 39% and in food, drink and tobacco for 32%. In textiles, paper, printing and building materials the proportion was about 22%–23%, and in clothing, wood products and leather only 10%–15%.

The average for all manufacturing industries was 29%, or 26% if mining, building and public utilities are added.

Regional Distribution of Industry.— Table VIII indicates the relative importance of the various regions of the United Kingdom in 1949.

A comparison with earlier censuses indicates the geographic shifts in working population. The principal changes in the years before 1949 were the increase in the importance of greater London and of the south of England in general, and also of the midland area, at the expense of the north of England, Wales and Scotland. These changes were not due to a movement of industry to the south but rather to contraction or expansion of industries concentrated in particular regions, notably the decline in the cotton industry in Lancashire.

Table VIII.—*Regional Distribution of Manufacturing Industry, United Kingdom, 1949*

Area	Establish-ments	Employment (000)	Net output (£000,000)	Wages and salaries (£000,000)
Northern	2,169	358	194	117
East and West Ridings of Yorkshire	6,618	745	423	232
N. midland	4,558	538	303	169
Eastern	2,450	301	178	100
London and southeastern	13,469	1,294	799	458
Southern	1,915	217	128	77
Southwestern	2,363	266	145	84
Midland	6,785	956	527	322
Northwestern	8,905	1,251	685	386
England*	49,691	5,990	3,416	1,967
Wales	1,722	231	139	78
Scotland	5,472	675	347	204
N. Ireland	1,209	167	67	39
United Kingdom*	58,094	7,063	3,968	2,288

*Includes 459 unclassified establishments not included in any region.

OTHER COUNTRIES

In addition to the United States and the United Kingdom a small but increasing number of countries make a practice of carrying out surveys yielding data relating to production and not merely to products. Details of these are given in a United Nations report on industrial censuses published in 1953, which also gives full information on the methods and requirements of production censuses. Canada early adopted the practice of the U.S. It passed from a decennial to a quinquennial inquiry after 1900, and the system of annual censuses of manufactures was established from 1917. Similar annual inquiries have been carried out in the other countries of the Commonwealth of Nations: in Australia from 1903; in New Zealand from 1918–19, following quinquennial inquiries extending back to 1867; and in the Union of South Africa from 1915–16. There were two previous inquiries in South Africa in 1904 and 1911 and none in either 1930–31 or 1931–32. Southern Rhodesia has taken a voluntary annual census of industrial production since 1938, and Northern Rhodesia since 1947. India took a detailed census for 29 industries in 1946. This was the first of an annual series whose coverage was extended in 1947 and 1950. The first census in Ceylon was carried out in 1951. The republic of Ireland made the first of such inquiries in 1926, then in 1929, 1931 and thereafter annually. These inquiries are very detailed in respect of subjects covered, comparable to the U.K. and U.S. inquiries; all of them give regional details.

All four Scandinavian countries conduct annual censuses of production, but the range of subjects covered is smaller than that of the British and U.S. censuses; additional information is available, however, from their censuses of establishments, held at less frequent intervals.

Several of the eastern European countries, among them Poland, Czechoslovakia, Hungary and Rumania. had taken annual censuses of manufactures of a limited scope before World War II, usually (except for Poland) not including data on the quantity of output. Of other major European countries Germany and Italy had very complete censuses of production relating to the years 1936 and 1937–39 respectively. A more restricted inquiry was also made by the German Federal Republic in 1950. In the Netherlands a Census of production was found necessary in connection with wartime organization in World War I and in 1918 an inquiry was made relating to 1916 and 1913. Later annual inquiries covered a small number of industries only, and referred to the bigger firms only. In Belgium the first of an annual series of censuses was taken for 1946. In France an attempt was made in 1931.

A number of the South American countries have taken censuses of production at infrequent intervals. The most recent censuses were taken in Brazil, Mexico and Guatemala for 1950; in Uruguay for 1948; in Argentina for 1946; in Colombia for 1944–45; and in Venezuela for 1936.

Bibliography.—United States: *General Summary*, vol. i, *Statistics by Industry*, vol. ii, *Statistics by States*, vol. iii, "Census of Manufactures: 1947" (1950); *Statistics for States and Counties*, vol. i (1946), *General Report*, vol. ii, "Census of Agriculture: 1945" (1947); S. Fabricant and Julius Shiskin, *Output of Manufacturing Industries, 1899–1937*, National Bureau of Economic Research (1939) ; Harold Barger and Hans H. Landsberg, *American Agriculture, 1899–1939*, National Bureau of Economic Research (1942).

United Kingdom: *Final Report on the First Census of Production* (1907) (1912); *Final Report on the Third Census of Production* (1924), parts i–iv (1930); *Final Report on the Fourth Census of Production* (1930), parts i–v (1935); *Report on the Import Duties Act Inquiry* (1933), parts i–ii (1935–36); *Final Report on the Fifth Census of Production and the Import Duties Act Inquiry* (1935), parts i–iv and final summary tables (1938–44); "Preliminary Reports on the Import Duties Act Inquiry (1937)," *Bd Trade J.* (1939); "Preliminary Reports on the Partial Census of Production 1946," *Bd Trade J.* (1948); *Final Report on the Census of Production for 1948*, vol. i–xii (1951–53); *The Report on the Census of Production for 1949*, vol. i–xii (1952–53); *The Report on the Census of Production for 1950*, vol. i–xii (1953); *Census of Production for 1950, 1948 and 1948 Summary Tables Part I* (1953); *The Report on the Census of Production for 1951*, vol. i–xii (1954–56). Preliminary information on later censuses is given in the *Board of Trade Journal*. *See* also A. W. Flux, "The Census of Production," *J. R. Statist. Soc.*, vol. 87, p. 351 (1924); H. Leak, "Statistics of the Censuses of Production and Distribution," *J. R. Statist. Soc.*, vol. 112, p. 67 (1949). *Report of the Committee on the Censuses of Production and Distribution*, Cmd. 9276 (1954); A. Maddison, "Output, Employment and Productivity in British Manufacturing Industry in the Last Half Century," *Bull. Oxf. Univ. Inst. Statist.* (Nov. 1955).

Canada: Dominion Bureau of Statistics, *The Manufacturing Industries of Canada*, summary report and detailed reports on individual industries (1870–1915, 1917 *et seq.*).

Australia: Commonwealth Bureau of Census and Statistics, *Bulletin on Production* incorporating the preceding summaries on *Manufacturing Industries* (for individual industries) (1911 *et seq.*).

New Zealand: Census and Statistics Department, *Statistical Report on the Factory Production of New Zealand* (1910–11 *et seq.*).

South Africa: Office of Census and Statistics, *Census of Industrial Establishments* (1915–16 *et seq.*).

Ireland Department of Industry and Commerce, *Census of Industrial Production* (1926 *et seq.*).

India: Directorate of Indian Statistics, *Census of Manufactures: India, 1946*, vol. i, ii (1949).

Scandinavia: Sweden: Kommerskollegium, *Industri* (annually from 1911); Norway: Central Bureau of Statistics, *Norges Industri* (1895–99 and annually, with few exceptions, thereafter); Denmark: Department of Statistics, *Industriel Produktionstatistik* (1905, 1913, 1916 *et seq.*) ; Finland: Central Bureau of Statistics, *Industristatistik*.

Germany: *Die deutsche Industrie: Gesamtergebnisse der amtlichen Produktionrtatistik* (1939); *Schriftenreihe des Reichsamts fur wehrwirtschaftliche Planung*, vol. i (detailed industry reports were compiled but not printed).

Italy: Instituto Centrale di Statistica, *Censimento Industriale e Commerciale 1937–39* (1938–48) (a summary of findings in three volumes, and nine volumes of monographs).

Other countries: Belgium: Central Statistical Office, *Recensement économique et social du 27 février 1937;* Switzerland: Federal Bureau of Statistics, *Statistique suisse des fabriques* (annual) ; Latin America: *see* N. B. Knox, *The Industrial Censuses of the American Nations*, U.S. Department of Commerce (1949).

General: United Nations Statistical Office, *Industrial Censuses and Related Enquiries*, "United Nations Studies in Methods," series F, no. 4, vol. i and ii (1953) ; Organization for European Economic Cooperation, *Industrial Censuses in Western Europe* (1951). (W. B. Ry.)

PRODUCTION MANAGEMENT is the process by which the physical output of a business organization is planned and the operations employed to produce the output are directed, coordinated and controlled. As production management has mainly to do with how, when and where products are to be made it is more important in manufacturing firms than in any other business organization. The techniques and methods of production management however are both widely applied. The problem of scheduling machine operations for preparation of customers' statements by a public utility, for example, may be analogous to the problem of scheduling machines for production of an item in a machine shop. The factors considered in an analysis of materials handling are basically similar, whether the site is a shop, a warehouse or an industrial plant. Likewise, choices among alternative sets of equipment for a nonmanufacturing function may be made in much the same way as they would be in the case of production equipment. While the term "production management" may be construed to take in more than "manufacturing management" and cover less than "industrial management," seldom is any clear distinction made among these labels. The following will make evident the objectives and approaches of the branch of management discussed. No particular purpose is served by insisting on one special title and rigid definition. It is convenient to refer to the management principles and practices described in the setting of the manufacturing firm and production-centred activities as production management.

Organizational Arrangements. — Production management is no more confined to a particular organizational segment within a firm than it is restricted to a particular type of firm. Eecause manufacturing firms frequently have production divisions and because heads of production activities frequently are given the title of production manager, there is a tendency to identify production management either as the management of a production division or as the work done by a production manager. In reality however it is unusual to find the whole of production management being accomplished by a single department; almost invariably persons other than production managers perform functions or make decisions that fall within the scope of production management.

Some management activities involved in planning what to produce and nhat methods of production to use are "staff" activities conducted in staff departments that are not under the administrative control of the production division. The "line" production organization is primarily concerned aith performance and has the responsibility of producing output of acceptable quality, in proper quantity, at the right times and at reasonable levels of cost. Since good organizational practice dictates that authority be commensurate with responsibility, the production organization usually has the final word about the execution of plans. Where production responsibility overlaps another kind of responsibility however an independent organizational unit may be created to handle the problems of coordination and planning that arise; or management may decree that certain decisions affecting production be made outside the division. In many firms, production-planning groups—staff agencies outside the manufacturing division—are expected to reconcile conflicting marketing and production goals such as sales division pressure for small-lot, specially designed items for favoured customers opposed by manufacturing division preference for long runs of standard products. Other specialized organizational subdivisions are frequently found in establishments where the scale and complexity of operations are such that some technical issues can best be handled by experts concentrating their efforts in a narrow field. Organizational arrangements and terminology vary, but separate departments or units may be set up for the performance of any of the following functions: product research, development and design; process development and design; specification and procurement of materials and supplies; standardization; inspection. testing and quality control; cost analysis and control; and study and preparation of work standards and methods. Usually some staff positions are created within the manufacturing division to deal with matters closely connected with its operations; other functional specialties are assigned outside the division.

To secure the advantages derivable from specialization and division of labour, the "line" portion of a manufacturing division is usually divided into departments in a way that reflects the physical organization of production. In small companies having only one plant, the functional form of organization predominates: production processes or manufacturing functions are represented individually by departments or closely related functions are grouped together to compose departments. For example, the line subdivisions in a functionally organized manufacturing division of a metal-working concern might be: (1) shipping. receiving and warehousing; (2) casting and forging; (3) machining; (4) plating and polishing; and (5) assembling and testing.

Although the functional type of organization is also found in large companies, either as the basic organizational form or within plants, some other variant is likely. For multiplant companies, individual plants may be designated as the primary organizational units of the manufacturing division; or, if several production facilities are located together, the geographical area may be made the administrative unit. Large companies with diversified product lines in some instances establish product divisions under which all operations and facilities required for production of a single product type or class of products are grouped. Product line organization is sometimes extended to the company as a whole, with a separate production department (and other line and staff departments as well) in each product division. Some manufacturing firms organize production operations according to the markets for which outputs are destined; *e.g.,* industrial machinery, industrial materials and components, consumer products and military products. Integrated producers who perform all or several of the manufacturing processes entailed in the transformation of raw materials to finished products may organize by production stages. as extraction, transportation, refining and separating, product treatment and packaging.

The representative production organization. then, tends to be built around a line and staff structure containing components to do the staff work of advising, coordinating, controlling and providing services to line executives and departments, in addition to line subdivisions to which responsibility for the conduct of operations is delegated. In small firms, the structure is generally simple and all internal staff services may be provided by one or a few departments; in large firms, intricate administrative structures with numerous levels and a number of superimposed organizational forms can be found. Engineering functions such as product and process design. plant engineering and industrial engineering may be centralized or split among divisions; research may be divorced wholly or in part from production; purchasing and inventory control may be combined or separated, handled as part of production or not. Which production staff services are provided within a manufacturing division and which provided outside it depends on the particular company situation and history.

Functions and Problems. — The management of production may be treated in terms of: (1) the functions normally performed; (2) the problems that must be solved or decisions that must be made; or (3) both the problems encountered and the functions performed in planning. directing and controlling operations. In this discussion. emphasis will be placed on decision making because though essentially the same problems have to be solved in every manufacturing enterprise, there are many ways in which tasks can be combined in jobs, jobs grouped by functions and functions distributed to organizational units.

In the ultimate analysis, production management consists of making choices about the use of money, men, materials and time in production; *i.e.,* production problems are simultaneously human, technological and economic. While one aspect may be dominant in a particular instance. a production decision generally involves selection from the available alternatives of an economical and technologically feasible solution conforming to enterprise objectives and subject to constraints imposed by human factors. Seldom can decisions about production be based on examination of a single factor. What is technically best can be disproportionately expensive. Capabilities of man-machine combinations and not just machines or human skills alone determine performance.

In order to reduce a review of production management problems to reasonable dimensions, some classification is necessary. At the first level a small number of general problems may be distinguished. each of which is resolvable into a series of specific subproblems at the second level of classification. It is helpful to think of production as a system whose over-all function is transformation of sets of inputs into sets of outputs. Two kinds of processes go on in the system: the physical processes of handling and working materials for conversion of material inputs to product outputs; and the decision-making processes that govern operations. When production is viewed in this way, the general problems of production management are discerned as deciding, on the one hand, what the system shall be—what physical equipment shall be employed, what methods of operation shall be followed, what form of organization and channels of communication shall exist and what rules shall be applied for making routine decisions—and deciding. on the other hand, how the system as a nhole shall function at any point in time—what the quantity and assortment of output shall be, which production facilities shall be utilized and at what rates and what the composition of inputs shall be. As the solution to each of these general problems is a composite of sub-problem solutions and the functions of production management are just the things that are done to arrive at decisions and put them into effect, this discussion may move immediately to specific problems.

Forecasting. — Predictions of what products can be sold and in what quantities they can be marketed usually originate outside the manufacturing organization. Forecasting is nonetheless an important part of the production management process since production programs are shaped by expected general economic conditions, the outlook for the industry and the results of specific product market studies. While accuracy in forecasting is most vital when new products are being introduced, and especially when their introduction accompanies the launching of a new business, it is always a prime determinant of the effectiveness of production planning.

Consideration of production factors begins once existence of demand for a product is demonstrated. After the general prospects for new products are determined and before much time, effort and money are spent in developing detailed sales forecasts and plans based on them, preliminary estimates of production capability should be made: this requires answers to a number of questions. What will production costs be? Are the existing or proposed production facilities suitable for the volume and quality of output involved? What particular production problems will be met; for example, are materials available in dependable supply, are there processing hazards to be guarded against, will the work force have to be expanded or given special training and will the production pattern fit with that of other products? When dealing with established products in going concerns, answers to such questions are more easily available, but the same kinds of factors must be reviewed each time production plans are formulated for an extended period. If it appears that production can be accommodated to fit general product and volume objectives, more refined sales forecasts and plans for financing, staffing, purchasing and marketing can be attacked.

When a sales forecast in its final form is delivered to production executives, its requirements — expressed as product quantities and delivery dates — must be translated into a production program. In firms that manufacture exclusively to customers' orders, forecasts may possess little detail beyond estimates of total volume and general nature of work to be expected for stages following the immediate sales period in which orders in hand are covered. Where manufacturing is performed in anticipation of sales, product characteristics are predetermined and stocks of goods are carried in inventory; sales forecasts and production will usually be in considerable detail. Preparation of the master schedule for production — which takes into account lags between production stages, inventory status in the several product lines, changing sales patterns and availability of various production facilities — by production executives and their staffs is the central planning activity in production management and the point at which the diverse elements in production are finally coordinated.

Production Planning and Control. — The importance and complexity of the task of anticipating and planning for production requirements accounts for the existence of departments of production planning and control as separate entities in manufacturing organizations. These staff groups may be assigned additional functions but their main focus almost invariably is on problems of routing, scheduling, control and dispatching.

Routing. — The routing problem is one of determining for each product to be made the sequence of operations to be performed. Each part must be routed through processes, machines to perform each operation must be chosen and the instructions to operatives of what should be done and how to do it must be written up. In plants of the type called "job-shop" where the production layout groups equipment in departments on the basis of similarity of functions and each product lot may follow a path through the layout that differs from what precedes and follows, rather complete instructions (job orders) relating to tooling, machine operation, product specifications and the like must accompany each individual job released to work. The routing sheet is the form on which most of this information is collected. In plants of the line production type where the production layout has equipment and work centres placed physically in the sequence that successive operations occur on a representative product unit and each product run follows substantially the same path, the routing has been built into the plant arrangement. While doing the original routing and layout design is a complicated job, determination and communication of the order of operations is routine thereafter.

Scheduling. — Scheduling consists of setting the times at which operations will be accomplished. When numerous orders or runs with complex routings requiring many transfers of materials during production are to be in process simultaneously, the task of arranging over-all schedules for products, operating schedules for departments and machines and schedules for supply of materials and parts is formidable. With fluctuating demands for products, it takes considerable skill and intimate knowledge of production to arrive at schedules that are both feasible and economical in view of requirements for overtime work, inventory levels, stable employment and balanced utilization of equipment.

Control. — The problem of control consists of seeing that things get done when and as planned. Quantity, quality, timing and cost are the principal controllable variables dealt with; the control process consists of comparing current progress to planned performance and initiating corrective action as deviations appear. The aspect of control which production planning and control groups are most directly concerned with is control of output through the preparation and enforcement of schedules. However, since it is often convenient to collect data on several dimensions of performance simultaneously, the report forms and procedures handled by the production control staff are likely to be multipurpose, and the staff itself acts in a coordinating role.

Dispatching. — Dispatching, the function of issuing orders and instructions to the workplace and securing data on performance for transmission to management, is important enough to warrant identification as a separate activity in production planning and control. When only general routings and schedules are set up and some freedom is left dispatchers regarding order of work and assignment to machines and operatives, it is essential that they exercise good judgment, make fast decisions and deal with supervisors and workmen skillfully if the system is to operate satisfactorily.

Inventory Decisions. — Inventory problems are closely connected with operations planning and scheduling and, in consequence, inventory planning and control functions are usually combined with production-planning functions in organizations. Inventories in production are either planned to function as buffers between processing stages to allow their independent operation or appear as unavoidable concomitants of operations.

Inventories of raw materials are maintained to facilitate an even flow to processes as protection against interruptions of supply or because quantity purchases offer economies. The size of work-in-process inventories depends on how production is organized, the size of lots transferred between operations and the way in which schedules are constructed. Finished goods inventories are maintained so that production can be stabilized by building up inventory during slack seasons which is depleted during rush periods and so that various assortments of ordered items can be shipped without delay.

The general inventory problem consists of deciding at what points in the production system stocks shall be held and what their form and size shall be. As some unit costs increase with inventory size — storage, obsolescence. deterioration, insurance, investment, etc.—and other unit costs decrease with inventory size — setup or preparation, shortage, etc.—inventory management in part consists of determining optimal purchase or production lot sizes and base stock levels that balance opposing cost influences. Another part of the general inventory problem is deciding the levels (reorder points) at which orders for replenishment of inventories are to be initiated.

In addition to analytical problems, inventory presents problems of system design. Inventoried items must be identified, coded and catalogued so that they can be located readily when needed. Stock additions and withdrawals must be recorded so that inventory status is readily ascertainable and cost figures are kept current. Provision must be made for physical custody of inventories, storage space arrangements planned and procedures for delivering parts and supplies from stock points to work centres devised.

Facilities Problems. — Attention has thus far been centred mainly on problems of planning operations in a production system, the presence of the physical components of the system being assumed. The capacity and operating characteristics of the system, of course, are set by instrumental decisions on plant and equipment; moreover, such decisions are long-run in nature and normally result in large expenditures. they are crucial for the success of the enterprise. Initial decisions about physical facilities for production, honever, are continually modified in the majority of concerns as they grow, as the pattern of output is adapted to altered marketing conditions and as need for replacement of equipment becomes apparent.

In large manufacturing concerns, decisions about the size and location of plants must be made. It is necessary to choose how manufacturing functions will be distributed among decentralized operating units and where plants will be placed in relation to markets and material sources in view of costs of transportation, plant construction and operation and factors such as climate. community attitudes availability of utilities and presence or absence of competitive or complementary industries. The location of a factory within a selected general area and its siting so as to capture advantages of accessibility, ease of expansion and low construction cost are also significant decisions for the single-unit manufacturing firm as well as the multiplant firm.

Design of the internal arrangement of the plant and choice of the type of construction are further facilities problems to be solved. Analysis of production requirements imposed by the attributes of the products to be manufactured usually precedes selection of a general layout as it indicates what production processes and equipment units must be provided. Limitations on space and physical arrangement are posed by the size and shape of proposed production and materials — handling equipment. the need for access to work and storage spaces and building requirements. Working within these limitations, the planners endeavour to develop a scheme of layout minimizing product flow distances in a logical, orderly, easily maintained and safe arrangement.

Process design and equipment selection normally proceed parallel with layout: the problems are simultaneously technical and economic The technical problem is determining how desired product attributes can be created in manufacturing processes and nhat equipment can serve; the economic problem is deciding among process and equipment alternatives on the bdsis of over-all cost. The same general factors operate both in the case of original equipment selection and replacement of equipment which becomes inefficient or technically obsolete uhether production, material handling or other equipment is under examination High original costs may be justified by correspondingly high durability. increasing quality of output, ease of operation or other operating advantages. Optimal equipage must be determined in light of unit capacity, rate of operation, expected life, maintenance requirements, direct cost of operation, adaptability and versatility and any relevant special considerations.

Other Problems. — The résumé of production management problems given here can only be indicative not exhaustive the list is virtually endless. Some mention, however, should be made of the other parts of production management. No production system is complete unless means for quality control have been built into it. Production management is responsible for clear specification of product and process standards complemented by procedures for inspecting. testing and evaluating conformance to quality objectives. Simplification of nork methods by application of motion- and time-study techniques is yet another powerful tool, as is its extension to development of time standards and incentive systems. All the personnel problems of selecting. placing, rating and compensating production employees come within the scope of production management. Finally, the total job of production management is rounded out with responsibilities for plant and equipment maintenance, material handling, traffic management, provision of plant services. and analysis and disposition of a multitude of other physical problems of production.

Analytical Developments. — Because much of production management consists of contending with physical processes and variables with reasonably predictable behaviours, it always has tended to rely heavily on quantitative analysis. Viewed one way, production management is simply an arrangement for solving the classic econoniic problem of allocating scarce resources to relatively unlimited ends. The conceptual apparatus of economic analysis, as for example its marginal cost-marginal revenue approach, is immediately usable for production decision purposes. Cost minimization models for determining optimum inventory levels and making choices among production methods and equipment alternatives have long been used as a matter of course. Applications of probability theory in sampling inspection and process control are commonplace *(see* PROBABILITY; PROBABILITY AND STATISTICAL THEORY) Empirical and computational approaches to scheduling, designing and operating production processes, setting work standards and laying out workplaces are part of the intellectual equipment of every competent production manager.

Developments in the field of operations research or, more broadly. in the management sciences make it possible to push the quantitative emphasis in production management even further. Mathematical programming techniques are applicable to a variety of production allocation and scheduling problems. Queuing theory is being utilized in analysis of production lines and maintenance problems. System simulation, made feasible by stored program electronic computers, is being used to study the characteristics of complex production systems with the aim of improving system designs and decision rules. As automation of production and automatic control technology continue to advance, more reliance on mathematical research can be expected. Substantial contributions to the solution of production problems are still to come from game theory *(see* GAMES, THEORY OF), organization theory and information theory.

Despite the possibility that production management and other specialized managerial functions may eventually disappear and be replaced by a "universal" management science, no immediate and discontinuous change looms. Analytical methods shown to be helpful in making production decisions will be drawn from varied sources and used; but production management mill not soon become a mere package of techniques or management by formula. Production decisions are made by people in human organizations existing in a dynamic environment in which only the fact of change is constant. The ratio of science to art in production management may increase steadily, but it increases slowly. *See* also MANAGEMENT SCIENCES. (J. D. Rs)

PRODUCTIVITY, ECONOMIC: *see* ECONOMIC PRODUCTIVITY.

PROFESSOR, a term now confined to a teacher of a special grade at a university or college (Lat *profiteri*, "declare publicly." "profess"). The educational use is found in post-Augustan Latin. In the universities of the middle ages the conferring of a degree in any faculty or branch of learning meant the right or qualification to teach in that faculty, whence the terms *magister*, "master." and *doctor* for those on whom the degree had been granted. To these names must be added that of "professor." The "three titles of Master, Doctor, Professor, were in the middle ages absolutely synonymous" (H. Rashdall, *The Universities of Europe in the Middle Ages,* i. 21. 1895).

The first endowed professorship at Oxford was that of divinity, founded by the mother of Henry VII in 1502 and named after her the Lady Margaret professorship. The foundation of the Regius professorship by Henry VIII in 1546 tended to the general modern use of the word In England subordinate public teachers in faculties, or in subjects to which a professorial "chair" is attached. are known as readers or lecturers. In colleges and universities of the C.S professor indicates a teacher of the highest rank.

PROFIT, a term used by businessmen to describe the result of their operations when that result is favourable. When the result is unfavourable the term loss is commonly used. Strictly speaking, the word profit means "result," whether favourable or unfavourable; but it is obviously more convenient to speak of an unfavourable result as a loss than as a minus profit. As used by businessmen, the word profit must not be confounded with profits assessable to income tax or supertax. The rules for determining the liability of individuals or companies to these imposts are determined by statute. and are extremely artificial; similarly, profits in the business sense must not be confused with the economist's idea of profit.

If it were practicable for the businessman to wait until his business was discontinued and wound up before attempting to arrive at any idea of what his profits were, it would be possible for him to accept the economic definition of profits as "the surplus remaining over from the employment of capital after defraying all the necessary expenses and outlay incurred in its employment, and after the capital has been replaced or provision made for its replacement." But the businessman has to determine his profits as he goes along (1) because in no other way can he determine the most advantageous way in which to carry on his business; (2) because, in general, it would be impossible to obtain capital for business purposes, save upon the terms of distributing profits not less frequently than once a year, so that those contributing capital to enterprise may receive in return income by way of dividends. Hence the necessity of determining divisible profits from year to year.

It is absolutely impossible to determine the profits of a going concern from year to year with precision, because nothing more reliable than estimates can then be formed of the value of its outstanding obligations and unrealized possessions. But it would be unwise to distribute the whole of the profits year by year even if they were ascertainable, as mere this to be done there would be no margin left to cover contingencies, and experience shows that unexpected losses are bound to occur from time to time. The problem that besets the businessman year by year is not therefore how to ascertain the precise annual profits, but how to determine a figure of profit which can be divided without unduly jeopardizing the future prospects of the undertaking.

Further, because distributions out of profits are made regularly at definite intervals and are treated by those who receive them as income, it is important that no kind of gain should be treated as divisible profits which by its very nature cannot be expected to recur.

Capital Profits and Revenue Profits.—The businessman accordingly distinguishes between capital profits and revenue (recurring) profits. and pays dividends only out of the latter. Capital profits are increases of wealth arising from causes not directly connected with the carrying on of the business of the undertaking; *e.g.*, increases in the value of its fixed assets (*i.e.*, those assets held permanently as part of its equipment), a rise in the market value of which adds nothing to the fund out of which alone dividends can be paid.

Indeed, a permanent rise in the value of fixed assets is a source of embarrassment rather than of congratulation, in that it increases the ultimate cost of replacements as and when such assets are worn out, and thus then at least tends to deplete the fund available for the payment of dividends. Conversely, capital losses arising from a fall in the value of fixed assets do not affect divisible profits so long as these assets continue to be equally effective as profit-earning equipment, while a fall in the cost of renewals is advantageous from a revenue point of view.

Of course, if and when a business is discontinued and wound up, capital losses and profits will materialize. If on balance there have been profits on capital, the fixed assets will realize more than they otherwise mould have realized, and a correspondingly larger sum will be available out of which to make a return of capital or, rather, there will be a balance of capital profits to divide after capital itself has been returned in full.

Conversely, if on balance there have been capital losses, the fixed assets will not realize a sum sufficient to enable the whole of the capital to be returned, and there will therefore be a realized loss on liquidation. Where the business is owned by a limited company, this means that the shareholders (or the holders of some class or classes of shares) will not receive the whole of their capital back; but if the business be owned by a concern not subject to limited liability. *e.g.*, a partnership, the members will have to contribute among them the ascertained loss pro rata, according to the shares in nhich they were entitled to participate in profits, and there will then be a sufficient fund to enable the whole of the capital to be returned to those who provided it.

In the case of a partnership, it is usual to divide the nhole of the profits as shown by the annual accounts; but in the case of a company, it is not usual to pay away as dividends the whole of the profits shown by the annual accounts. A part of these profits is normally held back as a reserve against unforeseen contingencies, and another part is normally "carried forward," partly with a view to equalizing dividends in good and bad years, partly to avoid the inconvenience of paying away profits which have perhaps not entirely been received in cash.

PROFITEERING, a term that came into use during World War I. It is generally applied when an individual or firm makes unreasonably large profits during a public emergency which adversely affects the fortunes of others; it usually connotes that the recipient of these profits has acted improperly in obtaining them. Although the term has been used most frequently in connection with wartime situations, it is applied during other types of emergencies as well; *e.g.*, excessive inflation. While the word itself is comparatively new. it describes an old phenomenon. During every war, some individuals and firms have made inordinate profits, particularly those producing and selling munitions.

Numerous situations make profiteering possible. For example, an embargo may shut off the supply of certain articles; the government may suddenly and substantially increase its purchases of scarce materials; individuals with higher incomes as a result of wartime employment may buy more goods and services; and with all this, the state may fail to effectively regulate prices and profits. The history of profiteering and its sequel, antiprofiteering legislation, discloses continuous public concern with the problem and greater refinements in the devices employed to eliminate it.

United States.—During the Revolutionary War the Continental Congress recommended to state legislatures that they regulate the prices of commodities and services in view of the "spirit of sharping and extortion . . . being confined within no bounds." Most of the state legislatures responded with laws that regulated the price of practically every commodity as well as labour wages. One of these laws was directed against the "wicked arts of speculators, forestallers, and engrossers, who infest every corner of the country."

During the Civil War. government suppliers often received higher than market prices for their goods. One supplier might have been preferred over another because he had hired an influential representative to deal with the government. An attempt to prevent such conduct was made by changing the procedures for awarding and checking on contracts. Contracting officials were required to advertise all contracts they proposed to award, where this was practicable, and new criminal statutes to eliminate bribes of public officials were enacted. In addition, a special commission was established to review certain contracts in connection with the awarding of which improper dealing was suspected. This commission had no power to require adjustment of contracts but the publicity given to these transactions persuaded some contract holders to agree voluntarily to accept lower prices than those for which they had originally bargained. No attempt was made during the Civil War however to eliminate profiteering which took place outside the area of government contracts or to control prices and the profits received under government contracts.

Before the Spanish-American War, congress for the first time sought to limit the profits of defense suppliers directly when it imposed a maximum price at which armour plate might be purchased by the navy department.

The outbreak of World War I increased the demand for United States goods. When the U.S. entered the war in April 1917, prices had risen 70%; there was also a sharp increase in corporate profits. Before the U.S. entered the war, congress made no serious effort to limit profits, confining itself in this regard to a special tax of

$12\frac{1}{2}\%$ on profits from the production of munitions and an 8% over-all excess-profits tax. After the U S. entered the war several devices were employed in an attempt to eliminate what was now called profiteering.

First, a new kind of contractual arrangement was evolved The profits of defense suppliers could not be controlled merely by requiring competitive bidding because as prices of raw material and labour began to rise rapidly contractors refused to take fixed-price contracts. In an effort to protect suppliers against the risks of unanticipated costs and the government against excessive prices, the government began to negotiate contracts under which the supplier was paid his actual costs plus a fixed percentage which represented his assured profit. It became apparent however that this type of arrangement stimulated the supplier to increase rather than decrease his costs of performance and was potentially more costly to the government

Second, congress and a variety of administrative agencies established maximum prices for certain commodities: basic raw materials and fuels, munitions of war and general consumption necessities. In general. profits were not considered to be sufficiently regulated by this method and a third device, the excess-profits tax, was ultimately relied upon as the principal method of eliminating excessive profits during World War I. The first such tax was imposed in 1916. The rate of tax upon excess profits was increased in subsequent years until it reached 80% in 1918. Although over-all profits of corporations declined in 1918, individual companies, especially those engaged in supplying the government directly, nere able to make what were regarded to be abnormal profits despite the measures just described.

While profiteering was doubtless curtailed by the more aggressive controls of World War I, it was by no means entirely eliminated. During the period between World Wars I and II there was a continual outcry against the war profiteering that had taken place. It was even contended that by their desire for profits, munitions makers had helped bring about the war. The American Legion backed various bills to limit mar profits and in 1924 the platforms of both the Democratic and Republican parties contained planks for the control of profits realized from war production.

The first positive action in this area was taken by congress in 1930 when it eitablished a commission to investigate methods of equalizing the burdens of war and determine how war profits could be eliminated: this commission recommended a wartime excess-profits tax of 95%. In 1934 the Nye committee of the senate began hearings to investigate the munitions industry. The committee recommended such measures as the nationalization of the peacetime munitions industry and the imposition of a wartime tax of 99% on personal incomes over $20,000 as well as an excess-profits tax on corporations. Although congress proceeded more moderately. it did take a step in the direction of eliminating large profits from defense contracts when it enacted the Vinson-Trammell act in 1934. This law, as amended and supplemented in the following years, limited the maximum allowable profits of airplane and vessel builders and certain of their suppliers to a percentage of the contract price: the allowed profit was 10% and 12% depending on the type of article involved. This limitation mas suspended in 1940 in favor of an excess-profits tax of 90% on all corporations, whether or not they were government suppliers. While this bill was designed primarily to raise revenue, it sought to achieve this by distributing the burden of national defense in a manner calculated to prevent profiteering.

With the entrance of the U.S. into the war in 1941 and the attendant expansion in munitions production, the concern over profiteering mounted. Congress initially used an approach similar to that employed in the suspended Vinson-Trammell act. It considered limiting the profit-cost ratio of munitions makers to 6%. While such an approach doubtless would restrict profits, it discouraged rather than encouraged reduction of costs and production of the most effective munitions in the most economical manner.

In 1942 a new and more flexible device for profit control called renegotiation was introduced; thereafter it played an important role in attempts to control profiteering. Renegotiation involved an annual review by the government of a supplier's profit after the performance of his contracts and the refund by him of portions of his profit that the government regarded as excessive under all the circumstances. The advantage of this procedure was that it provided a spur to efficiency since. in theory, the efficient producer might retain more of his profits than the inefficient producer.

Two other devices were employed to eliminate profiteering during the war: one was the excess-profits tax, already discussed; the other was price control. The Office of Price Administration was established in 1941, "to prevent spiraling, rising costs of living, profiteering, and inflation resulting from market conditions." The OPA imposed maximum prices on most commodities and services other than those sold to the military departments.

The activities of the renegotiation and excess-profit authorities suggest in some measure the extent of profiteering that occurred during the war. From defense expenditures of over $190,000,000,000 that mere subject to profit control, renegotiation led to the direct recovery by the government of over $10,000,000,000. Additional amounts estimated at about $4,500,000,000 were refunded through voluntary adjustment of contracts by firms subject to renegotiation. The government also recovered from the defense and nondefense sectors of the economy about $16,000,000,000 in excess-profits taxes.

In 1948. when the nation embarked on unprecedented peacetime expenditures for defense, profit controls in the form of renegotiation were reinstated, principally upon aircraft manufacturers and some of their suppliers. In 1950, after the beginning of the Korean war, profiteering again became a matter of major concern and a series of laws was passed by congress. The Defense Production act of 1950 conferred authority upon the president "to prevent profiteering." A new excess-profits tax law was enacted whose main purpose was the raising of revenue by assessing those "corporations whose profits are higher than they probably would have been in the absence of hostilities and a large military budget." Finally, in March 1951, a new renegotiation act was enacted which applied to most defense contractors and suppliers.

The first two laws ceased to be effective in 1953; as early as 1952 congress directed that price regulations be suspended immediately in cases where no inflationary pressures existed. The excess-profits tax lasted only a short time after the end of hostilities in Korea. Only the Renegotiation act of 1951 which applied solely to profits from defense contracts was continued although its scope was gradually whittled down so that its main impact was on the aircraft and space industries.

Great Britain and Etarope.—As in the United States, profiteering in England and on the continent is an old phenomenon; the legislation enacted to combat it is perhaps the best evidence that profiteering existed. Price control laws are found as early as the 4th century in the Roman empire. In 1793. while France was being blockaded by the British fleet, the French government passed the "Law of the Maximum," nhich fixed prices for grain and other commodities with reference to 1790 prices and set wages at a level of 50% above those of 1790. In England prices and wages were regulated from time to time from the 14th century.

Beginning in the mid-19th century, army purchasing procedures in England were centralized and tightened in an effort to eliminate profiteering; however. these procedures had to be loosened at the beginning of World War I when it became necessary to purchase uncommonly large amounts of supplies within a short time. Among other things, competitive bidding for contracts had to be abandoned.

As soon as purchasing controls were relaxed. much criticism developed concerning speculation and profiteering in mar contracts. As a result, the government took over production of many munitions; it also adopted new contracting procedures in connection with the defense production performed by the civilian sector.

Among these was the use of the target cost contract: this prescribed in advance a target cost of production and provided that if the costs actually incurred by the contractor were below this figure, then a share of these savings was to be paid to the contractor along with his actual costs and the profit previously agreed upon. The virtue of this type of contract as compared to the traditional fixed price was that it prevented a defense supplier from profiteering and at the same time gave him an incentive to produce as efficiently as he could.

The British government also began in 1915 to tax excess profits being generated from the war. This form of profit control spread rapidly to other parts of the British empire and all of Europe. In addition to these relatively new devices to combat profiteering the British government employed the old device of price fixing; by 1916 the maximum price of several commodities was being prescribed by the government.

The excess-profits tax was continued in England for a short time after the war; price fixing was not only continued but reinforced by the Profiteering act of 1919. Under this law, which was the first to include the term "profiteering" in its title, the Board of Trade investigated the prices of many commodities and the profits derived from dealing in them: it then issued reports reflecting the results of its investigations. The act lapsed in 1921 before it accomplished a great deal; the problem of profiteering to which it had been addressed ceased to exist as soon as unfavourable economic conditions began to push the price level downward.

The inflation which raged in Germany in 1923 resulted in the establishment of a cartel court which had the responsibility of bringing about reductions in and preventing increases in prices when profiteering seemed to be taking place. During most of the interwar period in Europe profiteering was not a matter of great concern; rather, during the great depression there was the apprehension that profits and prices were not adequate for the proper functioning of the economic system.

As soon as World War II began there was again a preoccupation with ptofiteering. Germany began the war with a thoroughgoing system of price control which at first sought to hold prices and wages at 1936 levels and which required justification for any price increases or for the maintenance of prices that appeared to be yielding excessive profits.

Bitter memories of World War I and its aftermath reinforced the resolution of the government in Great Britain as well to prevent windfall gains from arising as the result of the war. In 1939 the Price of Goods act was enacted to fix prices at levels designed to freeze sellers' incomes at prewar levels. This act and the Goods and Services act passed in 1941 prevented undue price rises at the retail level but was largely ineffectual at the manufacturer's level. The difficulty was that it was necessary to leave prices high enough to provide an incentive for the production required for the prosecution of the war. This meant that the low-cost producers frequently earned high profits; accordingly, the attack upon profiteering in this area had to be made from another direction.

In general an attempt was made to set firm prices on contracts; however, in order to minimize profiteering the government in many cases postponed the establishment of a firm price until production was well advanced and cost experience had been gained. The objection to this was that. to the extent that the price finally was based upon realized costs, the contractor had no incentive to keep down his costs. An attempt was then made to use target cost contracts as in World War I in order to restore this incentive, but it was usually as difficult to negotiate a realistic target cost in advance as it was to negotiate a fixed price. Ultimately, a choice had to be made in connection with each purchase between the fixed-price contract with its inherent risk that excessive profits would be realized by some contractors and various types of contracts under which the supplier's compensation was determined primarily with reference to actual costs incurred by him.

In general there was no attempt to recapture excessive profits from prime contracts after they were realized, as renegotiation did in the United States; however, an informal procedure resembling renegotiation was instituted with respect mainly to subcontractors. They were required to submit periodic over-all trading reports which disclosed the profits they had made from defense contracts; they were required to refund that portion of their profits considered by the contracting agency to be unreasonable. By 1948 some £57,000,000 had been recovered in this manner from several thousand contractors.

Beyond all this, an excess-profits tax was imposed which, after May 1940, was at the rate of 100% and which was computed with reference to profits earned from 1935–37. Parliamentary concern with the question was so great that the adoption of this extreme remedy against war profiteering did not result in the discontinuance of the other efforts to prevent excess profits.

After the end of World War II, most of the wartime controls over prices and production were maintained because of shortages. Food rationing did not entirely cease until the summer of 1954 and some price controls lasted even longer. Other measures directed against profiteering however lapsed at the end of the war.

BIBLIOGRAPHY.—H. S. Hensel and R. G. McClung, "Profit Limitation Controls Prior to the Present War," *Law and Contemporary Problems*, x, 187–217 (1943) ; W. Ashworth, *Contracts and Finance* (1953) ; W. K. Hancock and M. M. Gowing, *British War Economy* (1949) ; H. L. Wilkinson, *State Regulation of Prices in Australia* (1917) ; E. M. H. Lloyd, *Experiments in State Control* (1924) ; J. T. Koehler, S. Marcus and P. Nichols, Jr. "Current Renegotiation Problems," *Virginia Law Review*, 45:1–62 (1959) ; Richard C. Osborn, "Corporate Profits: War and Postwar," *University of Illinois Bulletin*, no. 77 (1954) ; S. Marcus, "What is Appropriate Public Policy for Profit Renegotiation?" *California Management Review* (Fall 1959). (S. MA.)

PROFIT SHARING is a system by which an employer pays to his employees a share of the profits of the undertaking in which they are engaged in accordance with a scheme defined in advance. The way in which profits will be divided between the shareholders and the employees is therefore known beforehand, and the amounts distributed vary from year to year according to the profits actually earned.

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As far back as 1889 an International Congress on Profit Sharing held in Paris defined profit sharing along these lines as payments made in accordance with a freely agreed scheme, of a share, determined in advance and not variable year by year at the discretion of the employer. of the profits of an undertaking to a substantial proportion of its ordinary employees. These payments are distinct from and additional to wages. which are generally paid by the undertaking at rates current in the industry and locality. By the requirement that schemes must be "defined in advance," profit sharing proper excludes gifts, gratuities or other payments made by an employer to his employees out of profits at his discretion without being bound by a scheme. An employer is usually free to terminate a profit-sharing scheme at any time, but until he does so he has bound himself to observe its provisions. The Paris definition excludes schemes in which a share in profits is paid only to a small number of administrative and technical staff and not to manual workers.

As the payments must be related directly to profits, any systems of production bonus, individual or group piece rates, or other methods of payment based on output are not profit sharing. Similarly, systems by which the total production or gross proceeds of an undertaking are divided in predetermined proportions—for example, by share fishermen, and in some forms of land tenure (*e.g.*, metayage)—must be excluded, as something other thin profits is being shared.

On the other hand, copartnership (*see* below) is a form of profit sharing if employees are given shares in the capital of the undertaking in which they work or if such shares can be acquired by them on specially favourable terms.

Early Examples.—France can claim to have been the pioneer in profit sharing, several schemes having been started before the middle of the 19th century. The earliest known example was that introduced by the French National Fire Insurance company in 1820, and in 1842 the Paris firm of E. J. Leclaire, house painters and decorators, started a scheme which attracted wide attention in France and abroad. During the next few decades other French firms started schemes, some of which were highly successful; for example, those introduced by Godin of Guise and by the Bon Marché store.

Development in Great Britain.—The French schemes attracted considerable attention in England about the middle of the 19th century, and their principles were advocated particularly by the Christian Socialists, who influenced co-operative societies to apply them to their employees. Later the co-operative movement developed along somewhat different lines, and most of the consumers' co-operative societies and the co-operative wholesale societies ceased to practise profit sharing, though the system was retained by some co-operative production societies especially in the boot and shoe industry and in clothing. printing and building.

Outside the co-operative movement the first important scheme was that of Henry Briggs, Ltd , a firm of Uorkshire colliery owners, which introduced profit sharing in 1865. At first the scheme was very successful, but the directors ended it because their employees took part in a strike for higher wages. During the period 1880 to 1910 about 240 schemes are known to have been started, at a rate of about 80 each decade, most of them being straight profit-sharing schemes, but some of them took the copartnership form by which employees aere given opportunities to share in profits by the acquisition of shares on specially favourable terms. The rate of growth was much greater during the years from 1910 to 1920 when prices were rising rapidly and big wartime and early postwar profits were being earned. More than 200 schemes were started in this decade. After the onset of depression in 1921 fewer schemes were started. but the number was still around 140 in the ten years to 1930. During the depression years of the 1930s still fewer schemes were started. However, during these interwar years more schemes were soundly based, as there was better knowledge of what was involved than when the earlier schemes were started. Some of the earlier schemes nere based on wrong motives and unsound methods, and about 85% of those started before 1900 had been discontinued by 1930, many of them having a life of only 10–20 years. A few, however, continued successfully for more than 50 years and were still in operation in the mid-20th century. Also many of the discontinued schemes could claim success during two or three decades. As would be expected more schemes are started in years of prosperity than during periods of depression, and the discontinuance of schemes is greatest in depression years.

Among firms with long-established and highly successful schemes mention may be made of Clarke, Nicholls and Coombs. Ltd.. J. T. and J. Taylor, Ltd., Reckitt and Colman, Ltd., Rowntree and Co. Ltd.. E. S. and A. Robinson, Ltd., Bryant and May, Ltd., and the Bradford Dyers' Association, Ltd.

An average of not much more than one-half of the employees participate, some being excluded because they have not worked uith the company for a specified minimum period or because in some schemes only adults are entitled to benefit. At the beginning of 1954, in approximately 350 profit-sharing companies in Great Britain, the number of participating employees mas fewer than 300,000, or less than 2% of the total number of persons in employment throughout British industry (excluding those in the nationalized industries, professions and central and local government services in which profit sharing could not be applied).

The industry in which profit sharing is most widely applied is the chemical industry. In most other industries there are some profit-sharing companies, though they form only a small minority in any industry. Until after World War II the biggest development was by the gas companies, especially in the London area. This began in 1889 when the South Metropolitan Gas company introduced a scheme by which employees were paid a cash bonus varying with the profits of the company. After revision the scheme took the form of copartnership, half the bonus due to the employees being used to buy for them ordinary shares of the company, and the other half being left with the company to accumulate with interest but with the right of withdrawal by the workers in special circumstances.

Finally, in 1920, the scheme was made statutory by legislation which provided that surplus profits, after payment of prescribed basic rates of dividend on capital, were to be divided in the proportion of three-quarters for the benefit of consumers by reducing the price of gas, and the remaining quarter in equal parts to the ordinary stockholders by increasing their dividends and to the employee copartners as a percentage bonus on their salaries and wages. 4s before, half the bonus was capitalized and the other half invested subject to the right of withdrawal in special circumstances. Nearly all the leading gas companies and many of the smaller ones introduced similar schemes, which proved highly successful and resulted in large amounts of the capital of the companies being owned by the workers. They were, however. terminated by legislation passed in 1948 to nationalize the gas industry; compensation was arranged to cover loss of the remuneration which the employees had received as copartners.

In the years of prosperity immediately after the middle of the 20th century, increased interest in profit sharing and copartnership was shown by certain leading firms, and both the Conservative and Liberal parties in Great Britain favoured the adoption of schemes as a means of promoting better relations between management and employees. The biggest company to propose a scheme was Imperial Chemical Industries, Ltd.. which announced in May 1954 a plan of the directors to introduce profit sharing which would initially cover about 75,000 of its total of 107,000 workers in Britain.

The scheme provided for payment each year to adult employees with $2\frac{1}{2}$ years' service or more of an amount equal to 1% of the employees' annual remuneration for each 1% by which the dividend to ordinary shareholders exceeded 5%. These amounts would be invested in the ordinary stock of the company at the current market price and would be held by trustees until an employee had a minimum of £25 of stock to his credit,, when it would be turned over to him without any restriction. The directors retained power to amend or terminate the scheme. They regarded it as a further step in their progressive personnel policy, and as a means of developing a better understanding among their employees of the economic problems of the company and of the country.

Types of Scheme. — Most schemes of profit sharing and copartnership have been devised on the initiative of individual firms, and in consequence schemes vary widely to suit the conditions of each company and the purposes and attitudes of the employers who introduced them. Some undertakings are in process of growth while others have reached stability, some are in industries which experience wide fluctuations in prosperity and need to set aside bigger reserves in good times to meet periods of depression than are required by undertakings in industries which enjoy steadier demand, and some undertakings have much higher labour costs in relation to total cost than others. In some companies, equity capital forms only a small proportion of total capital, whereas in others it is a high proportion or even the whole of the capital.

Profit *Sharing*.—Schemes are of three main categories, namely profit sharing alone, profit sharing combined with some kind of copartnership through ownership by employees of shares in the company, and shareholding without copartnership. Schemes of profit sharing usually provide first for payment of all working expenses, amounts necessary to cover depreciation and reserves, interest on debenture stock and preference shares and a specified percentage, often 5% or 6%, as dividend to ordinary shareholders. Then employees entitled to participate receive a defined share of any surplus profit. This surplus may be divided equally between employees and shareholders, or shared in some other proportion. An alternative is to distribute to employees an amount not exceeding a specified sum, say £50,000, the remainder of the surplus being paid in additional dividends to the ordinary shareholders. One variation is for one-half of surplus profits to go to the employees, one-tenth to the management and two-fifths to holders of ordinary share capital.

Where capital costs are high, less than one-half of surplus profits may be distributed to the employees, the proportion being sometimes only 10% of the surplus.

In order that an employee may be entitled to share in surplus profits, a qualifying period of employment in the firm is required by most schemes, the period often being a year, but in some schemes it is several years and in others only three months. Some schemes provide for bigger shares according to length of service, one scheme, for example, providing that an employee with ten years' service shall receive five times the share of an employee with one year's service; usually, however, when length of service is taken into consideration the increase is much less. Lateness is penalized in some schemes.

Some schemes restrict participation to adults in manual and similar grades; in others juvenile workers receive lower rates of payment than adults. Some schemes pay higher rates to managerial and other salaried staff than to manual workers, this method being based on the belief that salaried staff have a bigger influence than manual workers on 'the amount of profit. For this reason some schemes provide for payment of a higher rate to foremen than to manual workers.

Surplus profits are usually divided among the participants on the basis of each employee's wage or salary. This ensures that persons will share in profits roughly according to their value to the firm, the skilled workers receiving more than the unskilled. The amount which a worker receives varies considerably from industry to industry, from company to company and from year to year. A frequent rate, however, has been about 6% of earnings or an addition equal to about the amount a worker would earn in three weeks.

In more than one-half of all British schemes of profit sharing and share ownership the share of profits is paid in cash or is credited in a savings account. Nearly one-fifth of all schemes consist of the issue to employees of shares in the company on specially favourable terms or provide for the payment of dividends varying with profits on deposits made by employees. In a few schemes the amounts due to the workers are paid into a provident or superannuation fund.

Share *Ownership.*—Employees of a company, like any other persons, can buy its shares on the stock exchange, but some firms have made available special shares which can be obtained only by their employees. There is great variety in these schemes. but each is a method of saving and is intended, like profit sharing, to give employees a better understanding of the economic and financial problems of the firm for which they work and to increase their interest in its success. Some schemes combine profit sharing with share ownership by providing that the whole or part of the amount due to an employee may or shall be invested in the firm's shares. Thus, such investment may be voluntary or compulsory. Alternatively, shares in some schemes may be bought by installments paid out of personal savings, often by deductions authorized by the worker from his wages. The shares may be sold to employees at par, at market price or under market price.

These schemes, which enable employees to accumulate substantial amounts in shares over a period of years, have a greater "expectation of life" than profit sharing in which only cash bonuses are paid. As these amounts are savings which employees can ill afford to lose, many companies provide safeguards to maintain the value of the special shares issued to them. Dividends on employees' shares are usually at the same rates as on ordinary shares, but some companies issue special preference shares, with a specified rate of interest (*e.g.,* 6%), and these shares may or may not receive additional interest if dividends beyond a given rate are paid to ordinary shareholders.

Where a company has profit sharing and share ownership, participating employees receive their share in the profits and also interest or dividends on the shares they hold.

Most schemes impose restrictions on the holding of special shares, often providing that the shares must be returned to the company on the death of the employee or on his leaving the company's service. Many companies pay the par value when such shares are returned. but some pay the market value. Payment of par value protects these savings of employees against loss but reduces the value of the scheme as an education in the risk run by investors. The employee holders have a stake in the business by receiving dividends which vary with changes in the firm's prosperity, but their capital is safeguarded against the effects of such changes. Ordinary shareholders are free to sell their shares whenever they wish and can exercise their judgment when to sell so as to make a profit or avoid loss, but employees holding special shares are not able to do so, and this is one reason why they are often given the safeguard of a guaranteed value.

Copartnership.—Copartnership between employers and employees implies some participation by the employees in the management of the business. This may range from consultation in works councils or joint production committees to attending and voting at annual and other general meetings of shareholders and electing employee representatives to the board of directors. An increasing number of companies regularly give to their employees information about the economic and financial position of the business, its problems, policy and prospects. The managing director may make statements on these matters, and arrange for summaries to be published in the works magazine. In many firms. representatives of the employees take part in the management of welfare and social activities. These methods result in greater influence by employees on the business in which they work, and their status is raised.

Often the extent of copartnership with employees may be slight and nebulous. In copartnership in its more developed form, the holders of employee shares have the same rights as other shareholders to attend and vote at general meetings, and they also cooperate with management by some method of joint consultation. Only a few schemes provide for employee shareholders to be represented on the board of directors, and even then their representatives are in a minority and their influence is often small, as they lack adequate experience of the economic, financial and technical problems of the business. In these schemes, only those employees who have had considerable service with the firm (for example, ten years) and who hold a specified minimum number of shares can be nominated for election as directors.

Attitudes of Employers. — The fact that, after a century during the larger part of which there has been active propaganda in favour of profit sharing, not more than about 900 companies have adopted schemes, and that nearly one-half of this small minority of companies discontinued their schemes within two or three decades, is a clear indication that the great majority of employers have not been attracted by profit sharing.

Most employers consider that in the same way as they pay market prices for their raw materials, they should pay to their employees current rates of wages, and they point out that in periods of prosperity employees gain higher wages and thus share in prosperity. Profits should, in their opinion, accrue to those who undertake the financial risks of the business. Some argue that if employees share directly in profits they should similarly carry directly a part of the burden in years when losses are incurred. Many do not regard profit sharing as an appreciable incentive to more sustained effort, especially as those employees who work harder receive only the same share as those who make no greater effort. They claim that there is no satisfactory way of measuring what increase in output results from profit sharing. Against this, however, several hundred employers whose schemes have worked successfully, while not claiming that they can measure results in terms of increased output, are satisfied that profit sharing leads to better industrial relations. as the employees feel that the company is giving them a fair deal and that there is social justice in employees' participating directly in profits toward which they have contributed by their labours.

Attitude of Trade Unions. — Trade unions have been generally hostile to profit sharing and copartnership, partly because, in the early days, some employers used them as a weapon against the unions. The workers were told that they would gain more from these schemes than from action by trade unions to raise wages. Also workers in some firms were warned that the profit-sharing schemes would be terminated if they went on strike for higher wages and other trade-union demands. Trade unions fear that profit sharing will strengthen the loyalty of workers to their firm and weaken their interest in the trade-union movement. The policy of trade unions is to gain the best possible general level of wages and working conditions for their members. and in Great Britain the unions have worked to secure standard rates of wages throughout an occupation or industry. With profit sharing the workers' incomes would vary from firm to firm according to the profits of each, but British unions are not concerned with special differential advantages for employees who are fortunate enough to be employed by firms here and there which are exceptionally prosperous. Also. as profit-sharing schemes are usually introduced on the initiative of employers, the workers receive benefits which the unions have not won for them. The unions have found no method of regulating profit-sharing schemes by collective bargaining agreements.

The former hostility of trade unions changed somewhat in the interwar years and after World War II, and the attitude became one of indifference or mild acquiescence. This was largely because employers ceased to use profit sharing as a weapon against the trade unions but tended instead to discuss schemes mith their employees and often with trade-union representatives before introducing them. The greater strength of the unions would enable them to oppose successfully the misuse of profit sharing by employers. Workers in firms with profit-sharing schemes welcome the additional remuneration they receive.

Value and Limitations. — Reasons have been given why many employers have not introduced schemes and why many schemes have been discontinued after a few years. Those employers who have introduced schemes because they believed their workers would be stimulated to greater effort and that output would rise appreciably have been disappointed. This has been largely because profits depend upon many factors in addition to the efforts of the workers; for example, the efficiency of management and market demand for the products of the undertaking. As an inducement to greater production by the workers, the relationship between effort and reward is not close enough. Profit sharing is much less effective as an incentive than systems of payment by results where remuneration is directly related to the efforts of a worker, and where he receives his reward with little delay, whereas his share in profits is remote. having to wait until after the annual general meeting of the company. During periods of depression when profits have been small or nonexistent, schemes have foundered because they ceased to interest either employers or employees. A scheme may be sponsored by an employer who has faith in profit sharing and operates it successfully, but the firm may later come under new management unfavourable to profit sharing and the scheme is terminated. Even the success of some schemes has resulted in their being discontinued; for example, companies with stable profits have frequently distributed amounts which varied so little from year to year that the share in profits has finally been used to increase rates of wages and sharing of profits has been abandoned.

Profit sharing or copartnership provide only one among many ways of promoting good relations in industry. The most successful schemes have been those in companies where profit sharing or copartnership have formed part of a comprehensive program for promoting good will. Applied in this way, profit sharing and copartnership can strengthen the mutual interest which capital, management and labour have in the efficient running of the undertaking, ensure a better understanding by the employees of the. economic problems of business enterprise, broaden the basis of capital ownership and raise the status of employees.

Other Countries. — Detailed information is given in a separate section on the United States where profit sharing has had proportionately less application than in Great Britain, and where the rate of termination of schemes has been somewhat greater. In most of the countries of western Europe, including France. Germany, Belgium, the Netherlands. Switzerland and Italy, profit sharing has been adopted by a small number of firms but the numbers of firms and of participating employees have been relatively fewer than in Great Britain. Among these countries the greatest development is in France, where the biggest application is by insurance companies, some of which have had schemes in operation successfully for half a century. Among the few schemes in Germany which have had a long life, the best known is that of the Zeiss firm of optical glassmakers. In European countries copartnership is rare, most of the schemes providing that the share of profits due to employees shall be paid to them in cash or as credit in a savings fund. There are a few profit-sharing schemes in Australia, and also in New Zealand where an Employee Partnership institute has undertaken propaganda for copartnership.

Profit sharing is compulsory in Venezuela, this being required by the Labour law, and substantial amounts are paid annually to employees by the larger firms, including the oil companies. The law provides that specified proportions of profits shall be shared nith employees up to a maximum equal to two months' wages in large firms and one month's wages in small firms; the proportion ranges from 2.05% of profits in small firms to 12.45% in large firms. In Chile a law was passed in 1950 making it compulsory for firms to pay a share of profits to their white-collar employees. In France laws have been enacted to make profit sharing compulsory for workers' productive co-operative societies, but these societies, which are usually small, differ from the usual kind of business. In several countries, *e.g.*, France. New Zealand and New South Wales, permissive legislation has been passed to enable compliance with the Companies acts to be effected by undertakings wishing voluntarily to introduce profit-sharing schemes.

BIBLIOGRAPHY.—Ministry of Labour, *Report on Profit-sharing and Labour Co-partnership in the United Kingdom* (London, 1920); *Profit-sharing and Co-partnership,* statistical articles published annually, 1922–1938, in the *Ministry of Labour Gazette;* F. W. Raffety, *Partnership in Industry* (London, 1928); E. W. Mundy, *Profit-sharing and Co-partnership* (London, 1931); Bryce M. Stewart and W. J. Couper, *Profit Sharing and Stock Ownership for Wage Earners and Executives* (New York, 1945); Industrial Co-partnership association, *Co-partnership* (pub. quarterly, London). (J. H. RN.)

UNITED STATES

The term profit sharing is recognized in the United States to include varied types of plans and concepts. The old idea that a genuine profit-sharing plan had to provide that an employer would pay to his employees, over and above their regular wages, a share of the company's profits in accordance with a predetermined formula was modified in America by actual developments. Important companies which do not have a "predetermined formula" have shared profits with their employees over many years. A U.S. senate committee included under the term any plan which provided extra income from the employer, over and above regular wages, under a systematic plan. This was a broader concept than that generally accepted.

However, neither the National Industrial Conference board (NICB), which issued five reports on profit sharing (1920 to 1948), nor the Profit Sharing Research foundation (PSRF) reports considered profit sharing to be so inclusive. The latter. in its 1954 report, *Profit Sharing Patterns,* said: "Profit sharing is any procedure under which an employer pays employees, in addition to regular pay, special current or deferred sums based on the prosperity of the business as a whole." This concept was substantially the same as that of the National Industrial Conference board.

Some companies have "limited" profit-sharing plans which cover only officers and "principal employees"—those persons who know that their own efficiency directly affects profits. Such plans are primarily incentives to executive personnel and must be distinguished from "true" profit sharing, which shares a part of the profits mith rank and file employees. The remainder of this article discusses only "true" profit sharing.

Unions and Profit Sharing. — After 1940 profit-sharing plans were established in many U.S. companies whose labour relations were subject to union-management collective bargaining. This was a distinct departure from the situation which existed before 1940, when profit sharing and collective bargaining were seldom found in the same companies. Unions were suspicious of the bookkeeping procedures used in figuring profits; they looked upon profit sharing as a clever device to attach employees to their employers and weaken the appeal of unions; they thought that it would lead to "the speedup" and that it was incompatible with collective bargaining.

In 1954, 258,530 of 600,830 employees working for 300 companies with profit-sharing schemes were in unionized plants and 47,270 more in partly unionized plants. The reason for this change is clear. In 1942 new federal tax rulings enabled employees to get, in lieu of wage increases denied them during the war, profit-sharing benefits under plans conforming to certain government specifications. Naturally, unions were alert to this opportunity.

By the early 1950s some unions had changed their attitude sufficiently so that they wanted to include profit sharing in the list of matters dealt with in collective bargaining. For instance, in 1951 both General Electric company and the Westinghouse company received union requests that union-management committees be set up to explore the possibilities of profit sharing and that the report of such committees be considered during contract negotiations. Neither company agreed. but profit sharing may become a subject of collective bargaining at least in some industries.

History. — Previous to 1942 profit sharing never attained considerable proportions in the U.S. Though experiments with it began as early as 1867, only 50 plans were known to exist in 1896 and only 12 of them remained in operation until 1916. C. C. Balderston's study published in 1937 found only 67 plans in active operation at that time. But in 1942, sec. 165 of the Internal Revenue code. subsection (h), provided that employers' contributions to profit-sharing funds. collected and disbursed as specified by the code, should be deductible expenses for purposes of taxation and there was an immediate upsurge in profit sharing. With wage and salary rates practically frozen during the war many employers saw in tax-deductible contributions to profit-sharing funds a means of supplementing employees' wages and decreasing labour discontent. For concerns in excess-profit brackets only about 15% of each dollar set aside for profit sharing came out of the company and the other 85% out of money which would otherwise have been paid as taxes.

In addition to the value of the contributions and the investment earnings of the reserve fund to their credit, employees stood to gain from the fact that when they received the annuities to be paid to them after they retired, they would pay taxes only on the reduced income they would then be receiving. In other words, they would be in a lower income bracket than they were during the years when the fund was being accumulated.

An employer was not permitted by the federal tax code to deposit to the credit of an employee in any year a sum greater than 15% of the employee's wages or salary during that year. Moreover, the employers' contributions had to go into trust funds for deferred benefits. They could not be paid to employees as current cash income. The plan had to be for the exclusive benefit of employees and their beneficiaries, had to be put into written form and its provisions made known to the employees and, specifically, could not be a device to increase dividends of stockholders or to distribute more of the profits to officers of the company and supervisory employees.

Prevalence of Profit Sharing. — A substantial growth in profit sharing occurred from 1942 to 1954. In *Profit Sharzng Patterns* the opinion is expressed that the number of plans by the latter date ran into four figures. In the National Industrial Conference board survey in 1946, however, plans were reported by 401 companies out of 3.498 questioned. This was an increase from only 158 out of 2,700 companies studied in the 1939 survey. There was, 1942–54, a trend toward greater use of profit sharing, but such plans were still confined to a small minority of employers.

The bureau of internal revenue reported that up to Aug. 31,1946, it had processed 2,508 profit-sharing trust plans for establishments employing 1,312,226 people (cf. NICB report no. 97, p. 5). How many of these were actually put into effect and how many were actual profit-sharing plans is not clear.

Between 1947 and 1951 about 350 concerns joined the Council of Profit Sharing Industries. This organization's objective was to promote sound, well conceived profit-sharing plans.

The most complete studies published during the period 1948–54 covered only a few hundred plans. *Profit Sharing Patterns* was a study of 300 companies with 736,000 employees (1954), or 1.5% of the 48,948,000 nonagricultural wage earners in the U.S. Of these 300 companies, 7j employed 654,600 of the employees covered by the study. Though the report made clear it nas but a partial enumeration of the plans in existence, it undoubtedly constituted the most complete description published up to the mid-1950s of the kharacteristics of United States profit sharing during that period.

The 300 plans analyzed were in 31 states — 44% of them in New York. Illinois and Ohio. The largest concentrations were within 300 mi. of New York city, Cleveland and Chicago. Los Xngeles, Calif. was the only important concentration area on the Pacific coast. The plans were in a wide variety of industries: 223 plans, covering 397,900 employees in manufacturing industries; 38, covering 265,970 employees in wholesale and retail trade; 24, with 68,500 employees in finance and insurance; 14, with 3,590 employees in professional and service organizations.

Cash and Deferred Payment Plans. — Profit sharing may take the form of periodic (usually annual) payments in cash or deferred payments, usually retirement annuities, out of a trust fund accumulated over many years through employer contributions credited to each employee and invested for his benefit by the trust fund. The PSRF report stated that among the 300 companies studied intensively, cash plans predominated among small companies, deferred plans among large, and plans which combined cash and deferred methods characterized middle-sized companies.

Two factors account for the favour of the deferred plans among large companies. They became more interested, and so did unions, in providing wage earners with great lifetime economic security. And they wished to take advantage of the 1942 tax provisions. To do so their profit contributions had to be paid into a trust fund from which their employees would draw annuities in later years.

The smaller companies liked plans under which they could pay employees their shares of profits annually in cash or company stock because it is simpler, and perhaps safer, for them to pay off their obligations annually rather than to handle the complexities of long lived trust fund retirement plans.

Sears, Roebuck company. through a deferred payment plan started in 1916, built up a trust fund valued at about $350,000,000. The company contributed 45%; the employees 15%; and interest, dividends and appreciation in the value of Sears, Roebuck stock contributed the other $118,000,000 to the fund.

While the government restrictions were largely removed after the end of the mar, interest in such deferred payment plans continued at a high level.

Mortality of Profit-Sharing Plans. — The death rate of profit-sharing plans was high during most of the period after their introduction in the United States. There were many reasons. Employers who hoped that profit sharing would prevent unions in their plants or cause employees to be more "loyal" to their employer, that it would make employees work harder, prevent employees from going on strike, or even reduce labour turnover, were often disappointed in their expectations.

Industrial depressions also wrecked many plans. When employees fail to receive benefits to which they have become accustomed, it is hard to convince them that it is because the employer cannot make the payments. Employees' good will, co-operation or loyalty are not bought by a profit-sharing plan. Experience seems to indicate that where employers have discussed fully and continuingly with their employees the essentials of profitable business operations and have based their profit-sharing plans upon mutually shared understandings and objectives, the plans have been more likely to succeed.

The National Industrial Conference board revealed that of 202 companies which had profit-sharing plans in 1937, 35 or 17.3% had discontinued them by 1947. "The ratio of discontinuance is ten times as great among the current distribution plans as among the deferred plans." Nearly two-thirds of the plans discontinued had been operating for more than five years.

Characteristics of Profit Sharing in the 1950s. — Leaders in the profit-sharing movement by the 1950s had become aware that the successful management of profit sharing requires as careful attention to principles and techniques as other aspects of business management.

Such matters are vital as: (1) the skill with which an employer establishes good understanding of the plan among his employees; (2) the amounts and types of employer contributions; (3) the rules governing employee eligibility; (4) whether employees must or may contribute to a deferred plan fund; (5) the method of allocating benefits to employees; (6) whether employees shall have a vested right to the amount of the fund credited to them personally; (7) whether employees shall have a right to withdraw their shares if they take employment with another company; (8) frequency of payment under cash plans; (9) what per cent of the company's net profits shall be set aside for stockholders before any of the profits shall be available for profit sharing; (10) how and by whom the plan shall be administered; and (11) how employees' shares shall be computed.

BIBLIOGRAPHY.—*Monthly Labor Review,* U.S. Bureau of Labor Statistics, April 1923, for bibliography up to that date. Industrial Co-partnership Association, *Co-partnership* (quarterly); "Profit-sharing and Co-operative Production," special supplement to *New Statesman* (1914); *Ministry of Labour Gazette* (1928); S. Rowntree, *Practical Profit-Sharing* (1922), *Industrial Unrest: A Way Out* (New York, 1922); J. A. Bowie, *Sharing Profits With Employees* (New York, 1922); *The 19th Abstract of Labour Statistics* (1928); A. Trombert, *La Participation aux Bénéfices* (1912, tr. 1920); *Enquête sur la Participation aux Bénéfices,* Ministère du Travail (Paris); P. A. Knowlton, *Profit Sharing Patterns* (Evanston, Ill., 1954); Council of Profit Sharing Industries, *Profit Sharing Manual* (1948); F. Beatrice Brower, *Profit Sharing for Workers,* Studies in Personnel Policy, no. 97 (New York, 1948): This is the fourth report issued by the board since their *Practical Experience With Profit Sharing* (1920); "The Pitfalls of Profit Sharing," *Fortune* (August 1951); Hearings and Report by U.S. Senate Subcommittee on Finance, on "Survey of Experiences in Profit Sharing and Possibilities of Incentive Taxation" (Washington, D.C., 1939); John Spedan Lewis, *Partnership for All* (London, 1948; London, 1950); C. C. Balderston, *Profit Sharing for Wage Earners* (New York. 1937); Bryce M. Stewart and Walter Couper, *Profit Sharing and Stock Ownership for Employees and Executives* (New York, 1945); Kenneth M. Thompson, *Profit Sharing, Democratic Capitalism in American Industries* (New York, 1940); Gustave Simons, "Economic and Legal Aspects of Profit Sharing Plans," *Industrial and Labor Relations Review* (October 1948); C. M. Winslow and K. R. Clark, *Profit Sharing and Pension Plans* (Chicago, Ill., 1939).

Hearings and report by U.S. Senate sub-committee on finance, 75th Congress, Third Session, on "Survey of Experiences in Profit-Sharing and Possibilities of Incentive Taxation" (Washington, D.C., 1939).

(D. D. L.)

PRO FORMA INVOICE. When a consignment of goods is made for sale on commission, or when goods are forwarded on approval, it is usual to invoice them in a form identical with that of an ordinary invoice but bearing the endorsement "Pro forma." The consignee is thus fully advised of the contents, descriptions, qualities and prices of the goods consigned.

PROGNATHISM, the term applied with its opposite *Orthognathism,* to describe the degree of projection of the upper jaw.

PROGNOSIS, a term used in modern medicine, as it was in Greek, for an opinion, forecast or decision as to the probable course, duration and termination of disease. It is to be distinguished from "diagnosis," the determination or identification of a disease in a particular case from an investigation of its history, symptoms and findings.

PROGRAMME MUSIC, a nickname which is the only current term for instrumental music without words but descriptive of non-musical ideas. Musical sounds lend themselves to descriptive purposes with fatal ease. A chromatic scale may suggest the whistling of the wind or the serenades of cats. Reiterated staccato notes may suggest raindrops or the cackling of hens. Again, music is powerfully suggestive of emotion; and the emotions it calls up may fit some particular story, or may resemble those inspired by a sunset or a storm. But chromatic scales, reiterated notes, emotional contrasts and climaxes, are also normal musical resources; and nothing infuriates a musician more than the non-musical explanation of such things where the composer's aim was purely musical. Sound as it occurs in nature is too inorganic to form the raw material for art, and so there is no natural tendency in music to include, as a "subject," any item not inherent in the art-form. Explicit programme music has thus never been a thing of cardinal importance, though it has often been prominent and always popular. But the conditions of artistic creation are not to be confounded with any correct theory of art. The doctrine of art for art's sake is correct: but it concerns results, not processes; and many of the purest works of art have been produced for ulterior purposes.

Until recent times no composer has written for the voice without words; for speech is a privilege which the human voice will not willingly renounce. No doctrine of absolute music will prevent a good composer from shaping his vocal music to the words which he sets. Good literature will inspire him to explore and express its inner meaning. Bad literature may suggest to him the truths it misrepresents; and the great composers are quicker to seize the truth than to criticize its verbal presentation or to suspect insincerity. The earliest mature musical art was, then, inevitably descriptive, since it was vocal. While programme music derives many of its characteristics from ancient times, it cannot properly be said to have existed until the rise of modern instrumental music, based upon external ideas and independent of the use of words.

A complete code of musical symbolism came to maturity in the 16th century. Part of it was profoundly true and characteristic of moods; part was harmlessly mechanical; and a few details were manifestly false, as when "atra nox" is represented by a curiously jaunty rhythm because that rhythm is indicated by black notes. When symbolism, true or false, has thus arisen in vocal music it may be expected to retain its intention in music without words. But we must not expect too much descriptive power in early instrumental music; and when a scholar tells us that a funeral piece for organ by Froberger depicts in its final rising melisma the ascent of the soul to heaven, he unwittingly accuses Froberger of sinister intentions in a precisely similar funeral piece which ends with a descent to the lowest bass.

The resources of the modern orchestra can attain a realism which at first seems less ridiculous than that of earlier descriptive music. But the expensive realism of the dozen muted brass instruments that in Strauss's *Don Quixote* accomplish in ten rehearsals what a flock of sheep achieve extempore, is not less, but more childish than the thunderstorm in the Fitzwillian Virginal Book.

Beethoven's Theory of Expression.—On the other hand when superior persons object to the childishness of the birds and the thunderstorm in Beethoven's *Pastoral Symphony* it is they who are childish in supposing that realism is in question at all. The real cuckoo, nightingale and quail happen to be musical birds whose themes are exactly what Beethoven wants for a break in the rhythm at a point of *repose* in the coda of his slow movement. Similar final digressions can be seen in slow movements with no programme at all, *e.g.,* in the violin sonata of 24, the pianoforte sonata in D minor (op. 31 No. 2), and the string-quintet in C major, op. 29. Not a bar of the *Pastoral Symphony* would be otherwise if its "programme" had never been thought of. The "merry meeting of country folk" is a subject that lends itself admirably to Beethoven's form of *scherzo* (*q.v.*); and the thunderstorm, which interrupts the last repetition of this scherzo and forms a tremendous introduction to the peaceful finale, is as musical as other unique features in Beethoven's pure art-forms.

Beethoven is recorded to have said that he always composed according to a "picture" he had in his mind; and he sometimes gave his friends an explanation, jocular or evasive, of some particular composition. But the word *Bild* is much more indefinite than "picture"; and Beethoven's dull Boswell, Schindler, often exasperated him into defending himself by saying the first nonsense that would serve to stop foolish questions. Composers who have much to express cannot spare time for translating it into other terms than those of their own art. The *Eroica Symphony,* though inspired by Beethoven's short-lived belief in Napoleon as the liberator of mankind, is not programme music at all. The funeral march represents heroic death and a mourning world, but not the obsequies of a biographical subject; and when critics tell us that the finale is "an inappropriate concession to sonata form" they merely show themselves unmusical without thereby becoming literary. The profound and subtle sonata *Les Adieux, l'Absence et le Retour* is true programme music. It represents Beethoven's feelings on parting from the Archduke Rudolph when the royal family left Vienna shortly before its bombardment. It deals only with the parting, the absence and rejoining of the two men. Nothing is heard of war, and the sentiment is as deep as it is manly. Beethoven's private sketch-books record that the work is "written from the heart": no courtly formula, even if this was shown to the Archduke. Ingenuity is misplaced in tracing external details. (The end of the first movement of *Les Adieux* has been compared to the departure of a coach.) The real emotional basis is universal and musical.

Beethoven summed up the whole theory of great programme music in his note to the Pastoral Symphony; "rather the expression of feelings than sound-painting." Overtures to plays or operas cannot so easily dispense with story-telling; but Beethoven refuses to be drawn into a chronological series of illustrations. His overtures to *Coriolan*, *Egmont* and *Leonora* deal with salient emotions roused by their subjects. Wagner was able to place the substance of the *Coriolan* overture in Shakespeare's scene between Coriolanus and his mother and wife before the gates of Rome; but Thayer found that the forgotten poet Collin's play, which was Beethoven's subject, sheds far more light on the music. The music, however, once it took shape, could do without Collin or Shakespeare. The *Leonora* overture was at first (in the form known as No. 2) a huge prelude to the opera, with a gigantic exposition and development, and the shortest wind-up compatible with adequacy, after the trumpet-call behind the scene has relieved the tension. In the later version *(Leonora No. 3.)* Beethoven ruthlessly compresses the exposition until the trumpet-call becomes the middle point of the design, which afterwards expands in a further development, full recapitulation and a climax which makes this overture the first and greatest of all "symphonic poems" (*q.v.*). Critics who cavil at the trumpet-call as a weakness from the point of view of absolute music only show that they cannot tell absolute music from absolute nonsense. Distance is surely too elementary a phase of sound to be excluded from absolute music, nor can the fanfares of a trumpet be separated either from the instrument or from its associations. As a piece of absolute music *Leonora No. 3.* is a huge movement in sonata form rising steadily to a point at which the tension is relieved by the new incident of a distant trumpet-call, after which the music expands from sheer joy. Beethoven's maxim *mehr Ausdruck der Empfindung als Malerei* therefore holds here, and bridges the gulf between absolute and illustrative music.

Portrayal of Characters and Moods.—This is equally true with archaic and modern programme music; it is always characters and moods that are successfully portrayed, while chronology is useless and the illustration of incidents is apt to be ridiculous unless it contrives to be witty. Thus, the *Bible Sonatas* of J. Kuhnau (published in 1700) and their clever imitation in Bach's early *Capriccio on the Departure of a Beloved Brother* rely mainly on moods, and are successful with incidents only when these would be accompanied by music in real life or drama. If Kuhnau's music were half as vivid or inventive as his prose introductions it would be immortal. But much may be learnt from noting how his unconsciously humorous prose describes other things than the music attempts to portray and omits the very things in which the music is at its best. While Kuhnau strains himself, like a bad nurse telling bogey-stories, in his prefatory description of the size and appearance of Goliath, in the music it is the boasts *(le bravate)* of Goliath that are portrayed. The best movement in the Goliath sonata is a figured chorale *(Aus tiefer Noth schrei' ich zu Dir)* representing the terror and prayers of the Israelites. On the other hand the cast of David's sling, with the fall of Goliath, is not nearly so sublime as the fall of a tea-tray. Kuhnau's other subjects *(Saul cured by David's music; The Marriage of Jacob; The Healing of Hezekiah; Gideon,* and *The Funeral of Jacob)* are all thoroughly musical; more so than he succeeds in making them. Bach's *Capriccio* describes the anxiety and sorrow of the friends of the departing brother; and his utmost realism takes the form of a lively fugue on the themes of the postilion's coachhorn and cracking whip. Buxtehud illustrated the "nature and characters of the planets." This is an astrological, not an astronomical subject: the planets signify temperaments and their motions are the music of the spheres. No wonder, then, that this musical subject has been adopted in one of the outstanding masterpieces of modern orchestral music, *The Planets,* by Holst.

Adaptability of Lyrical Music.—Instrumental music on the lyric scale lends itself to illustrative purposes more readily than larger forms. Nearly all the harpsichord pieces of Couperin have fantastic titles, and a few of them are descriptive music. His greater contemporary and survivor, Rameau, wrote important operas and much extremely graphic harpsichord music. La *Poule*, with its theme inscribed "co-co-co-co-co-co-cocodai," is an excellent movement in spacious form, and is also one of the most minutely realistic compositions ever written. French composers have always contributed *con amore* to music that takes advantage of external stimulus; and already in 1801 descriptive music was considered so specially French that Haydn apologized for his imitation of frogs in *The Seasons,* saying that this "franzosische Quark" (rubbish), had been forced on him by a friend. But throughout the growth of the sonata style, not excepting Haydn's own early work, the tendency towards gratuitously descriptive music often appears; partly because there was no definite distinction between early symphonic music and overtures or incidental music to plays (*e.g.,* Haydn's *Il Distratto*). Dittersdorf's symphonies on the metamorphoses of Ovid are excellent music in which the descriptive elements do not disturb the symphonic form until the metamorphosis which is then illustrated in almost Wagnerian breadth. For instance, the first three movements of the *Change of the Lycian peasants into Frogs* show the rusticity of the peasants, the gracefulness of the goddess, and the rudeness of the peasants to the goddess; and then the finale indicates an altercation ended, after a pause, in a low mysterious quivering sound as of frogs in a marsh.

Dittersdorf is not a great composer; but many more learned and resourceful artists have shown less than his common-sense in distributing the descriptive and the formal elements of their music. It seems incredible that any composer could be so foolish as to commit himself to describing a chronological sequence in a sonata-form which compels him to go through a full restatement of events which only happened once; yet many composers refused to abandon either the sonata form or the chronological sequence. Lyric forms presented no such difficulties.

Schumann and **Spohr.**—Schumann sometimes invented his titles after his pianoforte lyrics were finished, and sometimes wrote on the inspiration of literature. In either case, as with Beethoven, the music throws far more light on the programme than the programme throws on the music. Musical people may profitably study E. T. A. Hoffman and Jean Paul Richter in the light of Schumann's *Novelletten* and *Kreisleriana;* but if they do not already understand Schumann's music, Jean Paul and Hoffman will help them only to talk about it. In revising his early works Schumann sometimes made them more musical and sometimes destroyed grotesque touches that are musically as well as psychologically true. For instance, in the *Davidsbündler-tanze* (op. 6.) the hot-headed Florestan, having finished an impassioned tirade, feels that he has been making a fool of himself. His last note pauses unharmonized and he sits down awkwardly. In a later edition, with unnecessary scruple Schumann suppressed this detail together with the prose titles and signatures. The fashion of fantastic titles affected even the most formal composers during the romantic period.

No one wrote more programme music than Spohr; and, while Spohr's programme constantly conflicted with the externals of his form and ruined the latter part of his symphony *Die Weihe der Tone,* it did not broaden his style. Mendelssohn's Scotch and Italian symphonies, and his Hebrides overture, are cases of generalized local colour. His Reformation symphony, which he himself regarded as a failure, and which was not published until after his death, is a descriptive work less attractive but more coherent than Spohr's *Weihe der Ton.* The overture to the *Midsummer Night's Dream* is a marvellous musical epitome of Shakespeare's play; and the comparative slightness and conventionality of its second theme closely correspond with Shakespeare's two pairs of lovers, though it does not illustrate their quarrels under the fairy spells.

Influence of **Berlioz.**—Berlioz made programme-music a vital issue in the 19th century. With an inextinguishable gift for voluminous composition he is utterly incapable of focussing his attention on either his music or his programme. The most trivial external detail may distract him at the height of his rhetoric. The moonshine and sentiment of the *Scène d'amour,* in his *Romeo and Juliet* symphony is charming; and the agitated sighing episodes which interrupt its flow, can be understood in the light of

Shakespeare's balcony scene, if not by their musical sense. But when Berlioz thinks of the nurse knocking or calling at the door, he makes a realistic noise without either musical or dramatic purpose. It does not interrupt the duet, nor increase the emotional tension, nor illustrate Juliet's artifices for gaining time, nor her agitation at the interruptions of the nurse. Perhaps this was the passage on which a lady once congratulated Berlioz for his vivid representation of *Romeo arrivant dans son cabriolet.* This piece of purely orchestral music has an introduction in which real voices are heard from convivial persons returning home from the ball. Berlioz complains that the public has no imagination and that therefore certain sections which presuppose an intimate knowledge of Shakespeare's play *avec le dénouement de Garrick* should be omitted. But what the public lacks for these sections is neither imagination nor familiarity with Garrick-Shakespeare, but a capacity to take the butterfly vagaries of Berlioz's mind as their basis of reference.

With all his absurdities, Berlioz's genius for composition carried him further towards a new music than Liszt was able to advance in his symphonic poems. These, as has been said in other articles (*see* MUSIC, sections 8–10, and SYMPHONIC POEM) are the beginnings of an instrumental music that achieves the same continuity as Wagner achieved in music-drama. But Liszt hardly even began to achieve the right sort of movement; and his conscientious plan of deriving the whole piece from transformations of a single figure was quite irrelevant even when it was effective. As a musical illustrator he is clever; but he ties himself down to chronological sequence, which, though it does not conflict with his forms, is always open to Weingartner's objection that it cannot control the pace of the listener's thoughts. The composer's first view-halloo may make one listener fancy himself in at the death of the Blatant Beast, while the mind of another will plod to the end, to learn that that event never takes place.

Strauss.—The symphonic poems of Strauss are invulnerable by this objection, even though it is often true of their details. Most listeners will probably identify Don Quixote's tilting at windmills with the passage in which Strauss uses a stage windmachine; but this represents a later adventure in which Don Quixote and Sancho are seated blindfold on wooden horses and are persuaded that they are flying on winged steeds through the air. Strauss's music, however, does not really depend on this sort of thing at all. His earliest symphonic poems are masterpieces of new form and movement: *Don Quixote* is sectional only because its subject lends itself to an episodic treatment which Strauss has as much right as Humpty Dumpty to call variations, and in it, no less than in *Also sprach Zarathustra, Ein Heldenleben,* the *Sinfonia Domestica* and their aftermath the *Alpensinfonie,* single designs are triumphantly accomplished in music of Wagnerian continuity. It is not necessary that the designs should be perfect. Uncles and aunts may interrupt it to say that the baby is the image of its dada or mamma; and the wickedness of critics may devastate pages of the music of the hero who gave them their opportunity when he paused on a dominant chord to look round for applause; but local defects do not annihilate fundamental qualities.

Caricature.—One thread remains to be gathered into this account. Caricature is a rare and dangerous element in music, but it is as old as Orlando di Lasso. Mozart, besides the subtleties of *Cosi fan tutte* and the comic parts of *Die Zauberflöte,* produced in his *Musikalischer Spass,* a burlesque of village players and bad composers. On paper the work is a delicious study in the psychology of "howlers," and in its finale Mozart idealises all the nightmare stagnation of the composer whose *tempo* gets faster and faster while his phrasing gets slower and slower. In performance the effect is even more surprising than analysis would lead the reader to expect. But the Leipzig editors of the parts have crowned Mozart's farce by correcting the mistakes!

Caricature enters prominently into Strauss's *Till Eulenspiegel, Don Quixote* and *Ein Heldenleben;* and also into many passages in Mahler's symphonies. Its danger is that it often opens these composers to suspicion when they intend to be touchingly simple.

But nothing is more vexatious than the laying down of *a priori* limits to what is legitimate for artists. If sermons in the mind of the painter help him to paint, and pictures in the mind of the composer help him to compose, by all means let them get on with the work. (D. F. T.)

PROGRESSIVE EDUCATION. Although the sources of progressive education go back to far before the 1850s, the movement sprang into prominence in both the United States and Europe simultaneously but independently at the end of the 19th century. This article traces its origins and European development and then describes its considerable effect on U.S. education and its decline as a separate educational movement.

Origins and European Development. — Modern progressive education has its ancestry in a complex of ideas and practices which, from the 16th century onward, have been concerned with a reconsideration of the nature of individual man, of the societies in which he lives and of the relationship between them. At different times the emphasis has fallen upon one side of the relationship or upon the other; now on the need to free the individual from social pressures which limit his development, now on the need to provide the kind of social environment which will foster this development. Jean Jacques Rousseau's *Émile* and *Du Contrat social* (1762) are source books for students of progressive education. The roots of the movement, as has been pointed out by W. H. G. Armytage, can be traced back to the utopian tradition which derived from Thomas More and Francis Bacon in the 16th century and embodied the notion that man can, as it were, make a fresh start, *i.e.,* redeem the loss of the fall, by founding a new society or by restructuring an existing one. The implications of this for education are seen in the work of Samuel Hartlib, John Dury and J. A. Comenius; in the communitarian approach of the Quakers to both religion and education; in the work of Robert Owen and in the practical application of Rousseau's ideas by J. B. Basedow, J. H. Pestalozzi, Philipp Emanuel von Fellenberg and Friedrich Froebel.

The link between social reform and education is implicit in the movement which led to the founding of Abbotsholme school for boys, Derbyshire, by Cecil Reddie in 1889. Reddie was a member of the Fellowship of the New Life, founded in 1882. The fellowship promoted the founding of experimental schools, and the utopian tradition is clear in their assertion: "All schools ought to be communities, miniature commonwealths or states, as they were in the Middle Ages."

A secession from Abbotsholme led to the foundation of Bedales at Petersfield, Hampshire (1893); this later became the first coeducational boarding school. Later progressive schools in England were St. Christopher, Letchworth, Hertfordshire, originally intended as one branch of a many-sided community life; Frensham Heights, Farnham, Surrey; King Alfred's, Hampstead; Malting House school, Cambridge; Beacon Hill near Harting, Sussex (founded in 1927 by Bertrand and Dora Russell); Summerhill, in Suffolk, founded by A. S. Neill; and Dartington Hall, Totnes, Devon. Most of these schools are coeducational and stress with varying emphases the freeing of the child from adult pressures and the provision of a rich and varied community life.

Abbotsholme inspired the founding in Germany of the Deutsche Landserziehungsheime (1898) by Hermann Lietz and in France that of L'École des Roches by Edmond Demolins in 1899. In Italy, in 1894, the sisters Agazzi opened a home for preschool children which stressed training in sense perception and play activities in rural surroundings, and this later became the model for preschool education in Italy. In 1907 Maria Montessori began her Children's Houses in Rome, and devised the "didactic apparatus" to enable children to develop their capacities by self-education (*see* MONTESSORI SYSTEM).

Other pioneers of new methods in education were Ovide Decroly in Belgium, Adolphe Ferribre in Geneva, and Elizabeth Rotten in Germany. In 1921 about 150 pioneers from countries throughout Europe met at an international conference in Calais. France, organized by Mrs. Beatrice Ensor who, in 1920, had initiated the *New Era,* a magazine for the exchange of ideas and experience concerning the new education. At this conference the New Education fellowship was formed to link pioneers in different parts of the world. After 1921 the fellowship organized many international conferences; national sections promoted its interests in 11 European countries as well as in Australia, India, Egypt, Pakistan, New Zealand, South Africa and South America. Until 1955 it was linked with the Progressive Education association of the U.S. (called, from 1945 until its end in 1957, the American Education fellowship).

After 1900, the progressive ideas and practices developed in the United States, especially those of John Dewey, flowed back to join with the European progressive tradition. The effect of this was to strengthen the emphasis on social education and the relating of the individual's needs to the needs of a rapidly changing society.

The influence on schools within state systems of education was seen in the development of "activity" and "centre of interest" methods in the education of young children, in the use of "projects" and "assignments" with older children, and in general in the greater emphasis on social and emotional education and the modification of the formal and the academic in both content and methods. After 1946 there was a sharpening of the criticism of progressive ideas and methods, with restatements of the traditional aims, and this in turn challenged the progressive movement to redefine its assumptions and objectives.

BIBLIOGRAPHY.—*Origins and European Developments:* Centre National de Documentation Pédagogique, *Éducation nouvelle* (1946); R. Cousinet, *Petite Chronologie de l'Éducation Nouvelle* (1954); L. B. Pekin, *Progressive Schools . . .* (1934); A E. Meyer, *The Development of Education in the Twentieth Century,* 2nd ed. (1949); A. Ferrière, *L'École active,* 2 vol. (1922); M. Agosti and V. Chizzolini, *L'Educatore contemporaneo,* 2nd ed. (1950); F. W. Roman, *The New Education in Europe,* 2nd ed (1930); M. Peers, *Ovide Decroly* (1942); E. M. Standing, *Maria Montessori* (1957); D. E. M. Gardner, *Long Term Results of Infant School Methods* (1950); B. M. Ward, *Reddie of Abbotsholme* (1934); V. Bonham Carter, *Dartington Hall* (1958); J. H. Badley, *Bedales . . .*, 2nd ed. (1924); A. S. Neill, *The Free Child* (1953); M. A. Bloch, *La Pédagogie des classes nouvelles* (1953); V. Mallinson (ed.), *The Adolescent at School* (1949); W. H. G. Armytage, *The Utopist Tradition in English Education* (1958).

New Education Fellowship Reports: W. Boyd, M. M. Mackenzie *et al.* (eds), *Towards a New Education* (1930); W. Rawson (ed.), *A New World in the Making* (1933), *The Freedom We Seek* (1937); K. S. Cunningham, W. C. Radford *et al.* (eds.), *Education for Complete Living* (1938).

Periodicals: *Education for the New Era* (subsequently the *New Era,* 1920–); *Pour l'Ère Nouvelle* (1922–); *Das werdende Zeitalter* (1922–32). (J. W. T.)

United States.—In the United States progressive education began during the latter decades of the 19th century as one aspect of that larger program of social reform known as the progressive movement. It was essentially a pluralistic phenomenon, comprehending a remarkable diversity of pedagogical protest and innovation. In the universities it emerged as part of a spirited revolt against formalism in philosophy, psychology and the social sciences. In the cities it was but one facet of a wider program of municipal clean-up and reform. Among farmers it became the crux of a moderate, liberal alternative to radical agrarianism. It was at the same time the "social education" demanded by urban settlement workers, the "schooling for country life" demanded by rural publicists, the vocational training demanded by businessmen's associations and labour unions alike, and the new techniques of instruction demanded by avant-garde pedagogues. It enlisted to its cause parents and teachers, starry-eyed crusaders and hard-headed politicians. And in less than two generations it transformed the character of the U.S. school.

The sources of progressive education lie in part in the stream of pedagogical reform in Europe from the 17th through the 19th century cited above. They lie also in the revolution wrought before the Civil War by Horace Mann and his confreres in convincing Americans of the necessity of universal education in a free society. The very success of this revolution, in bringing into primary and secondary schools a greater diversity of children than ever before, inevitably exerted a transforming influence on the character of the schools themselves. Finally, the sources of progressive education lie in the transformation of society itself under the pervasive influence of industrialism. The advancement of technical and productive processes and the growing complexity of urban life—compounded in the United States by large percentages of non-English-speaking immigrants—led to pressures for the schools to assume educational responsibilities formerly borne by family, shop and neighbourhood.

The first evidence of progressivism in U.S. education appeared as early as the 1870s. Francis W. Parker, later referred to by John Dewey as the father of progressive education, undertook to reform the Quincy, Mass., schools beginning in 1875. He vigorously attacked rote learning and introduced new pedagogical techniques designed to make school subjects more meaningful to children. His reforms attracted national—indeed world-wide—attention as "the Quincy system"

Following upon the revelations of the Russian system of technical instruction at the Philadelphia centennial 'exhibition of 1876, Pres. John D. Runkle of the Massachusetts Institute of Technology, Calvin Woodward of Washington university, and Col. R. T. Auchmuty, a New York businessman, sharply criticized the narrow intellectual emphases in the secondary school program, demanding a central place for industrial training and vocational education. Throughout the 1870s conventions of the National Grange and other farmer organizations passed resolutions deploring the lack of practical agricultural training in schools and colleges.

Protests like these multiplied during the following decade, and by the 1890s they had assumed all the earmarks of a full-fledged social movement. The themes of this movement were many and various, but they were one in their attack on the narrowness and formalism of traditional education. Businessmen's organizations, and later labour unions as well, contended that under the modern factory system apprenticeship had deteriorated into an exploitive rather than an educative relationship and that because of this, schools would have to assume the classical functions of apprenticeship. Settlement workers, sensitive to the pedagogical vacuums created by broken homes and working parents, and compellingly aware of the education of the streets, vigorously urged instruction in hygiene, domestic science, manual arts and child care. Likewise, rural educators, deploring the flight from farm to city, argued for a new kind of rural school which would orient young people to the joys and possibilities of country life and equip them technically to realize these possibilities. Finally, university professors and educationists, basing their proposals on the new sciences of psychology, sociology and pedagogy, pressed for revamped school programs which would afford greater importance to scientific studies, tie learning more closely to doing, and educate "whole children"—that is. pay attention to physical and emotional growth as well as to intellectual development.

Outstanding Americans from many walks of life espoused ideas such as these during the quarter-century before World War I, among them Theodore Roosevelt, Jane Addams, Jacob Riis, William James, Charles W. Eliot, Henry Wallace, Walter Hines Page, and James Earl Russell. No one saw the movement whole, though, quite as well as John Dewey. for 50 years the commanding figure among theorists of progressive education. In a series of books, pamphlets and essays, beginning with *The School and Society* (1899) and culminating with *Democracy and Education* (1916), Dewey illuminated the close relationship between progressive education and the larger social transformation being wrought by science, democracy and industrialism. The curse of traditional education, Dewey argued, had been its aristocratic character and its isolation from life. The crux of progressive education was its universality and its closeness to life. Dewey urged that schools be made into "embryonic social communities," active with the occupations and permeated with the values of the surrounding society. "When the school introduces and trains each child of society into membership within such a little community," he wrote, "saturating him with the spirit of service, and providing him with the instruments of effective self-direction, we shall have the deepest and best guarantee of a larger society which is worthy, lovely, and harmonious." (John Dewey, *The School and Society,* p. 44, The University of Chicago Press, 1900.) (*See* also DEWEY, JOHN.)

Progressive education made considerable headway on an experimental basis after 1890. Joseph Mayer Rice found in an 1892 survey that the school systems of Indianapolis and La Porte, Ind., and of Minneapolis and St. Paul, Minn., having freed themselves from undesirable political control, had begun to put teaching on a "scientific basis," to "develop the child in all his faculties instead of simply crowding his mind with facts," to introduce new work in manual and creative arts, and to seek desirable correlation among the several subjects of study. In 1896 Dr. and Mrs. Dewey founded a Laboratory school in Chicago specifically to test the validity of his pedagogical theories. In 1904 Junius L. Meriam established an experimental school at the University of Missouri, Columbia. and in 1907 Marietta Johnson opened her School of Organic Education at Fairhope, Ala. The following year, William Wirt, school superintendent of the newly created steel town of Gary, Ind., began the sweeping educational innovations which came to be called the "Work-Study-Play" plan. Widely publicized by the progressive press after 1914, the Gary plan represented the best-known effort to apply Dewey's precepts to the public schools of a burgeoning industrial community. Finally, vocational education of every sort advanced rapidly after 1900, and in 1917 congress passed the Smith-Hughes act providing federal aid for trade. agricultural, home economics and distributive instruction in public secondary schools.

The founding of the Progressive Education association in 1919 marks a significant divide in the history of the progressive education movement. since what had forinerly been a loosely defined revolt against pedagogical formalism now gained a vigorous organizational voice. Under the initial leadership of Stanwood Cobb and Eugene Randolph Smith, the association quickly gained a notable place in U.S. education. Its membership climbed steadily, passing 5,000 in 1927 and reaching a peak of 10.500 in 1938. Its quarterly. *Progressive Education*, launched in 1924, quickly became a clearinghouse for educational experiments of every conceivable kind. During the 1930s. aided by well over $1.000.000 in foundation money, the association sponsored a number of widely publicized experiments, among them an eight-year study involving 30 secondary schools and over 200 colleges and designed to test the effects of introducing greater flexibility into high school curricula. The results, published in 1942, were taken as decisively in favour of the experimental programs.

Spurred on by the efforts and propaganda of the association, progressive education won ever greater acceptance in school systems across the nation. Success, though, brought ideological schism in its wake; and the quarter-century after 1919 was marked by sharpening conflict over just what progressive education was, and what it meant. One group of educators, epitomized by Marietta Johnson, combined the doctrines of liberty and self-expression into a highly individualistic pedagogy which held that schools in which children are encouraged freely to develop their uniquely creative potentialities are the best guarantee of a larger society devoted to human worth and excellence.

A second group, following the leadership of George S. Counts during the 1930s, sought to tie progressive education much more closely to specific programs of political reconstruction, contending that educators could lead in the building of a new social order. A third group, typified by Elsie Ripley Clapp, saw the crux of progressive education in school activities directed to the social and economic regeneration of local communities. A fourth group, exemplified by Eugene Randolph Smith, concentrated on reorganizing and enlivening the traditional school studies. And finally, there were those like William Heard Kilpatrick, Boyd H. Bode and Den ey himself who continued to regard progressive education as the pedagogical expression of the larger philosophy of experimentalism, with its emphasis on naturalism, scientific method and democratic social planning. Given this conflict over goals, the movement during the later 1930s was increasingly paralyzed by a factionalism which weakened not only its forward thrust but its resistance to outside criticisms as well.

From its earliest days progressive education had elicited sharp and sustained opposition from a variety of sources. Humanists and idealists had vigorously criticized its naturalistic orientation, its Rousseauan emphasis on freedom and interest, and its cavalier treatment of the classics and foreign languages. During the 1930s a group calling themselves the Essentialists had taken progressives sharply to task for failing to pay sufficient attention to the need for disciplined study of systematic knowledge. A number of Christian educators, Roman Catholic and Protestant as well, had accused progressives of materialism and a general denial of supernatural spiritual values; while elements of the patriotic press had been unremitting in their charges of radicalism and "un-Americanism." Criticisms such as these became more insistent after World War II, when progressive doctrines in general seemed eclipsed by a revival of conservatism in U S. politics and social thought. Unable to meet the challenge, the Progressive Education association disbanded in 1955; and the journal *Progressive Education* ceased publication two years later. For all practical purposes, the movement died in 1957, but not without leaving an indelible impress on the thought, character and spirit of U S. education.

BIBLIOGRAPHY.—*United States:* John Dewey, *The School and Society* (1899), *Democracy and Education* (1916), *Experience and Education* (1938); John and Evelyn Dewey, *Schools of To-Morrow* (1915); Eugene Randolph Smith, *Education Moves Ahead* (1924); Agnes de Lima, *Our Enenzy the Child* (1926); William Heard Kilpatrick, *Education for a Changing Civilization* (1928), (ed), *The Educational Frontier* (1933); Harold Rugg and Ann Shumaker, *The Child-Centered School* (1928); Marietta Johnson, *Youth in a World of Men* (1929); George S Counts, *Dare the School Build a New Social Order?* (1932); Boyd H Bode, *Progressive Education at the Crossroads* (1938); Elsie Ripley Clapp, *Community Schools in Action* (1939); Harold Rugg, *Foundations for American Education* (1947); Lawrence A Cremin, "The Progressive Movement in American Education: A Perspective," *Harvard Educational Review,* 27 251–270 (1957); J. M. Rice, *The Public-School System of the United States* (1893); Robert H. Beck, "Progressive Education and American Progressivism," *Teachers College Record, 60:*77–89, 129–137, 198–208 (1958–59).

(L. A. C.)

PROGRESSIVE PARTY, U.S. Three so-called Progressive parties have in the U.S. represented third-party movements in the presidential campaigns of 1912. 1924 and 1948.

The Progressive party movement of 1912 began as an insurgent outbreak among Republican members of congress in 1910 against the speaker of the house of representatives. Joseph G. Cannon. Opposition to the administration of Pres. William Howard Taft crystallized in 1911 when the National Progressive Republican league was organized by Sen. Robert M. La Follette of Wisconsin. Theodore Roosevelt soon placed himself at the head of that Progressive movement. Alleging unfair tactics on the part of the "Old Guard," his followers left the Republican national convention in Chicago, Ill. (June 1912), and Roosevelt was nominated for the presidency by a Progressive national convention, also held in Chicago. early in August. As a result the Republican party was hopelessly split, Roosevelt receiving a popular vote exceeding that of Taft by more than 600,000. Woodrow Wilson, the Democratic candidate, carried all but eight states. The electoral vote was 435 for Wilson. 88 for Roosevelt, 8 for Taft. The popular tally was 6,286,000; 4,126,000 and 3,484,000 for Wilson, Roosevelt and Taft respectively.

In 1916 harmony was restored in the Republican party. Roosevelt declined a second Progressive nomination and supported the Republican ticket. During World War I partisanship was in abeyance, but upon its termination the old rift soon reappeared. The administration of Harding encountered dissatisfaction among farmers. as did the Coolidge administration.

In 1924 Wisconsin and other farm states, after sitting in the Republican convention at Cleveland, O., held a conference for progressive political action. Senator La Follette was nominated for president and Sen. Burton K. Wheeler of Montana, a Democrat. for vice-president. The platform promised a "house cleaning" of executive departments, public control of national resources, public ownership of railnays, tariff and tax reduction. Republican strategy in 1924 consisted largely in denouncing the alleged radicalism of the La Follette platform, while ignoring Democratic attacks. Coolidge won easily, and La Follette carried only Wisconsin.

Unlike its predecessors the Progressive party founded by Henry A Wallace in 1947–48 stressed foreign issues in its platform—principally abandonment of the Marshall plan and the Truman doctrine (*qq.v.*). This party was formally organized in Philadelphia, Pa., July 22–25, 1948, naming Wallace as its candidate for president and Sen. Glen H. Taylor of Idaho for vice-president. On Aug. 6, the national convention of the Communist Party of the U.S announced its support of the Wallace-Taylor ticket. In the presidential election of 1948, the party polled only 1,157,172 popular votes and no electoral votes.

Bibliography.—F. E. Haynes, *Social Politics in the United States* (1924); E. E. Robinson, *Evolution of American Political Parties* (1924); H. R. Bruce, *American Parties and Politics* (1927); George E. Mowry, *Theodore Roosevelt and the Progressive Movement* (1946), and *California Progressives* (1952); Russell B. Nye, *Midwestern Progressive Politics* (1951); Robert M La Follette, *Autobiography* (1913); Belle and Fola La Follette, *Robert M. La Follette*, 2 vol., (1953); Henry L. Stoddard, *As I Knew Them* (1927); Claude G. Bowers, *Beveridge and the Progressive Era* (1932); Matthew Josephson, *The President Makers* (1940).

(R. C. B.; R. Tu; X.)

PROHIBITION is a method for the legal regulation of the manufacture, sale and transportation of alcoholic beverages. It has such extensive and varied applications as to make its other uses in legal terminology of minor importance. National prohibition was adopted in the U.S.A. by the ratification of the 18th amendment to the constitution, Jan. 16, 1919, effective one year thereafter, and repealed by the ratification of the 21st amendment, Dec. 5, 1933. Both amendments were adopted by large majorities only after full and free discussion, with determined and well-directed opposition, and neither can truthfully be said to have been "put over" by a fanatical minority or selfish economic interest.

National prohibition was the logical result of nearly 100 years' experience with state and local prohibition. It was not adopted without due appreciation of the difficulties it would encounter, nor until other expedients were tried to avoid the necessity of this experiment. Some of these expedients and the legislative background of national prohibition and its repeal are more fully discussed in the article Liquor Laws and Liquor Control (*q.v.*). Well-considered public opinion, pro and con, with respect to prohibition, cut deeper across the lines of political parties, rural and urban life, churches and families than any other question of the generation in which the 14 years 1920–33 fell. Its application on a national scale over an area so large as the U.S.A., and to a population living under such diverse racial and climatic conditions, made it by common consent the greatest social experiment of modern times.

Local Option and State **Prohibition.**—Local option started in Maine (P.A. 1829, c. 133), Indiana (L. 1832, c. 170) and Georgia (A. 1833, 125) in the first third of the 19th century, and state prohibition in Maine in 1851. Most local option statutes permitted the electorate in local political units, usually counties, but sometimes cities, villages, towns and even districts of a city, to vote "yes" or "no" on licences to sell "on" or "off" the premises for a limited period, usually one or two years. Some statutes embodied the local option principle by requiring a licence applicant to get the approval of a majority or two-thirds of the voters in the area to which the licence applies; or providing that no licence be issued, if a majority petitioned for its refusal. Other variations of local option were tried. Thus Arkansas (Digest Stat., 1884, par. 4515) had prohibition with a "licence" local option, and Iowa bad prohibition for a time with selling permitted under the mulct law, Code (1897) par. 2448. (Cf. Clark Byse, "Alcoholic Beverage Control Before Repeal" [in "Alcoholic Beverage Control" (1940)], *Law and Contemporary Problems*, vol. vii, No. 4, Duke University Law School.)

Licensing systems date back to colonial times. Combined with local option they furnish for the U.S.A., in the light of its experience with both state and national prohibition, the best hope for the possible effective application of the principle of prohibition. A properly drafted high licence statute with local option for prohibition in well-defined areas, or a prohibition statute with local option for licence in carefully planned areas, would go far to remove the majority of the social evils of the liquor traffic without resort to absolute prohibition. State licence systems in the absence of similar legislation by congress have been upheld by the U.S. supreme court as a constitutional exercise of the state police power. (*Cf. The License Cases*, 46 *U.S.*, 5 How., 504, 1847).

State prohibition stems from the development of the temperance movement of the second quarter of the 19th century. In the first quarter that movement was primarily individualistic. The thousands of temperance societies in the northern states, most of them in New England, resulted from a great religious revival and their efforts centred in personal regeneration and what the individual could do for himself. Its progress though encouraging was too slow to stem the rising tide of liquor consumption and its disastrous social consequences. The next logical step was to federate the temperance societies in strong state and national associations and exert political power to regulate or prohibit the production and sale of intoxicating beverages. The greater and more influential national organizations like the Woman's Christian Temperance Union (W.C.T.U.), the National Temperance society, the Total Abstinence brotherhood (T.A.B.), the National Prohibition party and others took up the cudgels after the Civil War; and the Anti-Saloon league with its powerful state and national organization, in the closing years of the century.

The continuous agitation of the temperance societies resulted in "limited" state-wide prohibition by an Indiana statute (1816) making sale of liquor on Sunday illegal, and the "15 gallon" law in Massachusetts (L. 1838 c. 157) prohibiting sale of "less than 15 gallons of spiritous liquor or mixed liquor part of which is spiritous (except for medicinal and mechanical uses) to be delivered and carried away at one time." This apparently accomplished little and was repealed in 1840. The first absolute state prohibition law, due to Neal Dow, organizer of the Maine Temperance Union, was an act "to restrict the sale of intoxicating drinks," approved Aug. 7, 1846. It was too weak in many of its provisions to be effective but was strengthened by the act "for the suppression of drinking houses and tippling shops" approved June 2, 1851. This act repealed all but 13 sections, those containing certain enforcement provisions, of the 1846 statute. The Maine law of 1851 remained substantially unchanged for 70 years and became the model in the next decade for no less than 13 state-wide prohibition laws. But by 1863 in all but five of these states the statutes were repealed or invalidated by state supreme court decisions.

(*Cf.* Ernest A. Grant, "The Liquor Traffic before the Eighteenth Amendment." in *Annals*, vol. 163, Sept. 1932.)

The second stage of organized effort for state prohibition was an outgrowth of reconstruction following the Civil War. It began with the organization of the National Prohibition party in 1869 at Chicago, and the Woman's Christian Temperance Union (1874); marked the return of some states that had tried prohibition in the first period and had given it up; and reached its zenith in the decade 1880–90. Eight states enlisted but only three remained by 1904.

The third and last stage of state prohibition before national prohibition was tried covers the first two decades of the 20th century, was largely due to southern and western rather than New England forces, and was led by the Anti-Saloon League of America (1895) and the state anti-saloon leagues. Thus when national prohibition went into effect (Jan. 1920) state-wide prohibition under state laws was already in effect in 33 states (more than two-thirds of all the states), and in 18 of them by constitutional amendment adopted or ratified by referendum election. In addition Alaska, Puerto Rico, the District of Columbia and Hawaii were included in 1917–19 in the prohibition area. Ninety per cent of the townships and rural precincts, 85% of the counties and more than 75% of the villages of the United States were under prohibition by state legislation. Two-thirds of the members of the senate and house of representatives came from states or districts having state prohibition which together with local option had put 63.3% of the population and 95.4% of the land area under prohibition. These statistics and similar ones for local option alone may be misleading unless cautiously interpreted as to their real significance, as later experience with national prohibition amply demonstrated. They are not an exact measure of the dryness of a community because often they do not mean a desire to be rid of liquor altogether but only the ugly aspects of the saloon and the liquor traffic in a residential neighbourhood so long as ample supplies may be had from near-by wet areas. Many communities find the ubiquitous bootlegger the lesser evil, and "near-by" has been greatly extended by improved transportation facilities, roads and automobiles. (Cf. *The Local Option Fallacy,* Distilled Spirits Inst., Washington, D.C., rev. ed., Oct. 1942, p. 32; Raymond B. Fosdick and Scott, *Toward Liquor Control,* pp. 22–27.)

Federal **Aid** to State and Local Prohibition. — It has been said that "liquor consumption did not decrease during the period when the state-wide prohibition movement was strongest" (C. Byse, *op. cit.,* p. 561). The statistical support for such a statement is far from conclusive. Such evidence as does exist, like that regarding local option and state prohibition, must be examined with caution, and deductions and implications made with reserve. If per capita consumption of spirits, wine and beer be combined and some allowance be made for mounting illegal consumption in the years when state prohibition was strongest, possibly a fairly tenable case can be made for the assertion just quoted, but the implied charge that this is the measure of the so-called breakdown of state prohibition is far from true. The cost and difficulties of enforcement, and the protection of dry areas from the inroads alike of the liquor traffic and bootleggers from bases in near-by wet areas were objects of greater concern to the supporters of prohibition.

The states first sought in various ways to protect their dry areas by their own powers. For example, Texas in 1910 made the sale of liquors in no-licence territory a felony. All tried to check the flow of liquor having the constitutional protection of interstate commerce over which the federal government had exclusive jurisdiction. For 43 years the U.S. supreme court followed the rule laid down in the celebrated License Cases (46 U.S., 5 How., 504, 590, 1847) that state legislation could prohibit the sale of liquor without a licence even if imported in the original barrel brought in by interstate commerce. This reversed a ruling in 1827 that held a state law unconstitutional which imposed a licence tax on an importer of liquor. But the still more celebrated Original Package case in 1890 practically reversed the 1847 rule by holding that a state could not prohibit a liquor dealer from importing liquor in interstate commerce for resale in original packages (135 U.S. 100, *Leisy* v. *Hardin*). This nullified state prohibition and congress at once sought by the Wilson act (26 Stat. 313, 1890) "to divest intoxicating liquors of their interstate character" by providing that "liquors transported into a state . . . shall . . . upon arrival in such state . . . be subject to the operation and effect of the laws of such state enacted in the exercise of its police powers, to the same extent . . . as though such . . . liquors had been produced in such state." While this act presented grave constitutional difficulties, the supreme court upheld it in *In re Raher* in 1891 (140 U.S. 545), but in a later case (*Rhodes* v. *Iowa,* 170 U.S. 412, 1898) the court construed the word "arrival" to mean delivery to the consignee and not merely arrival in the state. So the mail-order business, skillful advertising and traveling salesmen still made the evasion of prohibition easy. The U.S. supreme court did try to help the states to find their own remedy, by upholding (1) a Missouri statute which imposed an inspection fee on all liquors shipped from other states into Missouri and offered for sale (190 U.S. 17, 1905), and (2) a South Dakota statute putting an annual licence charge on the business of soliciting orders to be filled from liquors at the time outside the state (*Delameter* v. *South Dakota,* 205 U.S. 93, 1907). In some other cases, however, the Wilson act was further emasculated, by refusing the state the right to prohibit C.O.D. shipments of liquor (*Adams Express Co.* v. *Kentucky,* 206 U.S. 129, 1907), and by not permitting a state to compel a resident-consignee to certify to a state official the quantity and kind of liquor to be imported, or a nonresident-consignor to attach a certificate to the package (*Vance* v. *Vandercock,* 170 U.S. 438, 1898).

The Webb-Kenyon Act.—Passed March 1913, over President William Howard Taft's veto, "An Act divesting intoxicating liquors of their interstate character in certain cases" (37 Stat. 699) was the most aggressive step that congress and the federal government had taken to aid state prohibition. Broader than the Wilson act which merely sought to remove the bar of the original package decision, it was intended to remove the federal protection which liquor enjoyed as an article of interstate commerce. It forbade the transportation of intoxicating liquors into a state by any persons interested therein "to be received, possessed, sold or in any manner used either in the original package or otherwise, in violation of any law of such state." Notwithstanding President Taft's own opinion, and that of his attorney-general, and able lawyers in the senate who advised him, to the effect that the act was unconstitutional, the supreme court sustained it in the Clark Distilling Co. cases, decided Jan. 8, 1917 (242 U.S. 311). This was further strengthened by the adoption of the Reed "bone-dry" amendment to the P.O. Appropriation act of March 3, 1917 (39 Stat. 1069, c. 162) which sought to eliminate completely the illegal mail-order liquor traffic.

The Webb-Kenyon law at first stimulated state prohibition. In 1914 state constitutional amendments were adopted by popular vote and substantial majorities in Arizona, Colorado and Oregon, but rejected by substantial majorities in California and Ohio. Statutory prohibition was adopted in Washington on an initiative measure by 18,632 majority, and in Virginia by a majority of 30,365 in 150,000 votes cast. Congress for the first time adopted in this year a resolution in one house by a majority vote (193–189), but it did not obtain the requisite two-thirds required for the submission of a prohibition amendment to the federal constitution. Considerable extension of dry territory under local option votes was secured in many other states. In 1915 Alabama re-enacted a prohibition law adopted in 1907 but repealed in 1911; and Idaho, Iowa, Arkansas and South Carolina adopted state prohibition statutes. Idaho also submitted to the people a constitutional amendment to the state constitution which was adopted the following year. The year 1916 also recorded the adoption of constitutional state prohibition in Michigan, Montana, Nebraska and South Dakota.

In 1917 the resolution for the submission of the prohibition amendment to the federal constitution received the necessary two-thirds vote in congress which also enacted prohibition for the District of Columbia and the territory of Alaska. A referendum on prohibition was voted on in Puerto Rico in July and adopted by 99,774 votes for prohibition to 61,295 against. Indiana, New Hampshire and Utah adopted state-wide prohibition statutes, and New Mexico, a state constitutional amendment. Minnesota voted also for a constitutional amendment by a majority of 15,932 of all the votes cast, but this was 756 short of the majority the state constitution required for its adoption. Missouri and California defeated constitutional amendments by substantial majorities. By the end of this year before the federal amendment was submitted for ratification, statutory or constitutional prohibition was the law in 25 of the 48 states, and in the District of Columbia. Alaska and Puerto Rico. In nearly every state in one way or another dry territory had been greatly extended.

In 1918, while ratification was proceeding, Florida, Nevada. Ohio, Texas and Wyoming adopted state-wide prohibition statutes, and Utah a prohibition amendment to its state constitution. Congress enacted a prohibition statute for Hawaii, and passed the War Prohibition act as an amendment to the agricultural appropriation bill. Several states adopted constitutional prohibition amendments in 1919.

The 18th Amendment. — The text of the amendment ratified Jan. 16, 1919, by the 36th state making the necessary three-fourths of all the states required for its adoption is as follows:

"Section 1. After one year from the ratification of this article the manufacture, sale, or transportation of intoxicating liquors within, the importation thereof into, or the exportation thereof from the United States and all territory subject to the jurisdiction thereof for beverage purposes is hereby prohibited.

"Section 2. The Congress and the several States shall have concurrent power to enforce this article by appropriate legislation.

"Section 3. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by the Legislatures of the several States, as provided in the Constitution, within seven years from the date of the submission hereof to the States by the Congress."

The amendment as ratified and proclaimed in effect on Jan. 16, 1920, was subsequently ratified by ten additional states, and in six of these (South Dakota, Idaho, Washington, Kansas, Utah and Wyoming) by unanimous vote in both houses of the legislature. Only two states (Connecticut and Rhode Island) did not ratify it. Dr. Ernest H. Cherrington in an article entitled "World Wide Progress Toward Prohibition Legislation" (*Annals*, vol. 109, p. 223, Sept. 1923) says: "No amendment to the Federal Constitution ever received as strong official sanction by the States as the 18th amendment. The original Constitution was adopted in the thirteen original States by a majority of about two to one. The aggregate vote in the State senates and State houses of representatives for the ratification of the 18th amendment shows a majority of more than four to one."

Forty-seven states enacted laws to help carry into effect the provisions of the 18th amendment, though one such law in Nevada was held unconstitutional because of a defect in title. New York, Montana and Wisconsin repealed their enforcement statutes by the end of 1929, but until then the great mass of state legislation tended to strengthen state efforts to enforce prohibition. In the next five years, however, by the end of 1934, all but nine states had voted to repeal their statutory or constitutional prohibition measures, or both, or they had enacted liquor control of the state monopoly or licence type, sometimes with local option for limited prohibition. After the repeal of the 18th amendment by the ratification of the 21st amendment, effective as of Dec. 5, 1933, and the repeal of the prohibition provisions of the Volstead act in Aug. 1935, there were only three states left (Kansas, Mississippi and Oklahoma) in 1942 with state-wide statutory prohibition.

THE ERA OF NATIONAL PROHIBITION

These 14 Years.—From Jan. 16, 1920, to Dec. 5, 1933, is 14 years lacking a few weeks, a short period in the life of a nation, but a momentous one in the social history of the American people. Not since the slavery issue of the middle years of the 19th century has any question been so widely debated, so bitterly contested or pursued with so much determination and idealism as national prohibition by the people of the United States. It came with surprising suddenness, yet the way had been prepared for over 100 years. The new techniques and devices of a greater variety of governmental agencies employed today in the work of liquor control, rather than prohibition, and a new reliance on scientific research for guidance on the complex problems of alcohol, as exemplified by the Research Council on Problems of Alcohol, of the American Association for the Advancement of Science, and as now carried on by temperance and educational organizations everywhere, and even by agencies of the liquor traffic itself, such as Distilled Spirits Institute, Inc.—these and other similar forces give some assurance that the "experiment noble in motive" of national prohibition may not have been in vain.

The Background Influences.—A sufficient indication of the long-time trends in prohibition legislation in state and nation has already been given to account in part for the tidal wave of demand for action on a national scale. Social and economic factors played perhaps as great if not a more important role than the more noticeable moral, religious and political influences organized with increasing effectiveness. New scientific knowledge in the early years of the 20th century caused a mounting public interest in health and efficiency, and the new industrial economics of expanding large-scale production brought increasing support, both moral and financial, to every effort to curb the liquor traffic and reduce the ravages of alcohol. New educational forces at work viewed with growing disfavour the saloon as the so-called poor man's club, and finally there was manifest everywhere increasing irritation with the saloon as a political menace.

World War I was not the cause of the demand for national prohibition though it probably did accelerate it. The absent soldier vote if cast at the time would not have made any substantial change in the decisions reached at the polls. As soon as the United States entered the war, two economic factors—the fear of the loss of manpower on account of intemperance, and the loss of food used in the manufacture of alcohol but needed to supply the army of the United States and that of its allies—served to crystallize an overwhelming sentiment in favour of permanent constitutional prohibition as well as war prohibition. The War Prohibition act of Nov. 1918, an amendment to the Agricultural Appropriation bill, enacted ten days after the Armistice was signed, did not go into effect until June 30, 1919, six months after the ratification of the 18th amendment, but it set a standard until the end of demobilization. It forbade the use of grain, cereals, fruit or other food products in the manufacture or production of beer, wine or other intoxicating malt or vinous liquor for beverage purposes, and made it unlawful to sell for any beverage purposes any such product or any distilled spirits from bond except for export. Such acts, together with earlier congressional enactments such as the Food Control act of Aug. 1917 and the act restricting or prohibiting the sale of liquor at military stations or to members of the military forces in uniform, or in or near military camps, all had a marked effect in support of national prohibition.

The Volstead Act.—The National Prohibition act (41 Stat. 305), popularly known as the Volstead act, and sometimes referred to as the Prohibition Enforcement law, passed the house of representatives, July 22, 1919, by a vote of 287 to 100, three members voting "present." It passed the senate with slight amendments and without a roll call on Sept. 4, 1919. The conference report was adopted in the senate, Oct. 8, without roll call or record vote, and in the house by a vote of 321 to 70 on Oct. 10. It then went to President Woodrow Wilson who vetoed it, and returned it Oct. 27. The house on the same day, by a vote of 176 to 55, passed it over the president's veto, and the senate did likewise the next day by a vote of 65 to 20. Therefore on Oct. 28, 1919, this measure became law applicable by its terms immediately for the enforcement of the War Prohibition act, and "when the 18th amendment to the Constitution goes into effect," intended to carry out the purposes of that amendment. The act is notable for its definitions, including the fixing of ½ of 1% of alcohol by volume as the test of intoxicating liquor, and the delegation of power to the commissioner of internal revenue to make regulations, with the approval of the secretary of the treasury, having the force of law, for carrying out the provisions of the act. The ½ of 1% definition was not new. It was in use in many state prohibition laws and had been the standard since 1902 for internal revenue taxation.

The constitutional validity of the adoption of the 18th amendment, and the constitutionality of the Volstead act with its definition of intoxicating liquor were tested in the U.S. supreme court and promptly sustained in the leading cases of *Hawke* v. *Smith*, decided June 1, 1920 (253 U.S. 221), and *Rhode Island* v. *Palmer*, decided June 7, 1920 (253 U.S. 350), in which the court disposed of several cases pending. Prohibition as embodied in the 18th amendment was held within the amending power, a part of the constitution, and "must be respected and given effect the same as other provisions of that instrument," and was "operative throughout the entire territorial limits of the United States . . . [and] of its own force invalidates every legislative act, whether by Congress, by a state legislature, or by a territorial assembly, which authorizes or sanctions what the [first] section forbids." The court had previously sustained the War Prohibition act and the ½ of 1% limit which it specified. The liquor interests hoped for greater latitude by construction of the first section of the 18th amendment which did not specify the content or define intoxicating liquor. The court, how-ever, without stating or discussing this contention, cited the war prohibition cases in support of the conclusion that while "recognizing that there are limits beyond which Congress cannot go in treating beverages as within its power of enforcement, we think those limits are not transcended by the provisions of the Volstead Act."

THE WORKING OF THE NATIONAL PROHIBITION ACTS

Enforcement.—The Volstead act provided for drastic enforcement, and was intended to give the government ample powers, through the commissioner of internal revenue of the treasury department, to detect and suppress all manner of violations. Congress was at liberty to amend these administrative features and set up any agency of enforcement it chose. It did in fact put the prohibition unit of the treasury under a new assistant secretary, and by the act of March 3, 1927, created a bureau of prohibition in the treasury department with a commissioner of prohibition responsible directly to the secretary of the treasury.

The Supplemental Prohibition Enforcement act of Nov. 23, 1921, (42 Stat. 222) made the already drastic regulations for physicians' prescriptions, and for sacramental wine, more so. It provided that only spirituous or vinous liquor, the latter containing not more than 24% of alcohol by volume, could be prescribed, and that not more than ¼ gal. of vinous liquor nor any quantity of liquor containing more than ½ pt. of alcohol could be prescribed for the use of any one person within 10 days, and that no physician might have more than 100 permits within 90 days unless to meet emergency needs, to be demonstrated to the satisfaction of the commissioner who issues such permits. These restrictions on physicians' prescriptions were upheld as constitutional by the supreme court in *Lambert* v. *Yellowley* (272 U.S. 581). Other provisions of the Supplemental act gave the enforcing authorities control over importations for non-beverage purposes; provided that both the Supplemental and the National Prohibition acts applied not only to the United States but to all territory subject to its jurisdiction; that liquor laws in force when the National Prohibition act was adopted, and not in conflict therewith, should continue in force; and also made it unlawful for any U.S. officer to search any private dwelling without a search warrant. The court, however, in 1925 in *Carroll* v. *U.S.* (267 U.S. 132) upheld the search of an automobile or vehicle of transportation without a warrant where the search was not malicious or without probable cause. A Georgia statute which prohibited the possession of liquor which had been legally acquired before national prohibition went into effect was upheld as within the police power of the state, in another supreme court decision, *Samuels* v. *McCurdy* (69 L. ed. 371). The department of justice approved the wider use of the padlock and abatement of nuisance provisions of sec. 22 and other sections of the National Prohibition act. The methods employed in the enforcement of prohibition, as in the case of tariff and revenue laws generally, and in other laws where there is a strong motive to defeat their purpose, raise many nice questions of constitutional guarantees of liberty and the protection of innocent persons, but the supreme court decisions throughout the prohibition era went far to sustain the government and congress in the exercise of the fullest constitutional powers to enforce prohibition.

The Concurrent Power. — The second section of the 18th amendment clearly indicates by the grant of concurrent power "to congress and the several states" the joint duty and responsibility of the national and state governments to enforce prohibition through co-operation and each government performing that part of the task for which it mas peculiarly fitted. In ***Rhode Island*** v. *Palmer* (253 U.S. 350) the court defined and interpreted "concurrent power" as the power to enforce prohibition by appropriate legislation, but not to enable congress or the several states to defeat or thwart it; that it is not joint power requiring that the legislation thereunder by congress to be effective should be approved or sanctioned by the several states or any of them; neither does it mean that the power to enforce is divided between congress and the several states along the lines which separate or distinguish foreign and interstate commerce from intrastate affairs. The court also added that concurrent power, "while not exclusive, is territorially co-extensive with the prohibition of the first section of the amendment, embraces manufacture and other intrastate transactions as well as importation, exportation and interstate traffic, and is in no wise dependent on or affected by action or inaction on the part of the several states or any of them."

As thus construed the concurrent power section of the amendment reserved to the states their police power over intoxicating liquors, with the single limitation that they could not exercise it to permit what the amendment prohibits. The former policy of strengthening the police power of the state by removing constitutional barriers was now changed to one of co-operation in which the states and the federal government had equal responsibility and power. It was not a grant of any new police power to the states, but an enlargement of the police power they possessed, by extending concurrent power to interstate commerce and to importation and exportation of intoxicating liquors. Neither did concurrent power impose any new obligation on the states, but merely emphasized an old one, as Governor Alfred E. Smith noted as follows: "After repeal there will still rest upon the peace officers of this State the sacred responsibility of sustaining the Volstead Act with as much force and as much vigor as they would enforce any State law or local ordinance" (memo accompanying his approval in 1923 of the repeal of the N.Y. Prohibition law).

If the plain intent and ideal of sec. 2, as interpreted by the U.S. supreme court, had been realized more fully, enforcement would not have broken down so soon nor would hare come the demand for repeal with overwhelming force in 1935. The states, however, with few exceptions, refused to co-operate whole-heartedly; and partly on account of old conflicts under the federal-state system, but chiefly because of practical politics and partisan advantage, by so doing sealed the doom of the 18th amendment.

Administrative Difficulties. — The chief obstacles to efficient enforcement did not come from the courts, but rather from administrative difficulties arising from untrained and incompetent personnel, and the lack of enforcement machinery, or its location in several departments of the government. The failure at the outset to put all enforcement officers under civil service caused increasing trouble. Some conflict and overlapping in the efforts of the treasury and the department of justice led the judicial conference of the senior circuit judges, with the concurrence of Chief Justice William Howard Taft, to recommend in Nov. 1924 that the prohibition unit of the treasury be transferred bodily to the department of justice, and that all appropriations for enforcement be expended under the attorney-general. It was thought that a closer co-ordination of the experience and technique of the treasury department with prosecutions by the department of justice would avoid the prosecution of trivial, futile and unimportant cases which crowded the dockets, and would enable district attorneys better to prepare those cases which would really deter the principal offenders. Partly because of the nature of the proceedings in federal courts requiring jury trial, and partly due to the absence of federal police courts to dispose of petty cases, "the resources of the federal government in administration and judicial machinery were sufficient to cope successfully only with what might be called the 'wholesale' aspects of the enforcement problem — smuggling, including report of arrests, seizures, etc., made by federal prohibition officers, the withdrawals of bonded liquors, the diversion and conversion of industrial alcohol to beverage uses, interstate transportation of liquors and the major conspiracies to violate the law, some of which are of giant proportions" (*see* BOOTLEGGING AND SMUGGLING). For the rest, state and local machinery would have to be relied upon to enforce the law.

In response to these and many other suggestions, and to bring the problems of prohibition enforcement more directly under the eye of the secretary of the treasury and the president, congress reorganized the prohibition unit, and created by act of March 3, 1927, a bureau of customs and a bureau of prohibition in the department of the treasury. This was recommended by the secretary of the treasury and centralized responsibility for enforcement of prohibition in a commissioner directly responsible to the secretary of the treasury. It provided for the appointment of a staff under the commissioner, subject to the provisions of the civil service law. In the opinion of the commissioner the civil service requirement did bring about a marked improvement in personnel, and enabled the new bureau to continue more effectively the policy previously followed, namely, decentralization of the prohibition service, and concentration upon the things that federal enforcement could do best, whether the state and local authorities did their part or not.

Treaties to check liquor smuggling were negotiated with Great Britain in Jan. 1924 (ratified and proclaimed, May 22, 1924) and the principal countries of Europe, and Canada, Cuba, Panama and Mexico. These treaties embodied the so-called 12-mile limit, or one-hour run, for boarding and examination of private vessels under foreign flags. They were liberally construed by the U.S. supreme court. (*See* SMUGGLING.)

The major effort in the reorganization of prohibition enforcement was the Prohibition Reorganization act of May 27, 1930 (Pub. No. 273, 71st Cong.). This act, effective from July 1, 1930, established the bureau of prohibition in the department of justice, and the bureau of industrial alcohol in the treasury department. They were previously a single bureau in the treasury department. It was a functional change which greatly accelerated improved enforcement of the prohibition laws, but it came too late to repair the public's shattered confidence in the enforcement agencies, either federal, state or local. Albert E. Sawyer, technical expert of the National Commission on Law Observance and Enforcement, thought that there were losses as well as gains in the reorganization, and that "the undeniable improvement in the effectiveness of prohibition work since the transfer may be the direct result of the aggressiveness which has characterized the attorney-general and his assistants." (For chart and excellent discussion, *see* "The Enforcement of National Prohibition," *Annals*, vol. 163, Sept. 1932, pp. 10–29.)

National Commission on Law Observance and Enforcement. — President Herbert Hoover appointed May 20, 1929, a commission of 11 eminent citizens including one woman, the president of Radcliffe college, to make "a thorough inquiry into the problem of the enforcement of prohibition under the provisions of the 18th amendment of the constitution and laws enacted in pursuance thereof, together with the enforcement of other laws." Eight days later the commission with George W. Wickersham as chairman met at the White House and President Hoover emphasized that he wanted a broad inquiry dealing not only with one law or the laws of the federal and state governments separately, but with the enforcement of, obedience to, and attitude toward all law.

The commission performed its task ably, thoroughly and with commendable speed. Through public hearings in various parts of the country, by special studies of experts engaged by the commission, it assembled from both official and unofficial sources much valuable data not previously available in consolidated form. A preliminary report was submitted in Nov. 1929, and a supplementary report in Jan. 1930. Both dealt chiefly with legal and constitutional questions of procedure in law enforcement. The president sent both reports to congress on Jan. 13, 1930, with a message, accompanied by memoranda from the attorney-general and the secretary of the treasury, endorsing recommendations for more centralization of administrative responsibility for enforcement, more courts and better judicial and prosecuting procedure (H.R.Doc. No. 252, 71st Cong., 2nd Sess.). Congress and the public alike, however, awaited the appearance of the major report on the larger issues involved. This appeared a year later with the title: "A Report on the Enforcement of the Prohibition Laws of the United States," and was sent to congress with a message from the president on Jan. 7, 1931 (H.R.Doc. No. 722, 71st Cong., 3rd Sess.). After a time several volumes of documents and evidence followed.

Thus the commission under pressure for too great speed in making a full report had not quite achieved the larger purposes for which it was organized. It was courageous in its exposé of the wealiness of the first seven years of what it called "imperfect enforcement," and sparing in its praise of the improvement of the three years of reorganization. The lack of a master plan, of skilful leadership, of proper co-operation and a united front between such important key agencies as the customs, coast guard, and prohibition bureau, and even the activities of the pressure groups and political forces, pro and con enforcement, are dealt with frankly and fearlessly, and if the report could have been issued five years earlier might have built up normal support of public opinion for normal observance of the prohibition laws. But in 1930 it was too late to expect that, and the commission seemed to think that some modification of the prohibition policy was necessary to restore public confidence in the enforcement agencies of government, either federal, state or local. Yet five of the nine major recommendations and conclusions of the report were squarely opposed to repeal of the 18th amendment; the restoration in any manner of the legalized saloon; the modification of the N.P. act to permit light wines and beers; authorizing federal or state governments to go into the liquor business; inadequate co-operation of the states. Condensed and authoritative statements and interpretation of the commission's report by its chairman, and chief technician, mill be found: (1) *Amer. Bar Ass'n Jour.*, vol. 16. Oct. 1930, pp. 654, 660–61 (Wickersham, "Program of the Commission on Law Observance and Enforcement"); (2) two articles by A. E. Sawyer, *Michigan Law Review*, vol. XXX, Nov. 1931, and *Annals*, American Academy of Political and Social Science, vol. 163, pp. 10–29, Sept. 1932.

The Economic and Social Results of Prohibition. — Here is the nub of the controversy that raged so violently in the decade preceding repeal of the 18th amendment. That much more heat than light emanated from the millions of spoken and written words on this theme was to be expected. Scientific standards of measurement and scientific data on which to base sound judgment were, for the most part, lacking, even for such items as uniform records of arrests for drunkenness, of law violations, prosecutions, sentences, alcoholic morbidity and mortality, etc., on which the government should have been able to disseminate accurate information. Looking back it is clear that the prohibition "authority" of the federal government, wherever located, did a poor educational job, because in the last analysis it was the social and economic aspects of national prohibition, rather than the moral or legal, that decided the fate of the 18th amendment. In every state of the union there was a middle-of-the-road contingent, which cast perhaps 75% of the vote. It could have been lined up for or against national prohibition on clear-cut statements of fact concerning social and economic consequences of one policy or another.

The report of the Federal Council of Churches (Research Bulletin No. 5, p. 83, 1925) is one of the best of the unofficial inquiries and furnishes some significant conclusions based on good scientific handling and sampling of questionnaire testimony of social workers. This shows a preponderant opinion at that time that prohibition had helped secure better furnished homes for working people; better mental health of the home as shown by better family co-operation, respect of children for parents, and of parents for children, and by better educational ideals; also larger proportion of the hsuband's income going to wife and family, and improved marital relations. Favourable community effects were recorded in this special poll: less children's delinquency; less malnutrition; liquor for minors less accessible. But in contrast the inquiry also showed more drinking by young people, and a worse attitude toward law enforcement and respect for laws in general. The Federal Council report, however, does not support the theory that prohibition had caused a moral breakdown among young people. The report's most conclusive finding is that social legislation is no substitute for social education, and that "the illicit liquor traffic will be finally overcome only when and where education in temperate living strongly reinforces the arm of the law."

Similar reports, not all of them so well documented, appeared from many social agencies, business men's organizations, and civic groups, and some dealt more definitely with the wage-earner's stake in prohibition. Still other reports emanated from organizations and groups opposing prohibition: the Association Against the Prohibition Amendment, Repeal Associates, Women's Organization for National Prohibition Reform, the Moderation League, the Crusaders, etc., presented studies of the new evils, and their social and economic consequences, attendant on the failure to enforce, or as some contended, the unenforceability of national prohibition. Matters emphasized in these reports are: the speakeasy as a substitute for the saloon; the public disregard for all laws; public corruption for protection of illegal traffic; the effect on the administration of justice of overflowing prisons and courts cluttered with prohibition cases; the threat, to social and economic security, of huge revenues from the illegal liquor traffic in the hands of well-organized criminals.

Among the many individual studies of the social and economic consequences of prohibition, typical and well-balanced, are: (1) Prof. Irving Fisher's Prohibition at Its Worst (1926) and Prohibition Still at Its Worst (1928), and his report to the American Economic Association (1927, A. E. Review, xvii, No. 1, suppl. March) which claimed that the country was at least $6,000,000,000 better off as a result of prohibition. (2) Prof. Herman Feldman's Prohibition: Its Industrial and Economic Aspects (1927) based on a nine months' personal study of industrial plants, documentary material, and questionnaires sent to 1,200 concerns with over 1,250,000 employees. Feldman finds that "the economic benefits of legal prohibition are based upon substantial prohibition in fact; on the actual abolition of the saloons, or their reduction to a negligible quantity, not on the mere change in name; on a greatly lessened consumption of alcoholic beverages; on a general influence in promoting temperance and discouraging over-indulgence." (3) Dr. Clark Warburton's Economic Results of Prohibition (1932), and in briefer form, *Prohibition* and *Economic* Welfare (Annals, American Academy of Political and Social Science, vol. 163, pp. 89–97, Sept. 1932). This is an able study, but largely negative in its conclusions and results because of the lack of positive statistical evidence and unwillingness to weigh or consider any other kind of evidence. In general, Dr. Warburton concludes that "prohibition had little to do with the prosperity of the Nation from 1923 to 1929 and the increased purchases during those years of many types of luxury and semi-luxury goods."

To this brief statement of very general conclusions from many sources, and in rather sharp contrast to that of Dr. Warburton, just cited, should be added the statement of Secretary of Commerce Herbert Hoover in an address before the U.S. chamber of commerce, as quoted in the Christian Science Monitor, March 11, 1925, as follows:

"There can be no doubt of the economic benefits of prohibition. Viewing the temperance question only from this angle, prohibition has proved its case. I think increased temperance over the land is responsible for a good share of the enormously increased efficiency in production, which statistics gathered by the Department of Commerce show to have followed the passage of the dry law. Exhaustive study from many angles of production . . . indicates that while our productivity should have increased about 15% due to increase in population, the actual increase has been from 25% to 30%, indicating an increase of efficiency of somewhere from 10% to 15%. . . . There is no question in my opinion that prohibition is making America more productive."

REPEAL OF THE 18TH AMENDMENT AND THE POST-REPEAL ERA

The revolt against the 18th amendment, and the agitation for its repeal, did not assume serious proportions until the presidential campaign of 1932 when it became a national issue. Conscientious objectors, like Dr. Nicholas Murray Butler, had voiced their protest even before the amendment was ratified. In the Borah-Butler debate in Boston, April 8, 1927, Dr. Butler said:

"The 18th amendment must come out of the Constitution because it does not belong there. It affronts and disfigures it. It contradicts every principle upon which the Constitution rests, and the difficulties, the embarrassments, the shocking scenes reported daily from every part of the land are the natural and necessary result of the inner contradiction that has been set up between the Constitution as it was and the 18th amendment added to it in 1919. . . .

"We talk of law enforcement. You cannot enforce conflicting laws—something must give way; and, when it is the 18th amendment and the legislation based upon it on the one hand and the whole body of the Constitution, the Bill of Rights, the whole of political English and American History on the other, which do you suppose will have to give way? It must be this new and invading element in our public law."

Such was the moral objection which was intelligently and forcibly presented by a sincere small minority. It might have won more sustainers if it had shown greater recognition of the economic facts that underlie public morals, and of the effectiveness of the constitution and the government it set up, to deal with the social problems of modern democracy.

The Modificationists.—They were a second and more numerous group of less conscientious objectors. They wanted more alcohol, "light wines and beer" (or by any other name the people might prefer), than the 18th amendment allowed under the implementing Volstead act, or than the supreme court would sanction if that act were amended to increase the ½ of 1% standard of intoxicating liquor. Hence they advocated repeal of the Volstead act, leaving to the states the enactment of such prohibitory laws as their citizens might desire the implement the 18th amendment within their boundaries and provide varying degrees of dryness or wetness to suit local tastes. Prof. Howard Lee McBain (Prohibition: Legal and Illegal [1928]) considered this suggestion and others like it to circumvent the 18th amendment, but his conclusions gave scant encouragement to those who did not want to conform to the dictates and spirit of national prohibition while the 18th amendment remained a part of the constitution.

The political demand for repeal lagged behind the changes taking place in public opinion. In 1928 the national party platforms of both major parties pledged vigorous (Republican) and honest (Democratic) enforcement, but by 1930 the state party platforms in 21 states (14 Democratic and 7 Republican) demanded repeal of the 18th amendment, and in 1932, both national party platforms favoured repeal with safeguards to protect state prohibition territory, or the submission of a proposal to revise in a way to furnish such safeguards.

Supporters of the Experiment.—Opposed to repeal or modification were two groups: (1) the extreme and uncompromising upholders of constitutional prohibition as the only practical method of dealing with the organized liquor traffic and bringing it under social control. In the main the officials of the Anti-Saloon leagues and most of the temperance societies, and such political leaders as Senator Morris Sheppard and Congressman Volstead were spokesmen for this group; (2) a large group of no less sincere but more moderate prohibitionists who were more keenly alive to the economic foundations and implications of national prohibition. This included such national leaders as Senator William E. Borah, Herbert Hoover and many captains of industry, like Henry Ford, Thomas A. Edison and others. This group favoured a longer trial and a greater effort to secure co-operation of both state and national governments, and enlist the active support of the great mass of law-abiding citizens, before saying that the 18th amendment and its supporting legislation could not be enforced. Many excellent suggestions offered in the W. C. Durant prize contest, Aug. 27–Nov. 30, 1928, "for the best and most practical plan to make the 18th amendment effective," showed conclusively that it was not lack of brains or technical skill on the part of the leaders who would and could have enforced the 18th amendment if they had had the strong support of a favourable public opinion such as caused its adoption. Countersuggestions showing the trend towards and the character of the demand for repeal, will be found in the W. R. Hearst temperance prize contest, Jan.–Apr. 1929, "for the best plan to repeal the 18th amendment and substitute in place of prohibition a more liberal and more American measure," later changed to "the best plan to achieve temperance." For a full account of these contests and the winning plans see W. C. Durant, ed., Laze, Observance, p. 573 (1929); and Francis J. Tietsort, ed., Temperance or Prohibition, p. 397 (1929).

The presidential campaign of 1932 settled the issue overwhelmingly for repeal. The plank in the Democratic platform was unequivocally for repeal, and the Republican plank, as recommended by the majority of the resolutions committee, apparently favoured the submission of a proposal to revise the 18th amendment with some safeguards attached. Dr. Butler, Senator Borah and other leaders claimed, however, that the minority recommendation of the resolutions committee favouring outright repeal more nearly represented the majority sentiment of the convention, but had been defeated by controlled votes. The *N.Y. Times* of June 7 and 9, before the Republican convention had acted, quoted two of the most influential supporters of the 18th amendment, John D. Rockefeller, Jr., and John R. Mott, as respectively in favour of repeal and resubmission.

Submission and Ratification of the 21st Amendment, Repealing the 18th.—The second session of the 72nd congress meeting within a month of the November elections lost no time in preparing a joint resolution which was adopted by two-thirds majority in both houses; in the senate, where the joint resolution originated, by a vote of 63 for, to 23 against, on Feb. 16, 1933, and in the house on Feb. 20 by a vote of 289 for, to 121 against. It was deposited in the department of state, Feb. 20, and the following day was sent by the secretary of state to the respective governors of the 48 states.

The proposed amendment, as subsequently ratified, becoming the 21st amendment to the constitution, reads as follows:

"Section 1. The eighteenth article of amendment to the Constitution of the United States is hereby repealed.

"Section 2. The transportation or importation into any State, Territory, or possession of the United States for delivery or use therein of intoxicating liquors, in violation of the laws thereof, is hereby prohibited.

"Section 3. This article shall be inoperative unless it shall have been ratified as an amendment to the Constitution by conventions in the several States, as provided in the Constitution, within seven years from the date of the submission hereof to the States by the Congress."

This was the first use to be made of the method of ratification by conventions instead of by legislatures, but in less than 10 months conventions did meet in 36 states which ratified and two (North Carolina and South Carolina) which rejected the amendment. On Dec. 5, 1933, the secretary of state certified the ratification. The president followed this certification on the same day with a proclamation, pursuant to sec. 217a of the National Industrial Recovery act, in which he declared the 18th amendment repealed. While the president did call on all citizens to co-operate with the government in getting rid of the illicit liquor traffic, and to note the new prohibition against wet states invading the territory of those who wished to remain dry, not even the president seemed to realize the full significance of the second section of the 21st amendment.. That was left for Justice Louis D. Brandeis and the supreme court to reveal in two little-noticed but remarkable decisions: (1) *State Board of Equalization of California* v. *Young's Market Co., et al.* (299 U.S. 59) decided in 1936; and (2) *Finch & Co.* v. *McKittrick* (305 U.S. 395) decided Jan. 3, 1939. The gist of these two decisions of Justice Brandeis may be seen in two sentences. One taken from the first, speaking of the 21st amendment, says that the words of the amendment "are apt to confer upon the States the power to forbid all importations which do not comply with the conditions which it prescribes"; and the other, from the second decision, to the effect that: "Since that amendment (the 21st), the right of a State to prohibit or regulate the importation of intoxicating liquor is not limited by the commerce clause." Prof. Noel T. Dowling of the Columbia university law school noted within a month after the first decision was handed down, its revolutionary character in constitutional law and history. He raises the question whether it was the intent of the 21st amendment to go so far, and whether the court would go the whole way to permit the states to put themselves in a position oi economic isolationism with respect to intoxicating liquors. The second decision gives an affirmative answer to both questions. (*See* Noel T. Dowling, "Liquor and the Constitution," *Independent Journal,* Dec. 18, 1936, Col. Univ.) The second section of the 21st amendment not only put the Webb-Kenyon law substantially in the constitution, and thereby placed it beyond the power of congress to change, but by the interpretation given to it in the Brandeis decisions "the states," as Prof. Dowling says, "seem to have been lifted to a new, surprising, extraordinary position of power in the American federal system."

After Repeal.—At the end of nearly a decade after repeal (1943) it was still impossible to predict how far the states would succeed with the new powers in doing what they failed to do before national prohibition, and what the federal government without their full co-operation failed to do during the era of national prohibition. The president's proclamation of repeal also promised federal aid, and among other things said: "The objective we seek through a national policy is the education of every citizen toward a greater temperance throughout the Nation."

Steady progress toward legal tax control was made by the Federal Alcohol administration and in the individual states through the licensing and monopoly control in all except those areas which, by local option, have prohibition. (*See* LIQUOR LAWS AND LIQUOR CONTROL.) During 1942, local option elections in nearly 1,500 geographical areas showed more pronounced dry gains than in any one of the previous nine years, all of which showed some dry gain. It was reported that in that period in over 12,000 local option elections the drys won nearly two-thirds of them. Both the liquor interests and the temperance forces were suspicious of each other fearing that advantage would be taken of the war situation to renew old controversies. Polls indicated a rising tide of dry sentiment even to a reported 36% in one poll favourable to national prohibition. Although there was something in the pattern of World War II events to suggest the antecedents of prohibition in the years 1917–19, the background of legislative demands and action was radically different. The temperate statement of the executive committee of the Federal Council of Churches on Nov. 27, 1942 (*Information Service,* Dec. 5, 1942), presented positive measures to control and reduce the evil effects of beverage alcohol, with particular reference to the wartime situation. These probably fairly represented the attitude of the Protestant Churches, and indicated the trend of thought in most of the temperance societies, Protestant and Catholic.

Too great or sole reliance on legal compulsion defeated national prohibition. The better course that combines education and restraint, both legal and voluntary, in the suppression of the evils of the liquor traffic, was well illustrated in a broadcast of Prime Minister Mackenzie King of Canada, on Dec. 16, 1942, from Ottawa, on "Temperance and a Total War Effort." He asked the provinces to further restrict the hours of sale to eight per day; he lamented the increased consumption of alcoholic beverages as unseemly in wartime when so many are sacrificing so much; and he announced the decision of his government under its war powers to prohibit after Feb. 1, 1943, all liquor advertisements throughout Canada for the duration.

Whatever may be said of prohibition, law, enforcement or repeal, these facts remain: During the prohibition era, a vast, illicit and vicious business of bootlegging was active. It could not have existed without enormous purchases, *in toto,* of bootleg stuff by otherwise reputable citizens who not only resisted the law but defied it and disobeyed it, thus lowering the standards of civic honour.

When repeal came in, it proved to be no immediate remedy for the appalling disintegration of social, intellectual and moral ideals, caused in large part by the illegal practices connected with bootleg liquor. In 1942, war brought additional questionings and difficulties. Many were inclined to believe that certain strict governmental protective and prohibitory measures might still be necessary for social welfare, but that the real progressive solution of the liquor problem might lie in the acceptance of individual responsibility; in voluntary commitment to the temperance cause; in scientific study; in home training and parental example; in the teaching and nurture of the church; and in better social customs.

In a word, the solution might lie more in the educational and spiritual realm, than in the legislative and political.

A new pragmatic emphasis on social and economic results and less controversy about ideologies may characterize the post-repeal era.

BIBLIOGRAPHY.—In addition to references already cited: P. W. Wilson, *After Two Years: A Study of American Prohibition* (1922); Fabian Franklin, *What Prohibition Has Done to America* (1922); A. Newsholme, *Prohibition in America* (1922); American Academy of Political and Social Science, "Prohibition and Its Enforcement," *Annals,* vol. 109 (1923); "Prohibition: A National Experiment," *ibid.,* vol. 163 (1932); E. H. Starling, *The Action of Alcohol on Man* (1923); V. G. Vecki, *Alcohol and Prohibition in Their Relation to Civilization and the Art of Living* (1923); C. M. and G. Gordon, *A Study of North American Prohibition* (1923); Ernest H. Cherrington, *The Evolution of Prohibition in the U.S.A.* (1920); T. N. Carver, "The Greatest Social Experiment of Modern Times," *These Eventful Years,* vol. 2, ch. 80 (1924); Moderation League, Inc., *A National Survey of Conditions under Prohibition* (1925–26); H. W. Farnum, "The Law of the Land and Our Moral Frontier," *No. Amer. Rev.,* vol. 221 (1925); D. Leigh Colvin, *Prohibition in the U.S.; a History of the Prohibition Party and of the Prohibition Movement* (1926); J. A. Krout, *The Origins of Prohibition* (1925); F. Ernest Johnson and H. S. Warner, *Prohibition in Outline* (1927); R. E. Hose, *Prohibition or Control* (1928); Peter H. Odegard, *Pressure Politics: the Story of the Anti-Saloon League* (1928); *National Commission on Law Observance and Enforcement,* 5 vols. (1931); Raymond B. Fosdick and Albert L. Scott, *Toward Liquor Control,* with ioreword by John D. Rockefeller, Jr. (1933); Leonard v. Harrison and Elizabeth Laine, *After Repeal,* with foreword by Luther Gulick (1936); "Alcoholic Beverage Control," *Law and Contemporary Problems,* vol. vii, No. 4 (1940); *State Liquor Legislation,* prepared by Marketing Laws Survey, U.S. Dept. Commerce, Works Progress Administration (1941); H. W. Haggard and E. M. Jellinek, *Alcohol Explored* (1942); publications and reports of: the Prohibition Unit (U.S. Treasury and Justice Depts.); annual reports of Attorney-General, Bureau of Int. Rev. (Treas. Dept.); also, Assn. Against the Prohibition Amendment, U.S. Brewers' Assn., Moderation League, Inc., Anti-Saloon League yearbooks, 1908–33; and other pubs., Intercollegiate Prohibition Assn., Nat. Woman's Christian Temperance Union, Scientific Temperance Federation, Women's Nat. Com. for Law Enforcement, Amer. Business Men's Research (formerly Prohibition) Foundation, Methodist Board of Temperance (Wash., D.C.), Distilled Spirits Institute (Wash., D.C.), Research Council on Problems of Alcohol (Bronxville, N.Y.) and the Council's *Quarterly Journal of Studies on Alcohol.*

See also: LIQUOR LAWS AND LIQUOR CONTROL; BOOTLEGGING; SMUGGLING; TEMPERANCE; "GOTHENBURG" LICENSING SYSTEM; LOCAL OPTION. (S. McC. L.)

PROHIBITION IN LAW, a term meaning the action of forbidding or preventing by an order, a decree, etc. As defined by Blackstone, prohibition is "a writ directed to the judge and parties of a suit in any inferior court, commanding them to cease from the prosecution thereof, upon a surmise either that the cause originally or some collateral matter arising therein does not belong to that jurisdiction, but to the cognizance of some other court." A writ of prohibition is a prerogative writ—that is to say, it does not issue as of course, but is granted only on proper grounds being shown. Before the Judicature acts prohibition was granted by one of the superior courts at Westminster; it also issued in certain cases from the court of chancery. It is now granted by the high court of justice. By the Judicature act, 1873, s. 24, it is provided that no proceeding in the high court of justice or the court of appeal is to be restrained by prohibition, a stay of proceedings taking its place where necessary. In the case of courts of quarter sessions, the same result is generally obtained by certiorari (see WRIT).

In Scots law prohibition is not used in the English sense. The same result is obtained by suspension or reduction. In the United States the supreme court has power to issue a prohibition to the district courts when proceeding as courts of admiralty and maritime jurisdiction.

Most of the states have also their own law upon the subject, generally giving power to the supreme judicial authority in the state to prohibit courts of inferior jurisdiction. (*See* LIQUOR LAWS AND LIQUOR CONTROL; TEMPERANCE.)

Prohibition is a writ which lies to restrain the unlawful exercise of judicial functions on the part of a lower court, issuing from a court of higher jurisdiction. Again, it may be used to restrain an official from doing an administrative, ministerial or legislative act not falling within his province.

PROHIBITION PARTY, THE NATIONAL, a minor political party of the United States which set as its primary objective the legislative prohibition of the manufacture and sale of intoxicating liquors. From time to time it also proclaimed its interest in other reforms. The party was organized in 1869 and in 1872 placed its first candidate for president in the field. It offered candidates for president and vice-president in every succeeding presidential election. Though one of the most persistent of the third parties, it polled fewer votes in most elections than some others of more radical character. Its highest figure, 271,058 votes out of a total of 12,043,603 cast, was in 1892. In 1948 it polled only 103,216 out of 48,833,680 cast. While the 18th amendment was in effect, the party agitated for its enforcement, but growing hostility to prohibition and the amendment's final repeal in 1933 forced the party to resume the political struggle within individual states.

PROJECTION, IN MATHEMATICS. Let A, B, C, D, etc., represent points of a straight line 1 and A', B′, C′, D′, etc., points of another straight line l′ in the same plane with 1. If the straight lines, AA', BB', CC', DD', etc., are all perpendicular to the line l′, the set of points A', B', C, D', etc., is said to be an orthogonal projection of the set, A, B, C, D, etc., (fig. 1). The correspondence between the two sets of points, by which A corresponds to A', B to B', etc., is called an orthogonal projection. In case the straight lines AA', BB', etc., are all parallel, without being necessarily perpendicular to l′, we use the term parallel projection instead of orthogonal projection (fig. 2). In case the lines AA', BB', CC', etc., all meet in a point O we speak similarly of central projection. In all three cases we say that the two sets of points A, B, C, D, etc., and A', B', C, D', etc., are in perspective and that the points of one set are projected into the points of the other set. The point O is called the centre of perspectivity or the centre of projection of the two sets of points as indicated in the accompanying diagram (fig. 3).

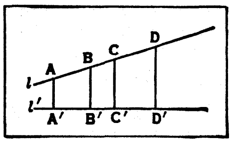

FIG. 1

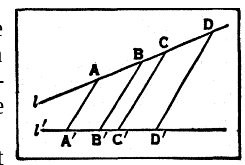

FIG. 2

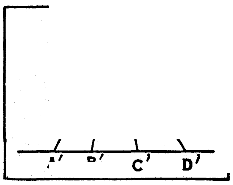
FIG. 3

These conceptions have been generalized in various ways. For example, let A, B, C, D, etc., be the points of any figure F in space and A', B', C', D', etc., be corresponding points of a figure in a plane π. If the straight lines AA', BB', CC', etc., are all parallel or all meet in a point O the figure in the plane π is called a projection of the other figure. If the lines AA', BB', etc., are all perpendicular to the plane π, the figure in π is called an orthogonal projection of the other figure. (*See* also DESCRIPTIVE GEOMETRY; PERSPECTIVE; PROJECTIVE GEOMETRY.) (O. V.)

PROJECTIVE GEOMETRY. Projective geometry is a branch of mathematics which originated in the study of projections as applied to problems of perspective in the drawing of pictures and in optical instruments. These practical applications are now studied under the captions of descriptive geometry (see DESCRIPTIVE GEOMETRY) and geometrical optics (*q.v.*), while projective geometry itself is cultivated for its intrinsic interest. It is a well co-ordinated and symmetrical theory of considerable aesthetic merit, which on the one hand enables us to view elementary geometry as a completed whole, and on the other hand serves as the starting point of the higher algebraic geometry. For a more detailed study the reader is referred to one or more of the text books listed at the end of this article. The article itself attempts merely to state some of the general ideas, definitions and theorems in an introductory way and without proof.

One-dimensional **Projectivities.**—The notion of projection is defined in the article on that subject (see PROJECTION, IN MATHEMATICS). Suppose that the points of a line a are projected into the points of a line b, and the points of b into the points of a line c, the points of c into the points of a line d, and so on, ending up with the points of the line k. Every point A of the line a then corresponds to a definite point K of the line k. This correspondence is called a *projective* transformation or projectivity, and is sometimes indicated symbolically by

$$. \; . \barwedge \{K\}$$

The set of all points of a line l is called a range (or a pencil or row) of points, so that in the books on projective geometry there is often talk of projective ranges. In case we wish to discuss the correspondence, not of all the points of a, but only of certain ones, say A_1, A_2, A_3, A_4, we may write

$$A_1A_2A_3A_4 \barwedge K_1K_2K_3K_4.$$

The first theorem about projectivities is that any three points of a straight line can be projected into any three points of a straight line. In other words the statement

$$A_1A_2A_3 \barwedge K_1K_2K_3,$$

is true whenever it is true, (1) that A_1,A_2,A_3 are distinct and collinear, and (2) that K_1,K_2,K_3 are distinct and collinear. It is also true that if the points A_1,A_2,A_3 and K_1,K_2,K_3 are on different lines the projectivity can be brought about by the intervention of not more than two intermediate projections. That is, if the points A_1,A_2,A_3 and K_1,K_2,K_3 are given on different lines it is possible to find a line b such that A_1,A_2,A_3 can be projected respectively into the points B_1,B_2,B_3 of b, and these points into K_1,K_2,K_3, respectively. If A_1,A_2,A_3 and K_1,K_2,K_3 are on the same line, three intermediate projections may be needed.

A second theorem is that any projective transformation of a line is fully determined by the fate of three of the points of the line. In other words, if it is specified that A_1 goes to K_1, A_2 to K_2, A_3 to K_3, then for any point A_4 of the line A_1A_2 there is a uniquely determined point K_4 of the line K_1K_2 to which A_4 goes. This theorem is often referred to as the *fundamental* theorem of projective geometry.

Points at Infinity.—From the point of view of elementary geometry, there are certain exceptions to these theorems, due to the existence of parallel lines. For example in fig. 1, the point A_0 is not projected into any point of the line b because the line from

A_0 to the centre of projection is parallel to b. This circumstance complicates the statement of the theorems about projections if we adhere to the point of view of elementary geometry. In projective geometry it is avoided by introducing the conception of points at infinity, or ideal points. To every straight line a there is attributed one point at infinity and every line parallel to a is said to meet a in the point at infinity of a. In fig. 1 the point A_0 is therefore said to be projected into the point at infinity of the line b. The points at infinity of the straight lines of a plane are said to constitute a straight line, the line at *infinity* of this plane. All the points at infinity of a three-dimensional space are said to constitute a plane which is called the plane at infinity.

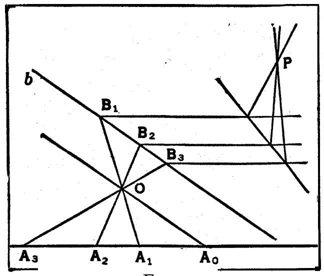

FIG. 1

We shall not attempt here to justify the conception of points at infinity. The question is discussed at length in the books on projective geometry. It may be remarked however that the ordinary points are just as much idealized as are the points at infinity. No one has ever seen an actual point or realized it by an experiment of any sort. Like the point at infinity it is an ideal creation which is useful for some of the purposes of science. With the aid of these conceptions we obtain great simplicity and symmetry in the statements of geometry. For example we have: (a)' any two points have one and only one straight line in common; (b) any two straight lines in a plane have one and only one point in common; (c) any two planes have one and only one line in common; (d) a straight line and a plane have one and only one point in common, unless the line lies in the plane; (e) a straight line and a point are on one and only one plane, unless the point is on the line. Each of these statements would have to be split up into at least two propositions in order to state its full content in the language of elementary geometry; and each of the propositions would be more complicated to state than the more general projective proposition in which it is contained.

Principle of Duality.—If we restrict attention to the points and lines of a single plane there is a duality between the two propositions (a) and (b) in the list above. They can be written:

(a) Two points are on one and only one line.

(b) Two lines are on one and only one point.

Either proposition remains true if the words point and line are interchanged. The same thing is true of every theorem of the projective geometry of the plane. If it is properly formulated it remains valid when the words point and line are interchanged. This statement is called the principle of duality in the plane. *(See* **DUALITY.**) Its exact meaning depends, of course, on what we mean by a theorem of projective geometry. This is explained below with the aid of the notion of the projective group.

After the principle of duality in the plane has been comprehended it is necessary only to state one of each pair of dual theorems. The other one goes without saying. Indeed, after we have arrived at a number of propositions from which we are going to deduce all the rest by logical processes without appeal to other knowledge, and after we have verified the duals of these fundamental propositions, we know in advance that the principle of duality will hold for all the theorems which we are going to derive. This way of dealing with the principle of duality requires that the material of projective geometry shall be organized as a distinct body of knowledge (see the remarks on axioms, etc., below).

The principle can also be established by showing the existence of "duality transformations" which carry every plane figure into a dual figure in which the points and lines of the first are replaced by the lines and points of the second.

There is also a principle of duality in space, according to which the propositions of three-dimensional projective geometry when properly stated remain valid when the words point and plane are interchanged. In the list above, the propositions (a) and (c) are dual, (d) and (e) are dual, and (b) is dual to the proposition that any two straight lines with a point in common are in a common plane. In like manner there are principles of duality in spaces of any number of dimensions.

Pencils of Lines.—We must now understand that the statements which we have made about one-dimensional projectivities hold without exception, and therefore include all the special cases which arise when one or more of the points in question is a point at infinity. Glancing again at fig. 1, it is evident that there is a one-to-one correspondence between the points of the line a and the lines through the point O which are in the same plane with a, namely, each point corresponds to the line joining it to O. Such a system of lines is called a pencil of lines and the point O in which all lines of the pencil meet is called the centre of the pencil.

The notions of projectivity and perspectivity are now extended so as to apply to pencils of lines as follows: The correspondence between a range of points and a pencil of lines in which each point lies on its corresponding line is called a *perspectivity;* and any correspondence between two pencils of lines, or between a pencil of lines and a range of points, or between two ranges of points which is the resultant of any number of perspectivities is called a *projectivity.* This definition includes the definition previously given of a projectivity between two ranges of points as a special case. Under this definition, in fig. 1, the range of points on *a* is projective with the pencils of lines at O and P as well as with the pencil of parallel lines; and each of these pencils of lines is projective with the others; each of the projectivities being a one-to-one correspondence determined by the figure. Just as in the analogous case of ranges of points, if a_1,a_2,a_3 are lines of one pencil and b_1,b_2,b_3 are lines of another pencil, there is one and only one projectivity in which a_1,a_2,a_3 correspond to b_1,b_2,b_3 respectively.

Conic Sections.—The corresponding lines of two distinct projective pencils of lines in the same plane intersect in the points of a conic section (*q.v.*), provided the line joining the centres of the two pencils does not correspond to itself. For example, in fig. 2, the two pencils of lines at A and B are projective in such a way that corresponding lines are perpendicular, and they intersect in points of a circle. If the corresponding lines had not been perpendicular the corresponding lines would have intersected in an ellipse, or in a parabola, or in a hyperbola.

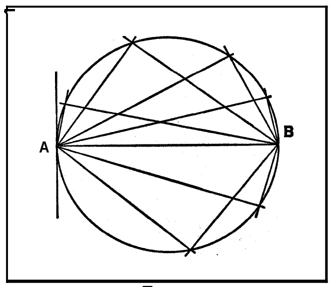

FIG. 2

This theorem of the generation of a conic by means of projective pencils makes it possible to deduce all the properties of conic sections from the theory of one-dimensional projectivities. For example, the fact that there is one and only one conic through five coplanar points, no three of which are collinear, is an immediate consequence of the fact that a projectivity between two pencils of lines is fully determined by the correspondence of three lines of the one pencil with three lines of the other. The theorem is a good example of the unifying power of projective geometry, for it includes as special cases a host of theorems about the construction of conic sections when the given five points are in special position from the point of view of elementary geometry. An equal number of additional theorems is obtained by applying the principle of duality in the plane; and a corresponding group of theorems about cones is obtained by space duality.

The Ruled Quadric.—Let A_1,A_2,A_3,A_4 be four points of a line a and B_1,B_2,B_3,B_4 four points of a line b which is not in the same plane with a. In case

$$A_1A_2A_3A_4 \;\overline{\wedge}\; B_1B_2B_3B_4,$$

then any straight line c which meets the three lines A_1B_1, A_2B_2, A_3B_3, will also meet A_4B_4. Hence there is a whole family of straight lines which meet the lines A_1B_1, A_2B_2, A_3B_3, A_4B_4. The lines of this family fill up a surface which is called a quadric surface because its equation is of the second degree. It is called a *ruled quadric* because of the straight lines which lie upon it. Indeed, the surface may be described as follows: let *a, b* and *c* be the three lines already described under these names. There is a family of lines each of which meets a, *b* and *c* and there is just one line of this family through each point of *a, b* or *c*. This family may be called the *first ruling* or *regulus* of the quadric. Any line which meets three lines of the first ruling meets all lines of this ruling, and the family of all such lines is a regulus just like the first ruling. The quadric consists of the points on the t o rulings. There is one line of each ruling through each point of the quadric, and the plane containing these two lines is tangent to the quadric. But for further discussion of this question the reader must be referred to the article on surfaces *(see* SURFACE) and to the appropriate chapters in books on projective and analytic geometry. The ruled quadric from the point of view of Euclid is either a hyperbolic paraboloid or a hyperboloid of one sheet, according as the plane at infinity is or is not tangent to it.

One-dimensional Forms.—This by no means exhausts the list of seemingly complicated geometric figures whose theory can be deduced from the simple propositions about one-dimensional projectivities. The essential element in any such deduction is to find a family of geometric figures which are in such a correspondence with the points of a line that the theory of projectivities can be applied. Any such family of geometric figures is called a *one-dimensional form*. Examples are: a range of points, a pencil of lines, the set of all planes having a line in common, the points of a conic section, the lines of a regulus, the generating lines of a cone, the points of a rational cubic curve in space, the tangents to a conic section, the set of all conic sections having four points in common, and so on. When the general ideas about projectivities of one-dimensional forms are combined with simple theorems about the particular figures to which they are being applied, they often give us flashes of insight into unexpected branches of mathematics, such as, for example, quaternions (*q.v.*) and biquaternions.

Cross Ratio.—If two points, A,B, go by projection to two points, A',B', there is no general relation between the distance AB and the distance $A'B'$. The same remains true of the ratios

$$\frac{AB}{AC} \text{ and } \frac{A'B'}{A'C'}$$

of two sets of collinear points A,B,C, and A',B',C'. But it is not true of the ratio of two ratios

$$\frac{AC}{AD} \div \frac{BC}{BD}$$

(each ratio computed with proper regard to algebraic sign). The fact is that

$$ABCD \barwedge A'B'C'D'$$

if and only if

$$\frac{AC}{AD} \div \frac{BC}{BD} = \frac{A'C'}{A'D'} \div \frac{B'C'}{B'D'}$$

provided the points in each set of four are collinear. Such a ratio of two ratios is called a *cross ratio* or a *double ratio* or an *anharmonic ratio.*

A cross ratio of four collinear points is the same as the corresponding cross ratio of any four points into which they are projected. This fact enables us to define the cross ratio of any four elements of any one-dimensional form, and in each case the cross ratio has a significant geometrical meaning. For example, we can define the cross ratio of four points of a conic as that of any four points of a straight line which are projective with the given four points of the conic. It then can be proved very simply that whenever the cross ratio $ABCD$ is -1 the tangents to the conic at A and B intersect on the line CD; and conversely, if the tangents at A and B intersect on the line CD then the cross ratio $ABCD$ is -1. Whenever the cross ratio $ABCD$ of any four elements of a one-dimensional form is -1 we say that the four elements form a *harmonic set* and that the elements *AC harmonically separate* the elements BD.

Co-ordinates in One-dimensional Forms.—If A,B,D are three elements of a one-dimensional form (*e.g.*, three points of a line) any fourth element C is uniquely determined by its cross ratio $ABCD$. That is, if C is given, the cross ratio is a unique number x, and if a number x is given, there is one and only one element C such that x is the cross ratio $ABCD$ (if $C=A$, $x=0$; if $C=B$, $x=\infty$; if $C=D, x=1$). The number x is what we call the *co-ordinate* of the element C of the one-dimensional form. A co-ordinate is a number which serves as a name for the element; and these names have been assigned in such a way that any two distinct elements have distinct names. It can be proved that any projectivity by which each element of a one-dimensional form corresponds to an element of the same form, can be represented by an equation

$$\bar{x} = \frac{ax+b}{cx+d}, \quad ad-bc \neq 0.$$

That is to say, for any projectivity of a one-dimensional form, there are four numbers a,b,c,d such that every element x is carried by the projectivity to that element whose name $\bar{x}$ is related to x by the equation written above.

Invariants of Binary Forms.—This theorem opens the way for a study of projective geometry by means of algebra. In practice it is found advantageous to use homogeneous co-ordinates. An element whose non-homogeneous co-ordinate is x is represented by any pair of numbers x_1,x_2 such that

$$\frac{x_1}{x_2} = x.$$

In case $x_2=0$, the pair of numbers $(x_1,0)$ represents the element ∞ (represented by B in the discussion above). Homogeneous co-ordinates give a multiplicity of names for the same element, for whenever

$$\frac{x_1}{x_2} = \frac{y_1}{y_2}$$

(x_1,x_2) and (y_1,y_2) represent the same element. Any homogeneous algebraic equation represents a finite number of elements. For example

$$px_1^3+qx_1^2x_2+rx_1x_2^2+sx_2^3=0$$

represents three elements, because there are three values of the ratio x_1/x_2 which satisfy this equation. The left-hand member of a homogeneous equation of this sort, of any degree, is called a *binary form* (binary because there are two variables).

A projective transformation is represented in homogeneous co-ordinates by linear homogeneous equations of transformation

$$\begin{aligned}\bar{x}_1 &= ax_1+bx_2 \\ \bar{x}_2 &= cx_1+dx_2\end{aligned} \qquad ad-bc\neq 0$$

and the projective geometry of one-dimensional forms reduces, algebraically, to the study of the effect of transformations of this sort upon binary forms. This study centres about the theory of *invariants (see* ALGEBRAIC GEOMETRY; TENSOR ALGEBRA) of binary forms, an invariant being a function which is unaltered except for a factor by the transformations. In geometric applications it is found, in general, that the vanishing of an invariant represents a geometric property which is unaltered by projectivities.

Two-dimensional Projective Geometry.—It is natural to call such collections of elements as the set of all points in a plane, or the set of all lines in a plane, or the set of all planes through a point, etc., *two-dimensional forms.* The concept of a projective transformation can be extended to two dimensions without difficulty. It turns out that any projective transformation of a two-dimensional form is fully determined by the fate of any four elements no three of which are in the same one-dimensional form.

Non-homogeneous co-ordinates are introduced in such a way that an element is named by an ordered pair of numbers (x,y, the first and second names of the element). If the elements are points, then these co-ordinates are ordinary cartesian co-ordinates *(see* ANALYTIC GEOMETRY). Homogeneous co-ordinates are sets of three numbers (x_1,x_2,x_3) such that

$$x = \frac{x_1}{x_3}, \qquad y = \frac{x_2}{x_3},$$

and projective transformations of the points of a plane into points of the same plane are given by equations of transformation of the type,

$$\bar{x}_1 = a_1^1x_1 + a_1^2x_2 + a_1^3x_3$$
$$\bar{x}_2 = a_2^1x_1 + a_2^2x_2 + a_2^3x_3$$
$$\bar{x}_3 = a_3^1x_1 + a_3^2x_2 + a_3^3x_3,$$

in which the determinant of the coefficients is not zero. These transformations are also called *collineations* because they transform collinear points into collinear points.

Geometry of the Complex Domain. — Since it is possible to perform all the operations of algebra with complex numbers (see COMPLEX NUMBERS)--that is to say with the numbers of the form $u+v\sqrt{-1}$ where u and v are real—it is possible to work out the algebraic theory of projective transformations on the assumption that the co-ordinates, x_1,x_2,x_3, and the coefficients of the equations of transformations, are complex numbers. The objects which are transformed are sets of triads of numbers (x_1,x_2,x_3) where a given set contains all triads $(\rho x_1,\rho x_2,\rho x_3)$ obtained by letting ρ be any real or complex number except zero. We call these objects complex *points*. The collection of complex points which satisfy a homogeneous first degree equation

$$ax_1+bx_2+cx_3=0$$

is called a complex line, and the collection of complex points which satisfy a homogeneous second degree equation a complex *conic,* and so on The totality of complex points is called a complex *projective* plane Thus there is built up, by simple algebraic processes, a complex *projective* geometry.

The propositions of this geometry are, to a large extent, the same as those of the projective geometry of reals. Two points determine one and only one line; two lines meet in a point; five points, no three collinear, determine a conic; and so on. But a great many propositions assume a simpler and more symmetric form than they do in the real geometry. For example, in the real geometry a line which is not tangent to a conic may meet it either in two points or not at all; in the complex geometry a line which is not tangent always meets the conic in two points. This is because the problem of finding the points of intersection of a straight line and a conic reduces to the solution of a quadratic equation. In general any geometric problem depending on the solution of an algebraic equation of higher than the first degree will assume a simpler form in the complex than in the real domain.

Among the complex points there is a sub-class consisting of those for which the ratios x_1/x_3 and x_2/x_3 (or x_1/x_2, if $x_3=0$) are real. The co-ordinates of these points can always be taken to be real, so that these points can be identified with the ordinary real points. Hence the real projective plane is habitually thought of by mathematicians as immersed in a complex projective plane. Every real straight line or real conic is thought of as containing not only all its real points but also a collection of complex points. Moreover, free use is made of imaginary straight lines, conics, and so on. For example, if we were to limit attention to real figures we should have to say that from certain points of the plane it is impossible to draw lines tangent to a given conic. From the point of view of complex geometry we say that there are two tangents through any point not on the conic; if the point is exterior to the conic the two tangents are real lines, but if the point is interior they are conjugate imaginary lines. No attempt is made to visualize the "imaginary" complex elements We simply make such inferences about them as follow by the rules of logic from the definitions adopted. The results so obtained are bound to be as self-consistent as any theorems about numbers.

Geometry of *N* Dimensions. — Three-dimensional projective geometry can be approached from the point of view of elementary geometry much as we have approached one and two-dimensional projective geometry in the discussion above, or it may be derived by a purely logical process on the basis of its own axioms; or it may be taken up analytically in the manner explained above for the two-dimensional complex geometry. Points are then defined in terms of sets of homogeneous co-ordinates (x_1,x_2,x_3,x_4). If these co-ordinates are restricted to real numbers we obtain the real projective geometry of three dimensions. If they are allowed to be any complex numbers we obtain the complex projective geometry of three dimensions.

From the algebraic point of view, there is no reason why the number of homogeneous co-ordinates should be restricted to four, and no such restriction is made by mathematicians. A point in a projective space of n dimensions is defined by $n+1$ homogeneous co-ordinates $(x_1,x_2, \ldots, x_{n+1})$ and projective transformations are defined by equations of the form

$$\begin{aligned}
\bar{x}_1 &= a_1^1x_1 + a_1^2x_2 + \cdots + a_1^{n+1}x_{n+1} \\
\bar{x}_2 &= a_2^1x_1 + a_2^2x_2 + \cdots + a_2^{n+1}x_{n+1} \\
&\;\;\vdots \\
\bar{x}_{n+1} &= a^1_{n+1}x_1 + a^2_{n+1}x_2 + \cdots + a_{n+1}^{n+1}x_{n+1}.
\end{aligned}$$

If the co-ordinates and coefficients are real we arrive at the real projective geometry of n dimensions, if complex, at the complex projective geometry of n dimensions

As the number n increases the geometry becomes more complicated because the number of primary figures to consider becomes greater, but it does not become more difficult in principle. It is no longer possible to visualize our results as we do in the one-, two- and three-dimensional cases, but the logical processes by which they are proved remain the same. In order to explain the situation rapidly we have based the conception of an n-dimensional space on the notion of co-ordinates, but this is not necessary. It can also be developed without the use of co-ordinates from a purely descriptive set of axioms.

Projective, Affine and Metric Geometry. — The set of all projective collineations of a plane form a group (see the article GROUP). The properties of any figure which remain unaltered when this figure undergoes the transformations of this group are called projective properties For example, the property of a curve of having a second degree equation, *i.e.,* of being a conic section, is unaltered. Likewise the property of a point, line and conic section, that the point is the pole of the line with regard to the conic, is a projective property. The theory of all projective properties of plane figures is the subject matter of the projective geometry of the plane,

The set of all projective collineations of a plane which leave a particular straight line invariant is a group which Is called an *affine* group, and the theory of those properties of plane figures which are unaltered when the figures undergo the transformations of this group is called affine geometry (see AFFINE GEOMETRY). The invariant line is called the line at infinity of the affine geometry. An affine group has several subgroups, the most interesting being the ones determined by requiring that two points of the line at infinity shall be invariant. If the two points are real, the subgroup is one studied in the special theory of relativity (*q.v.*) and includes the Lorentz transformations. If they are conjugate imaginaries, the group is the group of similarity transformatiocs of Euclidean geometry.

The Euclidean geometry can be characterized as the group of theorems which state those properties of figures which are left unaltered by the group of similarity transformations. Thus it makes no essential distinction between a large triangle and a small one which is similar to it, though it does deal with the ratio of the two triangles But the latter is an attribute of the figure composed of the pair of triangles, not of either triangle separately. The theorems of affine and projective geomerry are all included in Euclidean geometry, because any property which is left invariant by the projective group is of course left invariant by all its subgroups. Thus affine geometry is a subclass of very general theorems of Euclidean geometry which it seems desirable to isolate from the rest and study together. Projective geometry is a still smaller class of still more general theorems We seem by leaving out some of the details which distract our attention in the more elementary way of looking at geometry to get a deeper insight and a better grasp of the subject as a whole. Afterwards we are able to return to these details and grasp them rapidly by studying the particular subgroup which determines the Euclidean metric. A study of the latter group with special reference to the two invariant points gives a rapid and comprehensive survey of Euclidean geometry. For example. the circles are the conic sections which pass through these two points, and the points are therefore called the circular points at infinity. Perpendicular lines are pairs of lines which meet the line at infinity in pairs of points which harmonically separate the circular points. The four tangents to a real conic from the circular points meet, in general, in four other points. Two of these are real and are the foci of the conic, and so on.

Non-Euclidean Geometry. — Another subgroup of the projective group which is of great interest is the group leaving a conic invariant. In the real geometry there are two cases to consider according as the conic is real or is composed entirely of imaginary points. The theorems stating properties invariant under the first group constitute what is called the hyperbolic non-Euclidean geometry *(see* GEOMETRY: *Non-Euclidean Geontetry),* those stating properties invariant under the second group constitute what is called the elliptic non-Euclidean geometry. The metric geometry or system of measurement of geometric figures which is developed in these geometries is quite different from, though analogous to, the system followed by Euclid. Historically they were developed in antithesis to the Euclidean system, but they have the same projective geometry.

Axioms. — Since projective geometry is a collection of general and significant propositions from which it is possible to specialize in a variety of directions, it is an attractive idea to make projective geometry the starting point of the logical formulation of geometry as a whole and arrive at the various more special branches by a process of specialization. The still more general branches will of course continue to be reached by the process of generalization. The problem of stating the axioms in purely projective terms and deriving the theorems from this foundation by purely logical processes engaged the attention of several mathematicians.

History. — The conception of points at infinity goes back to G. Desargues *(1593–1662; q.v.),* and many of the individual conceptions of projective geometry can be traced back to remote antiquity; but it may be said to appear first as a definite branch of science in *1822* in the work of J. V. Poncelet *(q.v.).* The development of the science was participated in by nearly all the geometers of the 19th century, notably by L. N. M. Carnot, C. J. Brianchon, J. D. Gergonne. M. Chasles, A. F. Möbius, G. hlonge, J. Steiner, J. Pliicker. W. K. Clifford! L. Cremona, H. J. S. Smith and H. Wiener. The clear separation of projective from metric properties dates from the publication of the *Geometrie der Lage* of K. G. Ch. von Staudt (Nuremberg, *1847)* and his *Beiträge zur Geometrie der Lage* (Nuremberg, 1857). The formulation of the group-theoretic classification of geometries is due to F. Klein. The axioms and the logical organization of the science as a separate entity were studied by many mathematicians, notably M. Pieri.

BIBLIOGRAPHY.—Elementary: P. Field, *Projective Geometry* (1923); *D.* N. Lehmer, *An Elementary Course in Synthetic Projective Geonzetry* (1917); *G.* B. Mathews, *Projective Geometry* (1914). Advanced: *H.* F. Baker, *Principles oj Geometry* (1922); L. Cremona, *Elements of Projective Geometry* (1885); J. *L.* S. Hatton, *The Principles of Projective Geonzetry* (1913); *O.* Veblen and J. W. Young, *Projective Geometry* (1910); *A. N.* Whitehead, ***The*** *Axioms of Projective Geonzetry* (1906). (O. V.)

PROKOFIEV, SERGEI (1891–1953), Russian composer, was born at Ekaterinoslav, south Russia, April 23, *1891.* In 1910 the Rubinstein prize was awarded him for his first piano concerto. From the first his compositions attracted attention by their originality and audacity. In writing for the stage he chose subjects which had elements of grotesqueness or harsh satire, such as *Chout (The Buffoon)* (1921), and *The Love for Three Oranges (1921).* His *Scythian Suite* for orchestra had also an obvious program. Other orchestral works include the *Symphonie Classique,* a *Sinfonietta,* the *Overture on Yiddish Themes* and *Peter and the Wolf (1936).* He died near Moscow on March 4, 1953.

PROKOP, the name of two prominent Hussite generals.

1. PROKOP, surnamed Veliky ("the Great") or Holy ("the Bald"). was a married utraquist priest who belonged to an eminent family of Prague. Though a priest. he became the most prominent leader of the advanced Hussite or Taborite forces during the latter part of the Hussite wars, comman'ding them at their victories at Usti nad Labem (Aussig) in *1426* and Domazlice (Tauss) in 1431, during their frequent incursions into Hungary and Germany, particularly the Bohemian invasion of Saxony in 1429, after which Prokop concluded the treaty of Kulmbach (Feb. *6,* 1430) with Frederick of Brandenburg, burgrave at Nuremberg. He was the most prominent member of the Bohemian embassy to the council of Basel (1433). Following this fruitless journey, when renewed fighting broke out, he besieged the Romans at Plzen but was forced by indiscipline in his own camp to raise the siege and return to Prague. The Bohemian nobility, both Romanist and utraquist, having leagued itself against the Taborites, a struggle began at Prague. Aided by the nobles, the citizens of the old town took the more democratic new town, which Prokop unsuccessfully attempted to defend. He now called to his aid Prokop the Lesser. *(See* below.) They jointly retreated eastward from Prague; but their forces, known as the army of the towns, were defeated by the nobles at Lipan, between Kourim and Kolin, Prokop the Great perishing in this battle (May *30,* 1434).

2. PROKOP the Lesser, or PROKUPEK (the Bohemian diminutive of Prokop), was one of the greatest Hussite generals. Little is known of his early life. He took part in all the later campaigns of Prokop the Great in Germany and succeeded him as commander of the Taborite army besieging Plzen. After the formation of the confederacy of the nobles he was recalled by Prokop the Great, with whom he shared the command of the army of the towns at the battle of Lipan, in which he also perished.

PROKOPOVICH, THEOFAN (1681–1736), Russian archbishop and statesman, one of the ablest coadjutors of Peter the Great, was educated at the Orthodox academy of Kiev in Poland and at Rome in the College of the Propaganda. On his return to Russia he became professor, and subsequently rector, of the academy of Kiev. He reformed the teaching, substituting the historical method of the German theologians for the antiquated orthodox scholastic system. In 1709 Peter the Great, while passing through Kiev, was struck by the eloquence of Prokopovich in a sermon on "the most glorious victory" *(i.e.,* Poltava) and in *1716* summoned him to St. Petersburg. Theofan was rapidly promoted, becoming in 1718 bishop of Pskov and finally; in 1724, archbishop of Novgorod. As the author of "the spiritual regulation" for the reform of the Russian church, Theofan must: indeed, be regarded as the creator of "the spiritual department" superseding the patriarchate and better known by its later name of the Holy synod, of which he was made the vice-president.

PROLETARIAT. In ancient Rome the proletariat *(proletarius)* constituted the body of poor, landless freemen. It included artisans and small tradesmen who were gradually impoverished by the extension of slavery. The proletariat was the lowest rank among Roman citizens, literally "producers of offspring" *(proles)*; the first recognition of its status was traditionally ascribed to Servius Tullius. Its power resided exclusively in the rights its members enjoyed as Roman citizens. In some periods of Roman history it played an important role, not as an independent force but as a mass following, in the political struggles between the Roman patricians and the wealthy plebeians. Since it had little opportunity for productive work, which was performed in the main by slaves, its existence was largely parasitic on the Roman economy. On occasions it was quieted by doles of bread from the state and diverted by spectacles.

Marxian Socialist Theory. — The proletariat, in the restricted usage adopted by Karl Marx *(q.v.),* designates the class of wage workers engaged in industrial production whose chief source of income is derived from the sale of their labour power. As an economic category it is distinguished in' Marxian literature from the poor, the working classes and the *Lumpenproletariat.* Because of its subordinate position in a capitalist society and the effects of periodic depressions on wages and employment, the proletariat is described by Marxians as usually living in poverty. But it is not therefore identified with the poor, for some members of the proletariat, the highly skilled or labour aristocracy, are recognized as not poor, and some members of the entrepreneurial class as not wealthy. Despite synonymous use in agitational literature. the term proletariat is distinguished from the working class as a generic term. The former refers to those engaged in industrial production, the latter to all who must work for their living and receive wages or salary, including agricultural labourers, white-collar workers and hired help occupied in the distribution services. The *Lumpenproletariat* consists of marginal and unemployable workers of debased or irregular habits and also includes paupers, beggars and criminals.

The proletariat in this sense appeared comparatively late on the historical scene. Its existence is essentially bound up. according to Marxian analysis, with the development of modern capitalism. Many causes have been assigned for the emergence of the proletariat, the chief of which is the expropriation of the peasants from their individual holdings by the statutory enclosure of commons land, forced sales and bankruptcies, thus compelling them to drift to the cities where they could find a market for their power to work. The proletariat was therefore considered as an urban phenomenon whose size was vastly extended by the Industrial Revolution. Among the contributory factors of the process of proletarianization have been cited the breakup of the medieval guilds, the dispersion of the monasteries, the liberation of the serfs and large increases in the population relative to the possibilities of employment in traditional vocations. The incidence of these factors on the rise of the proletariat varied from country to country.

Capitalist Class as Creator and Enemy of Proletariat.— According to the Marxian analysis, the existence of the proletariat as a definite class presupposes the existence of the capitalist class. Where the capitalist class disappears or becomes subordinate in the control of production to other social groups that abrogate the free market, there is no longer a proletariat. This conclusion, together with the prediction that in the course of its evolution capitalist society necessarily becomes polarized into two classes. was questioned in the light of 20th-century developments in Germany, the U.S.S.R. and the United States. The assumption that in time the proletariat would constitute the overwhelming majority of the population was also challenged on the ground that increasing mechanization and rationalization of production led to a relative decline in the number of unskilled, manual workers and an increase in the numbers of those engaged in managerial functions and distribution services.

More significant in Marxian theory than its meaning as a strictly economic category is the social-psychological conception of the proletariat. Slowly educated by their hardships and their struggles for better conditions and wages, the workers are believed to become conscious of the objective antagonisms that divide them as a class from their employers. The first stage in their awareness is usually marked by the organization of trade unions within the existing framework of society. The second is their acceptance of doctrines which teach either that they cannot permanently improve their human existence in a commodity-producing society because unemployment, crisis and war are endemic to its operation, or that a more just and efficient organization of social relations is possible which would increase their material welfare and remove invidious social distinctions. The third stage is reached in the development of political parties which take on the designation of labour or socialist parties whose ultimate program is directed not to the improvement of the individual lot of the worker or to facilitating social mobility from class to class, but to the reconstruction of the whole society which, in abolishing all traditional economic classes, would abolish the proletariat as a class.

Further, by setting up a common faith and objects of ideal allegiance, Marxians seek to unify the diverse ethnic, religious and national differences among the proletariat and to reinforce the sense of solidarity which is presumably born out of consciousness of common material interests. In respect to this function of proletarian ideology, it should be observed that it enjoyed some limited success in overriding ethnic and religious differences among the members of the proletariat, but failed almost completely in transcending consciousness of national differences. In times of national conflict, the proletariat behaved no differently from the *bourgeoisie* of their respective countries.

Marxians seek organizational support for their ideology primarily, but not exclusively, among industrial workers for two reasons. The first is the assumption that whereas the economic grievances of all other working groups, such as the farmers, intellectuals and lower middle classes, can be removed without fundamental social change, the position of the industrial worker is so tied up with the exigencies of capitalist production that he cannot be liberated except by transformation of capitalism itself. The second is the expectation that, in the event of a struggle for power, the industrial workers will be most strategically situated in determining the issue—an expectation also called in question by the development of modern industrial and military technology.

Communist Party the Self-Designated "Vanguard of the Proletarian."—The appeals of proletarian ideologies nevertheless have been addressed to the community at large, to all men of "insight" and "good will," couched in moral terms which try to invoke the ideals of justice, humanity and human freedom Many elements in the population are won to adherence to proletarian causes whose social antecedents are by no means proletarian. It has been widely observed that many outstanding political leaders of working-class parties in all countries have been drawn from other classes. And since most inspirers of proletarian ideologies have rarely been members of the working class, it has been inferred that the working class, left to itself, is not likely to develop beyond the level of trade unionism The universalism implicit in the premises of proletarian ideologies led their carriers to proclaim that they represented the best understood interests not only of one class in the community, but of the masses of people. In this way the voice of moral prophecy acts to give force and persuasive effect to the analysis of historical destiny. The result, sometimes concealed, sometimes acknowledged, is a broadening of the meaning of proletariat from a term designating a narrow economic class to a term that loosely encompasses all who support the ideology of the class, and ultimately to the masses who are presumed to enjoy its future benefits.

The various ambiguities in the meaning of the term proletariat come to a head in the phrase "the dictatorship of the proletariat." As Marx used it, it denotes the political rule of the proletariat, through representative organs, during a transitional period from capitalism to socialism. It is a dictatorship in that political power is used to abolish the social relations of production which create profit and rent. Since Marx assumed that the proletariat would constitute the overwhelming majority of the population as the polar class to the *bourgeoisie,* the dictatorship of the proletariat was conceived as a form of workers' democracy. It was not conceived as a dictatorship of the minority or of a political party, but of a social class, and emphatically not the dictatorship of a political party over the proletariat. This is evidenced not only by the language of the *Communist Manifesto,* but also by F. Engels' public reference to the Paris Commune as an illustration of a proletarian dictatorship.

After the Russian October Revolution of 1917 the meaning of "the dictatorship of the proletariat" changed. Lenin, Trotsky and Stalin declared that it represented substantially the dictatorship of a minority political party. This party consists of the self-denominated vanguard of the proletariat, although its members need not be proletarian in origin. It speaks and acts for the whole of the proletariat and ultimately for the whole working class. The latter, however, cannot freely accept or reject its leadership since no rights of opposition to the ruling party are recognized. To add to this shift in meaning, it should be observed that although the U S.S.R. was officially proclaimed to be a socialist society without any classes, it continued to be characterized as a dictatorship of the proletariat. Under such circumstances the term proletariat is emptied of differentiating content and functions more as a sloganizing device than as a precise designation of a social or economic group. Because of these ambiguities, the term must always be interpreted in relation to the specific historical situation and the concrete social context in which it is employed. *See* BOLSHEVIKS; COMMUNISM; COMMUNIST PARTY; MARXISM; SOCIALISM.

BIBLIOGRAPHY.—K. Marx and F. Engels, *Manifest der Kommunistischen Partei* (1848); K. Marx, *Das Kapital,* vol. 1 (1867; Eng trans., 1887); W. Sombart, *Der Moderne Kapitalismus* (1916), *Der Proletarische Sozialismus* (1924); N. Lenin, *State and Revolution* (1917; Eng. trans., 1932); J. Stalin, *Leninism* (1926; Eng. trans.. 1928); G. Briefs, *The Proletariat* (1937). (S. HK.; X.)

PROLOGUE, a prefatory piece of writing, usually composed to introduce a drama. The Greek *prologos* included the modern meaning, but was of wider significance, embracing any kind of preface. In Greek drama, a character, often a deity, stood forward or appeared from a machine before the action of the play began, and made from the empty stage such statements as it was necessary that the audience should hear. It was the custom to explain everything that had led up to the play, the latter being itself, as a rule, merely the catastrophe following on the facts related in the prologue. The importance, therefore, of the prologue in Greek drama was very great. With Euripides, as has been said. it takes the place of "an explanatory first act." On the Latin stage the prologue was often more elaborately written than in Athens, and in the careful composition of the poems which Plautus prefixes to his plays we see what importance he gave to it; sometimes, as in the preface to the *Rudens,* Plautus rises to the height of his genius. Molière revived the Plautine prologue in the introduction to his Amphitryon; Racine introduced Piety as the speaker of a prologue to Esther. The tradition of the ancients vividly affected the early English dramatists. Not only were the mystery plays and miracles of the middle ages begun by a homily, but when the modern drama was inaugurated the prologue came with it, directly adapted from the ancient practice. Thomas Sackville prepared a sort of prologue in dumb show for his Gorboduc of 1562; and he also wrote a famous Induction (practically a prologue) to a miscellany of short romantic epics by diverse hands. In the Elizabethan drama the prologue was very far from being universally employed. In the plays of Shakespeare it is rare. After the Restoration, prologues became obligatory. They were always written in rhymed verse, and were generally spoken by a principal actor or actress. See also EPILOGUE.

(E. G.; E. E. K.; G.W.A.)

PROME, a district in the Pegu division of lower Burma, with an area of 2,938 sq.mi. and a pop. (1941) of 436,714. It occupies the valley of the Irrawaddy, between Thayetmyo district on the north and Henzada and Tharrawaddy districts on the south. There are two mountain ranges. The Arakan Yoma extends along the western side. The portion of the district on the right bank of the Irrawaddy is broken up by thickly wooded spurs running southeastward. Cultivation is confined to the parts adjacent to the river. On the eastern side lies the Pegu Yoma, and north and northeast of the district its forest-covered spurs form numerous valleys and ravines, the torrents from which unite in one large stream, the Na-win. The staple crop is rice, but cotton and tobacco are grown, while the custard apples are famous. The forests yield teak and cutch.

The early history of Prome is veiled in obscurity. After the conquest of Pegu in 1758 by Alompra, the founder of the last dynasty of Ava kings, Prome remained a portion of the Burman kingdom till the close of the second Burmese war in 1853, when the province of Pegu was annexed to British territory. Prome, the chief town, is on the Irrawaddy, 161 mi. N. of Rangoon, pop. (1953) 36,997.

PROMETHEUS, in Greek mythology son of the Titan Iapetus by the sea nymph Clymene or by Themis (occasionally other parents are named). He was the friend and benefactor of mankind. He defended men against Zeus, who, according to a widely diffused mythical theory, desired either to destroy the human race and supplant it by a new and better species, or to avenge himself because men had got the better of him. The pedigree and early exploits of Prometheus are given by Hesiod.

At a meeting of gods and men at Mecone, it was the business of the assembly to decide what portions of slain animals the gods should receive in sacrifice. On one side Prometheus arranged the best parts of the ox covered with offal, on the other the bones covered with fat, as the meat was covered in Homeric sacrifices. Zeus, invited to make his choice, chose the fat and found only bones beneath. A similar fable of an original choice, in which the chooser is beguiled by appearance, recurs in Africa and North America. Zeus, enraged at this trick, according to Hesiod, or, according to other versions, desirous of exterminating the few people who had escaped the deluge of Deucalion, either never bestowed the gift of fire or later withdrew it. Prometheus stole fire, concealed in a hollow fennel stalk (Hesiod, Works *and Days)*; and a fennel stalk is still used in the Greek islands as a means of carrying a light (*cf.* Pliny, *Nat. Hist.*, xiii, 126). According to some legends, he gained the fire by holding a rod close to the sun. Probably the hollow fennel stalk in which fire was carried got its place in myth from the fact of its common use. Prometheus is thus found in the position of the fire bringer, or fire stealer, and so connected with a wide cycle of similar mythical benefactors, divine, human or bestial, among various peoples.

In considering the whole question of fire mythology, one must beware of the hasty analogical method of reasoning t~~ common among mythologists. For example, when a bird is spoken of as the fire bringer, we need not necessarily conclude that, in each case, the bird means lightning. Again, because a hero is said to have stolen or brought fire, we need not regard that hero as the personification of fire nor explain all his myth as a fire myth. The legend of Prometheus has too often been treated in this fashion, though he is really a culture hero, of whose exploits, such as making men of clay, fire stealing is no more than a single example. Prometheus and Hephaestus (*q.v.*) are frequently brought into contact, generally as opponents; in some forms of the legend, Prometheus steals fire from Hephaestus' workshop, not from heaven. It is quite possible that Prometheus was an old and genuinely Greek deity, whose province included fire and its earlier industrial applications, but that he was later superseded by the popular oriental deity. If such were the case, it must have been very early, before either Homer or Hesiod wrote, probably not long after the first coming of the Achaeans to Greece. (A. L.; H. J. R.)

PROMETHIUM (symbol Pm, atomic number 61), is often referred to as the missing member of the rare earth series. Considerations, based on the Mosley diagrams and modern theories of atomic structure, indicate that an element should exist with this atomic number, having the properties of the trivalent rare earths. Numerous claims have been made concerning its existence based on new lines observed in the arc spectra of rare earth concentrates or on X-ray lines observed in connection with these concentrates. In 1926 B. S. Hopkins. J. A. Harris and L. F. Yntema were the first definitely to claim the discovery and concentration of this element and offered considerable evidence in support of their claims, based on the arc spectra, the absorption spectra in solution and the X-ray emission spectra. They named the element illinium after the University of Illinois where the work was performed. In the same year J. M. Cork, C. James and H. C. Fogg claimed its independent discovery and measured its X-ray spectra. L. Rolla and L. Fernandez claimed priority in this discovery and named the element florentium. This element is definitely known to occur among the fission products of plutonium, thorium and uranium and considerable quantities (grams) are known to exist in the residues from the atomic chain reacting piles built during World War II. In 1947 J. A. Marinsky, L. E. Glendenin and C. E. Coryell first isolated element 61 from atomic reactor residues. Later it was claimed that the absorption spectra and arc spectra of element 61 isolated from the uranium chain reactions are different from the spectra of that element as claimed by Hopkins. As a result of these claims, the International Union of Chemistry accepted the name promethium for this element, as suggested by Glendenin and Marinsky, instead of illinium as suggested by Hopkins. Controversy continued as to whether nonradioactive element 61 existed. Evidence indicated that if it did exist naturally it must be present in nature in very minute quantities. (See RARE EARTHS.) (F. H. SP.)

PROMISSORY NOTE: see BILL OF EXCHANGE.

PRONGHORN or PRONGBUCK, the sole existing representative of a family (Antilocapridae), intermediate between deer and cattle; the forked horns resemble those of the latter group, but are annually shed and renewed. Standing about 3 ft. high at the shoulder, the male pronghorn has the black horns rising vertically above the eyes. The colour is bright sandy fawn, with much white on the face, three white bars on the throat and white under parts and buttocks. The long white hair on the buttocks can be erected and expanded into bunches, these being guides to the herd when in flight. The tail is short. Female pronghorns produce one or two young at a birth, and are either hornless or furnished with more or less rudimentary horns. Pronghorns (*Antilocapra americana*) are among the swiftest running mammals. They inhabit the open plains of the temperate districts of western North America, where they were formerly abundant.

PRONUNCIATION. By means of his organs of speech man has at his disposal, for the purpose of speech, certain devices. He can make a great variety of sounds and, subject to the limitations imposed by the physical structure of his speech apparatus, he is able to modify these sounds in certain ways: (1) he can modify the length of time during which a sound persists; (2) he can modify the degree of physical energy devoted to the production of a sound; (3) he can, in the case of sounds that involve a periodic vibration of the vocal cords, regulate the periodicity of this vibration so as to produce varieties of pitch. These modifications of length, stress and pitch may serve different purposes, or may be used in various combinations.

Nature.—The spoken variety of a language consists of a certain number of sounds, influenced by the three modifications outlined above. These features, in the case of any given spoken language, constitute what may be termed the acoustic matter of the language, and the reproduction of these acoustic features by a speaker is what is known as a pronunciation of the language. The term "pronunciation" is used to denote the general acoustic features of a language; thus we speak of English pronunciation, or the pronunciation of Marathi. It is also used to denote the particular variety of acoustic phenomena used by an individual speaker, or by a particular section of a community; thus we may speak of disliking a man's pronunciation, or of liking the pronunciation of a certain district or social class.

Analysis of Pronunciation. — Detailed analysis of the pronunciation of individual speakers is the foundation of knowledge of the pronunciation of languages and dialects, and those whose business it is to carry out such analysis should so train themselves that they can give reliable and accurate information upon all the aspects outlined above. Sounds must be described in detail, and the modifications, their function and distribution must be noted. Such detailed description of pronunciation is necessary for:

(1) The study and teaching of the mother tongue, and of foreign languages.

(2) The devising of scientific systems of orthography for hitherto unrecorded languages.

(3) Comparative philological work.

(4) Pronouncing dictionaries.

Pronunciation and Language. — A spoken language persists as a language so long, and only so long, as those who speak it pronounce it in such a way as to be readily intelligible among themselves throughout the area in which the language is spoken. Local variants, or fashions of pronouncing, arise in proportion to the extent of the territory over which the language is spread, but so long as those who use these local variants are conscious that they are in the main using the same language, and provided that they continue to use the written language common to the rest of their compatriots, their speech will be regarded as a variant, a dialect, of the main language.

If, for political or other reasons, any one group of dialect speakers desires a linguistic tradition of its own, and proposes to make a new written form of its pronunciation, embodying a new and local vocabulary, then the seed of a new language is sown. In the past, whenever a language has, through the political expansion of a nation, spread over an area larger than that which gave it birth, disintegration has set in, beginning with divergence of pronunciation, ending with the establishment of new languages. Thus Sanskrit has given birth to the Aryan languages of India—Hindi, Bengali, Marathi, Gujarati, etc.; Latin has given us Italian, Spanish, French, Portuguese and Rumanian.

Pronunciation and Nationality. — Speech habits, among which must be included habits of pronunciation, differ from language to language. There is, however, a certain measure of similarity between the pronunciation of the various languages of a language family; and the language families of the world differ among themselves as considerably in the matter of pronunciation as in any other respect. The clicks of the Hottentot Bushman languages are found only in certain of the Bantu languages. The cerebral consonants of the Aryan and Dravidian languages of India are seldom found in other language families. When a language takes over words from another language and embodies what are called foreign words, the pronunciation of such words will be made to fit in with the general scheme of pronunciation of the borrowing language. French words taken into English will receive English sounds, English rhythm, English stress and English intonation. The very considerable Arabic element in Persian is pronounced in the Persian way, for the pronunciation system of Persian has nothing in common with that of Arabic. So European words are squeezed into Japanese moulds.

It very seldom happens that a language will adopt exotic sounds, or embody in its system sounds other than those which are its linguistic heritage. Instances of this, however, do happen. The cerebral consonants of the Indo-Aryan languages, which are uncommon in the rest of the world, are presumed to have been taken over from the Dravidians. The Arabic 4 is preserved in educated Urdu, but in southern Urdu colloquial is replaced by χ (the sound of "ch" in "loch"), and in Persian, except in the case of speakers who are influenced by a knowledge of Arabic, it is generally replaced by ǥ (the sound of Arabic غ).

Representation of Pronunciation. — Among a civilized community, language consists of two forms—a series of sounds, and a series of visual symbols, or letters, representing sounds. This method of making a visual language is known as a phonetic method of writing, and the system of symbols used is known as an alphabet.

On the other hand the visual language may be made without any apparent reference to the pronunciation of the oral language. Such a system is known as an ideographic system.

Most of the languages of the world have a phonetic visual form, the important exception being Chinese. The most widely used alphabets are the Roman, the Arabic and the Indian, each with certain additions and modifications. The Arabic alphabet, for instance, is made to represent such widely diverse phonetic systems as those of Arabic, Malay, Hausa, Persian, Urdu and, until recently, Turkish.

So it has come about that alphabets, designed to represent the pronunciation of specific languages spoken many centuries ago, have spread over the modern world and are used to express the pronunciation of many languages that have nothing in common with the pronunciation systems for which they were designed.

Since, as has been said, sight and sound are irreconcilable, it follows that any attempt to represent by means of visual symbols things that have no visual existence will be at best but partially successful, and will rest upon a variety of conventions. Each symbol will originally do duty for one "sound"; various devices may be employed to indicate the relative length of sounds, if it is felt desirable to denote this feature of the pronunciation; the position of what is known as the stress or accent may, or may not, be marked; it may be evident from other data. The intonation is not as a rule indicated, but there are certain devices, such as punctuation marks, interrogation and exclamation marks, and the use of a form of type differing from the rest, which are conventionally associated with certain features of the intonation.

The phonetic medium, although evidently the most expedient, is a clumsy one for the general purpose of representing language, but it is the only one for representing pronunciation. The world's great alphabets are, as is seen, in reality obsolete, because each was designed to represent the pronunciation of one language many centuries ago. When extended to other languages they have proved either inadequate or redundant. The Roman alphabet, suitable for a language such as Latin with its simple system of five vowel sounds, is completely inadequate for English with its twelve vowel sounds. The Arabic alphabet, designed for the peculiar word formation of Arabic, with its scanty vowels and abundant consonants, is inadequate for the Persian vowel system, and redundant for the Persian consonant system. Similarly the Devanagari alphabet proves inadequate to represent the pronunciation of the modern Indian vernaculars.

When, for various reasons, the visual language is a poor representation of the existing state of the pronunciation of a language, the language is commonly said to be unphonetic. This means that there is an absence of regularity in the conventional relationship between sound and symbol, which may be due to the unsuitability of the alphabet, or to the fact that the visual language, having become established in popular use at some distant period, has refused to register the phonetic changes that have taken place since. Attempts to readjust the relationship between spelling and pronunciation are usually vigorously resisted in all languages, there being a universal desire, apparently, to see in the historical form of the visual language something either sacred, as in the case of Arabic, or etymologically valuable, as in the case of English. In some parts of the English-speaking world tentative attempts at this readjustment, which is known as spelling reform, are being made.

Where, as in the case of many African languages, no traditional visual languages exist, systems of writing, usually with the Roman alphabet, less frequently with the Arabic alphabet, have been designed; but there again the inadequacy of the alphabets has proved a serious obstacle. The sound systems of the great African language families have nothing in common with the sound systems of Europe, and little in common with one another. It is interesting to note that there a special alphabet has been designed, based largely on the Roman, suitable for the representation of the pronunciation of the principal African languages.

To remedy the deficiency of traditional alphabets, many more detailed and adequate visual systems have been designed for the representation of pronunciation. These are of four classes:

(1) Based on no existing visual forms; *e.g.,* the Bell-Sweet system.
(2) Based on a code; *e.g.,* Jespersen's Analphabetic system.
(3) Based on existing Roman letters with abundant diacritical marks; *e.g.,* the Lepsius alphabet.
(4) Based on existing Roman signs, but using new letters instead of diacritical marks; *e.g.,* the International Phonetic Association alphabet.

One or other of these systems must be used when it is desired to describe a pronunciation in detail, as in pronouncing dictionaries, descriptions of languages, and in comparative philological works.

Phonetically there is little to choose between these systems, but recent investigation into their comparative merits would appear, upon psychological, pedagogical and typographical evidence, to favour alphabets of the fourth class.

Influence of Spelling upon Pronunciation. — There is observed, in the case of highly civilized and educated communities, where the majority of the speakers are familiar with the visual language, a very marked influence exerted by the visual language upon the pronunciation. The visual language, which was originally designed to represent the pronunciation and to be subservient to it, tends to become the criterion of accuracy and to dominate the pronunciation.

As familiarity with the visual language increases, so a new standard of accuracy in pronunciation arises, namely, the printed word. This is very evident from a consideration of the pronunciation of English place names. Historical pronunciations are being abandoned in favour of pronunciations more in keeping with the visual forms which became familiar only with the advent of postal and railway communication. Daventry is now pronounced as written, though a local pronunciation, Daintry, existed for centuries. It is interesting to record these old pronunciations, but it is doubtful whether they can now be restored to general use. If Daintry is to be admitted at the expense of Daventry, then "ain't" must be given preference to "haven't," for the principle that governs the disappearance of the medial "v" is the same in both cases. The influence of the visual upon the spoken language is likely to be a prominent feature in determining the future pronunciation of language.

Standards of Pronunciation. — The impression that one form of pronunciation is better than all others appears to be common in the languages of most civilized communities; it is found even in the case of those African languages that have never been written. The prestige of this form of pronunciation varies from language to language, and the degree of adverse criticism levelled at those who do not use it varies from country to country. It is by no means certain that there is now, or that there has ever been at any time in any language, with the possible exception of classical Arabic, what is popularly called a standard pronunciation; but it is quite evident that the desire for such a criterion is widespread.

The greater the territorial extent of the nation, the greater will be the number of metropolitan centres; the more organized and complex the social life, the greater will be the number of social classes, each with its own conventions of pronunciation. Where, as in the case of English, separate nationalities, at different ends of the earth, speak the same language, there will tend to grow up in each centre of national life a different ideal as to what is considered the most desirable pronunciation. There is no more evident manifestation of national entity than a national language, and a new national language will begin when any one of the national groups of the English-speaking world desires to establish a national standard of pronunciation at variance with that in vogue in the geographical area where the language was born. History tends to teach that disintegration was inevitable in the conditions that prevailed in the past; it may be checked by increased oral communication, increased intermingling of population, but most of all by the definite teaching throughout the area of one form of pronunciation. This teaching has preserved the entity of classical Arabic; it has not prevented the disintegration of the Arabic into the various colloquial pronunciations that prevail in the different parts of the Arabic-speaking world.

In England there are local variants and class variants of pronunciation. The higher we ascend the social scale in all districts, the greater the uniformity in the pronunciation. The uniformity of the educational system — public school and university — of certain social classes leads to a uniformity in the pronunciation of those classes. This type, provided it is free from pedantry and affectation, is generally regarded as the nearest approach to a standard pronunciation of southern English. It is the style of pronunciation heard most often in public speech, in parliament, in the church, in the law courts, in the universities and the public schools, and in such of the state schools as recruit their teaching staff from the ranks of those who use this style of pronunciation. In detail it may differ slightly from county to county, from school to school, from speaker to speaker, but in the main it is recognizable as one pronunciation. Those who use it have approximately the same vowels; its rhythm is the same wherever it is heard; its intonation follows the same general principle; it uses the same means to achieve the effects of emphasis; and it is characterized, among other things, by a peculiar treatment of the "r" sound. In most of these respects southern pronunciation differs from what is known as northern pronunciation, and in all of them it differs from U.S. and Canadian pronunciations which have their own vowels, their own rhythm, their own intonations, their own distinctive treatment of the "r" sound, which reacts in no uncertain manner upon their vowel systems. The U.S. and Canada have their own pronunciation problems, for their enormous geographical extent is giving rise to local varieties and localized standards. There is no standard pronunciation of English in these countries, any more than there is in Great Britain. The increased use of intercontinental oral communication by means of telephone and wireless broadcasting, the interchange of teachers and actors, and the use of the speaking film, may tend toward a certain degree of uniformity in the pronunciation of the English-speaking world, but these must be supported by definite action on the part of those responsible in all countries for the teaching of the mother tongue. It is agreed that a uniform pronunciation of English is desirable, but it is by no means certain how it is to be brought about.

In 1926 the British Broadcasting corporation set up an advisory committee to deal with doubtful questions of English pronunciation, and to settle, in the case of (1) unfamiliar words, (2) words having alternative pronunciation of equal currency and authority, (3) foreign words, upon one pronunciation to be used by the official speakers of the corporation. The first list of this committee's recommendations was published in 1928.

Change of Pronunciation. — The study of language reveals an inability, on the part of pronunciation, to persist unchanged in any given place or community over a long period of time. The universal law is change; during their lifetime languages change slowly, imperceptibly, but nevertheless surely. It is not possible to assign any adequate reason for this universal and eternal change. It is possible that the change has its origin in man's physical and mental limitations. The link that holds the speech of one generation to that of the next is but a feeble one; speech persists as a series of recollected auditory images, associated with certain kinesthetic movements, which are however of secondary importance as far as the speaker is concerned. He is more concerned with the expression of his thought than with the physical adjustments by means of which his thought receives audible expression. This combined mental and physical process appears to produce upon the mind of the listener impressions of a fugitive character, which are less durable than the impressions created by the combined visual and physical processes involved in the visual language. Speech, as such, perishes instantaneously, having no permanent existence, being handed on by oral tradition, and suffering during the centuries like all else that lives only by word of mouth. So pronunciation changes from age to age. partly because it hangs on so fragile a thread as man's aural memory, and partly because the unconscious physical processes that give rise to the sounds in themselves suffer modification owing to the lack of consciousness with which they are controlled.

"Pottage" and "porridge" are now different words. They are in reality but two pronunciations of the same word, and the curious story of their separate existence can still be learned by listening to the bus conductor who announces Swiss Cottage as Swiss "Corridge" It is probable that wider study will tend to establish the fact that a given speech sound, under given conditions, will always change in a certain way. But it must not be forgotten that it has hitherto proved impossible to define what is meant by the term "speech sound," and it should be remembered that the governing conditions are likely to prove more complicated than they appear upon examination of cases that have happened in the past. The principles governing the change in vowel sounds, the formation of which involves no tactile sensation in the mouth, appear to have nothing'in common with the principles governing the change of consonant sounds. in the formation of which there is definite contact between two parts of the mouth, or enough constriction to give an impression of contact.

Teaching of Pronunciation. — The study of the mother tongue, and of foreign languages, if it is to be sound. must rest upon a knowledge of pronunciation, which lies at the root of things so widely apart as sentence structure, syntax, rhythm and systems of versification.

The teaching of pronunciation requires, on the part of the teacher, training of a highly specialized order. and it should not be considered that a teacher is competent to teach the pronunciation of a language merely because that language happens to be his mother tongue. We are all, without special training, unaware of the various features that constitute the pronunciation of our language; we become conscious that there is a highly complicated system underlying our pronunciation only when we hear the system disturbed by foreigners who speak our language badly; *i.e.,* with the pronunciation system of their own.

The pronunciation of most European languages has been studied on modern phonetic lines, and there is an abundance of reliable literature on the subject. Research into the phonetic structure of American, Asiatic and African languages is proceeding, and reference libraries of gramophone records of languages and dialects are being established in many universities.

Pronunciation of the mother tongue is taught in the principal centres of education in the countries of Europe and America. It has already been stated that the traditional pronunciation of Arabic, reputed to have been that used by Mohammed, is still regularly taught throughout the Mohammedan world.

In Europe there is, in the case of French, a traditional stage pronunciation taught at the Conservatoire in Paris, and used in the state theatres and opera house. In Germany an attempt has been made to standardize a form of German pronunciation suitable for the theatre throughout German-speaking countries.

No such attempt at standardization has been made in England or America. As far as England is concerned, the pronunciation current upon the stage is that used by the educated people in the southeastern part of the country.

This pronunciation, with, however, a certain degree of latitude, is taught in England for use on the stage, in public speaking, and in singing. In the universities and public schools of England the pronunciation is left to look after itself, but there is a strong tradition as to what is and what is not permissible.

In the state schools there appears to be an awakening to the importance of equipping children with a form of pronunciation that will not prove a handicap in social life; and endeavours are being made to provide instruction.

Conclusion. — It is difficult to forecast the future, for we are faced with a new set of conditions. Increased speed of transport has made the world smaller; the complication of modern life leads to an international vocabulary; increased travel and increased oral communication familiarize us with hitherto unfamiliar pronunciations; the increase of education familiarizes millions with visual language, while wireless broadcasting tends to make the inhabitants of a widely spread linguistic area acquainted with a selected form of pronubciation. It is possible that these combined forces may tend to prevent linguistic disintegration of the principal languages of the modern world. (A LL.-J.)

PROOFREADING, the process of correcting for the press printed proofs of articles, books or other matter before publication. That the proofreader's profession goes back to the early days of printing is proved by reference to a corrector of the press in a book printed by R. Pynson in 1530 (the word proofreader seems originally U S.). A Pynson contract of 1499 also held the author finally responsible for correction of proofs In modern practice proofs are made first in galley (usually three or four pages unbroken on a long sheet). the first rough proof usually being corrected by the printer before being sent to the publisher and ultimately to the author. Page proofs and galley proofs frequently bear queries that show the proofreader's skill involves not only seeing that there is an exact correspondence between the copy given to the printer and its printed form, but also the catching of errors of fact. Lawsuits between printers and authors, and lists of errata. author's apologies and complaints at not seeing proof in printed books were common through the 15th. 16th, 17th and 18th centuries and are not unknown in modern publication.

Marks commonly used in proofreading follow:

	Delete	em |	Em dash
	Delete and close up	en |	En dash
	Reverse	; |	Insert semicolon
	Close up		Insert colon and en quad
#	Insert space		Insert period and en quad
¶	Paragraph	? |	Insert interrogation point
	Indent one em		Query to author
	Move to left		Use ligature
	Move to right		Spell out
	Lower	tr	Transpose
	Elevate	wf	Wrong font
	Insert marginal addition	bf	Set in **boldface** type
	Even space	rom	Set in roman type
	Broken letter	ital	Set in *italic* type
	Push down space	caps	Set in CAPITALS
	Straighten line	sc	Set in SMALL CAPITALS
	Align type	lc	Set in lower case
	Insert comma		Lower-case letter
	Insert apostrophe	stet	Let it stand
	Insert quotes	no ¶	Run in same paragraph
= |	Hyphen	ld	Insert lead between lines

BIBLIOGRAPHY.—Percy Simpson, *Proof-reading in the Sixteenth, Seventeenth, and Eighteenth Centuries,* Oxiord Books on Bibliography, vol. 1 (1935). R. A. Hewitt, *Style for Print and Proof-correcting* (1957), a practical guide. Other guides include: Oxford University Press, *Rules for Compositors and Readers,* 36th ed. (1952); F. H. Collins, *Authors' and Printers' Dictionary,* 10th ed. (1956); British Standards Institution, *Leaflet* 1219 (1958); University of Chicago Press, *Manual oj Style,* 11th ed. (1949); U.S. Government Printing Office, *Style Manual,* rev. ed. (1959).

PROOF SPIRIT. The term is applied to standard mixtures of ethyl alcohol and water which form the basis of customs and excise duties in Britain, U.S. and elsewhere. A distilled liquor was originally defined as proof spirit if, when poured over gunpowder and lighted, it would burn and finally ignite the .powder. If the alcohol content is less than 49.3% by weight, the water left after the burning of the alcohol is sufficient to prevent ignition of the powder.

In the United States proof spirit is held to be that alcoholic liquor which contains one half its volume of alcohol of a specific gravity of 0.7939 at 60° F., referred to water at 60° F. as unity (*Gauging Manual*, U.S. treasury department). Proof spirit has, at 60° F., a specific gravity of 0.93426 *(in vacuo)* 100 parts by volume of the same consisting of 50 parts of absolute alcohol and 53.73 parts of water. The difference of the sum of the parts of alcohol and water and the resulting 100 parts of proof spirit is caused by the contraction which takes place when alcohol and water are mixed. The specially designed hydrometers used in determining the alcoholic strength of aqueous solutions are so graduated as to indicate the number of parts by volume of proof spirit equivalent to 100 parts of liquor at the standard temperature of 60° F.; and they read 0 for water, 100 for proof spirit and 200 for absolute alcohol.

In Great Britain the Spirits act of 1816, legalizing Sikes' hydrometer for revenue purposes. gave for the first time a legal definition of proof spirit as follows: "that which at the temperature of 51° F. weighs exactly ++ of an equal measure of distilled water." Unfortunately, the act did not specify the water temperature thereby giving rise to considerable controversy. Subsequently, documentary evidence was produced which established that the temperature of the water was intended to be 51° F. Later investigation established the fact that at 60° F. proof spirit has a specific gravity of 0.91976, compared with water at the same temperature. and that it contains 49.28% by weight or 57.10% by volume of ethyl alcohol.

Spirits at strengths other than proof may be described as containing a percentage of proof spirit or as being overproof or underproof. The percentage of proof spirit is that number of volumes of proof spirit which can be obtained from 100 volumes of the mixture. Thus at 50° F., 100 volumes of absolute alcohol if diluted with water to proof strength give 175.35 volumes. It is therefore said to contain 175.35% proof spirit or to have a strength of 75.35% overproof.

In the Dutch system, proof spirit contains 50% of anhydrous alcohol at 15° C. (59° F.). (D. G. Z.)

PROPAGANDA is the making of deliberately one-sided statements to a mass audience. It is an act of advocacy in mass communication. Although the fact of propaganda is old, the term is comparatively modern. Usage was affected when the organization set up in 1622 by the Roman Catholic Church to carry on foreign missionary propaganda was called the College for the Propagation of the Faith.

In order to reach the mass audience, propagandists rely upon every medium of communication—oral, printed, pictorial, plastic, musical or dramatic. Every new channel is promptly laid hold of When the art of printing from movable type appeared in Europe, the printed word began at once to overtake oral media as the preferred means of persuasion. In the 20th century the motion picture, radio and television helped restore the spoken word to its former eminent position.

Communication effects are sometimes obtained with the aid of physical devices which are not usually employed for the purpose. The act of killing is no ordinary method of communication, yet killing is spoken of as "propaganda of the deed" when political assassinations are carried out as a means of affecting attitudes. Since any act of policy may influence mass opinion regardless of the means employed, an important part of total policy is the calculating and managing of psychological impacts. The most comprehensive term is "propaganda" or "communication" policy. When directed against an enemy in wartime, this is "psychological" or "propaganda" warfare.

Propaganda as an act of advocacy is distinguished from such closely allied uses of communication as instruction. information and inquiry. It is advocacy to editorialize or to select the content of channels of communication for the purpose of influencing attitudes on controversial issues. When the government distributes a pamphlet on the care and feeding of babies, the act is informative and instructive, not propagandistic, unless there is doubt about the authenticity of what is said. or the desirability of babies is in debate It is inquiry, not propaganda, to analyze controversial doctrines for the sake of sharing enlightenment. Private arguments among intimates are not spoken of as propaganda unless they are part of a campaign to spread controversial viewpoints, which indeed they often are. The mass audience with which the propagandist is ultimately concerned is not only characterized by size, but by the relative impersonality and shallowness of the tie that exists between the communicator and his audience.

Determiners **of** Propaganda.—The study, as well as the practice, of propaganda has a long history. The use of mass means of communication for military purposes was advised in *The* Book of *War* in the 5th century B.C. Sun-tzu wrote that "In night fighting beacons and drums are largely used; in day fighting, a great number of banners and flags, and the enemy's eyes and ears are confounded." In the East Indian classic of statecraft, Kautilya's *Arthaśāstra,* it is noted that "Astrologers and other followers of the king should infuse spirit into the army by pointing out the impregnable nature of the array of his army." Secret agents should circulate among the enemy, spreading rumours of their certain defeat.

From Graeco-Roman times are inherited manuals on how to win an argument and even how to win an election. The literature of propaganda has manuals on converting the heathen, indoctrinating the young, instigating subversion, preventing subversion, obtaining gifts and making sales. Indeed, there are few purposes for which there is no book of know-how.

Despite these practical guidebooks, it was only in comparatively modern times that scholars and scientists began to assess the place of mass persuasion in the social process. Many incentives for propaganda activity are known. Leaders of political and social revolutions often see that they can save soldiers and money by using symbols to induce obedience to a new regime. The foundation was laid for large and enduring empires when conquerors learned to convert rather than exterminate the conquered. The fifth-column technique of penetrating a state with political propaganda was probably the result of observing the successful missionary operations of the great proselyting religions of Buddhism, Zoroastrianism, Christianity and Mohammedanism.

Propaganda is a favoured instrument in the hands of political oppositionists, since it is both elusive and cheap. The unification of Germany, Italy, and of every modern state was preceded and accompanied by the fervent promotion of national sentiment, often by persecuted minorities. The propagandas of social revolution developed modern methods of persuasion to the highest pitch, working especially through party and auxiliary organizations.

Nonpolitical movements depend upon propaganda to induce hostile authorities to refrain from interfering with them. A movement is nonpolitical when it disclaims any intention of changing the institutions of power and favours rendering unto Caesar that which is Caesar's. All movements have consequences, however, which in some degree affect the internal and external balance of power, regardless of conscious purpose. The holders of power, sensing the degree to which all social processes are linked together, often persecute minority movements or try to manipulate them for political ends. Nevertheless, propaganda has sometimes been effective in staving off political intervention, especially when the propaganda appeal is made in the name of natural or divine law.

It is no surprise to discover that incentives to engage in propaganda decline when hopes are frustrated. Labour movements have gone through periods of revulsion against "mere talk" in favour of "strictly economic" methods or even terror.

Perhaps the greatest incentives for propaganda in the 20th century have been economic and connected with the growth of industrialism. Advertising fanned the spirit of speculation which fed the reservoirs of capital upon which the expansion of commerce and industry depended. Since the advantages of large-scale production could be realized by the successful stimulation of consumer demand, advertising trained hundreds of millions of buyers to change their tastes in clothes, interior decoration, personal adornment, cooking and amusement.

The use of mass persuasion was furthered by the spread of literacy and of education generally, and by the enormous growth of mass media. In free countries the media generate special interests of their own in propaganda, since controversy makes circulation and circulation boosts revenue from advertising.

The volume of propaganda is affected by whatever discredits the old or reduces the difficulty of acting in new ways. In the United States arose a "culture pattern of novelty," with great zest for the new gadgets turned off the assembly lines of industry. In order to reduce the difficulties connected with acquiring something new, simplified designs appear continually on the market. Consumer credit, liberal allowances on trade-ins and related practices are examples of ways invented to ease the path of the purchaser.

Of significance to propaganda is the sheer size and heterogeneity of a population. Even in totalitarian states a vast labour of internal persuasion is essential to overcome the bonds of attachment to the old. or the sentiments of fear, hatred and confusion at the prospect of a new way of life. In soviet Russia (after 1921) the full orchestra of poster, broadcast and lecture was mobilized in a series of gigantic campaigns on behalf of literacy. proper care of tractors and elementary habits of personal hygiene. Glacierlike resistance was thawed by the blowtorch of symbols supported by every other influence.

The most general conclusion about propaganda is that it increases whenever the equilibrium of society is threatened or upset, and decreases with the restoration of the imperilled equilibrium or with the emergence of a new level of adjustment. This hypothesis needs to be more specific in order to account for the use of propaganda, rather than coercion, when social equilibrium is endangered. In addition, the likelihood of propaganda is increased whenever there are traditional institutions of freedom, whether free government, free market, free education or free religious proselyting.

Summing up in another way, it can be said that during any given period the volume of propaganda activity depends upon such factors as: the intensity of the determination on the part of propagandists to introduce or to discourage new acts; the availability of mass media and the prevailing level of literacy and general education; the degree of discontent with the old and the difficulty of the new; the number of persons asked to perform or to refrain from performing a new act; and the depth of devotion to persuasion in place of coercion. Whatever arouses controversy is likely to foster propaganda until the incentives which sustain the use of mass persuasion are reduced and rival methods of social action are tried; or discontent is dissipated without result (that is, catharsis occurs); or a new positive adjustment is made in prevailing social practice.

Strategy. — The proper strategy of propaganda depends upon the over-all frame of policy and the circumstances which favour or stand in the way of success. The overriding aims of policy range from the comprehensive reconstruction of society to local and immediate matters, and from complete reliance upon persuasion to the ultimate elimination of propaganda.

When a comprehensive plan of social change is pursued by peaceful means, a major problem of strategic planning is whether to expedite success by making concessions of detail. At one time in China the Jesuits dressed like native scholars as a means of modifying the strangeness of the Christian mode of living. The pope decided to forego immediate advantages and put a stop to these practices. In the absence of unified command. Marxian Socialists split into many branches over the nature and timing of revisions. Leading revisionists softened or abandoned the doctrine of violent class struggle and entered electoral or cabinet coalitions.

A related question of strategy is how far to concentrate upon the teaching and preaching of doctrine. and hon far to go in using auxiliary appeals. Lenin insisted upon the necessity of propaganda, which he defined as indoctrination, and also of agitation, which meant the exploitation of concrete grievances. In foreign missionary work, auxiliary activities became standard means of providing an indirect approach to prospective converts. Buddhist missions always encourage charity, but it is reported that in China the translation of the Buddhist canon played a more important part than good works, since the translation aroused the curiosity of the scholar class. On a humbler level. it is known that it has long been established commercial practice to supplement the verbal appeal of advertising nith "giveaways" and prizes.

Sometimes the task of propaganda is to prepare the way for activities which, if fully disclosed in advance, mould unquestionably fail. Before the seizure of power in Germany, the National Socialist strategy was to prevent a combination of Socialists. Communists and conservatives which would have stalled their advance. Once the National Socialists were in power, the problem was transferred to the arena of world politics and became that of forestalling joint action by west and east while the country rearmed, occupied the Rhineland. absorbed Austria, partitioned Czechoslovakia and began war against Poland. After the break with Russia, the major strategic aim mas to pry apart east and west in order to escape from two-front war. Historians of the American propaganda of secession and independence from Britain, such as Evarts Greene, commented upon the skill of the leadership in carrying along many moderate persons who, though not desiring independence, had co-operated with the radicals to such an extent that they could not effectively withdraw.

The correlation of propaganda inside the frame of totalitarian policy involves many fundamental and, at first sight, paradoxical problems. One long-run objective of totalitarian policy is the substitution of ritual and ceremony for discussion and persuasion, hence of propaganda. A totalitarian state is a command state that swallows the whole society. The task of managing the media of communication under such conditions is to foster a world of fantasy wherein the hero at the top of the pyramid is the champion of all against the encircling forces of evil which, though powerful, cannot ultimately prevail. The propagandist does not use current happenings for news and comment, but for sermons and fables adorning the dogma is infallibly interpreted by the ruling machine. Since commands from above allow no answering criticism from beneath. healthy self-assertion is repressed or turned against the lower strata or the outside world. In such a garrison-police state leaders live in perpetual anxiety of losing control and require the reassuring balm of ritual adulation. All this is in vivid contrast to the operation of a free society which revels in the clash of news and views.

Tactics. — The tactical problems of the propagandist are to adapt the situation to the limits imposed by strategy. This implies that some policies, persons, groups and institutions must be presented in a favourable light, while others are put at a disadvantage. Appropriate audiences and channels must be chosen to obtain the desired effects. An organization capable of the degree of devotion and expertness called for by the objectives sought must be assembled. The choices open to the tactician are ultimately to disseminate. to withhold or to modify a statement; to use, omit or block a channel; to select or reject a person.

In deciding what to disseminate, the perspectives of the audience must be given careful consideration. These perspectives consist in conceptions of the self and in cherished demands and expectations. Perspectives can be conveniently classified according to culture, class, crisis and personality. Assume that the tactical problem is to induce as many surrenders as possible from among enemy soldiers and officers. The propagandist will take note if enemy culture has long inculcated the ideal of military honour. He will try to discover whether there are circumstances in which the enemy admits that it is honourable to give up. Let us suppose that the answer is "yes. nhen no military purpose can be served by resistance." and "when an authoritative procedure is laid down" for members of the armed forces. The propagandist therefore circulates statements to the effect that further resistance has no military sense. He will also provide an authoritative-appearing directive to be obeyed. For use among the Germans in World War II. a "safe conduct" pass was developed which was a surrender leaflet printed in an official shade of green ink, with parallel translations in three languages and signed by the supreme commander. The propaganda tactician took class differences into account by working out special ways of addressing officers and men on programs. It was also recognized that the youth of Germany had grown up in a crisis period in which their values and loyalties had been given special shape. Appeals were therefore aimed at different age levels in the German army. Personality differences were considered on the theory that the older army leaders were less ruthless types than the fanatical youth.

In deciding what to withhold, the perspectives of the audience continue to be crucially important to the tactician. In World War II it was generally understood that German audiences were wary of being "deceived once more" by Allied statesmen, and that they were on guard against propaganda. British and U.S. propagandists decided to take the long road of winning confidence through accurate reporting. The plan was to win the "battle of credibility" by adhering to the truth, especially by playing up statements which the audience could directly verify. As a result of studying what the audience of a totalitarian country could believe, true statements were often toned down, not to deceive, but to sound plausible. Military successes, weapon production, food supplies and quantities of equipment were sometimes understated in order to carry conviction.

In deciding whether to remain silent or to reply in response to an accusation, it is essential to bear in mind that the pattern of conduct deemed appropriate for an honourable man differs widely. In some upper class circles only statements by a class equal are taken with enough seriousness to warrant reply. Sometimes the honourable man is expected to display the utmost indignation in denying accusations. Elsewhere the badge of innocence is calmness. In many cases it is difficult to judge how much influence an adverse whispering campaign can have. When Pres. Woodrow Wilson mas the target of a campaign against his character, he declined to take any notice of it on the'ground that it was false and that all who knew him understood it was false. He thought that he would give more currency and dignity to the "smear" by replying in public than by keeping silent.

So far as facts are concerned, it is generally agreed that some facts cannot be successfully concealed from an audience. Hence it does less damage to release bad news promptly than to appear both unreliable and inefficient. Railroads learned to release news of accidents and air lines followed suit. Often there are facts which are extremely disagreeable to both sides if disclosed. In bitter controversies it is customary for propagandists to obtain from intelligence services material which can be used privately to intimidate an adversary from spreading material that stigmatizes one's own candidate or cause.

Innumerable devices are at the command of the working propagandist for nullifying statements. Thus a Russian spokesman remarked that the nazis had created a new category of war casualty, the "slightly killed." Wit, humour, calmness, the casting of doubt upon sources, the combining of favourable and unfavourable news, and the playing down of unfavourable statements are standard ways of modifying adverse references. Also there are ample means of inflating favourable statements by emphasis and elaboration.

A continuing tactical problem is how much to praise the self and to condemn rivals or enemies. Commercial competitors for the same large market usually refrain from attacking one another on the theory that doubt is cast upon the type as well as the brand of product. Unlike business propaganda, it is characteristic of political propaganda to present politics as a drama in which the forces of good and evil stand opposed to one another. Revolutionary or urgent reform movements commonly try to induce a sense of guilt among opponents and self-righteousness among adherents. This tactic may succeed in provoking conflicts of conscience, since agreed value standards are applied to the disadvantage of the old and the advantage of the new.

In selecting media the propagandist keeps in mind considerations similar to those which apply to the choice of statements. If the problem is to nin the support of the rich, powerful and wellborn, favourable mention in organs which they look down upon is no asset. If the aim is to win confidence among the masses, the task is to enlist the leaders and media which they trust.

In the choice of media time considerations are important, since if aims can be accomplished over long periods the more permanent media, such as scholarly books, magazines and schools, have a significant role. If the goals are short run, the tactician must adapt to the existing network and employ fast rather than slow media.

The audience of a going channel has selected itself on the basis of predispositions which cannot be disregarded. During World War II. U.S. broadcasters to Germany quickly learned that crisis audiences differ from other kinds. Clandestine listeners who had risked their lives to hear news and comment from the outside world were furious when they tuned in on entertainment.

In the choice of personnel for propaganda work, one question is when is it a good thing to be emotionally involved. The history of propagandas of religion and revolution make it clear that dangerous propagandas need to be in devoted hands. Where less sacrificial considerations are at stake professional talent can be employed in the same way that a lawyer takes over the claims of a client, not because the claim is right but because the client has a right to be heard.

The 20th century has been notable for the rapid application of the social and psychological sciences to the problems of propaganda technique. It is standard operating procedure to pretest posters, labels, slogans and other details before they are brought to the notice of the eventual audience. A pretest uses a small group which is representative of the large audience which it is planned ultimately to reach. Posttests are utilized in the hope of evaluating the effectiveness of propaganda messages or channels. These tests are of the utmost diversity. They may be based on brief or prolonged interviews, upon the participant observation of behaviour, upon the analysis of a wide range of responses such as voting, giving, buying. selling, depositing, hoarding, investing, quarrelling, fighting, joining. seceding, boycotting, striking or attending. Methods have been devised to describe in quantitative terms the contents of the media of communication. Research is also done upon the control pattern that prevails in different countries, such as the degree of government monopoly or regulation, of private monopoly or competition.

Control. — It is impossible to scan the long history of attempts to control propaganda without being impressed by the power that men attribute to words. The fear of propaganda is fed by apprehension of the magical potency of language for the infliction of harm. These primitive attitudes continue to be an undercurrent in civilizations where the dominant attitude about language is detached and managerial. The only control problems that disturb a modern totalitarian regime are questions of expediency in the realm of power. In nations nhere the dignity of man is upheld, the issues are more complex, since the institutions appropriate to a free society include freedom of information, propaganda and political decision. Freedom is part of the respect due to the individual and is a condition of enlightenment and democracy.

But freedom of utterance is nowhere without qualification. No free society fails to use community coercion against some forms of speech on the ground that the results endanger important values without corresponding gain. Some gestures are condemned as obscene because we believe that youth will be corrupted if they are exposed to or use such gestures. Some communications are called fraudulent, libelous or slanderous. and left outside the protection of the community. In controlling propaganda the aim is to safeguard news and comment without permitting incitement, which is an act of coercion.

A consensus arose about the more extreme situations in which words become part of a coercive act. It is incitement when uniformed, armed and trained formations organize and act. Such activities signify that society is dissolving and can be restored only by bringing coercion back into the hands of organized government.

There is less agreement about what to do about statements provocative enough to arouse the anger of members of an audience whose religious, ethnic or political sentiments are affronted. One view is that restrictions must be imposed when there is "clear and present danger" to public order. A more daring conception is that it is the purpose of a free society to maintain a kind of public order where coercive acts are not permitted in response to words, however offensive.

In time of war, popular governments are compelled to recognize that statements circulated by an enemy are part of the enemy's coercive activities. But what of statements uttered by members of the commonwealth who have no connection with a foreign power? Some defenders of freedom assert that enough protection is given to the body politic if repressive measures against domestic propaganda are kept at a minimum and reliance is put upon the positive advocacy of the majority viewpoint, coupled with the disclosure of parallels, intended or unintended, between domestic propaganda and the line taken by the enemy. It is conceded that without remarkably successful civic training in self-restraint, the police and the courts, to say nothing of the ordinary citizen. may be unable to tolerate dissent in the midst of crisis.

One of the greatest dangers arising from the prevalence of propaganda in a free society is that the vigorous prosecution of special interests prevents the formation of a genuine public will. In times of general crisis this may put democratic countries at a disadvantage when, on the assumption that the globe is in a chronic state of civil war, the ruling groups of totalitarian countries institute and maintain strict censorship and propaganda. The purpose on the one hand is to insulate the home audience from outside influences, and on the other to obtain maximum access to nontotalitarian audiences.

The very presence of propaganda raises searching problems for the friend of freedom. Does the calculated manipulation of attitudes imply a denial of respect for freedom of opinion? This is true if the forum of communication is not equally accessible to all and if educational opportunities are open only to the privileged. Hence. in countries that aspire toward freedom, stress is laid upon measures designed to achieve genuine equality., The legislative and judicial institutions of society proceed by the use of discussion in order to subject rival propaganda claims to a common discipline of balanced presentation and of critical evaluation of evidence. Whatever solutions of the control of communication are achieved, it is evident that the degree of protection received by unpopular opinion and propaganda will continue to be one of the chief working tests of freedom.

BIBLIOGRAPHY.—Bruce Lannes Smith, Harold D. Lasswell and Ralph D. Casey, *Propaganda, Communication, and Public Opinion; A Comprehensive Reference Guide* (1946) ; Bruce and Chitra Smith, *International Communication and Political Opinion; A Guide to the Literature* (1956) ; Daniel Lerner, *Sykewar; Psychological Warfare Against Germany, D-Day to VE-Day* (1949) ; George G Bruntz, *Allied Propaganda and the Collapse of the German Empire in 1918* (1938) ; Edward L. Bernays, *Crystallizing Public Opinion (1923)*; Leonard W. Doob, *Public Opinion and Propaganda (1948)*; Alex Inkeles, *Public Opinion in Soviet Russia; A Study in Mass Persuasion* (1950).

(H. D. L.)

PROPANE, a colourless, gaseous compound of carbon and hydrogen, the third member of the paraffin series following methane and ethane. The formula for propane is C_3H_8. It is separated in large quantities from natural gas. light crude oil and oil refinery gases and is commercially available as liquified propane or as a major constituent of liquified petroleum gas (LPG).

As with ethane (*q.v.*) and other paraffin hydrocarbons. propane is an important raw material for the ethylene petrochemical industry. The decomposition of propane in hot tubes to form ethylene also yields another important product, propylene. From propylene organic chemicals like acetone, propylene glycol and many others are derived. The oxidation of propane to such compounds of carbon, hydrogen and oxygen as acetaldehyde is also of commercial interest.

Although a gas at ordinary atmospheric pressure, propane is readily liquified under elevated pressures. It is therefore transported and handled as a liquid in cylinders or tanks. In this form, alone or mixed with liquid butane, it has great importance as a fuel for domestic and industrial uses and for internal-combustion engines.

In the mid-20th century, world reserves were estimated at about 10,000,000,000 tons. The annual production was about 0.2% of this figure. Consumption was about equally distributed among chemical uses, LPG and as an unseparated constituent in natural gas used as fuel. (F. B. B.)

PROPELLANTS, chemical compounds or mixtures of compounds used to: (1) propel rockets or missiles or (2) to propel projectiles through the tubes of guns, howitzers, mortars or other firearms. Their propelling force results from rapid burning and evolvement of hot gases that exert a sustained forward force or pressure on the missile or projectile. One important feature of a propellant is that it supplies its own oxygen, whereas fuels such as coal and gasoline must obtain oxygen from the air. This feature is essential for missiles to continue accelerating as they reach outer space.

SOLID PROPELLANTS

History.—Gunpowder, or black powder, was the original propellant that used controlled explosive forces. This material may have been known much earlier than the 14th century and may have been used in various rockets and other mysterious fire-producing devices, but the evidence is not donclusive. For more than 550 years. uith some variation in composition and physical form. gunpowder adequately served man in the full range of firearms, both military and sporting. (*See* GUNPOWDER.)

But gunpowder had recognized deficiencies. Because it was a mechanical mixture of carbon, sulfur and potassium nitrate or sodium nitrate. its composition and properties were bound to vary. Gunpowder was also far from clean burning, it left troublesome residues in guns and produced large clouds of smoke and usually bright muzzle flashes. Other problems were caused by the tendency of some of the ingredients, notably the nitrate, to absorb moisture; there were also serious hazards in the manufacture of gunpowder.

The successor to gunpowder as a propellant was a substance called smokeless pomder. the term smokeless reflecting the cleaner burning of the nitrocellulose propellant as compared with gunpowder Nitrocellulose. originally termed guncotton. was invented accidentally in 1845 when Christian F. Schonbein (1799–1868), a German chemist, is said to have spilled some nitric acid on his wife's cotton apron. In modern terminology, guncotton means nitrocellulose with a nitrogen content of 13% or more. The term more common than guncotton is high-grade nitrocellulose.

The first attempts to utilize nitrocellulose as a propellant were unsuccessful, some actually disastrous, for two main reasons: (1) the material was chemically unstable, because of the reactions of the residual acid in the fibres, and (2) the raw fibrous nitrocellulose presented an excessive burning area to the flame front. Later the stability problem was solved by a more complete removal of the residual acid from the nitrocellulose fibres and by an addition of chemical stabilizers such as diphenylamine.

Schonbein is also credited with being the first to treat nitrocellulose with alcohol and ether to form collodion (*q.v.*). However, it remained for Paul Vieille (1854–1934), a French physicist and chemist, to utilize this colloiding action of solvents in molding the now homogeneous mass into shapes of controlled dimensions and surface areas. This was an extremely important discovery because it laid the groundwork for successful development of colloidal nitrocellulose propellants with improved and controllable ballistic characteristics. The French army adopted the new and more powerful propellant about 1885 as poudre B.

The next step in propellant development occurred in 1888 when Alfred B. Nobel (*q.v*), a Swedish chemist and engineer, discovered the solvent and colloiding actions of nitroglycerin on nitrocellulose and combined them into a more powerful propellant termed ballistite. As it contained both nitroglycerin and nitrocellulose, it was described as a double-base propellant.

In 1890 Sir Frederick A. Abel a British chemist. invented cordite, another double-base propellant consisting of 65% nitrocellulose, 30% nitroglycerin and 5% mineral jelly. Cordite was made by extruding the colloid into long cords, whereas both Vieille and Nobel had rolled the colloid into sheets and then cut the sheets into flakes of various sizes. Before the end of the 19th century, the U.S. navy adopted smokeless powder, favouring the single-base type of Vieille and using nitrocellulose of approximately 12.6% nitrogen — it was often called pyrocellulose or simply pyro.

Early 20th Century. — These two general types, single-base and double-base, served almost exclusively as standard propellants for military and civilian use during the early 20th century. Even when the rocket or jet-propelled type of weapon came into military use, the double-base propellant, still termed ballistite, found extensive application.

After World War I, important refinements were made in U.S. army single-base propellants. For example, the ingredients dinitrotoluene and dibutylphthalate were added to the nitrocellulose, effectively moisture-proofing the propellant grains. Ingredients in this improved propellant were also proportioned to eliminate muzzle flash when fired from the French 75 mm. gun which was extensively used by the Allied armies. The new propellant was known as flashless-nonhygroscopic (FNH) or more officially as duPont FNH-M1 in recognition of the co-operative developmental efforts of E. I. duPont de Nemours and company. Later it mas designated as propellant M1, and a slight variation for the larger guns as propellant M6. Table I shows the nominal formulas and two calculated properties of these important U.S. propellants.

TABLE *I.—Data on M1 and M6 Propellants*

Ingredients	M1	h16
Nitrocellulose (13.157,) N	85	87
Dinitrotoluene	10	10
Dibutylphthalate	5	3
Diphenylamine*	1	1
Isochoric flame temperatures (°K)	2417	2570
Ballistic force (ft.lb./lb.$\times 10^{-3}$)	305	317

*Diphenylamine is added and serves as a chemical stabilizer for the nitrocellulose.

World War II Era.—During World War II a number of important developments affected the military propellant field. A more nearly flashless gun propellant (cordite N) was introduced in England. Rockets and jet-propelled missiles gained in importance of the first magnitude. Large rockets. in turn, brought into prominence another type of solid propellant, termed composite, as well as liquid propellants.

Cordite N was a triple-base type that contained a third explosive compound, nitroguanidine, in an amount of approximately 55%. This compound was also used by Germany and perhaps other countries, but usually with somewhat smaller percentages of nitroguanidine. The high nitrogen content (55%) in nitroguanidine imparts a special cool-burning property to the propellant, thus aiding in flash control and reducing erosion rates. Addition of salts such as potassium sulfate (K_2SO_4) in small percentages (cordite N/P) further increased the flashless properties of this type of propellant, though even 1% of K_2SO_4 greatly multiplied the amount of smoke produced.

Cordite N propellant was adopted in the early 1940s for many guns in the United Kingdom services and in Canada, and by the U.S. navy even for its largest guns. The U.S. army adopted a slight modification of cordite N as the M15, carefully designed for optimum flashless-smokeless performance where this double feature had special importance, as in tank guns. The U S. army also adopted a further modification as the M17, designed especially to impart maximum muzzle energy to solid armour-piercing types of projectiles. Typical nominal formulas and important characteristics of these three triple-base propellants are shown in Table II.

These values of flame temperature and force represent about the normal range for military gun propellants. Double-base types for mortars, rockets and recoilless rifles have considerably higher flame temperatures.

Small Arms.—The earliest small arms propellant was gunpowder and many a vivid picture comes to mind of the western U.S. pioneer tamping the powder charge and the bullet into his muzzle-loader. The earliest colloidal propellant was probably made in the form of flakes but later more progressive burning, and therefore greater efficiency, was secured by using an extruded grain with a single perforation and by applying a deterrent coating to the outside of the grains. This design was standard for almost all types of military rifles and culminated in the development of the well-known IMR (Improved Military Rifle) propellant by the duPont company. The IMR propellants and most other small-arms propellants were of the single-base type, although some double-base types were used in pistols and shotguns.

TABLE *11.—Approximate Formulas and Calculated Properties for Cordite N, M15 and M17*

Ingredients	N	M15	M17
Nitrocellulose	19.0	20.0	22.0
Nitroglycerin	18.7	19.0	21.5
Ethyl centralite*	7.3	6.0	1.5
Nitroguanidine	54.7	54.7	54.7
Crvolite	0.3	0.3	0.3
Isochoric flame temperature (°K)			
Ballistic force (ft.lb./lb.$\times 10^{-3}$)	2450 320	2	3364

*Diethyl diphenyl urea.

In the United States the non-military use of small-arms propellants has always been considerable; this was especially true during the early periods when game was plentiful and was a significant item of food. More recently the small arms ammunition market has been expanding in the area of sporting contests and target practice.

An important propellant development was made by the Western Cartridge company (later a division of the Olin-Mathieson Chemical corporation) in the 1930s. The propellant was called Western ball powder. The production technique was to dissolve or disperse the nitrocellulose and other ingredients in a solvent such as ethyl acetate. Upon agitation and the addition of a protective colloid, the lacquer was broken up into small spherical globules. The process provided an effective means of purifying the nitrocellulose and also lent itself well to making either single-base or double-base propellants. The particular design submitted for military use in small-arms weapons showed a significant improvement in the form of longer barrel life for the weapons. The novel spherical form and design of the propellant grain may have contributed to this fortunate result. However, the relatively low flame temperature of the particular composition in use in those specific tests appears to have been the most significant factor. See also SMALL ARMS, MILITARY.

Rockets and Missiles.—As noted earlier, the double-base ballistite type was the popular solid propellant used in rockets of small and some medium sizes—notably the bazooka (*q.v.*). As made by the extrusion process, ballistite had definite limitations as to diameter of strand. Therefore, as missile sizes increased, various casting and pressing processes had to be devised to fabricate larger sizes of propellant grains required by the motors. Various complex shapes of grain were also needed to produce the desired burning characteristics. (The word grain is still used to designate discrete particles regardless of size.)

The casting and other methods of fabrication opened the way for the composite type of propellant for missiles and JATOs (jet-assisted take-off devices) with an almost unlimited range of sizes and capabilities. In these heterogeneous mixtures of chemical compounds there may be fuels, either organic or metallic; oxidizers (nitrates. perchlorates, etc.); binders and other special-purpose ingredients such as burning-rate controllers or accelerating additives.

The composite type of propellant provides for considerable flexibility in design and in the variety of fabrication methods. Solid-propellant grains may be cast with liquid nitroesters or other compounds filling the voids, thus providing the typical heterogeneous mass with evenly distributed components. The casting or pressing may be done in a special mold or an inert plastic container which later acts as an inhibitor and thus restricts burning to the end of the composite mass. Or the entire charge may be cast or pressed into the missile motor itself, the walls of which automatically provide an inhibiting action.

To develop a solid propellant for a given purpose, skillful design and careful manufacturing control are essential for each specific application because of the many severe performance requirements and limitations placed upon modern propellants. In addition, most propellants, especially in military use, must be stable chemically and ballistically for safe storage over long periods of time. The chemical compounds must include only such ingredients as are compatible or nonreactive until actual functioning is desired.

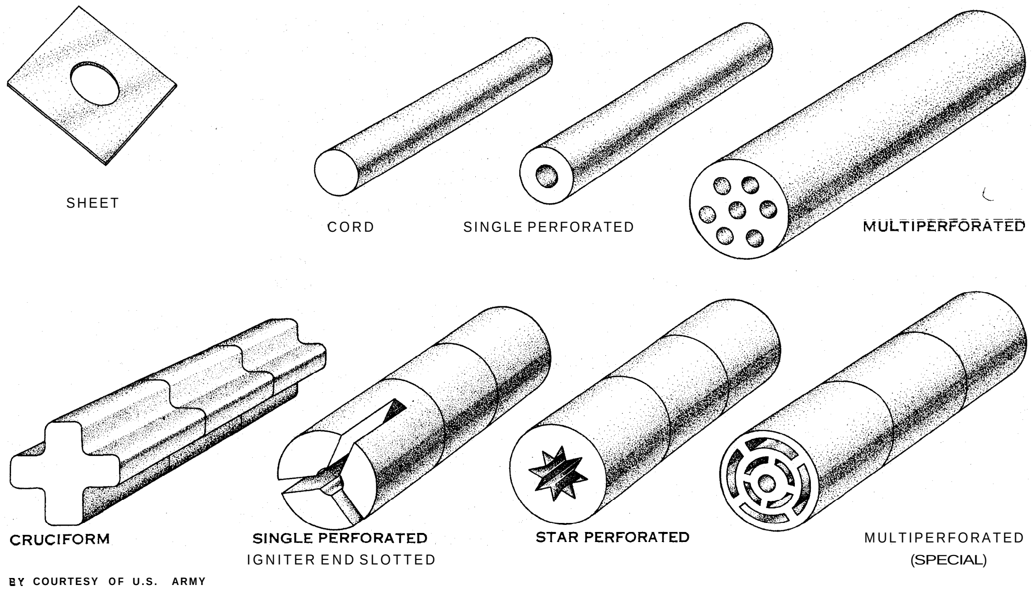

FIG. 1.— SOLID-PROPELLANT GRAIN CONFIGURATIONS

Certain stabilizing compounds such as diphenylamine may be needed to neutralize the effects of the possible slow hydrolysis of nitrocellulose or other nitrates.

LIQUID PROPELLANTS

Although solid propellants have been the work horses for many centuries, liquids have gained distinctive roles in modern missile technology. The experiments of Robert H. Goddard (*q.v.*) in the 1920s charted the course; he visualized a system using liquid hydrogen and liquid oxygen as being capable of energizing even an interplanetary rocket. The German V-2 missile of World War II was a milestone in actual application of two liquids, alcohol and liquid oxygen (LOX).

Liquid systems are of two types: monopropellants and bipropellants. A monopropellant may be a single compound such as ethyl nitrate, or it may be a compatible mixture such as hydrazine, hydrazine nitrate and water. Bipropellants consist of two liquids. one an oxidizer and the other a fuel; they are kept separate until they reach the combustion chamber. Most bipropellants ignite spontaneously on contact and are therefore said to be hypergolic. Typical oxidizers are liquid oxygen, fuming nitric acid and hydrogen peroxide; fuels include aniline, hydrazine and alcohol. Monopropellants are usually chosen for the few gun applications of liquids; most liquid-missile systems use bipropellants because of their greater energy capabilities.

The choice between liquid propellants and solid propellants for a given missile often depends upon the nature and severity of the launching and flight requirements and on the limitations of the missile system itself. In practice the larger missiles may utilize two or more stages, with liquid and solid propellants in different stages of the same missile. Each stage consists of a separate motor that may be discarded after propellant burnout is complete.

Another important factor is the time period required for operational stability. Many solid propellants remain essentially unchanged for years, whereas the high energy of liquid oxygen is available for a very short time unless elaborate refrigeration is provided. Practical considerations include tactical convenience and safety in supply, transportation, handling and storage. Solid propellants are easy to handle and may be kept for long periods in a ready-to-fire status; liquid propellants offer higher specific impulse but at the cost of many tactical problems.

Perhaps the two most fundamental properties of many propellants, at least solids, are that their functioning is essentially a surface-burning phenomenon and that the burning rate at any instant depends upon the pressure existing in the surrounding gaseous medium. Thus, Vieille in 1888 showed that the burning rate r is proportional to the pressure P: $r = c\ P^n$, where c is a constant characteristic of the chemical composition and n is essentially constant, usually in the range 0.8 to 1.0. Surface burning (rather than detonation of the mass, as in explosives like TNT) is utilized to guide the reaction toward maximum efficiency. Thus the pressure may be sustained by designing the solid-propellant grain so that the area exposed to the flame front remains constant, or may even increase, as burning proceeds. This is done by varying the geometry of the grain (see fig. 1) or by using inert deterrent materials on grain surfaces. The value of c in Vieille's lam may be altered materially in modern practice by incorporating selected high-energy fuels (as magnesium or aluminum), by rate control strands, by using additives with a high-burning rate and by incorporating special ingredients that broaden the pressure-time curve and thus increase the total-thrust energy imparted to the missile.

For long-range missiles the urgent demand is for the maximum possible power or sustained thrust. The fundamental measure for power of a given propellant is specific impulse (abbreviated I_{sp}). In the simplest form $I_{sp} = F/W$ sec., where W is the average rate of propellant consumption in pounds per second. to produce the average total thrust F in pounds. This relationship shows the value of high-energy compounds, capable of producing high values of F; and of chemicals with low molecular weight, thus lowering the value of W. In these relationships liquid compounds show great potential gains over solids, because of the variety of fuels containing hydrogen and of such high-energy oxidizers as liquid oxygen, fluorine and ozone.

Fig. 2 indicates the broad possibilities for specific impulse, but

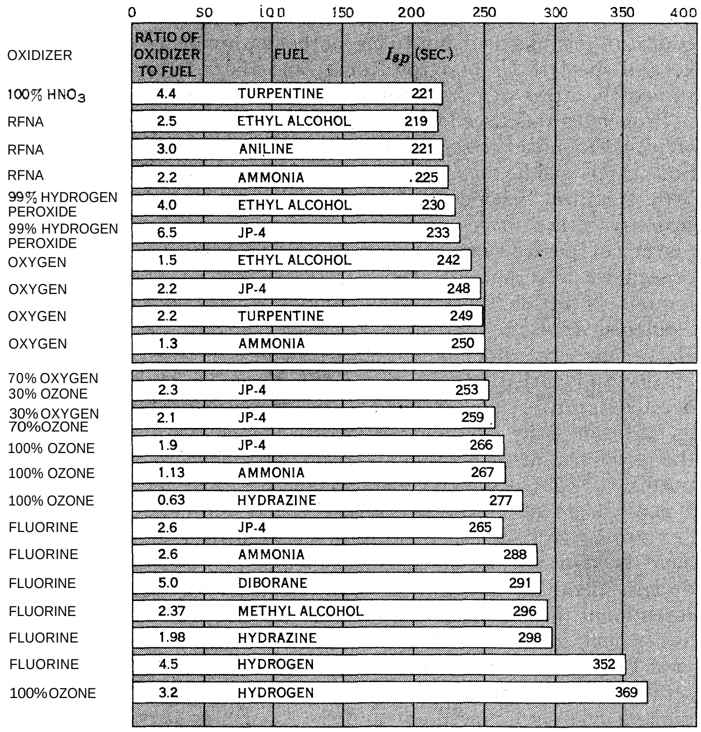

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FIG. 2.— THEORETICAL SPECIFIC IMPULSE (I_{sp}) FOR LIQUID-PROPELLANT COMBINATIONS

of course the practicability of using these high-energy combinations depends upon many other factors. By way of comparison, double-base solid propellants develop a specific impulse of about 230 sec., composites do somewhat better, in the order of 250 to 290 sec. These values for **I„** should be contrasted with the fig. 2 levels of up to 369 for high-energy liquid systems. Such values of **I„** may well be approaching the upper limit attainable by combinations of conventional chemical compounds. Further increases into ultraenergy regions may depend upon success in harnessing free radicals and atomic energy sources.

See also AMMUNITION, ARTILLERY; MISSILES; ROCKETS.

BIBLIOGRAPHY.—T. L. Davis, *The Chemistry of Powder and Explosives,* 2 vol. *(1941–43)*; R. N. Wimpress, *Interior Ballistics of Solid-Fuel Rockets (1950)*; *Selected Combustion Problems,* ed. by NATO Advisory Group for Aeronautical Research and Development (AGARD) *(1954)*; *Symposium (International) on Combustion,* ed. by the Combustion Institute, Pittsburgh, Pa., issued periodically; S. S. Penner, *Chemistry Problems in Jet Propulsion (1957)*; Beryl Williams and Samuel Epstein, *Rocket Pioneers on the Road to Space (1958)*; *M*. J. Zucrow, *Aircraft and Missile Propulsion, 2* vol. *(1958)*; *ARS (American Rocket Society Journal)*; Marcel Barrère et *al., Rocket Propulsion (1960)*; .S. S. Penner and J. Ducarme (eds.), *The Chenzistry of Propellants (1960).* (*B. E. An.*)

PROPELLER. For a description of the propeller as applied to aircraft see AIRCRAFT PROPULSION. For marine propellers, see NAVAL ARCHITECTURE: Resistance and Propulsion.

PROPERTIUS, SEXTUS (c. 50–*c.* 15 B.c.). the greatest of the elegiac poets of Rome, was born of a well-to-do Umbrian family at or near Asisium (Assisi). Ovid says that Propertius was his senior, but also his friend and companion; and that he was third in the sequence of elegiac poets, following Cornelius Gallus, who was born c. 70 B.c.. and Tibullus, and immediately preceding Ovid himself, who was born in 43 B.C. It may be supposed then that he was born c. 50 B.C.

His early life was full of misfortune. He lost his father prematurely; and after the battle of Philippi and the return of Octavian to Rome, Propertius, like Virgil and Horace, was deprived of his estate to provide land for the veterans, but, unlike them. had no patrons at court and was reduced from opulence to comparative indigence. When the widespread expropriations had provoked an insurrection, Propertius lost another of his relatives, who was killed by brigands while making his escape from Perusia (Perugia), the centre of the revolt. The loss of his patrimony, however, did not prevent Propertius from receiving a superior education, thanks no doubt to his mother's providence. Eventually he and she left Umbria for Rome; and there, c. 34 B.C., he assumed the dress of adult manhood.

Propertius was urged to take up a pleader's profession; but, like Ovid, he found in letters and gallantry a more congenial pursuit. Soon afterward he made the acquaintance of Lycinna (about whom little is known beyond the fact that she subsequently excited the jealousy of her successor, Cynthia) and was subjected to all her powers of persecution (*vexandi*). This passing fancy was succeeded by a serious, attachment! the object of which was the famous "Cynthia." Her real name was Hostia (according to Apuleius, Apologia, 10); and she was a courtesan of the superior class, somewhat older than Propertius and, it seems. of singular beauty and varied accomplishments. Her own predilections led her to literature; and in her society Propertius found the intellectual sympathy and encouragement which were essential for the development of his talent. Her character, as depicted in the poems, is not an attractive one; but she seems to have entertained a genuine affection for her lover. Their intimacy lasted from c. 29 to 24 B.C. These years must not. however. be supposed to have been a period of unbroken felicity. Apart from minor disagreements an infidelity on Propertius's part excited the deepest resentment in Cynthia; and at some time he was banished from her society for a year. When he had known Cynthia for about a year Propertius published his first book of poems, which was inscribed with her name. Its publication placed him in the first rank of contemporary poets and procured him admission to the literary circle of Maecenas. The subsequent relationship between the poet and his mistress, honever, was one of growing disenchantment; neither was faithful to the other; the mutual ardour gradually cooled; motives of prudence and decorum urged the discontinuance of the connection; and disillusion changed insensibly to disgust.

Although their parting might have been expected to be final, it is not certain that it was so. Though Cynthia, whose health appears to ,have been weak, does not seem to have survived the separation long, the poem (iv, 7) in which Propertius describes a dream of her that he had after her death suggests that they were once more reconciled and that in her last illness Cynthia left to him the duty of carrying out her wishes with regard to the disposal of her effects and her funeral. Almost nothing is known of the subsequent life of the poet. He was alive in 16 B.c.. as some allusions in his last book show. Moreover, two passages in the letters of the younger Pliny mention a descendant of the poet, one Passennus Paulus; and this had given rise to the suggestion that Propertius may have married in order to comply promptly aith the *leges Juliae* of 18 B.C. (which offered inducements to marriage and imposed disabilities upon the celibate) and had at least one child.

Propertius had a large number of friends and acquaintances, chiefly literary men belonging to the circle of Maecenas. Among them may be mentioned Virgil, an epic poet called Ponticus, a certain Bassus (probably the iambic poet) and at a later period Ovid He says nothing of Tibullus or of Horace, who also never mentions Propertius. This reciprocal silence may be significant.

In person Propertius was pale and thin, as was to be expected in one of a delicate and even sickly constitution. He was very careful about his personal appearance and paid an almost foppish attention to dress and gait. He was of a somewhat voluptuous and self-indulgent temperament. which shrank from danger and active exertion. He was anxiously sensitive about the opinion of others. eager for their sympathy and regard and. in general, easily influenced by them. His over-emotional nature passed rapidly from one phase of feeling to another; but the more melancholy moods predominated. A vein of sadness runs through his poems, sometimes breaking out into querulous exclamation, but more frequently expressed in gloomy reflections and prognostications. He had fits of superstition, which in healthier moments he despised.

The Poems.—The poems of Propertius, as they have been preserved. consist of four books containing just more than 4.000 lines of elegiac verse. Book i. the *Cynthia* or *Monobiblos*, was published probably in 29 or 28 B.C As its title indicates, it is concerned almost exclusively with the poet's passion for Cynthia. The arrangement of the poems is. in the Alexandrian manner, one of artful disorder: the phases of the liaison and of Propertius's feelings are described in a series of brilliant isolated impressions, in nhich a strict chronology is carefully avoided (compare Ovid's *Amores*). This is not the only reason why it is unsafe to draw inferences about Propertius's actual life and loves from his poetry. Throughout, but particularly in the first book, reality and convention, experience and literary artifice, love and learning, are too intimately blended for the reader to be sure of disentangling them. It is important to remember the poet's essentially urban character and the relatively small and highly sophisticated circle of redders to whom his poetry was intended to appeal. for them his mythological allusions, uhich are frigid and indeed barely intelligible to the modern reader, mould be immediately moving and evocative. Books ii and iii, which were published probably c. 25 and *c.* 22 B.C. respectively, are of somewhat more varied composition than book i. The poet's love for Cynthia still dominates them. but his tone is more declamatory and less personal, and other themes are heard.

Book iv (c. 16 B.C.) offers a remarkable contrast. Propertius had indeed already announced, at the beginning of book iii. that he aspired to follow in the footsteps of Callimachus and Philetas, but there he had been referring only to formal and stylistic obligations, not to subject matter; whereas now (iv. 1, 61–70) he proposed, as the Roman Callimachus. to deal with the history and antiquities of Rome in the manner of the Aetia. In fact such themes. which were taken up later by Ovid in the *Fasti,* only occupy five of the poems in the book The rest, a varied collection, include the poem (3) which seems to have given Ovid the idea for his *Heroides;* a delightfully humorous description of Cynthia's surprising Propertius in the act of being unfaithful to her (8); and the eulogy of the dead Cornelia, which some have thought to be his finest work (11).

The writings of Propertius are noted for their difficulty and their disorder. The workmanship is unequal, curtness alternating with redundancy, and carelessness with elaboration. A desultory sequence of ideas, an excessive vagueness and indirectness of expression, a peculiar and abnormal latinity. a constant tendency to exaggeration and an immoderate indulgence in learned and literary allusions — all these are obstacles lying in the way of a study of Propertius. But those who surmount them will find their trouble well repaid. For power and range of imagination, for freshness and vividness of conception, for truth and originality of presentation, few Roman poets can compare with him when he is at his best; that is, when he is carried out of himself. when the discordant qualities of his genius are, so to say, fused together by the spark of immediate inspiration. His vanity and egotism are redeemed by his fancy and his humour.

Two of the lasting merits of Propertius seem to have impressed the ancients themselves. The first they called *blanditia,* a vague but expressive word by which they meant softness of outline, warmth of colouring, a fine and almost voluptuous feeling for beauty of every kind and a pleading and melancholy tenderness; this is most obvious in his descriptive passages and in his portrayal of emotion. His second and even more remarkable quality is poetic facundia, or command of striking and appropriate language. Not only is his vocabulary extensive but his employment of it is extraordinarily bold and unconventional: poetic and colloquial latinity alternate abruptly, and in his quest for the striking expression he frequently seems to strain the language to breaking point.

Propertius's handling of the elegiac couplet, and particularly of its second line. deserves especial recognition. It is vigorous, varied and even picturesque. In the matter of the rhythms, caesuras and elisions which it allows, the metrical treatment is much more severe than that of Catullus, but noticeably freer than that of Ovid, to whose stricter usage, however, Propertius increasingly tended (particularly in his preference for a disyllabic word at the end of the pentameter). An elaborate symmetry is observable in the construction of many of his elegies, and this has tempted critics to divide a number of them into strophes.

Influence. — As Propertius had borrowed from his predecessors, so his successors. Ovid above all, borrowed from him; and *graffiti* on the walls of Pompeii attest his popularity in the 1st century A.D. In the middle ages he was virtually forgotten; and since the Renaissance he has been studied by professional scholars more than he has been enjoyed by the general public. To the modern reader, acquainted with the psychological discoveries of the 20th century. the self-revelations of his passionate, fitful, brooding spirit are of peculiar interest.

BIBLIOGRAPHY.—For the text of the poems *see* the editions by E. A. Barber (1953) and by M. Schuster, 2nd ed. rev. by F. Dornseiff (1958). For the text with introduction and commentary *see* the edition by H. E. Butler and E. A. Barber (1933); also that of book i only by P. J. Enk, with bibliography (1946). There are English translations in prose by H. E. Butler, with the Latin, in the "Loeb Series" (1912) ; and in verse by S. G. Treemenheere, 2nd ed. (1932), and by E. H. W. Meperstein, with bibliography (1935). *See* further F. Plessis, *Études critiques sur Properce et ses élégies* (1884); W. Y. Sellar, *Horace and the Elegiac Poets* (1899); R. Helm, "Propertius," in Pauly-Wissowa, *Real-Encyclopadie,* vol. xxiii (1957). (J. P. P.; E. J. Ky.)

PROPERTY: see COMPENSATION; JOINT TENANCY; HUSBAND AND WIFE; LAWS OF REAL PROPERTY AND CONVEYANCING; PERSONAL PROPERTY.

PROPERTY, PRIMITIVE: see AGRICCLTURE. PRIMITIVE; COMMUNISM, PRIMITIVE; LABOUR, PRIMITIVE; LAND TENURE, PRIMITIVE; MARRIAGE.

PROPHET (προφήτης), a Greek word used in the Greek Old Testament to translate the Hebrew *Nābī* נביא and consequently adopted into other European languages. In classical Greek it denoted one who, uttering or interpreting an oracle, was believed to speak not his own thoughts but a revelation "from without"; *cf.* the description of Cassandra (Agant.) and the Prophet of Apollo (Eztmen.), by Aeschylus; of the blind seer, Teiresias, by Sophocles (Oed. Tyr.), and by Euripides (Bacchae); of the Cumaean Sibyl, by Virgil (Aen vi.); and note Plato, *Timaeus* 71 b., where be argues that persons who seek to give rational meaning to oracles "are not to be called prophets at all," but only those who speak in ecstasy. At the Delphic Oracle, however, not the frantic priestess, the Pythia, was designated "prophet," but the Guardians of the Shrine who ostensibly shaped her frenzied ejaculations into comprehensible replies. Etymologically προφήτης denoted "forth-telling," not "fore-telling"; but since προ could mean "before" in time, and since prophecies constantly dealt with future events and foreknowledge is not deemed to occur in conditions of normal consciousness, the notion that prediction and ecstasy are the essential elements in prophecy was an easy growth. Thus in the Hellenic period Philo of Alexandria looked on divination and oracular interpretation as imposture, but had high regard for the ecstatic who "speaks nothing of his own." Προφήτης was the best word available in Greek, for rendering the Hebrew *Nābī* (it was preferable to μάντις), but the Hellenistic view of prophecy as ecstatic prediction obscured for centuries the wealth of religious interest in the Hebrew prophets. Why προφήτης was used to translate *hm-ntr,* the title of certain Egyptian priests, is unascertained.

HEBREW PROPHECY

The Hebrew noun *Nābī* ("Prophet," *pl. Nebi'im)* is obscure in origin. Derivations implying intense excitement (נבע "to bubble up"; נבע Assyr., "to fall in transports") are etymologically improbable. The verbal form (an intensive) used in Hebrew often denotes frenzy or even lunacy, but this may reflect merely one aspect of prophetic development, and the fact that it is an intensive stem may imply simply that it is a loan-word in Hebrew. Conceivably it is not Semitic at all — there are Hittite possibilities. The likeliest Semitic connections are Arab. naba'a "to announce" (conjug. ii.); Bab.-Assyr. *nabû* "to name" (cf. the god, Nebo, Is. 1 1) *Nābī,* like προφήτης, may thus in origin be a colourless term: "One who utters a god-given message."

The Fanatical Prophets. — From a trustworthy narrative in I Sam. x. we learn that bands of prophets (*Nebī'īm*), devotees of the national deity, Jehovah (Yahweh), existed c. 1000 B.C. at Hebrew localities (Gibeah, Ramah). Stimulated by rhythmic music, dancing and chanting, they wrought themselves into ecstasies when their frenzied behaviour and abnormal physical power exercised hypnotic effect over onlookers (I. Sam. x. 5–13), and, as it seemed to testify the might of the god whose spirit possessed them, encouraged popular trust in Jehovah and resistance to the Philistines. Since there is no earlier reference to collective prophesying in Hebrew history (Nu. xi. 25 sqq. cannot be regarded as of the Mosaic age), probably it was a feature of Palestinian-Syrian religion, first evoked in Israel in Samuel's time. There is no direct evidence for Wellhausen's assertion that "among the Canaanites such Nebi'im had long been familiar" but the indirect evidence is impressive. An Egyptian record (c. 1100 B.C.) relates how an envoy, Wenamon, secured a hearing when a youth in attendance on a Phoenician prince prophesied ecstatically in Wenamon's favour. Very instructive is the famous passage in I. Kings xviii. 19 sqq. concerning the 850 prophets of the (Phoenician?) Baal and of the Asherah, maintained by Queen Jezebel. At a much later period the orgiastic rites celebrated by devotees in honour of certain ostensibly Greek deities (Apollo, Dionysos) prove to have connections with the Baal worship of Syria and Phoenicia (so T. H. Robinson). When parallel phenomena are still exhibited by the dervish fraternities in Islam, it seems probable that this form of religious excitement was peculiarly congenial to the peoples of Western Asia Minor, and may well have been of immemorial antiquity in Palestine.

Certain it is that fanatical prophets became a feature of Israelitish society. They are mentioned in connection with many towns of special sanctity and importance, *e.g.,* Bethel, Jericho, Samaria. Possibly they had some organization (the phrase "schools of the prophets" has no warrant), and were supported by popular piety or by kings anxious to obtain inspired counsel in perilous moments. Along with the priests and the wise men, they were esteemed one of the three indispensable sources for the guidance of the State (Jer. xviii. 18). Even in the post-exilic period they lingered on, distinctive by their rough mantle and leathern girdle, mouthing out oracles for the superstitious (cf. the χρησμολόγος in Aristophanes, Birds, 959 *sqq.*)—so great a public nuisance that father and mother are exhorted to slay the son turned "prophet" (Zech. xiii. 3). The causes of degeneracy can be discerned. Thanks to Eastern respect for the psychologically abnormal, the calling afforded a livelihood and might attract impostors, for it was easy to share in, or simulate, ecstasy, and declare "Thus saith Jehovah." The violent emotions were dangerous to the moral stability of even the honest Nᵉbi'im, and if simpler means of inducing ecstasy failed, the temptation to use noxious drugs was great.

The fanatical prophets, it may be concluded, manifested a real patriotism that helped to establish the State during the Philistine and the Syrian conflicts, but contributed nothing to the discernment of those dynamic religious beliefs which, as the power of Assyria and Babylon rose and engulfed .the petty monarchies of Israel and Judah, alone made possible the astounding survival of the Jewish nation.

The Seer.—But the word *Nābî* acquired a wider connotation. Later than the age of Samuel it came to be applied to persons who in earlier times would have been called Seers (*Rō'eh*, "Visionary"; or *Hōzeh*, "Gazer": I Sam. ix. 9). The Seer, ubiquitous in antiquity and ranging in dignity from the itinerant soothsayer to the guardian of some famous sanctuary, was credited with power, through interpretation of omens or (more impressively) through trance-visions, to gain knowledge from a spiritual being inaccessible to ordinary men: he was, as others were not, a "man of God." Balaam (Nu. xxii.–xxiv.) is typical: "essentially an Arab *Kāhin* or seer of that early type which combined the priest's offices of ritual and sacrifice, the diviner's reliance on omens and lots, and the prophet's experience of ecstasy and dreams" (G. A. Smith). The possibilities in the calling for good and evil are obvious. Affinities with the baser forms of divination—wizardry, necromancy, etc.—were close, and degenerate seers became only too numerous in Israel (Is. ii. 6, Mic. iii. 7), notwithstanding a strong tradition that such arts were peculiarly abhorrent to the God of Israel (I Sam. xxviii. 3, sqq. Ex. xxii. 18, Is. viii. 19). But the famous seers created the expectation of individuals in mysterious contact with God, "standing in his counsel," "knowing his secret," whose words should therefore have absolute authority in hours of crisis. Much more than the Nᵉbi'im with their collective "inspiration," the seer is of the lineage of the great prophets. Yet a distinction may be drawn. The ordinary seer made his powers his profession and livelihood (Am. vii. 12), and his functioning was habitually passive: he waited to be consulted. The great prophets were men of diverse callings, driven by an irresistible constraint actively to declare to Israel the word of its God. Thus to his contemporaries Samuel was not one of the Nᵉbi'im but the Priest-Seer of Ramah, whom a Saul could consult about strayed animals. Later generations rightly accounted him a prophet of the great type because of his initiative in rousing the people against the Philistines, in creating a monarchy, and later in rejecting Saul for David.

The Higher Prophecy.—But all the seers and prophets of antiquity would have but infinitesimal interest, were it not for the appearance in Israel of certain individuals of amazing spiritual insight, whom we, like their contemporaries, for lack of a better word must call "prophets." Their work and words endow Prophecy with almost inexhaustible importance for religion and for social organization. The diversity of the occupations and circles to which these higher prophets belonged is significant. A few, especially in the earlier period, pertained to the professional prophetic class: Samuel was a famous seer, Gad and Nathan official prophets of David's court, Micaiah one of the recognized Nᵉbi'im (I Kings xxii.—a passage which should be studied). But Elisha was a prosperous farmer: Amos a shepherd of Judaea, Isaiah a citizen of Jerusalem. Micah a Judaean villager. Jeremiah a youth of ancient priestly family. Ezekiel a priest of the Temple. The unifying characteristic is that to each came an overmastering conviction that, temporarily or permanently, he must forsake his way of life and declare what God would say to His people. Their prophesying was the constraint of a vocation, not the pursuit of a profession. When their teaching is coordinated certain principles they held in common can be analysed (*see* articles on the several prophetical Books; BIBLE: Old *Testament*, etc.) with results sufficiently impressive. But such surveys are meagre and mechanical: what counts is the stress of circumstance from which the great ideas were won, and the heroic application of beliefs to events. Knowledge of Hebrew prophecy is knowledge of the lives of glorious personalities; only when name after name of the prophets calls up the memory of lonely insight into truth, of unbreakable loyalty to duty, maintained through scorn and hatred and despite despair, can its splendour be realized.

Historical Development.—Complex as are the Pentateuchal narratives concerning Moses, it seems certain that an influential section of the mixed population under the Hebrew monarchies held a tradition that a great leader of prophetic character (yet not an ordinary seer, Nu. xii. 6–8; but such as Samuel had been, a man whom a Hosea or Jeremiah could call a Prophet, Ho. xii. 13, Jer. xv. 1) had led their ancestors out of Egypt to the independence of the desert, and had fired them with such confidence in the God Jehovah as had given them the unity necessary for a successful assault on Canaan. However dimly recalled, and by however few, the tradition of Moses, it may be held, preserved potent ideas: that Jehovah required a standard of morality that differentiated Him from other gods, and that in Moses himself—remembered as a life of splendid patience and mercy, of unswerving integrity and awe-inspiring intimacy with the invisible God—there had been seen a true servant of Jehovah. Subsequently in Canaan the leadership of Samuel not only established the national existence, but created in the popular consciousness the sense that their kingdom was truly, and not nominally, a theocracy, where kings must heed the word spoken by God's prophets to an extent startling in the ancient East (I. Kings xxi. 7). The vigilance of prophetic censorship over the dynasty was notably displayed against David (by Gad and Nathan), against Solomon (by Ahijah), against Rehoboam (by Shemaiah); and momentously in Elijah's adamantine opposition to Ahab and Jezebel, whereby the alliance with Phoenicia was broken and Israel Left to face unsupported the impending attack by Damascus.

The deep motives in the higher prophecy now became apparent. Not by political wisdom was Elijah actuated, but solely by an imperious religious instinct which swept aside all other considerations in the assertion that Jehovah demands an absolutely exclusive worship, and that He champions the rights of the humblest against even the king. This principle holds good throughout. Attempts (cf. Winckler) to explain the actions and attitude (*e.g.*) of Isaiah or Jeremiah primarily by political foresight or predilections can be shown in detail to be misconceived. Prophecy had created the nation, and wished to sustain it; not, however, in the interests of the nation, but in the interests of its God. The important account of Elijah's flight to Horeb, I. Kings xix. (taken in conjunction with the sequel: Elijah's sense of a commission to anoint Jehu king over Israel, and Hazael over Syria, followed by the achievement of those ends by Elisha, his disciple, and by high-minded prophets) shows that the parable read by Elijah in the quiet of the enduring mountain, following the storm, was not that the ways of God are gentleness alone, but on the contrary that the prophet's resolve to overthrow the house of Ahab must be pursued to its bitter end through revolution in Israel and war with Syria. The nation must pass through the tumult: thereafter the unalterable good purpose of its God would be apparent. In face of the grim realities of evil true religion must send first not peace but a sword.

The Golden Age.—*A* century later (*c*. 7jo B.C.) the Golden Age of Hebrew prophecy, wherein the universal aspects of religious truth were perceived as the real significance of Israel's national faith in Jehovah, began with the oracles of Amos and Hosea in Northern Israel, to be continued in Judah, especially by Isaiah, Micah and Jeremiah. For Amos there is but one God of the whole earth, controller of other nations as well as Israel, whose favour everywhere is determined solely by such concern for moral conduct that not even the wrongs of a slave go unheeded by Him. Amos is styled the "Prophet of the Justice of God," but the phrase is wholly inadequate. Positive goodness, forbearance, mercy, kindness are the inexorable divine demand. Between Jehovah and Israel a special relation exists; but the implication is not (as the people imagine) favouritism, but responsibility: "to whom much is given, of them shall much be required" (Am. iii. 2). Faced by the iniquities of their times, earlier prophets had assailed the dynasty at whatever risk to the national fortunes; but Amos, appalled by corruptions that rotted society from top to bottom, uttered logically a judgment almost incomprehensible to the ancient mind—God will bring overwhelming ruin upon the nation itself (Am. vi.–ix. passim). Lastly, Amos marks a new era for religion by his special declaration that the immemorial forms of worship—sacrifices, fasts and feasts—are sheer futility: God is to be sought not through material offerings, but spiritually in upright and generous conduct (Am. v. 5, 14, 21–24). Here is the enunciation practically, if not also theoretically, of ethical monotheism. The profundity of these beliefs, which thenceforth became the gospel of the higher prophets, needs no emphasising. Not unjustly Amos has been called the forerunner of Kant.

To Hosea love seemed fundamental in the attitude of God to Israel. Deeper than the necessity for moral retribution lay the divine love. It has been observed that Amos and Hosea significantly complement one another; they "form a pair—law and love" (S. A. Cook).

Taught, it would seem, by some poignant personal experience, Hosea agonized with the dilemma: God must shatter the sinful nation, yet to do so would seem to end his gracious purpose in defeat (Ho. xi. 8, 9). What if the disaster, which is sure, be after all a means to an end—πάθει μάθος? Out of the ashes of Retribution, Hope must rise (Ho. ii. 15). Far more deeply than Amos, Hosea probed the problem of sin. The cultus was not merely futile; it was a prime source of iniquity, and must be abolished. He pities the masses; they sin indeed, but it is for lack of knowledge (Ho. ii, 8). Thus was prophecy released from pessimism. However near and overwhelming the "day of the Lord" in judgment, the prophet must exhort men to penitence and belief in an ultimate divine salvation.

The view (Gressmann. H. Gunkel) that Amos and his successors inherited a cut-and-dry eschatological expectation of woe followed by bliss—whether derived from native Israelite sources (Sellin) or influenced by Egyptian (Ed. Meyer) or Babylonian literature—rests on inadequate or misinterpreted evidence. The message of doom announced by Amos was startling to his hearers, and it would seem that the higher prophets' anticipation of some impending judgment catastrophic yet congruous with an undefeated divine purpose was radically the unaided product of their own reflection on the righteousness, power and goodness of God. In Hosea and Isaiah the element of hope beyond catastrophe is prominent. Whether it was conceived vaguely. or more definitely (Messianic) depends on the dubious authenticity of certain passages (see REVELATION. BOOK OF: MESSIAH).

For the achievement of an order of perfect righteousness apocalyptic cataclysm is, in reality, irrelevant; since love cannot be compelled. In their passionate pleading for reform the prophets mere feeling their way to a deeper comprehension, which at last was attained when Jeremiah based his hope of a divine consummation simply on faith in God's effecting the moral regeneration of the human heart (Jer. xxxi, 31–34).

Isaiah and Jeremiah.—The task which lay before the great prophets of Judah (c. 740–586 B.C.)—who, in contrast to the facile optimism of the ordinary prophets "healing lightly the hurt of the daughter of Zion," continued convinced that the ruin of the state was at hand—was to discover how faith in Jehovah could survive the political destruction. In effecting this infinitely difficult task it was their sublime achievement "to liberate the eternal truths of religion from their temporary national embodiment. and disclose their true foundation in the immutable character of God and the essential nature of Man" (Skinner).

To Isaiah is due the conception of an Israel within Israel, a believing nucleus; a "Church of God." Convinced that he knew the mind and power of the living God ("Mine eyes have seen the King, the Lord of Hosts," Is. vi, 5), he reasserted on a higher level the earlier prophetic claim to control the national policy. Thorough social reform must accompany quiet trust in God, and in Him alone, for the fate of the nation (*cf.* Is. xxx, 15). Assyria is resistless, not in virtue of its vaunted might but because it is the weapon in Yahweh's hand against his sinful people (Is. x.). Whatever sufferings it inflicts in invading Judah will be the discipline of divine wisdom, and will leave behind a purified remnant of the faithful in Zion, through whom God's purpose shall be fulfilled (*cf.* Is. x, 20–23, xxviii, 16). Rejected by king and people, apparently he gave substance to his hopes by seeking disciples who accepted his principles (Is. viii, 16). At the crisis of the Assyrian invasion (701 B.C.?), he foretold the inviolability of Zion and this momentary form of his teaching was preserved in popular memory superstitiously apart from its spirit and the moral conditions on which his doctrine of Faith (Trust) rested (*cf.* Jer. vii, 1–15).

"Prophecy had already taught its truths, its last effort was to reveal itself in a life"—the life of Jeremiah. Living through the dreadful years mhich saw the two successful sieges of Jerusalem by the Babylonian armies, ending in the destruction of the city and temple and the deportation of its chief inhabitants, Jeremiah found himself forced either to utter unrelieved predictions of ruin to a people distracted alternately with panic and delusive relief, or, being silent, to deny the conviction of inspired knowledge that burned like a fire in his bones. The task entailed for him desperate loneliness, hatred and persecution—sufficient torment to a man of shrinking and sensitive temperament. But further he was tortured at times by doubt of his inspiration. Was he but self-deceived or even deceived of God? Were the confident prophets of peace right? And if the nation perished, how could the worship of Jehovah survive? "Hitherto there had been nations with their religions, but there never had been in the world a religion without a nation to act as its embodiment" (A. C. Welch). Out of the agony of his perplexity, preserved in some infinitely moving passages (Jer. xv, 10–18, xviii, 9, 10, 14–18, xx. 7–18) came the solution: recognition of how wonderful mas the fact of the relation between his conscious self and the Divine Being he longed to serve. In his ultimate peace in God and victory over "fears without and fightings within," me mark the beginning of the modern view of religious faith. Whatever the function of the nations in God's sight, no conception of a moral God is credible unless the unit of divine interest be the human personality.

"Jeremiah had discovered that, wheresoever men live, they may find God, if in humility they do justice and love mercy. So he wrote (xxix, 4–14) to the exiles in Babylonia to live there that life of goodness which the prophets had seen to be the worship God desires: a momentous letter, for in the acceptance of his belief lay the continuance of the Jewish race, and the future of religion "The spirit of Jeremiah, mhich breathed out on his people after his death, bore fruit in an experience of fellowship with God which satisfied the deepest aspirations of the human soul" (Skinner).

It was now conceivable that religion might survive the state. The last act of the higher prophecy was to give effect to the possibility. Through the constructive idealism of Ezekiel, and the magnificent, monotheistic, oracles preserved in Is. xl–lv, and no less through the courage and insight of Haggai and Zechariah, whose exhortations effected the rebuilding of the temple in Jerusalem (520 B.C.) and thus set religion in the iorefront of the renascent community's life. the Jews—sole link between the ancient Semitic empires and the new era of Persian and Greek domination—began both to preserve their identity in exilic settlements, and in Palestine to revive as a people increasingly conscious that it existed through, and for, its distinctive faith.

The Achievement of Prophecy.—Tine prophets were thus the saviours of their people. But their achievement should be realized in a wider setting. In their declaration of monotheistic belief and social idealism the world received an interpretation of human life applicable to every people and every age.

Ethical Monotheism.—For intelligent men they shattered for ever the mental and moral dangers of polydaemonism and polytheism, proclaiming instead the reality of one only God, to be conceived as the infinitude of moral perfection. If modern terminology is permissible, they held both the transcendence and the immanence of God, and whatever the philosophical obscurities, this doctrine of God, as not less than "personal" in His relation to us, has been the succour of the human spirit, and the source of high and generous virtue for western civilization. The precise stage at which monolatry (God as the only Being his people must worship, but one among other gods) rose into the pure monotheism patent in II Isaiah—whether it goes back to Amos, to Elijah, to Moses—cannot be determined; for who shall measure genius? Perhaps the question is wrongly put. In antiquity no one ceased to believe in the existence of many spiritual beings (*cf.* Eph, vi, 12), and practical monotheism was achieved whenever it was felt that there is but one creative Spirit, alone meriting worship, other "gods" being wrong conceptions of God as He truly is, or lesser Spirits who beguile men's worship, and their images assuredly "non-entities," the works of men's hands.

The *Worth* of the Individual.—The prophets discovered the immeasureable worth of human personality. It may be that not until Jeremiah did the significance of the individual's aspiration towards God become vividly apparent; but his experience was creative. and thereafter, aided by Ezekiel's teaching concerning individual responsibility, the instincts of personal piety were liberated to reach out, even through the problem of death, into deeper confidence in Man's worth to God. But this religion of the individual, the product of Prophecy's fundamental thinking and genius for ultimate values, was in no wise individualistic. The heart of prophetic doctrine had been insistence that the mill of God is to create a world-order of perfect justice, and that, so long as the moral obligations of each and all go unhonoured, and the lowliest is denied mercy and kindness, there shall be no peace ior Man. To the prophets thereiore we owe that inestimable incentive ior good, the idea of the "Kingdom oi God" as the goal of social order.

Worship.—"In primitive life," wrote Robertson Smith, "all spiritual and ethical ideas are still wrapped in the husk of a material embodiment. To free the spiritual truth from the husk was the great task that lay before the-ancient religions . . . but none of the ritual systems of antiquity mas able by natural development to shake itself free from the congenital defect inherent in every attempt to embody spiritual truth in material forms. A ritual system must always remain materialistic, even if its materialism is disguised under the cloak of mysticism." (Religion *of* the Semites, ed. by S. A. Cook, mhose note, p. 676, should be studied.) The prophets' criticism of worship was revolutionary, but fundamental and constructive, because they saw with absolute lucidity that true worship is a relation of personality, thereiore spiritually, and not materially, determined. The human spirit can so use, or regard, material objects that (with vigilance) they may be symbolically or aesthetically helpful to the communion of God and man; but the material must never under any circumstances be treated as in itseli an indispensable aid, or barrier, to the reception of divine influence by man. To suppose so is fatally to misapprehend the essential nature of a personal relationship. The prophets were clear: "God's iavour is to br iound by man's becoming, like Himself, just and merciful . . . Not gifts hut fellowship, and the way to fellowship lay not through the sacrificial system re-interpreted, but through conduct: not giits but justice, not sacrifice but mercy" (G. Buchanan Gray, Sacrifice, p. 44).

Privilege—The prophets did not abandon the old idea of Israel as a nation privileged of God; but they transfigured it by the contention that privilege is responsibility, election a call to service. And prophecy itseli culminated in the vocation of Jeremiah to a life of sorrow and suffering, heroically accepted ior a nation that hated him; and secondly, in the Servant-Songs of II Isaiah (see ISAIAH) where the iunction of Israel is conceived as a selj-sacrificial consecration, through unparalleled trials, for the redemption of mankind.

Knowledge of God.—There were many prophets in Israel. How came it that the few advanced toward a rational faith, and the many—equally convinced that their "Word" was from the Lord—failed? To whom, and why, is revelation given? Here again Jeremiah is illuminating. No outward criteria, he felt, avail to discern the true from the ialse prophets. Ultimately he saw that they mere not sensitive, as he was, to the moral obliquity around them, or alive to the evil in their own heart; and he rested at last on the iaith that if he surrendered himself absolutely to God's service, accepting whatever loneliness, pains or even death it might entail, God would speak truly through him (Jer. xv. 19). But this attitude had been the basic fact regarding all the great prophets; diverse in many ways, they were men of absolute sincerity and self-surrender. The example of their character is the last and greatest gift of the prophets to mankind, ior it is the clue to sound religious experience everywhere: "the pure in heart shall see God."

The Prophetic Consciousness.—Until as late as the 17th century A.D., interest in the prophetic writings mas almost exclusively concentrated on the predictive element.

As to this aspect, it should be noted that there are indeed instances oi fulfilled presentiments (*e.g.*, Ez. xxsiii, 21, 22), and close correspondences of events with prophetic anticipations: but the prophets are wronged when, as is still sometimes maintained, the validity of their inspiration is ielt to depend crucially on fulfilment of predictions, instead of broadly on the rightness of their interpretation oi Life as ethical duty, dependent on the reality of the living God. The Suffering Servant anticipates Jesus Christ because the prophet was inspired by the vision of a life of absolute self-sacrifice, and Jesus accepted the conditions of that life and endured its issues. After the Reformation recognition of the poetical form oi the prophetic literature led to the necessary analysis of the Books bearing the prophets' names. Criticism in the 19th century was marked by enthusiasm for the prophets as preachers of social righteousness; hut present research, psychological and historical, reveals them primarily as men of religious genius, who must be studied in intimate connection with their eastern environment. In modern times it is urged (especially G. Holscher) that the inner experiences, and outward behaviour. of the great prophets were closely akin to the ecstasies of the early Nᵉbi'im. Certainly the subconscious is a highly important consideration in studying Hebrew prophecy, but the theory has been pushed to extremes and is sometimes maintained by grotesque forcing of the evidence. There ought to be more careful discrimination of terms. and "ecstasy" reserved for conditions in which the subject has lost ali control oi mind and body. Stress, inducing at times trance, with audition and vision, is exemplified in the great prophets (especially the "Call" experiences, *cf.* Is. vi); but to argue that these men virtually never ielt conviction break on them at any less intense level of the infinite gradations of emotion, never saw an illuminating parable in nature, never employed a symbolic action, unless in a state of uncontrolled ecstasy, is to go too far. There are indications that they distrusted increasingly the iervours oi their opponents (so A. B. Davidson). Whatever resemblances they had to the ordinary prophets, it is the profound differences that will repay study. The extreme forms of the theory are ruled out by the grand consistency of the great prophets: the coherence of their teaching is the supreme psychological fact; and either the oracles me possess are the record of passionate but conscious reflection, or in these men conditions existed which caused the subconscious to produce the rational and the relevant to an unparalleled extent. In any event, an Amos or an Isaiah is infinitely better understood by the analogy of Paul, with his vision on the Damascus road and his enthusiastic yet controlled temperament, than of the ecstatic seer or frenzied Nᵉbi'im. It is true that the Hebrew prophet says, never "I saw," "I know," but "The Lord shewed me," "Thus saith Jehovah." Explanation is found in the psychological ideas which he shared with his contemporaries. H. Wheeler Robinson rightly emphasizes that Man was regarded as intimately dependent on God in his psychical as well as his physical properties; his "breath-soul" open to the invasion of spirits divine and demonic. Hence not only in the trance-experience, but under any intense emotional stress the Hebrew felt that he had "become another man." the "spirit of the Lord had laid hold upon him"; so that it is easy to realize sympathetically why the prophet mas convinced that he spake never of himself hut as "the messenger of Him that sent me."

The Prophetic Succession.—Hebrew prophecy possesses the unity of a single movement, having origin, development and climax. It ended not in exhaustion, but in the liberation of energy, manifested in personal piety, in efforts to systematize the great ideas (Judaism), and in inextinguishable Hope of a divine purpose in the world (Apocalypse). Hebrew Prophecy recurs not, but "true" prophets—called by many names. Saint. Preacher, Reicrmer, Scholar—have not ceased to be; ior it was part of the work of prophecy to reveal that "all the Lord's people should be prophets." and that the prophet is he for whom God is the living God. Whenever discernment of truth in new aspects is Imperative, the interpreting prophetic personality is prominent, and is ever the vitalizing element in religion. Amidst the turmoil at the close of the last century B.C. and the first A.D., it is easy to see why individuals appeared who were manifestly prophetic in type—John the Baptist, Jesus Christ (though the term be inadequate for Him), Paul. Johanan ben Zakkai.

PROPHETS IN THE CHRISTIAN CHURCH

In the nascent organization of the Christian communities (Acts xi, 27, Eph. iv, 11, 1 Cor. xii, 28) prophets are mentioned, ranking next to the Apostles. Sometimes itinerant. sometimes settled in one locality. they were the evangelists of the early Church, credited with a direct spiritual inspiration (χάρισμα) for enlightenment and edification. Men can be appointed to an office; they cannot be appointed to prophecy. The conviction that in Christ all things were made new evoked minds sensitive to spiritual issues.

Therein the Christian prophets were in the true succession; but in all else how different irom the lonely Hebrew seers. The Christian prophets were expected to provide intelligible utterances (I Cor. xiv, 32), and were thus differentiated from the ecstatic "speaker in tongues," while they were also distinct from the permanent local officials—catechists, deacons, presbyters, bishops. From the valuable information in the *Didache* it appears that the high regard felt for them lasted fully a century; yet their position was always precarious. Sane enthusiasm might lapse into futile ecstasy (I Cor. xiv, 29–33). Hypocrites might simulate the gift—the *Didache* insists that the prophet is worthy of maintenance and respect only if his piety is indubitable and his conduct "worthy of the Lord." The prestige of the permanent officials increased in comparison with the occasional prophet, whose sole virtue seemed to be his edifying speech. But that gift might also be found among the regular ministers: and if so, how preierable! Lastly the zeal of the prophets might claim an authority over or make ascetic demands on the church which roused antagonism. At the end of the 2nd century the wild prophesying in the Montanist party (significantly oi Phrygian origin) hastened the end. Armed with the now-accepted Canon of Holy Scripture ("the law and the prophets until John"), the authorities ruled that "Ecstasy was of the devil not of God" and that "Prophets must not accept giits," and ere long they ceased as a distinctive class in the church's organization.

BIBLIOGRAPHY.—The literature on this subject is so extensive that only a selection of important, or recent, works can here he cited. In addition to commentaries on the several prophets, and discussions in volumes dealing generally with the religion of Israel, see W. R. Smith's Prophets of Israel, 2nd ed., with notes by Cheyne (1895); A. B. Davidson, article "Prophecy" in Hasting's *Dict.* Bib. (1902); C. F. Kent, Israel's *Prophets* (1910); G. A. Smith, Early Poetry *of* Israel (1910); Sellin, A. *T. Prophetismus* (Leipzig. 1912); G. Holscher, Die *Propheten* (Leipzig, 1914): M. Buttenmieser, Prophets *of Israel* (1914); A. R. Gordon, *Prophets of* the O.T. (1916); E. König, article "Prophecy, Hebrew," in *E.R.E.* (1918); Welch, Visions of *the End* (1922); Duhm,

Israels Profeten, 2nd ed. (Tübingen, 1922); Skinner, *Prophecy and Religion* (1922); T. H. Robinson, *Prophecy and the Prophets,* with bibliography by Peake (1923); Peake, *Roots of Hebrew Prophecy* (1923); Wiener, *Prophets of Israel* (1923); S. A. Cook, in *Cambridge Ancient History,* vol. iii, with biblio. (1925); J. M. P. Smith, *Prophets of Israel* (1925); Micklem, *Prophecy and Eschatology* (1926); and Fascher, II ροφήτης (1927). On Hebrew psychology in relation to the prophets, H. Wheeler Robinson, *Christian Doctrine of Man* (1913), and articles in *The People and the Book* (1925) and *O.T. Essays* (1927). On prophets in the Christian Church, *see* Selwyn, *The Christian Prophets* (1900); Mitchell, article "Prophecy, Christian," in *E.R.E.* (1918).
(W. A. L. E.)

PROPIOLIC ACID forms colourless crystals melting at 18° C. to a liquid that boils at 144° C. It is soluble in water and has an odour like that of acetic acid. It has the constitution of acetylenemonocarboxylic acid, $HC\vdots C.CO_2H$, and is of interest as being the simplest acetylenic acid. It is obtained by the following reactions: succinic acid is brominated, and dibromosuccinic acid by the action of alcoholic potassium hydroxide yields acetylenedicarboxylic acid, $CO_2H.C\vdots C.CO_2H$. This acid or its monopotassium salt on boiling with water loses carbon dioxide, and propiolic acid is produced. Furthermore, carbon dioxide reacts with monosodium acetylide, C_2HNa, under pressure to give the sodium salt of propiolic acid. On exposure to light, propiolic acid polymerizes into trimesic acid (benzene-1:3:5-tricarboxylic acid). (G. W. Wd.)

PROPORTIONAL REPRESENTATION, an electoral arrangement designed to secure that the representative assembly shall be an exact reflection, a "snapshot," of the voting strength of parties among the electorate. To its proponents the case for proportional representation (P.R.) is fundamentally the case for representative government; every trace of opinion, be it ever so small, ought to be represented in the legislature as near as possible to its proportional mathematical claim.

Opponents of P.R. consider the system logical only if parliament is conceived, in the words of Edmund Burke, as "a Congress of ambassadors from different and hostile interests." If, on the other hand, parliament is "a deliberative assembly of one nation with one interest, that of the whole," the majority system is required. The latter introduces a process of integration, making it necessary for all parties to appeal to a cross section of the various groups of which a country consists. Thus, a common denominator is found for all of them.

P.R. owes its intellectual standing in continental Europe and Latin America mainly to Victor Considérant, and in the Anglo-Saxon countries to John Stuart Mill. Mill emphasized the need for adequate representation of minorities; Considérant felt that while final parliamentary decision required the rule of the majority, the earlier stage of parliamentary deliberation was well compatible with the introduction into a parliamentary body of a variety of groups by P.R. The appeal of these arguments has been widespread. The end of World War I left, among the countries generally accepted as democratic, only the Anglo-Saxon countries and France with the majority system.

In the case of both the majority system and of P.R. there are a number of variations. In Great Britain, the members of the commonwealth and the United States, the plurality system dominates; in a single-member district the candidate with the highest vote is declared elected even if he has secured less than 50% of the total. Imperial Germany used the system of runoff elections; if no candidate had an over-all majority in the first ballot, a second ballot decided between the two strongest competitors. In the France of the third republic a more liberal form of the second ballot was used, in which all candidates, even those who had not participated in the first ballot, could compete. The candidate with a plurality of the votes won, although coalitions between the rightist and leftist parties usually cut down the number of candidates and made attainment of an absolute majority likely. These coalitions were often connected with unsavoury intrigues. To obviate these difficulties, Australia adopted, for its house of commons, the alternative vote, which requires an absolute majority and where there is only one ballot, in which the voter instead of marking his choice with an "X," marks the candidates in the order of his preference (whence "preferential vote" system), 1, 2, 3, etc.; and then the returning officer eliminates the bottom candidates in turn, distributing among the top candidates the preferences marked on the eliminated ballots.

All varieties of majority voting deviating from the plurality system increase the chances of minor parties and have proved incompatible with a two-party system. P.R. attempts to do more than assure an absolute majority for the victorious candidate. It begins by creating large constituencies with a number of seats. In the English Proportional Representation society's suggested program, called the "single transferable vote," a constituency of at least 300,000 inhabitants was suggested and at least five seats. In the German system prevailing between 1919 and 1933, the constituencies averaged nearly 1,000,000 electors, and 15 or 16 representatives. The severalty of representatives made it possible for any well-knit minority with a quota of votes (*i.e.,* the lowest number required, in the circumstances) to get representation. Votes cast for a member were not to be lost to the party if he personally should fail, for they were transferred or accredited to other members of the party who held them to make up the quota. This can be done in a number of ways. The system advocated in England is that the voter shall be free to indicate his preference by numbers against the long list of candidates, the returning officer then distributing the surplus preferences of successful candidates and those with no chance among those who are designated by the preferences, until all the seats are filled by those with quotas. This system leaves the voter free of party dictation.

Other list systems permit the voter to mark a preference for one or several candidates; in some cases, such preferences may even be given to candidates of more than one party. The parties get the mathematical share of the seats to which their aggregate vote entitles them. In Germany each party got one representative for each 60,000 votes it secured, while fractions of 60,000 were added together for each party (within certain limits), and again for each such 60,000 the party was permitted to nominate an extra member.

The French system of P.R., adopted in 1945, was based on party lists, in the framework of the *département.* It was feared that this election law, which, because of the D'Hondt system, favoured large parties, would, if applied in the elections of 1951, have given the Gaullists and Communists a majority of the seats even with somewhat less than a majority of the votes. Therefore, it was provided that wherever a party or a coalition of parties secured the absolute majority of the votes in a constituency, it obtained all the seats, although for Paris and its suburbs, where the extremists were strong, a form of P.R. more favourable to the centrist parties than the D'Hondt system was used.

Germany used for the bundestag elections of 1949, as well as for a number of elections within the various Länder, a system which combined single-member constituencies with P.R. In each of the constituencies the candidate with a plurality of the votes was elected. Over-all proportionality between the votes cast for a party and the seats attributed to it was attained by distributing additional seats, usually 40% of the total, on a so-called "reserve list," to the parties which had obtained fewer seats than corresponded to their share of the votes.

The merits of P.R. lie, according to its supporters, in its equity. The demerits of the system as they operate in Europe are these: (1) The personal contact between member and constituency is reduced; in its place the party machine rules by deciding the order of candidates on the list and by requiring teamwork among candidates which results in the "star" man helping the mediocrities. (2) A premium is placed upon the use of mechanical devices to make electors go to the poll—this is a direct result of a large constituency. (3) Small parties are kept in existence, or encouraged to organize themselves, which seriously disturbs the process of parliamentary government where a compact and single-party majority in office faced by an opposition similarly constituted is essential to stability, vigour and responsibility of executive. Opponents of the system hold that in a number of countries, including Italy and Germany, the various factors making for the weakness of democracy would not have sufficed to make possible the victory of dictatorship had it not been for the dispersal and the demoralization of the prodemocratic forces by P.R.

P.R. has, in the form of the single transferable vote, also been used for a number of U.S. cities, most of which, however, later abandoned it. Adopted to facilitate the victory of reform groups over political machines, it was held to have led to the frustration of the voter who could not cope with its complexities, to the intensification of racial and alphabetical voting and (in particular in New York city) to the election of extremists. By 1952, only nine municipalities retained it, six of them in Massachusetts. The leading P.R. city is Cincinnati, O.

France took a step away from P.R. in the election law of 1951 and Italy in the election law for municipalities adopted during the same year; in 1952 the Greek government endorsed the majority system after the U.S. ambassador had, with the approval of the U.S. state department, expressed the view that P.R. led to a degree of instability which jeopardized the success of U.S. aid. The proponents of P.R. scored a success, however, when in 1950 the single transferable vote, also used in Ireland, was adopted for the Australian senate.

Bibliography.—*For P.R.:* J. H. Humphreys, *Proportional Representation* (1911) and *Practical Aspects of Electoral Reform* (1922); C. G. Hoag and G. H. Hallett, *Proportional Representation* (1926); George H. Hallett and C. G. Hoag, *Proportional Representation—the Key to Democracy,* 2nd ed. (1940). *Critical of P.R.:* H. Finer, *The Case Against Proportional Representation* (1924); F. A. Hermens, *Democracy or Anarchy? A Study of Proportional Representation,* with introduction by C. J. Friedrich (1941), and *Europe Between Democracy and Anarchy* (1951). The case for P.R. is also presented in the P.R. department of the *National Municipal Review;* this department is the successor to the *Proportional Representation Review.*
(H. Fi.; X.)

PROPOSITION. In scholastic and traditional logic, a proposition was understood as an expression in words having the meaning of an assertion. An example is Petrus Hispanus, *c.* 1245, "Propositio est oratio verum vel falsum significans indicando." Thus a proposition is not simply a declarative sentence, in the grammatical sense, but is such a sentence taken together with its meaning. Consequently propositions may be different though the sentences are the same (*e.g., I am hungry,* uttered by two different persons). And also, although this consequence is less emphasized by traditional writers, propositions are different when the sentences are different and even if the meaning is the same (*e.g.*, *Tempus fugit* and *Time flies*).

The usual scholastic term was the Latin *propositio*—first found in this meaning in the writings of Lucius Apuleius, *c.* 150, and Manlius Severinus Boethius. *c.* 500. However, *enuntiatio* (enunciation)—a term taken from Cicero—was also employed, and some of the scholastics used this as the general term, reserving *propositio* for some more special meaning.

This scholastic-traditional notion of a proposition is inconvenient or unsatisfactory in many contexts because of its dependence on the particular form of expression in words, or on a particular language. Hence the different notion of a mental proposition (*propositio mentalis*) came to be introduced, and also, chiefly later, that of a judgment (*iudicium*).

According to William of Ockham, and later scholastics who followed him, the mental proposition must be formed internally before a corresponding proposition in words is put forward. It is not of any language. Its parts are mental terms or concepts, which are analogous to the spoken or written terms and share with them all properties essential to the meaning. but not such purely grammatical properties as having a particular (grammatical) gender or belonging to a particular declension or conjugation.

The notion of a judgment. as the mental act of assent or dissent, has some mention in the writings of various scholastics. and was made an explicit part of the treatment of logic by Petrus Ramus and later by such logicians as Isaac Watts (*1725*) and Christian Wolff (*1728*). It was still later that the definition of a proposition as a "judgment expressed in words" became a commonplace.

Immanuel Kant. and many traditional logicians who have followed him, replace the consideration of propositions almost entirely by that of judgments. Thus Kant speaks usually, though not always. of an analytic or synthetic judgment (German, *Urtheil*) rather than proposition (German, *Satz*), of a categorical judgment, etc.

However, the mental proposition and the judgment have a psychological reference which may often be as unsatisfactory as the dependence on a particular language which is involved in the traditional notion of a proposition. For some purposes at least there is needed a more abstract notion. independent alike of any particular expression in words and of any particular psychological act of judgment or conception—not the particular declarative sentrnce, but the content of meaning which is common to the sentence and its translation into another language—not the particular judgment, but the objective content of the judgment, nhich is capable of being the common property of many. Such an abstract notion may be seen in the Stoic *Lekta* (*see* LOGIC, HISTORY OF) and the *complexe significabilia* of some 14th and 15th century scholastics, but these ideas fell into oblivion and were reintroduced in different terminology in modern times. By modern logicians the word "proposition" has come to be used for the abstract notion, and we shall therefore here distinguish between *proposition in the traditional sense* and *proposition in the abstract sense.*

Bernard Bolzano attributes the use of *propositio* for proposition in the abstract sense to G. W. von Leibniz in *Dialogus de Connexione inter Res et Verba*. This may be a misunderstanding. But this dialogue does set forth clearly one important ground of the need ior the abstract notion. An explicit distinction between the sentence and the proposition (in the abstract sense) which the sentence expresses is made by Bolzano in his *Wissenschaftslehre* of *1837*, where *Satz an sich* is used for the latter. Gottlob Frege in *1892* uses *Gedanke* for the sense of a declarative sentence, giving to this German word (as he explains) an objective, rather than its more natural subjective, meaning. *Proposition* is used in the abstract sense by Bertrand Russell in *The Principles of Mathematics* (1903), where Russell recognizes that Frege's *Gedanke* is approximately "what I have called an unasserted proposition," and in *Principia Mathematica* A. N. Whitehead and Russell speak of "what we call a 'proposition' (in the sense in which this is distinguished from the phrase expressing it)." Russell also uses *proposition* in the traditional sense; *e.g.* in *Introduction to Mathematical Philosophy* defining a proposition as "a form of words which expresses what is either true or false"; but more recent writers have generally followed him in the abstract usage.

See R. M. Eaton, *General Logic*, i, 3–5 (New York, 1931); Xlonzo Church, *Introduction to Mathematical Logic*, sec. 04 (Princeton, 1955). (Ao. C.)

PROPYLAEA, the name given to porches or gatehouses at the entrance of sacred or other enclosures in Greece; propylaea usually consisted, at their simplest, of a porch supported by columns both without and within the actual gate. The name is especially given to the great entrance hall of the Acropolis at Athens, which was begun in 437 B.C. by Pericles. Probably because of political difficulties and the outbreak of the Peloponnesian War, the building was never completed according to plan, but the portion that was built was among the chief glories of Athens and afforded a model to many subsequent imitators. The architect was Mnesicles; the material Pentelic marble, with Eleusinian blackstone for dados and other details.

The plan of the Propylaea consists of a large square hall, from which five steps lead up to a wall pierced by five gateways of graduated sizes, the central one giving passage to a road suitable for beasts or vehicles. On the inner side. facing the Acropolis, this mall is faced with a portico of six Doric columns. At the other end of the great hall is a similar portico facing outward; and between this and the doors the hall is divided into three aisles by ro s of Ionic columns. The western or outer front is flanked on each side by a projecting wing. with a row of three smaller Doric columns between antae at right angles to the main portico. The north wing is completed by a square chamber which served as a picture gallery, but the south wing contains no corresponding chamber, and its plan has evidently been curtailed; its front projected beyond its covered area, and it is finished in what mas evidently a provisional way on the side of the bastion before the little temple of Athena Nike.

From this and other indications W. Dorpfeld inferred that the original plan of Mnesicles was to complete the south wing on a plan symmetrical with that of the north wing, but opening by a portico on to the bastion to the west; and to add on the inner side of the Propylaea two great halls, faced by porticoes almost in a line with the main portico. but with smaller columns. This would have interfered with sacred objects such as the precinct of Artemis Brauronia and the altar of Nike. and the architect was probably forced to modify his plan even before work on the building stopped. The Propylaea were approached in Greek times by a zigzag path, terraced along the rock; this was superseded in Roman times by a broad flight of steps. In medieval times the Propylaea served as the palace of the dukes of Athens; they were much damaged by the explosion of a powder magazine in *1645*. The tower of Frankish or Turkish date that stood on the south wing was pulled down in *1874*.

The term is also applied to various monumental gateways of modern times, especially in Germany. Examples are: the propylaea at Munich (1862) and the Brandenburger Tor in Berlin (*1784*). *See* GREEK ARCHITECTURE.

See W. J. Anderson and R. P. Spiers, *The Architecture of Ancient Greece*, rev. by W. B. Dinsmoor, new ed. (1950); D. S. Robertson, *A Handbook of Greek and Roman Architecture*, 2nd ed., corrected (1943). (E. GR.; C. M. RN.)

PROPYL ALCOHOLS, two compounds of this name, with the same formula C_3H_7OH exist, and both come into prominence in connection with modern developments of industrial organic chemistry.

Normal propyl alcohol, $CH_3.CH_2.CH_2.OH$, is obtainable as a by-product in the synthesis of methyl alcohol (*q.v.*) by condensing carbon monoxide and hydrogen in presence of a zinc-chromite or zinc-cobalt-chromite catalyst at 400° C. under zoo atm. pressure. (*See* PRESSURE CHEMISTRY.) It is a colourless fragrant liquid boiling at 97.4° C. and miscible with water in all proportions. It cannot be separated from water by distillation since the two compounds form an azeotropic mixture. (*See* DISTILLATION.) n-Propyl alcohol occurs in fusel oil and may be prepared by any of the synthetic methods applicable to primary alcohols. (*See* ALCOHOL.)

Isopropyl alcohol, $(CH_3)_2CH.OH$, is manufactured on an extensive scale from propylene, $CH_3:CH:CH_2$, obtained by the cracking of petroleum. *(See* OLEFIN.) This olefin is absorbed in sulfuric acid. the liquid diluted with water and distilled. when isopropyl alcohol is obtained. It is a colourless. fragrant liquid boiling at 82.7° C. It is used as a solvent and as a reagent in organic chemical synthesis.

PROPYLON, in architecture, a monumental entrance gate; in Egypt two great piers with a flat lintel set before the front pylon of a temple In Greece a columned porch on both sides of a wall of doors gives entrance to a sanctuary or agora.

PROSCENIUM, originally, in the Greek theatre, the colonnade supporting a platform in front of the scene building (*σκηνή*, Latin *scena*). Scenery was set between the columns. In the modern theatre the word proscenium is used particularly in connection with the arch (proscenium arch) framing the stage.

PROSE, the plain speech of mankind, when written or composed without reference to the rules of verse. It has been usual to distinguish prose very definitely from poetry (*q.v.*). Pierre de Ronsard said that to him prose and poetry were "mortal enemies." But "poetry" is a more or less metaphysical term. which cannot be used without danger. For instance. an ill-inspired work in rhyme cannot be said to be poetry, and yet most certainly is not prose. On the other hand, a work of highly wrought nonmetrical writing is often called a prose-poem. This shows that the antithesis between prose and poetry is not complete. Prose, therefore, is best defined as comprising all forms of careful literary expression which are not metrically versified. and hence the definition from *prorsus* (direct or straight), the notion being that it is straight and plain, and is used for stating that which is true in reason or fact

Prose, however, is not everything that is loosely said. True, it is the result of conversation, but that conversation is not necessarily, nor often, prose. Prose is not the negation of all laws of speech; it rejects merely those which depend upon metre. What its laws are is not easy to say. But this is plain; as prose depends on the linking of successive sentences, the first requirement is that these sentences should be lucidly arranged. In prose, that the meaning should be given is the primal necessity. But as it is found that a dull, clumsy, monotonous arrangement of sentences is fatal to the attention of the listener or reader, it is needful that to plainness should be added various attractions and ornaments. The sentences must be built up in a manner which displays variety and flexibility. There should be a harmony, and even a rhythm, in the progress of style, care being taken that this rhythm and this harmony are not recognizably metrical. Again, the colour and form of adjectives, and their sufficient yet not excessive recurrence, is an important factor in the construction of prose. The omission of certain faults, too, is essential. In every language grammatical correctness is obligatory. Here we see a distinction between mere conversation, which is loose, fragmentary and often even ungrammatical; and prose, which is bound to weed away whatever is slovenly, and to watch closely lest merely colloquial expressions should slip in. What is required is a moderate and reasonable elevation without bombast or bathos. Not everything that is loosely said is prose, and the celebrated phrase of M. Jourdain is not exactly true, for all the loose phrases which M. Jourdain had used in his life, though they were certainly not verse, were not prose either. We must be content to say that prose is literary expression not subjected to any species of metrical law.

Greek. — The beginnings of Greek prose are very obscure. It is probable that they took the form of inscriptions, and gradually developed into historical and topographical records. We come down to something definite when we reach Hecataeus and Herodorus; and, although their writings have disappeared, we know enough to see that by the jth century B.C. the use of prose in its modern sense had been established. We even know the character of the style of Hecataeus, and we hear of its clearness, its grammatical purity, its individuality — qualities which have been valued ever since. These writers were succeeded by Hellanicus, who wrote many historical books now lost, and by Herodotus, whose noble storehouse of chronicle and legend is our earliest monument of European prose. When once non-metrical language could be used as by Herodotus, it was plain that all departments of human knowledge were open to it. But it is in Ionia and the Asiatic islands that we find it cultivated by philosophers and critics. The earliest of these masters of prose survive only in much later records of their opinions; in philosophy the actual writings of Thales, Anaximander, Pythagoras and Empedocles are lost, and it is likely that their cosmological rhapsodies were at least partly metrical. We come into clearer air when we cross to Attica: Thucydides' priceless work has most fortunately come down to us; and Xenophon continued it in the spirit of Thucydides, and carried Greek prose to a great height of easy distinction. But it is in philosophy that prose in Greece gains flexibility and variety, proving itself an unsurpassed vehicle for the finest human thought. The philosopher Plato is the greatest prose writer of Greece, and, in the view of many well qualified to judge, of the world. In his dialogues we see what splendour, what elasticity, what exactitude, this means of expression had in so short a time developed; how little there was for later prose-writers to add. The rhetoricians were even more highly admired by antiquity than the philosophers, and ancient, unlike modern, opinion would perhaps have set Demosthenes higher than Plato. In Aristotle we see the conscious art of prose-writing subordinated to the preservation and explanation of facts, and after Aristotle's day there is little to record in a hasty outline.

Latin. — The Romans obeyed the universal law by cultivating verse long before they essayed the writing of prose. The earliest historians of whom we have definite knowledge, Fabius Pictor and Cincius Alimentus, wrote in Greek. The earliest annalist who wrote in Latin was Hemina; the works of all these historians are lost. A great deal of primitive Roman prose was occupied with jurisprudence and political oratory. By universal consent the first master of Latin prose was Cato, the loss of whose chief works is to be deplored; we possess from his pen only a treatise on agriculture. In the next generation we are told that oratory was carried to the highest point by Marcus Xntonius and Licinius Crassus — "by a happy chance their styles were exactly complementary to one another." Unfortunately none but inconsiderable fragments survive to display their qualities. Happily, however, those qualities were combined in a man of genius, whose writings have come down to us; this is Cicero, whose prose exhibits the Latin language to no less advantage than Plato s does the Greek. From 70 to 60 B.C. Cicero's literary work lay mainly in the field of rhetoric; after his exile he was chiefly occupied with theoretical treatises. The beautiful essays of his old age comprise two little masterpieces, *De amicitia* and *De senectute* (45 B.C.). It is to the collection of the private letters of Cicero, published after his death by Atticus and Tiro, that we owe our intimate knowledge of the age in which he lived, and these have ever since been held models of epistolary prose. Of Cicero's greatest contemporary, Julius Caesar, much less has been preserved, and this is unfortunate because Roman critical opinion placed him among the very chief of prose-writers; but we retain his *Commentaries*. The prose of Sallust, who followed Caesar, is hard, brief and sententious. The writers who succeeded him neglected these qualities, and Latin prose became more diffuse and rhetorical. But it was wielded by one writer of the highest genius, Titus Livius, who enriched the tissue of Latin prose with ornament which hitherto had been confined to poetry; this enables him "to advance without flagging through the long and intricate narrative where a simpler diction must necessarily have grown monotonous" (Mackail). The periodic structure of Latin prose, which had been developed by Cicero, was carried even further by Livy. The style of Pollio, who wrote a *History of the Civil Laws*, was much admired, and the loss of this work must be deplored. A different species of prose, the *plebeius sermo*, or colloquial speech of 'the poor, is partly preserved in the fragments of a Neronian writer, Petronius Arbiter. Of the Latin prose-writers of the silver age, Seneca, Quintilian and Tacitus, nothing need here be said.

English. — The independence of English prose is a fact which rests on a firm basis. "The Code of Laws of King Ine" dates from the 8th century, and there are various other legal documents which may be hardly literature in themselves, but which are worded in a way that seems to denote the existence of a literary tradition. After the Danish invasion, Latin almost ceased to be known, and translations began to be required. In 887, Alfred wrote in English, with the help of scholars, his *Hand-Book;* this, probably the earliest specimen of finished English prose, is unhappily lost. His English version of the *Cura pastoralis* was probably completed in 890. Later still Alfred produced translations from Bede. Orosius, Boethius and other Latin authors, and, in 900, closing a translation from St. Augustine, we read "Here end the sayings of King Alfred." The prose of Alfred is simple and clear without pretension. After him the first name of eminence which we encounter is that of Aelfric, who, about 997, began to translate, or rather to paraphrase. certain portions of the Bible into a very finished English. A little later vigorous prose was put forth by Wulfstan, archbishop of Pork (d. 1023). At the Conquest, the progress of English prose was violently checked, and, as has been said, it "was just kept alive, but only like a man in catalepsy." The *Annals* of Winchester, Worcester and Peterborough were carried on in English until 1154. Except in a few remote monasteries, English ceased to be used, even for religious purposes, and the literature became exclusively Latin or French. We may perhaps say that modern English prose begins with the *Testament of Love* of Thomas Usk (*c.* 1388). To the same period belong *The Tale of Melibee* and *The Parson's Sermon* by Chaucer; the treatises of John of Trevisa, whose style in the *Polychronicon* has a good deal of vjgour; and the three versions of the *Travels* of Jean à Barbe, formerly attributed to "Sir John Mandeville." The composite text of these last-mentioned versions really forms the earliest specimen of purely secular prose which can be said to possess genuine literary value, but again the fact which has been ascertained that "Sir John Mandeville" was not an original English writer robs it of much of its interest

The anonymous compiler-translator can no longer be styled "the father of English prose." That name appears to belong to John Wyclif, who. in the course of his career as a controversialist, more and more completely abandoned Latin for English. The translation of the English Bible was begun by Nicholas Hereford. The completion of this work is usually attributed, but on insufficient grounds, to Wyclif himself A new version was almost immediately started by John Purvey, another Wyclifite, who completed it in 1388. We are still among translators, but towards the middle of the 15th century Englishmen began, somewhat timidly, to write original prose. Capgrave, an Augustinian friar, wrote a chronicle of English history down to 1417; Sir John Fortescue produced about 1475 a book on ***The Governance of England;*** and Reginald Pecock attacked the Lollards in his *Repressor of Over Much Blaming of the Clergy* (*c.* 1450). The prose of Pecock is sometimes strangely modern, and to know the ordinary English prose of the 1jth century it is more useful to turn to *The Paston Letters.* The introduction of printing into England is coeval with a sudden development of English prose, a marvellous example of which is to be seen in Caxton's edition of Malory's *Morte d'Arthur,* in which the capacities of the English language for melody and sweetness were for the first time displayed. Caxton himself, Lord Berners and Lord Rivers, added an element of literary merit to their useful translations.

With the Renaissance, *Richard* **Ill.,** whether by Sir Thomas More or by Cardinal Morton, was a work of considerable importance; *Utopia* (1516) was unfortunately composed in Latin, which still held its own as a dangerous rival to the vernacular. In his *Governour* (1531) Sir Thomas Elyot added moral philosophy to the range of subjects thought proper for English prose In the same year Tyndale began his version of the Bible, the story of which forms one of the most romantic episodes in the chronicles of literature; at Tyndale's death in 1536 the work was taken up by Coverdale. The *Sermons* of Latimer (1549) introduced new elements of humour and vigour. The earliest true biography was the *Life* of *Cardinal Wolsey,* by George Cavendish, written about 1557, but not printed until 1631. In the closing scenes of this memorable book, which describe what Cavendish had personally experienced, the perfection of easy English style is reached for the first time. The prose of the middle of the 16th century—as exemplified in Sir Thomas Wilson, Roger Ascham, and Sir John Cheke—is clear, unadorned and firm, these Englishmen holding themselves bound to resist the influences coming to them from Italy and Spain. Equal simplicity marked such writers as Foxe, Stow and Holinshed, who desired a straightforward prose in which to present their information. But Hoby and North introduced not a few exotic graces, and prepared the way for the innovations of Lyly in *Euphues* (1579). The extravagances of Lyly outdid those of his continental prototypes, and euphuism became a disturbing influence which, it may be, English prose has not, even yet, entirely thrown off. In spite of its popularity, it was opposed in its own day, not merely by the stately sobriety of Hooker, but by the sweetness of Sir Philip Sidney. Raleigh wrote an English prose perhaps more majestic than any which preceded it, but he revelled in length of sentence and ponderosity of phrase, so that the prestige of *The History of the World* on the whole delayed the emancipation of English prose. The direct influence of euphuism was seen for some time in the work of poets like Lodge and Greene, and divines like Andrewes; its indirect influence in the floweriness and violence of most prose down to the Restoration.

Donne had a sonorous majesty of style; and Burton could use English with humour and vivacity when he gave himself the chance In spite of the skill with which, during the civil wars and the Commonwealth, authors like Jeremy Taylor, Fuller and Milton manipulated prose, and in spite of the magnificence of Sir Thomas Browne, it was not until shortly before the Revolution that English prose reached its perfection. According to Dr. Johnson, Sir William Temple (1628–99) was the first writer who gave cadence to English prose. The new tendency was all in favour of brevity and crispness of shorter sentences and easier constructions. Not a little of the majesty of the earlier age was lost; but for practical purposes prose became a far more businesslike implement than it had hitherto been. The treatises of Halifax, or the sermons of South, mark the change. The power of English speech was first comprehended perhaps by Dryden, who combined dignity and even pomp of movement with an ease and laxity on occasion which gave variety to prose, and approximated it to ordinary speech. This then may be called the foundation of modern English prose, which has extended into no departments not recognized, at least in essence, by Bunyan, Dryden and Temple. The ensuing varieties have been mainly matters of style. In the 18th century, for instance, there was a constant alternation between a quiet, rather cold elegance and precision, which was called the Addisonian manner, and a swelling, latinized style, of which Johnson is the most famous exemplar. But as far as arrangement and syntax are concerned, it cannot be said that English prose has altered essentially since about 1680. It is, however, to be noted that in the course of the 19th century attempts were made to restore the beauty and variety of early 17th-century diction.

Icelandic.—The independent invention of prose by the Icelanders is one of the most singular phenomena in history. It resulted from the fact that story-telling was a recognized form of amusement in the isolated life of an Icelandic household. Something of the same kind had existed in Norway before the exodus, but it was in Iceland that it was reduced to an art. It is remarkable how suddenly the saga, as a composition, became a finished work. The deliberate composition of sagas began about the year 1030, and it is recorded that Ari Fródi (1067–1148) was the first man in Iceland who wrote down stories. Many of Ari's books are lost, but enough survive to show what Icelandic prose was in his hands, and the impress of his rich and simple style is felt in all the succeeding masterpieces. Snorri, and the anonymous authors of *Njala*, *Laxdaela,* and the rest, exhibit simple prose style at its highest. The great historian. Sturla (1214–84), is the latest of these classic writers of Iceland, and after his death there was a rapid decline. The splendid prose of these two centuries stands unrelated, an unparalleled portent in European literature.

Spanish.—In Castilian, as elsewhere, verse is far advanced before we meet with any distinct traces of prose A religious treatise is attributed to a monk of Navarre, writing in the 13th century. Between 1220 and 1250 a chronicle of Toledo was indited. But the earliest prose-writer of whom Spain can really boast is King Alphonso the Learned (1226–84), in whose encyclopaedic treatises "Castilian makes its first great stride in the direction of exactitude and clearness" (Fitzmaurice-Kelly). Almost all the creditable prose of the end of the 13th century is attributed to Alphonso, who was helped by a sort of committee of authors. The king's nephew, Juan Manuel (1282–1347), author of *Conde Lucanor,* carried prose to a further point in delicacy and precision. The poet Ayala (1332–1407) was another gifted artificer of Spanish prose, which suffered a setback in the hands of his successors, Santillana and Mena. It rose once more in *The Sen* of *Histories* of Pérez de Guzmán (1378–1460), in whom the lucid purity of Castilian prose is for the first time seen. In the 1 jth century the shapeless novel of chivalry was predominant, while in the age of Ferdinand prose decayed. The next great writer whom we meet with is Guevara (d. 1545), whose *Dial of Princes* exercised an influence which even extended to English prose (in North's well-known version). The historians of this period were of less value. The earliest picaroon novel, *Lazarillo de Tormes* (1554), introduced a new form and exhibited Castilian prose style in a much lighter aspect. Still greater elegance is met with in the writings of Juan de Valdés and of Luis de León. Of the latter Fitzmaurice-Kelly says that "his concise eloquence and his classical purity of expression rank him among the best masters." The instrument, accordingly, was ready to the hand of the supreme magician Cervantes, whose *Don Quixote* was begun a few years (about 1591) after *Los Nombres de Cristo* of Luis de León. The prose of Lope de Vega is stately and clear: but admittedly has little importance in comparison with his verse. Quevedo's style had the faults of antithesis and obscure ingenuity; but his *Visions* (162;) are of course famous. The latest struggles of a decadent critical conscience, battling against affectation, are seen in Graciin (1601–58) and Molinos (*c.* 1640–97). When Spanish prose revived in the 19th century, in the person of Larra (1809–37), the influence of French models was found to have deprived it of distinctly national character: while giving it a fresh fluidity and grace.

French. — There had long been a flourishing versified iiterature in the vernacular of France, before anyone thought of writing French prose. It was the desire to he exact in giving information which led to a partial divergence from metre. The translator of the *Chronicle of Turpin* mentions that he writes in prose "because rhyme entails the addition of words not in the Latin." Thus about 1200 verse began to be abandoned by chroniclers who had some definite statements to impart. They ceased to sing; they wrote as those around them spoke. The earliest French prose was translated from the Latin, but Baldwin VI. (d. 1205) is said to have commissioned several scribes to compile in the vulgar tongue a history of the world. If this was ever written it is lost, but we possess a *Book of Stories* written about 1225 by a clerk at Lille, which may fairly be said to be the beginning of French prose history. When once, however, a taste for prose was admitted, the superiority of that medium over verse as material for exact history could not but be perceived. The earliest French prose-writer of genius was Villehardouin, who put down memoirs of his life between 1198 and 1207; he left his hook, *The Conquest* of *Constantinople*, incomplete. In the history of prose, Villehardouin takes an eminent place. In his style are seen many of the most precious elements of French prose, its lucidity, its force, its sobriety and its charm. He had been trained as an orator, and was content to write as he had learned to speak. He was followed by other admirable writers of memoirs, Robert of Clari, Henri of Valenciennes, the anonymous chronicler of Béthune, to whom we owe the famous description of Bouvines, and the Minstrel of Reims. The last-named finished his *Récits* in 1260. These works in the new easy manner of writing were found to be as elegant and as vivacious as any in verse. They led the way directly to the earliest historian of modern Europe, Joinville, who finished his *Histoire de St. Louis* in 1309. A century later Froissart left his famous *Chroniques* unfinished in 1404, and again 100 years passed before Philippe de Commines dropped the thread of his *Mémoires* in 1 j11. These three are simply the most eminent figures in a great cloud of prose-writers, who helped to facilitate the use of the national language. In the 15th century, moreover, Antoine de la Salle deserves mention as practically the earliest of French novelists. But with the Renaissance came the infusion into France of the spirit of antiquity, and in Rabelais there was revealed an author of the very highest genius. The year 1532, in which the first brief sketch of *Gargantua* appeared, was critical in French literature. In 1549 appeared the *Défense et illustration de la langue française* of Joachim du Bellay, in which the foundations of French literary criticism were firmly laid. The liberation of the language proceeded simultaneously in all directions. In 1 j39 it was officially decreed that all judicial acts were thenceforward to be written "en langage maternal français." Calvin led the theologians, and his precise and transparent prose gave the model to a long line of sober rhetoricians. It is in Calvin that we meet for the first time with a simple French prose style, which is easily intelligible to-day. There is some pedantry in St. François de Sales, some return to the spirit of mediaeval French in Montaigne; so that the prose of these great writers seems to us more antiquated than that of Calvin. Yet the *Institution* belongs at latest to 1560, and the immortal *Essais* at earliest to 1580. We are approaching the moment when there should be nothing left for French prose to learn. But we pause at Brantôme, in whom the broad practice of French as Froissart and the mediaeval chroniclers had used it was combined with the modern passion for minute and picturesque detail With the beginning of the 17th century there sprang up almost an infatuation for making prose uniformly dignified, for avoiding all turns of speech which could remind the reader of the "barbarous" origins of the language; the earliest examples of this subjection of eloquence to purely aristocratic forms have been traced back to the *Servitude volontaire* of La Boétie (1530–63). In the pursuit of this dignity the prose writers of the 16th century ventured to borrow not words merely but peculiarities of syntax from Greece and Rome. The necessity of remaining intelligible, however, checked excess, and after a few wild experiments the general result was discovered to be the widening of the capacities of the language. In the 17th century a great stimulus was given to easy prose by the writers of romances, led by d'Urfé, and by the writers of letters, led by Balzac, with whom French prose lost its heaviness and its solemnity; it became an instrument fit to record the sentiments of social life; here was discovered what Voltaire calls the *nombre et harmonie de la prose.* French style became capable of still more when it was used by Descartes and by Pascal to interpret their majestic thoughts. At this moment, in 1637, the French Academy was founded, for the distinct purpose of purifying and enlarging the French language; and in time, out of the midst of the academy, arose the important *Remarques* (1647) of Vaugelas, a work of grave authority, which was the earliest elaborate treatise on the science of prose in any language. Antiquated as Vaugelas now seems, and little regarded by modern writers his work is still the basis of authority on the subject. In common with his colleagues he laid down laws by which harmony of structure, a graceful sobriety and exactitude of expression, could be secured to every practised French writer. He was not accepted as infallible, even in his own age; he was immediately exposed to the criticism of La Mothe le Vayer, who, however, was radically at one with him regarding the basis of his definition. The great demerit of the early academicians was that they knew little about mediaeval French. They thrust everything aside which they regarded as barbarous, and the work of the 19th century was to recover from a past behind Rabelais elements of great value which the 17th had arbitrarily rejected. In the succeeding centuries there has been a vast extension of the practice of French prose, but in spite of all neologisms, and of the waves of preciosity which have periodically swept over the French language, the treatise of Vaugelas remains the final code in which the laws that govern French prose are preserved.

Italian. — The case of prose in Italian has this unique feature that, instead of gathering form obscurely and slowly, it came into sudden existence at the will of one of the greatest of writers. Latin had almost universally been used in Italy until the close of the 13th century, when Dante created a vernacular prose in the non-metrical part of his *Vita Nuova* (c. 1293). For a long time the prose of Dante stood practically alone, and Petrarch affected to despise the works which his great predecessor had written in the vulgar tongue. But about 1348 Boccaccio started his *Decameron,* which gave classic form to the prose romance of Italy. It should have been greatly to the advantage of Italy that in the hands of Dante and Boccaccio prose was born full-grown, and had not to pass through the periods of uncertain development which awaited it elsewhere. After this brilliant beginning, however, there was a decline, the writers of the next age lacking the courage to be independent of antiquity. There was a return to Latin phraseology which made many works almost macaronic in character; the famous Hypnerotomachia of Colonna is an instance. Something of the purity of Boccaccio was recovered by Sannazaro in his *Arcadia* (1489); even Sannazaro, however, did not see how needful it was to cast off Latin constructions. At length Machiavelli and Guicciardini succeeded in releasing prose from the yoke of Rome, and in writing undiluted Tuscan. In the 16th century the prose writers of Italy became extremely prolific, with Pietro Bembo at their head. The novelists were now prominent, but, although they take a foremost place in the history of Italian literature, there was little art in their employment of language. Many of them were born out of Tuscany, and, like Bandello, never learned the rules of pure Italian prose. Since the 16th century Italian would seem to have undergone no radical changes, and its prose has been stationary in form At the close of the 19th century a new school of writers, with Gabriele d'Annunzio at its head, created a demand for a new prose, but the remedy suggested by these innovators was neither more nor less than a return to Boccaccio and Machiavelli.

German. — The earliest attempts in German prose belong to the age of Charlemagne, and the first example usually quoted is the Strassburger *Eidschwüre* of 842. For all literary purposes, however, metrical language was used exclusively during the *mittelhochdeutsch* period, which lasted until the end of the 13th century. What little prose there was, was limited to jurisprudence and theology. David of Augsburg (d. 1272) is named as the earliest vernacular preacher, but only one of his sermons has reached us. More important was Berthold "the Sweet" (1220–72), whose sermons were published in 1824. Historical prose began with the Saxon Chronicle of 1248. There was little to record in the next two centuries, until prose was revived by Geiler von Kaisersburg (1445–1510) in his sermons. About the same time translations were made of the Decameron and other Italian novelle. The development of prose in Germany is. however, negligible until we reach Luther's Bible (N.T.. 1522), on which all classic German prose is based. Johann Fischart composed important secular books in the vernacular, in particular the Bienenkorb (1579) and an imitation of *Gargantua* (1575), the earliest German novel. Nearly a century passes before we reach the curious picaresque romance of *Simplicissimus* (1669) of Grimmelshausen. But the neglect of prose by the German nation was still general. Even men of the stamp of Leibnitz wrote in Latin or French. What Luther had done was, however, completed and confirmed in the middle of the 18th century by Lessing, the creator of modern German prose. The critical period in this revival was 1764 to 1768, which saw the production of Laocoon and the *Hamburgische Dramaturgie.* We pass presently to Jean Paul Richter, and so to Goethe, in nhose hands German prose became the organ of thought and eloquence which it has been ever since.

PROSECUTION, the procedure by which the law is put in motion to bring to trial a person accused of crime (see CRIMINAL LAW; INDICTMENT). In theory in Great Britain the king is in all criminal offenses the prosecutor, because such offenses are said to be against his peace, his crown and dignity, but in practice such prosecutions are ordinarily undertaken by the individuals who have suffered from the crime. This is a different procedure from that prevailing in Scotland and European continental countries, nhere a public department or officer prosecutes offenses.

In the Cnited States, crimes against the federal government are prosecuted by the different United States attorneys under the general supervision of the United States attorney general. In the states, prosecution is by district, state's or county attorneys, somewhat under the supervision of the state attorney general. Sometimes a special prosecutor is named.

PROSERPINE, generally accounted the Latin form (*Proserpina*) of Persephone. See PERSEPHONE.

PROSODY, CLASSICAL. Ancient Greek metre differs fundamentally from modern English metre in that it is based not on stress but on quantity. Greek verses are composed of comparatively complicated and rigid patterns of long and short syllables. Most Latin verse too is composed on a quantitative system in imitation of Greek.

Greek. — The length of a syllable is determined by the length of the vowel sound contained in it: w, η and diphthongs are long by nature; a, ι, υ may be long by nature (*e.g.*, χωρᾱ, λῡω, ῑμεροs). Vowels with ι subscript or a circumflex accent are long.

A vowel may become long by position when followed bv two or more consonants, or by the letters ζ, ξ, ψ; *e.g.*, ἐλπιζον κεαρ. But certain combinations of consonants, known as "mute and liquid," do not invariably lengthen the preceding vowel. Such combinations are: πλ. φλ, κλ, χλ, τλ, 0X, κμ, τμ, θμ, πν, φν, KV, χν, θν, τν, πρ, φρ, κρ, τρ, Op. The letters β, y, δ lengthen the preceding vowel always when followed by μ or ν, usually when followed by λ, but not when followed by p. In Sappho and Alcaeus combinations of mute and liquid almost always lengthen the preceding vowel; in Homer, Pindar and Bacchylides more often than not; in Attic drama usually not.

Elision.—When a word ending with a short vowel is followed by a word beginning with a vowel. the final vowel of the first word is usually omitted, *e.g.*, τωνδ' ἀπαλλαγην.

Epic *Correption.*—In Homer a final long vowel or diphthong may be shortened when the following word begins with a vowel; *e.g.*, ἐγω̆ οὐ.

Crasis.—Certain short words ending in a vowel may fuse with the initial vowel of the following word; *e.g.*, και ἐμε becomes κἀμε.

Synezesis.—Certain pairs or groups of vowels other than diphthongs may sometimes be scanned as one syllable; *e.g.*, εω, μη οὐ.

Hiatus.—Where a final vowel is follo ed by an initial vowel without either vowel being in any way affected, there is said to be "hiatus." In many apparent hiatuses in Homer the consonant "digamma" (ϝ) was originally present, although not written in the manuscripts. The digamma is sometimes present in Pindar.

Greek verse is of two main types: spoken, or "stichic," and sung, or lyric.

Greek Lyric Verse.—Some lyric verse is composed in set stanzas, notably the sapphic and alcaic (*q.v.*), but most in "strophae" (see STROPHE), stanzas, often long and complicated, composed according to the poet's fancy. These stanzas may be analyzed into verses. The Greek verse is roughly equivalent to the line in English poetry, although one verse is often printed as more than one line in Greek texts. The end of a verse always coincides with the end of a word. When a verse ends with a vowel and the following verse begins with a vowel there is hiatus. The last syllable of a verse is always, in principle, long. If a short syllable occurs at the end of a verse, it is counted as long and called *brevis* in longo.

Each verse consists of one or more "cola" (κῶλον ["limb"]). Some cola are analyzable into "metra" (μέτρον ["measure"]). The elements used in the composition of both metra and cola are. long (–). short (⏑), anceps (⏓, meaning that the position may be occupied by either a long or a short syllable), biceps (⏖ the position may be occupied by either one long syllable or two short ones). Thus ⏓–⏑– is described verbally as "anceps, long, short, long," and –⏖ as "long, biceps."

Metra.—Iamb (⏓–⏑–), trochee (–⏑–⏓), dactyl (–⏖), anapaest (basically ⏑⏑–⏑⏑–, but all four elements are bicipitia), ionic (⏑⏑––), cretic (–⏑–), choriamb (–⏑⏑–). Cola are usually formed of two or more metra of the same type and are named according to the number of metra they contain; *e.g.*, ionic dimeter ⏑⏑––|⏑⏑––. (See IAMBIC; TROCHEE; DACTYL; ANAPAEST; CHORIAMBIC VERSE.)

Catalexis.—Many types of colon may be varied by the omission *of one quantity at or near the end. Thus,* ⏓ – ⏑ – | ⏑ – – *is a catalectic iambic dimeter;* ⏑⏑ – – | ⏑⏑ – *is a catalectic ionic dimeter.*

In the following types the cola are not analyzable into metra.

Aeolo-Choriambic.—Basic *constituents: anceps, choriamb,* – ⏑⏑ – ⏑ –. Two ancipitia *commencing the colon form the* "aeolic *base." A common aeolo-choriambic colon. the "glyconic" (q.v.), consists of base and* – ⏑⏑ – ⏑ –. *Longer cola, the so-called "asclepiads." are formed by the addition of one or two choriambs between base and* – ⏑⏑ – ⏑ – *(see* Choriambic Verse).

Prosodiac-Enoplia.—Cola *of this type combine single-short and double-short rhythm They cannot be analyzed and are perhaps best regarded as prolongations of* – ⏑⏑ – ⏑ –. *Examples are:*

– ⏑⏑ – ⏑ ⏑ – ⏑ – –
καρδιοδηκτον ἐμοι κρατυνεις
⏑⏑ – ⏑ ⏑ – ⏑ –
βιον ᾧ τε δοκει ψεγω.

Dochmiacs.—The *dochmiac may be regarded as an unusually long and variable metron. It consists of anceps,* two *bicipitia, anceps. biceps. The most common forms are:* ⏑⏑⏑ – ⏑ –, ⏑ – – ⏑ –, – ⏑⏑ – ⏑ –. *Dochmiacs are confined to Attic drama.*

Dactylo-Epitrites.—These *occur in Attic drama, and about half the extant poems of Pindar are composed in this metre. Its most common constituents are* – ⏑⏑ – ⏑⏑ – *(hemiepes),* – ⏑ – *(cretic) and* – ⏑⏑ – *(choriamb). which are linked together by ancipitia, usually long, to form compounds like*

– – ⏑ ⏑ – ⏑ ⏑ – – – ⏑ –
κλειναν Ἀκραγαντα γεραιρων εὔχομαι.

The link anceps may sometimes be omitted, and verses may begin with acephalous (headless) elements, e.g.:

⏑ ⏑ – – ⏑ ⏑ – ⏑ ⏑ – – – ⏑ –
Ἀσιας εὐροχορου τριπολιν ναυον πελας.

Several types of metre may be combined in the same stanza. Iambs are found combined with most types of metre. Aeolo-*choriambs and prosodiac-enoplia often occur together. Dochmiacs sometimes receive an admixture of iambic. Dactylo-epitrites are rarely mixed with other metres.*

Greek Stichic Verse.—This *is composed in lines* (στίχοι) *of the same length and type: dactylic hexameters in Homer. etc.. iambic trimeters and trochaic tetrameters in the spoken portions of* drama. Stichic *lines are always divided by word-end at or near the middle. If this division falls within a metron it is called "caesura" (marked thus: ||), if at the end of a metron "diaeresis." (For the rules governing caesurae and other features of stichic composition see* *Hexameter*; *Iambic*; *Trochee*; Anapaest; *Elegy.)*

Latin.— The Saturnian (q.v.) is the only indigenous Latin verse. Other metres are borrowings and adaptations from Greek.

The length of syllables is determined as follows: *Diphthongs are long. A single* vowel followed *by a single consonant may be long or short by nature; e.g., mălus "bad," but mālus "mast." A vowel followed by* two *consonants is long by position. The vowel is not* always *lengthened if the second of the two consonants is l* or *r; e.g., volŭcri* or *volūcri. If, however, the first consonant and the following l or r belong to different* words, *the preceding vowel is always lengthened; e.g., arcebāt longe.* Vowels *are always lengthened before ll and rr.*

Elision occurs when a word *ending with a* vowel *or a* vowel *and m is followed by a word commencing with a vowel; e.g., conticuer(e) omnes, quamqu(am) animus. The* vowel *i must be distinguished from consonantal i, printed in older texts as j; e g, vitis Iaccho, Coeumqu(e) Iapetum, but auxiliūm iubeat, irē* iubes. *Initial h does not count as a consonant; i.e., it does* not *lengthen or prevent elision (e.g., omnīs humo, monstr(um) horrendum). In Latin texts elided syllables are printed, not replaced, as in Greek, by apostrophe.*

The principal types of Greek metre used in Latin are dactylic hexameters and elegiacs. Horace uses various lyric metres. notably sapphics and alcaics (q.v.), asclepiads, glyconics, etc. (see Choriambic Verse *and* Glyconic). *Catullus and* Martial *use the "choliamb" (see* Iambic) *and the "phalaecian" or* "hendecasyl*lable," an aeolo-choriambic colon composed of base,* – ⏑⏑ – ⏑ –, *bacchiac* (⏑ – –):

– – – ⏑ ⏑ – ⏑ – ⏑ – –
Cui dono lepidum novum libellum
– ⏑ – ⏑ ⏑ – ⏑ – ⏑ –
arzda modo pumic(e) expolitum.

Iambic trimeters of Greek type are found in Catullus, Horace and Seneca (see Iambic).

The verse of republican comedy differs fundamentally from the metres enumerated above. The lines are analyzable into feet, not metra. *The equivalent of the iambic trimeter, the "iambic senarius." consists of six* feet, *the last of which must be an iamb* (⏑ –). *In the other feet a spondee* (– –), *a tribrach* (⏑⏑⏑), *a dactyl* (– ⏑⏑), *an anapaest* (⏑⏑ –) *and even (especially in the first foot) a proceleusmatic* (⏑⏑⏑⏑) *may be substituted. There is usually caesura in the third foot, sometimes in the fourth:*

⏑ ⏑ ⏑ ⏑| – ⏑ ⏑|– || –|⏑ –| – –|⏑ –
ego quia non rediit filius quae cogito.

The iambic octonarius (eight feet) and septenarius (seven and a half feet) also occur in comedy.

The "trochaic septenarius" (equivalent of Greek trochaic tetrameter catalectic) is the commonest verse in comedy after the iambic senarius. The seventh foot must be a trochee (– ⏑). Spondees, dactyls, anapaests and tribrachs may be substituted in the first six feet. There is usually diaeresis after the fourth foot:

⏑ ⏑ –| – ⏑|– ⏑ ⏑| – –| – ⏑⏑⏑|–⏑|– |
ubi me dixero dare tanti testis faciet ilico.

In comedy the rules governing the length of syllables differ in some respects from those for other types of classical Latin verse. Syllables which would elsewhere *be long must in comedy sometimes be scanned as short. Pronouns especially are often shortened; e.g., ĭlle, ĭste. Adjacent vowels are often contracted into one syllable by synezesis, as fuisse, seorsum:*

– –| ⏑ –| ⏑ –|⏑ || ⏑ ⏑| – –| ⏑ –
non fuit necess(e) habere; sed id quod lex iubet.

The reasons for these particularities are much disputed. Some metricians attribute them to the presence of stress; others deny that stress had any influence on Latin versification.

Study **of** Classical *Metre.— The most important ancient work on metre* which *has survived is an abridgment of the treatise of Hephacstion (q.v.). This work,* however, *records theories formulated when the principles of classical metre were no longer well understood. His chief mistake* was *to attempt to analyze all types of Greek metre into short "feet" (e.g., iamb* ⏑ –, *as in Latin comedy, instead of* ⏓ – ⏑ –). *This system is still found in out-of-date metrical works. His terminology (e.g., names of feet) has been adopted even in English metrical theory, to* which *it is* ill-*suited. Since about* 1800 *classical metricians have discarded much of Hephaestion's theory and terminology, but misleading terminology is still in use. and there are few reliable modern works.*

Bibliography.—U. von Wilamowitz, *Griechische Verskunst* (1921); Paul Maas, *Griechische Metrik* (in A. Gercke–E. Norden, *Einleitung in die Altertumswissenschaft*, 2nd ed., 1929; 3rd ed. in Eng. trans., 1962); A. M. Dale, *The Lyric Metres of Greek Drama* (1948), "The Metrical Units of Greek Lyric Verse," *Classical Quarterly*, vol. 2–3 (1950–51). Useful summaries are: B. Snell, *Griechische Metrik*, 2nd ed. (1957); W. J. W. Koster, *Précis de métrique latine* appended to *Traité de métrique grecque*, 2nd ed. (1953); F. Crusius, *Römische Metrik*, 4th ed. rev. by H. Rubenbauer (1959); D. S. Raven, *Greek Metre* (1962). For complete scansions of Pindar and Bacchylides see B. Snell's editions of those poets in the Teubner series (1953 and 1949). For complete scansions of the lyrics oi Greek drama see 0. Schroeder, *Cantica* (1907–16) in the Teubner series. On the metres of Sappho and Alcaeus see D. L. Page, *Sappho and Alcaeus* (1955). (L. P. E. P.)

PROSPECTING: see *Mine Prospecting and Development.*

PROSPECTUS: see Company; *Corporation.*

PROSPER OF AQUITAINE *or Prosper Tiro (c.* 390–*c.* 465), *Christian writer and disciple of St. Augustine, was a native of Aquitaine. In* 431 *he appeared in Rome to interview Pope* Celestine *regarding the teachings of St. Augustine and then all traces are lost until* 440. *the first year of the pontificate of Leo I, who had been in Gaul and probably had met Prosper. Prosper* was *soon in Rome, attached to the pope in some secretarial or notarial capacity. Gennadius (De script. eccl. 83) mentions a* rumour *that Prosper dictated the iamous letters of Leo I against Eutyches. The date of his death is not known, but his chronicle goes as far as 455, and the fact that* Ammianus *Marcellinus mentions him* under the year 463 seems to indicate that his death was shortly after that date Prosper attacked the Pelagians in a polemical poem of about 1,000 lines, *Adversus ingratos*, written about 430. After Augustine's death he wrote three series of Augustinian defenses. especially against Vincent of Lerins *(Pro Augustino responsiones)*. His chief work was against Cassian's *Collatio*, his *De gratia dei ut libero arbitrio* (432). He also induced Pope Celestine to publish an *Epistola ad episcopos Gallorum* against Cassian He corresponded with Augustine and made an abridgment of his commentary on the Psalms, a collection of sentences from his works. He also put into elegiac metre, in 106 epigrams, some of Augustine's theological dicta

Prosper's *Epitoma chronicon* is a careless compilation from St. Jerome in the earlier part, and from other writers in the later, but the lack of other sources makes it very valuable for the period from 42j to 455 of which he had personal knowledge. There were five different editions, the last of them dating from 455, after the death of Valentinian. For a long time the *Chronicon imperiale* was also attributed to Prosper Tiro, but without the slightest justification.

PROSTEJOV or PROSSNITZ, an old town in Olomouc, Czech., lies in the fertile valley of the Hanna, a tributary of the Morava. Pop. (1950) 33,183. Germany occupied the town in March 1939, at the time of Czechoslovakia's dismemberment.

PROSTHODONTICS is the branch of dentistry that deals with the artificial replacement of natural teeth and associated tissues for the restoration or maintenance of function, appearance, comfort and health of the patient. This type of dentistry is divided as follows: (1) fixed partial denture prosthesis; (2) removable partial denture prosthesis; (3) complete denture prosthesis; and (4) maxillofacial prosthesis.

History. — The earliest dental prostheses known are banded bridges made by the Etruscans and wired restorations constructed by the Phoenicians. In early history human teeth, animal teeth or teeth carved from wood or ivory were substituted for natural teeth, and complete dentures for either the upper or the lower jaw were sometimes carved from one solid piece of wood or ivory. Early prosthetic appliances were crude, awkward and almost useless in mastication; they mere unhygienic and unsightly.

Porcelain teeth were introduced during the latter part of the 18th century, and in the 20th plastic teeth came into use. Continued research with both these materials has produced lifelike imitations of teeth to match the large number of variations found in the colours and forms of natural teeth. Gold alloys and chrome alloys possessing the correct amount of rigidity, yet with sufficient flexibility to be suitable for clasps, bars, bases and attachments, have been highly developed. Methods and techniques of manipulating the various materials, and specialized instruments and equipment used in the construction of prosthetic restorations. have kept pace Crowns. bridges and partial or complete dentures (*see* below), as well as the several maxillofaciai replacements, can be made so realistic in appearance and so functional that they almost defy detection.

Fixed Partial Denture Prosthesis. — This includes the design, construction and maintenance of dental restorations such as crowns and bridges that cannot be readily removed from the mouth by the patient or dentist. These types of restorations are rigidly fixed to the natural teeth. which furnish support to them, and may be made of porcelain, plastic or metal. A crown is a replacement used to restore the natural form of an impaired tooth that cannot be preserved by an inlay or other type of restoration. A bridge, as the name implies, consists of a span of one or more artificial teeth, with abutment attachments that are cemented to the adjacent natural teeth in the mouth.

Removable Partial Denture Prosthesis. — This includes the construction and maintenance of dental restorations so designed that they can be removed at will by the wearer or dentist. A removable partial denture consists of a base, constructed of plastic material or metal, or a combination of the two, which accurately fits the mouth ridges and tissues and supports the artificial replacement teeth in proper alignment. It is held in position in the mouth by flexible metal bands or clasps encircling adjacent natural teeth, or by other means of attachment to the teeth.

Complete Denture Prosthesis. — This involves the artificial replacement of all the natural teeth and associated tissues in either the upper or the lower jaw or in both. In this type of prosthodontics, restoration of the functions of mastication, speech and appearance is of the greatest importance. Establishing and maintaining these functions by means of artificial dentures is accomplished by attaching porcelain or plastic teeth to bases (plastic material. metal or a combination of the two) that have been accurately adapted to the soft tissues of the mouth.

Maxillofacial Prosthesis.—This deals with the artificial replacement of tissues in cleft palates and other oral abnormalities. Cleft palates are abnormal openings of varied size and form in the palate of the mouth, usually of congenital origin. Mastication, swallowing and speech are seriously impaired by this type of abnormality. Closure of the opening by inserting a removable prosthesis can greatly improve these functions. Maxillofacial prosthesis has also come to include artificial restorations of some extraoral conditions of the face and head, resulting from accident or disease, or congenital.

Prosthodontics as a **Specialty.**—Accident, extensive disease or congenital abnormality may present conditions that make artificial replacement very difficult and require specialized skills, ideas and ability. In the United States, dentists with the necessary training and experience to deal with all types of dental prostheses, after examination by the American Board of Prosthodontics (authorized in 1948 by the American Dental association). are granted certification by that board, designating them as specialists in the field of prosthodontics. In the United States and also in Great Britain special training in prosthodontics, additional to that taught at the undergraduate level, can be obtained in many dental schools. *See* also DENTISTRY; TEETH, ARTIFICIAL. (B. L. H.)

PROSTITUTION is defined in the *Shorter Oxford English Dictionary,* in relation to women, as "the offering of the body to indiscriminate lewdness for hire." A prostitute is defined as "a woman who is devoted or (usually) offers her body to indiscriminate sexual intercourse, especially for hire." Both definitions are confined to women, but male prostitution is a universal problem, though not so commonly encountered: the dictionary definition could equally well extend to males as well as females. In general parlance, prostitution has acquired a wide meaning implying some form of debasement or degradation not necessarily physical. The legal attitude is more restricted and varies in different countries. In British common law the term common prostitute "is not limited so as to mean anyone who permits acts of lewdness with all and sundry or with such as hire her when such acts are in the nature of ordinary sexual connection. We are of the opinion that prostitution is proved if it be shown that a woman offers her body commonly for lewdness for payment in return" (lewdness in this definition was given a very wide meaning and was not confined to full intercourse). The payment of money is by no means a necessary ingredient of the legal offense: for example, in the United States under some statutes a woman prostitute is defined as a woman who submits herself to indiscriminate sexual intercourse with or without hire. In this article the words "prostitute" and "prostitution" will be used to denote promiscuity in return for money or its equivalent without any specific attachment to the particular partner. unless the context implies some other meaning.

The phenomenon of prostitution is universal, and in every civilized country legal measures, varying in severity, are taken to keep it more or less under control While the law takes cognizance of overt manifestations, which are for the most part connected with economic factors and with prostitution as a trade. the sociologist, the psychiatrist and the psychoanalyst have to consider the more profound emotional problems where the money-earning factor is not necessarily emphasized.

HISTORY

Primitive Peoples and the Ancient World. — Studies in social anthropology do not concern themselves very much with prostitution Among primitive people the existence of polygamy and the early age of marriage conceal or even obviate promiscuity for hire. If promiscuity were alone the test then the practice of the utmost sexual freedom would be within the definition. From studies of existing primitive communities it would appear that sexual freedom and strict observation of the matrimonial norm vary considerably. Margaret Mead in her book *Male and Female*

(New York, 1949; London, 1950) does indeed refer to the prostitution of slaves captured in war by the Manus tribe in Melanesia: this is done in order to make money by a tribe described as "efficient puritans" among whom there is a general devaluation of sex.

In rather more advanced communities, the prostitution of unmarried girls seems to have been a common practice and the reasons for it are various: namely, as a puberty ceremony (that is, a sacrifice of virginity) ; as a puberty rite to earn a dowry: and as religious prostitution in the service of a goddess. Generally, however, the system of female kinship. where descent was traced through the mother and not through the father. would seem to have gone hand in hand with a greater laxity in morals than is observed by Christendom, where marriage is accepted as "the voluntary union for life of one man and one woman to the exclusion of all others."

In Babylon, in Cyprus, among the Phoenicians and in many parts of western Asia it is recorded that women prostituted themselves as a religious duty at the sanctuary of a goddess. whose name varied with the locality. Sir James Frazer in The Golden *Bough* observes that, despite the change of name, her type remained constant, namely, the great Mother Goddess of western Asia (see GREAT MOTHER OF THE GODS; APHRODITE; also ASTARTE). The Babylonian custom, as recorded by Herodotus, required every woman, rich or poor, to sit in the temple of Ishtar and have intercourse with a stranger: who signified his choice by throwing a silver coin of no matter how small value into her lap. The woman had then to accept the coin and have intercourse with the stranger. Ill-favoured women under this system might wait a long time, even years. before they had performed their service. Once the rite had been observed the woman was absolved from her obligations to the goddess; and then, according to Herodotus, money would in no case purchase her. The customs in Cyprus and elsewhere seem to have followed a similar course. In some cases, and perhaps generally, the man had to be a stranger.

Whatever the motive for these customs. whether as a sacrifice of virginity, to earn a dowry or as a religious service, the practice was a solemn religious duty. It is a widespread belief that a woman never forgets the first man with whom she has had intercourse. On this hypothesis. the practice of submitting to a stranger in the service of a goddess may have been an emotional safeguard, attaching the woman primarily to the deity rather than to an individual. Frazer suggests that these religious duties were closely knit with the reproductive energies of nature as a whole. Their observation reflects an earlier period of sexual communism where marriage was unknown or barely tolerated as an immoral infringement of these old communal rights.

Attempts have been made to trace the origin of religious prostitution to the purely secular and precautionary practice of destroying the bride's virginity before her marriage. There is no doubt that, in some communities, there is a fear that a man will be endangered by some peril attaching to virginity. It is certain that defloration of virgins has played and still does play an important role; but its significance is far from clear. This custom is thought ultimately to have developed into the *jus primae noctis* (*q.v.*) vested in the local lord or priest. The rites accompanying the sacrifice of virginity in a woman are paralleled perhaps by the puberty rites observed in primitive communities in relation to youths as recorded, for example, by Theodor Reik in *Probleme* der *Religionspsychologie* (Leipzig and Vienna, 1919).

Among the Jews, who stood apart from the surrounding peoples, the object of the Mosaic law was clearly to preserve the purity of the race and the religion. Prostitution in itself was not forbidden, but it was to be confined to foreign women. Jewish fathers were forbidden to turn their daughters into prostitutes (Lev. xix, 29). and the daughters of Israel were forbidden to become prostitutes (Deut. xxiii. 17), but no penalty was attached to disobedience, except in the case of a priest's daughter, who was to be burned (Lev. xxi, 9). There is abundant evidence in the Old Testament that prostitution prevailed extensively in Palestine, even in the earlier and more puritan days. The women were forbidden Jerusalem and places of worship; they infested the waysides, and there is some evidence of a distinctive dress or bearing, which was a marked feature of the trade among the Greeks and Romans. The remarkable series of ordinances laid down by Moses in the interest of public health contains unmistakable recognition of venereal disease and its contagious character (Lev. xv).

The earning of a dowry is also shown by ancient customs to have been a motive for prostitution. The girls of Lydia regularly prostituted themselves to earn a dowry, and the Palau (Pelew) Islanders systematically prostituted their daughters for hire and derived an income therefrom, perhaps with the intention likewise of providing them with a dowry. A similar custom was prevailing as late as the early years of the 20th century among the Ouled Naïl of Algeria: the girls of this tribe would go to the larger towns (*e.g.*, Biskra) as dancing girls and earn money by prostitution; then they would return home and marry; and the more money they had acquired. the more desirable they were considered as wives. While it may be that this motive of earning a dowry had itself originally some religious rather than economic purpose, it is clear that in later times the economic aspect featured much more largely. In communities of varying states of advancement the practice certainly grew up for the bride to be bought by the prospective husband; but in the course of time the custom of transferring property in return for a bride was superseded by that of the parents' presenting a dowry to the daughter. This change occurred perhaps with the gradual introduction of monogamy, when the supply of women outstripped the demand. with the result that no longer did the future husband pay for the lady; instead, the father endowed her as a method of encouraging the prospective bridegroom.

Superficially at least, then, prostitution was in many countries once connected with religious worship. The priests in early times seem to have often been the state's financial experts; and it cannot be doubted that the money paid to the women in the temples came in the course of time to find its way into the priests' coffers. An example is provided by the huge temple of Aphrodite in Corinth. where there was a large staff of prostitutes in attendance to accommodate sailors frequenting the port. It may therefore be suggested that the advent of the secular brothel did not take place until the system that regulated prostitution in accordance with religious rites had broken down, while the demand for tht prostitute's services continued.

The regulations of Solon in Athens were designed to preserve public order and decency. He established houses of prostitution (dicteria), which were a state monopoly and confined to certain quarters. The *dicteriades* were forbidden the superior parts of the' town and were placed under various disabilities: they were compelled to wear a distinctive dress and. far from being connected with religion, were not allowed to take part in religious services. These laws do not seem to have been carried out at all effectually and were presently relaxed; but it is clear that, as time went on. the Athenian authorities experienced the difficulties encountered by modern administrations in carrying out state regulation. On the other hand the hefaerae, independent courtesans of the most expensive class. had an enviable place in Greek society, where their intellectual as well as their physical attainments were widely respected (see ASPASIA; PHRYNE; LAIS).

In ancient Rome the moral tone seems to have been of a very different stamp: the Romans combined a pride of race like that of the Jews with a regard for public decency like that of the Athenians and had also a standard of austerity all their own. In early times female virtue was highly honoured and strenuously preserved by the Romans (*e.g.*, in their institution of the Vestal virgins): to frequent the company of prostitutes was accordingly considered disgraceful—though we may cite the opinion, attributed by Horace (Satires, i, 2) to the conservative Cato, that it was right (*aequum*) for young men driven by lust to go to brothels rather than molest other men's wives. The Roman system of regulation was especially severe: prostitutes were placed under stringent control (their registration by the police foreshadom-s modern European practice), had to wear distinctive dress and to dye their hair or wear yellow wigs and were subject to various civil disabilities. The state's taxation of prostitutes, which had been transmitted from the Roman republican to the imperial period and had been further regulated by Caligula. was however partly renounced in the Christian 4th century by Theodosius (on the representations of Florentius, a wealthy patrician, who offered to make good the loss of revenue out of his own pocket) and was finally abolished in the jth by Xnastasius I, and the old registers were destroyed. Then some of the civil disabilities of prostitutes were removed by Justinian in the 6th century. Edward Gibbon attributes Justinian's action to his desire to marry Theodora, whose life had been notorious; but though no doubt she influenced him in the matter. Gibbon admits her virtue after marriage and gives her credit for "the most benevolent institution" of Justinian's reign, the rescue home for fallen women in Constantinople. This though it did not succeed, marks a turning point in the treatment of a class which had never met with public sympathy before.

The Middle Ages.—In the middle ages prostitution was tolerated, the caprice of the passions being recognized as a necessary evil. Nevertheless, efforts were made to check it, or at least to keep it nithin reasonable bounds. Christianity put an increasing emphasis on chastity and on the sanctity of the marriage vows, though the observation of the monogamous status of marriage was accepted only gradually. Saint Augustine of Hippo took the view that a plurality of wives. as distinct from a plurality of husbands, is not contrary to the nature of marriage. "*plures enim feminae* ab *uno viro fetari possunt, una* vero a *pluribus* non *potest*" ("for more women than one can be made pregnant by one man, whereas one woman cannot [at the same time] be made so by more men than one": De *Bono Conjugali*). He and others following him regarded this natural law as modified at a later date by the institution of monogamy as a discipline imposed by the divine authority on Christians. In furtherance of the more humane Christian doctrines, attempts were made to better the lot of prostitutes and to induce them to reform. The church indeed became exceedingly active in prevention and rescue work and was assisted by a devout and zealous laity: rescue missions were organized, convents were founded everywhere for the reception of penitents. and dowries were subscribed to procure them husbands. . Fulk of Neuilly was a conspicuous figure in this work, holding missions, preaching and collecting large sums for marriage dowries. Pope Innocent III pronounced it a praiseworthy act to marry a prostitute; and Gregory IX wrote to Germany that brothel-keepers were not to prevent prostitutes from attending missions and that clergy and laity who drew profit from prostitution were banned. "Urge bachelors," he wrote, "to marry repentant girls, or induce the latter to enter the cloister."

Meanwhile, apart from the church's doctrine, the feudal order of society had its own influence on the mediaeval attitude toward relations between the sexes. In feudal times, when the possession of land was the criterion of wealth and status: marriage among the greater landowners, though subject to the laws of the church, was most often primarily a political matter, to be arranged by open bargaining between overlord and overlord or between the heads of the two families concerned; love, then, did not enter into the question (indeed it would appear that love, as understood in the 20th century, is a comparatively recent development in human life). Women of the highest rank in feudal society were thus treated to a large extent as salable chattels; and their status cannot have been without its reflection in the contemporary attitude toward women in general. On the other hand! the feudal service due from a vassal to his lord provided the model for the lover's service to his lady according to the code of chivalrous or courtly love which the troubadours conceived and formulated in the 11th, 12th and 13th centuries. This new idealization of love was clearly hard to reconcile with indiscriminate recourse to prostitutes; but insofar as courtly love was regarded as existing not between husband and wife but extramaritally (a "court of love" is said in fact to have pronounced love between husband and wife to be impossible), it must have contributed to the divergence from Christian standards that made prostitution acceptable to those at least who were not chivalrously in love.

In an era when almost the whole population came to be divided into guilds, prostitutes would appear to have iormed a regular guild of their own; at the very least, they seem to have had a recognized function in social life. A general distinction, however, can be made between the resident prostitutes. who lived in "bordells," and the itinerant ones, who were either vagrant or else informally attached as camp followers, to the temporal or spiritual armies that snept to and fro across Europe, now waging wars, now fulfilling vows. Prostitution indeed was not merely tolerated but protected, licensed and regulated by law and constituted in many places a source of public revenue.

In France prostitutes were distinguished by a badge and forbidden to wear jewels and fine stuffs and to frequent certain parts of the towns. Public brothels on a large scale mere established at Toulouse, Xvignon and Montpellier: at Toulouse the profits were shared between the city and the university; at Montpellier and Xvignon the trade was a municipal monopoly and farmed out to individuals; at Avignon. where the establishment was kept up during the whole period of the popes' residence, the inmates were subjected to a meekly examination. In some parts of France prostitutes paid a tax to the seigneur. In Germany, according to Fiducin, the public protection of Lustdzrnen was a regular thing in all the large tonns during the middle ages. Frauenhauser, similar to the French brothels, existed in many places. In Italy and also in Spain the system appears to have been very much the same: in Bologna prostitutes had to wear a distinctive dress, in Venice they were forbidden to frequent the wineshop, and in Ravenna they were compelled to leave a neighbourhood on the complaint of other residents. In Naples. moreover, a court of prostitutes was established, having jurisdiction over everything connected with prostitution. It led to great abuses and was reformed in 1589 and abolished about a century later.

In England the most notorious "bordells" or "stews" were those which occupied a row of buildings in the Borough (Southwark) near London bridge, originally licensed by the bishops of Winchester (according to John Noorthouck) and subsequently sanctioned by parliament; John Stow quotes the regulations enacted in the year 1161, during the reign of Henry II. These bordells were closed in 1506 but reopened until 1546, when they were abolished by Henry VIII. In London also we get an early regulation directed against the spread of venereal disease: the act of 1161 forbade the bordell-keepers to have women suffering from the "perilous infirmity of burning"; and by an order of 1430 they were forbidden to admit men suffering from an *infirmitas* nefanda. As in other countries. regulations respecting the dress of prostitutes were made in England: by a royal proclamation of Edward I, the wearing of miniver or sendal (a kind of thin silk) on hoods and dresses was forbidden to prostitutes.

The Reformation and Its Aftermath.— The spread of humanist ideas since the mediaeval beginnings of the Renaissance was bound to raise the status of women; and the rise of monarchical absolutism in the 16th century meant the end of the old feudal order, which, as we have seen, tended to keep them in subjection. The Reformation brought a radical change in sexual morality: not only was the former insistence on celibacy, which had deprived the many thousands of clerks of any licit outlet for incontinence, abandoned in many countries, but also, to balance this liberalization of marriage, the Christian condemnation of extramarital licence was emphasized. The Reformers' stricter attitude to unchastity was moreover echoed by the Catholics of the Counter Reformation, conscious as they were of the harm that had been done to the church by its toleration of more licentious conduct. In this climate of opinion the many statutes enacted throughout Europe to control the prostitutes were apparently enforced to some effect: for example, in Strasbourg, where the cathedral seems formerly to have been a common place of resort for soliciting and the open activity of the numerous prostitutes a scandal, there were by 1536 only two brothels, and four years later public prostitution seems to have been effectually suppressed. In England under the Commonwealth, fornication was made a felony upon a second conviction, punishable by death, without benefit of clergy (1650); but this statute was repealed at the Restoration.

From the legal point of view in England, meanwhile, the type of offense with which prostitutes might ordinarily be charged began to pass, after 1640, from the jurisdiction of the ecclesiastical courts to that of the common law. Public nuisance then became the basis of prosecution, a development of this being the misdemeanour which is committed by anyone who does any grossly indecent act in any open or public place in the presence of more than one person. The liberty of the subject was jealously guarded, and intervention was not permitted except in the case of a disturbance such as would have necessitated action even in the most respectable mansion in the land. Brothels, however, were included among the establishments against which the Disorderly Houses act of 1751 was aimed.

The Industrial Revolution.— After the creation of the police force in the 19th century. the control of prostitution and its offshoots took on a more ordered appearance (see below). Almost concurrently. however. the question of prostitution began to assume a problematic form as the industrial revolution set its mark upon the world: mass movements took place away from the country into the towns, where people were crowded together under wretched housing conditions, their leisure occupations restricted and their everyday work monotonous and emotionally unsatisfying. The modern problem of prostitution is essentially an urban one, its character largely depends on the size and locality of the town.

Henry Mayhew, in an appendix to his London Labour and the London Poor (London. 1861), divided prostitutes into three classes: first, those women who were kept by men of independent means; second, those women who lived in apartments and maintained themselves by their trade; and third, those who dwelt in brothels. There were in addition the amateurs who took money but only practised prostitution as a sideline to their daily occupation (this latter group included servant girls and nursery maids). The squalor of the slums combined with addiction to drink induced a terrible apathy and recklessness in these women. The open running of night houses, where the men and women could meet as though on a more reputable social occasion, was another aspect of the trade. Yet even under these conditions the spread of enlightenment and education in the shape of an energetic police force and better parochial management was making itself felt.

The religious revivalist movements. such as the Evangelical movement and the Salvation Army, during the latter half of the 19th century, do not, from all accounts, seem to have had a very profound effect on the poorer classes as a whole. The general report seems to have indicated indifference to religion. This is brought out in relation to London by Charles Booth in Life and Labour of the People in London (London. new ed., 1902–03). Though this author deals with the years 1890 to 1900, he quotes ministers of religion who had been in their respective parishes for 30 years or more. On the other hand, the rescue work undertaken by the various missions established in poverty-stricken areas was remarkable. The success achieved was mostly confined to the women who had recently joined the ranks of the prostitutes; many of these were promptly picked out and in some way rehabilitated. The workers effected this change through their personal influence, though they themselves were inspired by deep religious feeling. According to the reports. they found that the favourable time for persuading a prostitute to change her way of life was immediately after the birth of the first child; with this we may compare the experience of later social investigators in the U S.S.R., who found that one of the most significant times for reclamation was during the treatment for venereal disease.

Legislation and Police Procedure, 19th–20th Centuries.— The law and morals are not of course coterminous, and in all countries the administrative problem of enforcing legislation so closely related to variable moral codes of behaviour is fraught with difficulties: as soon as the law enters the sphere of morals, both its interpretation and its execution may be called in question as unjust or indeed immoral, at least by some members of the community, so that it loses all its certainty and the reverence that rightly belongs to it. In Great Britain. for example, the Contagious Diseases Prevention acts of 1864, 1866 and 1869, which introduced a measure of state regulation and inspection of prostitutes, had to be suspended in 1883 and repealed in 1886 as a result of the campaign initiated against them in 1869 by Josephine Elizabeth Butler (*q.v.*), the founder of the International Abolitionist federation; thenceforward there was little that the law could do in relation to the prostitutes themselves except to see that the police maintained a certain standard of order, which had. of necessity, to be regulated by local conditions and by the reaction of the public at any given moment (see below). In some countries, on the other hand, special "morals police" were instituted, with more power than the English "vice squad" and with the function, among others, of observing the inscribed women and watching the uninscribed; but the arbitrary power that these "morals police" could exercise caused considerable misgiving. Yet again, some countries, for instance Belgium, favoured the employment of women police to deal specifically with prostitutes. It may be stated, however, that the laws controlling prostitution and kindred offenses in the different countries of the world are very similar once the fundamental distinction has been made between those of countries in which houses of prostitution have been abolished by law and those of countries which permit brothels and require prostitutes to be inscribed (of course, some countries cannot be classified in this way).

In Great Britain, legislation. apart from laws dealing with soliciting and offenses against decency in public places, is directed not at the prostitute or her client but against those third parties—brothel-keepers, procurers. pimps—who find her commerce so easy to exploit. For these purposes a brothel has been defined, in reference to a statute of 1885, as premises used by at least two women for the purposes of prostitution. The Criminal Law Amendment act of 1885 (in this connection see STEAD, WILLIAM THOMAS), as amended, and the Vagrancy act of 1898, as amended, legislate against the keeping of brothels, against procuration (including procuring for the purpose of gross indecency between males) and against a man's living on a prostitute's immoral earnings. Offenses between males are further dealt with by the Offences against the Person act of 1861. The punishment for a person found guilty under these statutes is a sentence of imprisonment of varying length. The Children and Young Persons act of 1933 affords protection to children and young persons. The laws relating to soliciting in England are for the most part contained in the Vagrancy act of 1824, the Metropolitan Police act of 1839, the Town Police Clauses act of 1847 and the Criminal Law Amendment act of 1951; in addition, there are local bylaws. The punishment for soliciting is usually a fine but can, in certain cases, be a short term of imprisonment. The practical outcome of the law on soliciting, as interpreted by the courts, is reflected in the regulations promulgated for the guidance of constables by the commissioners of police (see for example the Report of the Street Offences Committee, *1928,* [Cmd. 3231], p. 24, which quotes with approval the orders laid down for Edinburgh).

The difficulties that attend the abolition of houses of prostitution in a country where they have been long established are illustrated by the course of events in France. In 1946, state registration was ended and the maisons de *tolérance* were closed; then a subsequent law. in the same year. established a *fichier* sanitaire for all prostitutes and regulated their inscription for purposes of hygiene (*i.e.,* for contact-tracing and the treatment of venereal disease); and a further enactment (1948) seemed to make prostitutes subject to examination even before their occupation mas proved, the effect being practically a return to the regime of state registration.

The law of 1946 had indeed resulted in the closing of the brothels in France, but little was done for the rehabilitation of their inmates, and it soon appeared that the latter were pursuing their old trade under worse conditions than before. Marthe Richard, a national heroine of World Wars I and II, who had been among the first to urge the closing of brothels in Paris and indeed was held to be primarily responsible for the enactment of the law, showed that she had changed her mind about the rightness of the measure (see her book, *L'Appel* des sexes, Paris. 1951). To make a compromise between the abolitionists and those who wanted to repeal the law of 1946 it was proposed that brothels should be allowed in the neighbourhood of army camps at least.

In the United States, brothels or houses of prostitution are illegal in most states. as also is procuring; and the majority of the states penalize soliciting and living on the earnings of prostitution. A detailed analysis of the laws controlling prostitution and kindred offenses in the various states is contained in the *Digest of Laws and Regulations Relating to the Prevention and Control of Syphilis and Gonorrhea* (American Social Hygiene Association, Inc.. New York, 1940, with supplements). It may here be remarked that the attempt to "clean up" Chicago in 1929 provided a notable demonstration of the danger of driving prostitution underground, where it can become more vicious and disruptive to society than when it is allowed to exist, to some extent, openly (*see* Walter C. Reckless, *Vice in Chicago,* Chicago, Cambridge, 1933). Such a development is to be expected on the closing of brothels when at the same time no fundamental alteration of the social pattern is effected: the removal of the controls exercised by the brothel system clears the way for a "vice racket" in which both prostitute and client are exploited by third parties. In the United States strictly business organizations largely took control of prostitution, managing it on a national or regional basis; this, however, was generally true also, though in a lesser degree, of many other abolitionist countries.

By the second half of the 20th century, then, legislators might be confronted with the dilemma of choosing between an abolitionist policy, active support for which was forthcoming from many quarters both religious and secular, and a policy of regulation, arguments for which could be drawn from sad experience. There was thus little cause for surprise whichever policy was adopted: in Dec. 1954, for instance, the Argentine government, despite the contemporary world's general tendency toward abolitionism and in the face of the particular abolitionism of the Catholic Church: authorized the re-opening of brothels. on the ground that their suppression in 1937 had led to an increase of venereal disease, sexual perversion and crime; and less than a month later, in Jan. 1955, a majority in the Italian senate, disregarding the cautionary spectacle that France had just provided. approved Lina Merlin's bill for abolition. which, it was estimated, would involve the closing of more than 700 licensed houses and the planning of "reeducation" for some 4.000 women.

In the U.S.S.R., the bold claim was made that no prostitution exists (*see* H. E. Sigerist and J. Older, *Medicine and Health in the Soviet Union,* New York, Toronto, 1947; E. H. Culver, "An Experiment in Social Hygiene," *British Medical Journal,* London, 1937). No doubt the claim asserted that no brothels or trafficking in the streets existed any longer. While it is difficult to know to what extent the emotional problem had been affected, the legislation and administrative orders promulgated indicated that the problem had been treated very seriously. Before the Revolution, prostitution existed on a very large scale in Russia. The desire of the revolutionaries to abolish it would seem perhaps to emanate from the urge toward female emancipation and equality of the sexes. With regard to prostitution, the Soviet authorities repeatedly emphasized that the war against it should on no account degenerate into a war against prostitutes. It was maintained that the disappearance of prostitution in the U.S.S.R. was due in effect to the changing of the cultural patterns in Russian and Soviet society. The exact meaning of this asseveration is difficult to assess: the U.S.S.R. is a very large country comprising a number of republics, each with its separate codes of law and in a varying stage of development; and in some of these republics tribal customs, in particular those connected with child marriage and with the bride price. would seem to have survived for a long time.

For a detailed account of international activity for the suppression of the traffic in women and children, culminating in the assumption by the United Nations of the "functions and powers of the League of Nations" in this respect, *see* WHITE-SLAVE TRAFFIC.

PSYCHOLOGICAL ASPECTS

The psychiatrists and the psychoanalysts see prostitution as a much wider problem than the lawyers do: they trace its roots to emotional factors. perhaps via economic ones. The theory of instincts in classical psychology differentiates between two groups of instincts: those of self-preservation and those for the propagation of the species. One group represents the interests of the individual. the will to live; the other, the interests of the race, that is, the instinct of reproduction. Prostitution utilizes the latter to satisfy the former. Arthur Schopenhauer, one of the precursors of this school of thought. was of the opinion that in true sexual passion the advantage of the individual is subordinated to the needs of the race. (*Die Welt als Wille und Vorstellung,* 2nd ed., Leipzig, 1844). In the light of this classical theory, Tibor Agoston ("Some Psychological Aspects of Prostitution: the Pseudopersonality," *International Journal of Psychoanalysis,* London, 1945) points out that prostitution would be a deflection of the race-preservation instinct from its original aim, insomuch as sexual intercourse, which theoretically serves the preservation of the species, is carried out for the purpose of earning a living. The psychoanalytic observations respecting prostitution and the prostitute take into consideration factors relating to the instincts which have been classified and described. Edward Glover (*Psychopathology of Prostitution,* Institute for the Study and Treatment of Delinquency, London, 1945) suggests that prostitution is connected with the lack of or deficiency in a love-object: "Promiscuity serves to deny that there was a one and only parental object of infantile love." Agoston also believes that psychiatric experience shows that promiscuousness in prostitution implies an intentional, defiant indifference in the selection of partners: anyone at all will do; the relationship is usually marked by brevity; the partners are contemptuous of each other and remain incognito; and the incognito is fortified by fictitious tales about themselves and their families. It may follow from this "façade" theory that in fact the parties to prostitution act out a phantasy in a manner satisfactory to themselves: unable to face the reality of married life with its everyday pleasures and compromises, satisfaction is found in an imaginary relationship, which either replaces or supplements ordinary conjugal relations. The content of these phantasies may be infinitely varied, from dreams of grandeur to pleasure in degradation.

It is impossible to consider remedies or causes in relation to prostitution till more is known of the emotional problems involved or, indeed, till it is quite clear what type of person is in question. "It is absurd." says Edward Glover, "to talk at large of remedies for prostitution without establishing a reasonably exact classification of prostitutes. For that part, we ought also to have an accurate survey of allied groups. including, for example, the enthusiastic amateur, the gold-digger, the type of individual who marries for money. But if we go so far we might well consider the significance of the dowry and the marriage settlement." There are already many different classifications of the prostitutes who come before the courts in different countries; but further light can be shed on the subject by taking into consideration women who are blatantly promiscuous but should not strictly be called prostitutes as they do not ply their trade openly or for direct reward: the wealthy nymphomaniac, for example. or even any women of substance who refuse to confine themselves to one man. The police do not usually concern themselves with women of this latter type, and indeed it would be difficult to show that money or its equivalent passed to them, even though there would certainly be an element of barter in the sense of gifts or pleasures. That money is a precipitating factor in many cases of true prostitution is undoubted; but the deeper problem of why the particular trade of prostitute is chosen and why many in dire poverty do not take the same course is left unanswered.

The age of prostitutes is worth considering in this connection. The average age of prostitutes is found to lie generally around 27 years of age or perhaps a little younger (*see* Tage Kemp, *Prostitution,* London, New York, 1936; the League of Nations report, *Prostitutes: Their Early Lives,* 1938; L. F. Freed, *The Problem of European Prostitution in Johannesburg* (Cape Town and Johannesburg, 1949). What becomes of the one-time prostitute is a matter that has never been investigated in any detail; but it is generally agreed that the majority of prostitutes do disappear. There is evidence to show that some marry and settle down to a conventional married life; others retire as respectable spinsters. It would be reasonable to conclude that with maturation a greater emotional stability is achieved; on the other hand, the increase in years would result in a loss of attractive power.

No approach can be made to the subject of the prostitution of women unless the counterpart, the men who constitute the demand, is considered. On the whole it is fair to say that one does not cause the other: the inclination must first be present in either party. To speak broadly, there are at least five chief types of men who frequent prostitutes, namely: young men and students in the experimental stage of development; men sexually isolated. whether for a short or for a long time, such as soldiers and commercial travelers; vicious or sexually perverted men; married men with frigid or invalid wives; and the men who have defective love-objects. such as the pimp and the gigolo.

The gigolo is generally of good education. well-dressed and pleasing to women. He attaches himself to older women of wealth, who provide for him, and at the same time carries on relations with others. The pimp, less-educated counterpart of the gigolo, lives on a prostitute's earnings, arranges her work and treats her, generally, with brutality.

It is sometimes said that female homosexuality is linked with prostitution as a cause or precipitating factor. It is difficult to say how much reliance can be placed upon this asseveration. Research workers have records of prostitutes with strong and acknowledged homosexual inclinations; and the opinion that this inclination is developed in a marked degree during terms of imprisonment or confinement in reformatories is notably supported by information gathered from prostitutes in Denmark.

Exclusively male prostitution, that is, the prostitution of males to males, though it clearly falls within the definition of prostitution, is invariably treated as a distinct phenomenon, being altogether inseparable from the general problem of homosexuality.

In conclusion it should be mentioned that Cesare Lombroso and Guglielmo Ferrero were of the opinion that the natural form of regression in women was prostitution, not crime. This point of view might at first seem to be at variance with the main arguments set forth in this article. It does however accord with the hypothesis that in many women sexual activity is a substitute for antisocial behavior—a view supported to some extent by criminal statistics and by many persons who have been associated with female criminals.

BIBLIOGRAPHY.—For prostitution among primitive peoples *see* the authors cited above, especially T. Reik and M. Mead; also J. D. Unwin, *Sex and Culture* (1934). For legal, criminological and social aspects *see* Sir W. Blackstone, *Commentaries on the English Law* (1809); T. E. James, *Prostitution and the Law* (1951); Havelock Ellis, *The Task of Social Hygiene* (1912); the U.S. official *Digest of Laws and Regulations Relating to the Prevention and Control of Syphilis and Gonorrhea* (1940), with supplements; the League of Nations' publications *The Traffic in Women and Children* (1927), *The Trafic in Women and Children in the East* (1934), *Prostitutes: their Early Lives* (1938) and *Methods of Rehabilitating Adult Prostitutes* (1939); also works of H. Mayhew and C. Booth cited in the text above. For psychoanalytical aspects *see* the works of Tibor Agoston and E. Glover. For special studies *see* I. Bloch, *Die Prostitution* (1912); and A. Flexner, *Prostitution in Europe* (1914). (T. E. J.)

PROTACTINIUM, a chemical element, has the symbol Pa, atomic number 91 and chemical atomic weight 231.05. It is the second member of the rare-earthlike transition series, the actinide series, which includes the elements of atomic numbers 89 to 103 inclusive, and in which an inner electronic shell (the 5f shell) is being filled, but it also resembles tantalum in its chemical properties.

The first isotope (mass number 234) was discovered in 1913 by K. Fajans and O. H. Goring, who named it "UX_2" or "brevium." The long-lived isotope. Pa^{231}, was discovered by O. Hahn and L. Meitner in 1917, and independently by F. Soddy and J. A. Cranston at about the same time. The name for this isotope, protactinium (progenitor of Ac^{227}), has now been generally adopted for element 91. Over a dozen radioactive isotopes, natural and artificial, are known, of which Pa^{233} is of especial interest as the progenitor of fissionable U^{233} produced by the absorption of neutrons in thorium.

The isotope Pa^{231} (half life 34,300 years) is a member of the natural. $4n+3$, radioactive family and exists in uranium ores to the extent of 0.34 parts per 1,000,000 parts of uranium. Using this source the first pure protactinium was isolated by A. V. Grosse and others in 1934. Protactinium can also be synthesized in quantity by irradiation of ionium (Th^{230}) with neutrons from nuclear reactors.

Metallic protactinium is quite electropositive. The element displays the tetrapositive and pentapositive oxidation states with an estimated potential of $+0.1$ volts for the $Pa(IV) \rightarrow Pa(V)$ couple. The former state behaves like the other tetrapositive actinide elements in aqueous solution and in the solid compounds. The pentapositive state undergoes hydrolysis so readily that it is extremely difficult to keep in acidic solution. and complexing agents such as fluoride ion are often used for this purpose. Included among the identified solid compounds are Pa_2O_5, PaO_2 (and intermediate oxides), PaH_3, PaF_4, $PaCl_4$, PaOS, and probably $PaBr_4$, PaI_4, PaN_2, PaF_5, $PaCl_5$, $PaBr_5$ and PaI_5. (G. T. SG.)

PROTAGORAS (*c.* 490–after 421 B.C.), of Xbdera in Thrace, was the first and the most famous of the Greek sophists. He is a principal character in Plato's Protagoras. His work entitled Truth began with the statement "Man is the measure of all things," which was probably intended to express the relativity to the individual of all perceptions and, as some hold, of all judgments as well. In *Concerning the Gods* he professed agnosticism as to whether the gods exist or not. Several other writings of his are listed, and he was perhaps the first to study grammar systematically. He professed to teach the art of politics and, as a friend of Pericles, had considerable success in Athens, exercising a great influence over contemporary thought on moral and political questions.

For iragments and testimonia *see* H. Diels and W. Kranz, *Fragmente der Vorsokratiker,* vol. ii, 7th ed. (Berlin, 1954). *See* also M. Untersteiner, *The Sophists,* Eng. trans. (Oxford, 1954). (G. B. KD.)

PROTEACEAE, a family of dicotyledonous plants comprising about 50 genera and some 960 species. of which about 600 are Australian. including the silky oak (*Grevillea robusta*) introduced into Ceylon for shade and timber, the Queensland nut (*Macadamia ternifolia*), cultivated in Hawaii, California and Florida, and the Australian honeysuckles (*Banksia*); there are about 260 species in southwestern Cape of Good Hope, including the silver tree (Leucadendron argenteum); the remaining species have a wide but irregular distribution in Asia, Africa, America and Australasia. Most of the species are trees or shrubs, and the majority are xerophytic (*i.e.,* inhabit arid country).

PROTECTION. By protection in the restricted sense is meant the use by the government of special forms of regulation or restraint, particularly import duties and analogous fiscal expedients, in order to encourage or to maintain essential industries which are endangered by foreign competition. The free-trade theory assumed that every man knew his own interest better than anyone else did; that everyone would follow his own interest rather than the interest of anybody else; and that the interest of the individual coincided with the interest of the community. On these assumptions rested the whole doctrine of *laissez faire* (*q.v.*). Society was an aggregate of individuals assumed to be equal to one another in the competitive struggle. Protection, on the other hand, involved a different conception. There was the interest of the individual. the interest of trade and the interest of the commonwealth. The last was the most important. On the free-trade theory the government should not interfere by tariff or other regulations in order to foster trades which did not make their own way in the competitive struggle, or to direct existing trades into channels in which they did not flow under purely individualist conditions. Insofar as such attempts were successful they involved loss to the whole body.

The country practising free trade was realizing "natural" conditions; tariffs or other regulations which interfered with such conditions were artificial, imposing obstacles in the way of the free movement associated with the "natural" state. Protection was therefore prejudicial to the realization of the greatest prosperity. A reversion to protection as a policy involves not merely the sporadic use of tariffs in order to safeguard particular industries, but a conception of the state. To the free trader wealth is the end in view; to the protectionist wealth is the means. The real end governing the policy of protection may not be economic at all in the narrow sense. but may be national or imperial solidarity and power. though undoubtedly a protectionist holds that while the free-trade policy may lead to the greater wealth of individuals, the protectionist policy. properly administered, will bring about a balance of economic activities, involving a higher maximum of efficiency to the community as a whole and a more equitable distribution between the economic groups.

If agricultural enterprise under free competition and free trade could not be made to pay, the free trader would abandon it and concentrate on those industrial activities that under such conditions are more profitable. The protectionist on the other hand would argue that this is a shortsighted view. In the first place agriculture is necessary to the state for its security. the maintenance of a healthy population and many other purposes not directly and immediately economic. But more than that, the protectionist would say that it is absurd from the economic point of view for a country to sacrifice its agriculture. for agriculture is the guarantee of a large home market for the country's manufactures, and the large and expanding home market is the best security for the successful exportation of manufactures. Given the home market, continuous running of the manufactories, and the proportionate reduction of the burden of standing charges, cheapens cost of production and makes possible easier entry into markets abroad and a higher remuneration for the workers at home. The free trader would say that if an industry does not pay its way under a policy of free importation, it is better that the capital employed in that industry should be invested in some other branch of economic activity which is remunerative; that the artificial maintenance of such an industry by the imposition of protective tariffs is an economic loss to the community. The protectionist would point out that the capital of such a depressed industry cannot be transferred to another industry, that capital is in the concrete form of factories and workshops and machines and many other forms which cannot be realized if the industry has fallen. It may indeed be desirable in certain circumstances to abandon it, but such a question cannot be decided without weighing carefully the number of persons employed, the possibility of their finding employment in other industries, the place of the industry in the national life, its relation to other industries in the scale of production. the possibility of obtaining its products in a suitable manner from other sources, its bearing on national security, and many other considerations of the highest importance. The free trader would not use tariffs or other artificial means for establishing in a country a new industry not hitherto practised. If such an industry were not likely to develop as the result of the unaided efforts of individuals, the free trader would not use government aid to promote it. The protectionist would consider the resources available in the form of raw materials, the possibility of acquiring the necessary skilled labour, the available organizing ability, the demand for the products of such an industry at home and the accessibility of markets, and if the prospects were favourable would not hesitate to impose a definitely protective tariff with the intention of encouraging the industry in view, even though for a few years it might involve higher prices to consumers at home, and he would do that all the more readily if there was plenty of capital for investment in the country for which he was responsible.

The Fall of the Old Policy.—In the middle ages the source of England's wealth was the exportation of raw materials, with which it purchased the manufactures and the luxuries of other countries. In those ages many of the regulations adopted were not. as they have been regarded by free-trade writers, restraints upon liberty, but the conditions of its exercise. Freedom is only possible where there is security. Before the close of the middle ages manufactures were greatly extended as a result of encouragement, by the native aptitude of the people and by the immigration of skilled artisans. Movements analogous to those of modern times took place on a small scale, and there were signs of a growing nationalism long before the close of the middle ages. Action taken by the trading companies, especially the great Merchant Adventurers company, encouraged foreign trade, and we can trace in numerous statutes the foundations of what was subsequently called the mercantilist system. Then took place a development not dissimilar to that in continental countries in modern times. Internal barriers were removed. England and Scotland were united. Great Britain and Ireland became one economic area. By that time the United Kingdom, under the policy which was so widely condemned later on by economists, achieved economic supremacy. With apparently illimitable supplies of coal and other requisites of production. Britain's industries growing by leaps and bounds from the use of new inventions, the whole organization and structure of great industries rapidly changing, the old laws and methods of regulation became obsolete, and the tariffs worked out to suit the more primitive stages of industrial development were simply embarrassing or irrelevant in the new conditions. Attempts to adapt them failed and the old duties were swept away. It might have been more statesmanlike and prudent to keep at least the framework of the old system, but with wealth as the supreme end in life and with the opportunities which the new industrialism gave. this was the accepted course of contemporary statesmen. By 1860 free importation mas the established policy of the country and the methods by which English statesmen had built up the economic power of the country were remembered simply as the economic fallacies of a former generation.

The Mercantile System in England.—The older policy was not protection in the narrow sense in which the word has been used in modern controversy. The idea of building up a great industrial commercial state by that policy ran through most of the economic measures which were adopted, affecting agriculture. trade and commerce. commercial treaties, finance, labour legislation. the poor lams and colonial policy for several generations. and discriminating duties were imposed not from logical necessity or through loyalty to some theoretical system, but as practical expedients like any other form of regulation to deal nith problems as they were at the time understood. Whole trades and branches of trades were left free. The mercantilism of England was always different in important respects from the Colbertism of France (see COLBERT, JEAN BAPTISTE) and the tariff systems, generally, of continental states. Adam Smith comments on the "liberality" of English policy as contrasted with that of other states. It was a "free-trade" system in (1) its extension of the powers of the central government over the trade and industry of the country at the expense of local and sectional bodies. close corporations. etc.; (2) the consequent equalizing of opportunities and development of free enterprise; (3) the "nationalizing" of great trades such as the East India trade. the trade of the Levant, etc.; (4) the removal of internal restrictions, such as those on the corn trade; (5) the introduction of free trade first between England and Scotland and then between Great Britain and Ireland.

The term "free trade" was used in many different senses in contemporary literature and practice, but scarcely at all in its modern sense. It was applied to the freedom of intercourse between states as secured by treaty, to privileges granted to alien traders by which they were put on equal terms with the denizens of the country. It sometimes suggested illegality, piracy and unfair avoidance of established regulations; it mas applied to the "interlopers" who carried on free trade with no regard to the regulations of the chartered companies. and to the smugglers who escaped the payment of duties levied by the state. In modern times free trade does not necessarily involve the meaning applied to it in England. but the policy of free exchange and the levelling of conditions by means of a tariff or other regulations to secure equality of competition between the countries concerned. Free importation in the modern English sense is peculiar to England, just as in England the term protection has come to be restricted in its application to the imposition of duties. It is also to be noted that the role played by the colonies under the mercantile system was roughly that which Richard Cobden (q v.) and his followers expected both colonies and foreign countries to play when the United Kingdom adopted free importation, and if the mercantilists sometimes imposed special regulations to direct colonial trade into channels considered favourable for the development of the mother country, the adherents of the Manchester school not infrequently used the power and influence of England to keep the economic activities of neutral and eastern countries in a stage considered favourable to the interests of British industry and to prevent the due expansion of those countries on lines more in accordance with the wishes of their people and the national resources.

There is a further distinction between the older system and Cobdenism. Both were forms of national as distinct from imperial policy, but under the former'the colonies had a great part to play. They were in a position in relation to the United Kingdom entirely different from that of foreign countries, and the system of preferences which then existed would have lent itself to the building up of the empire. Under the Cobdenite system the colonies had no part to play at all different from that of foreign countries, and the "interests of the consumer" took the place of the "interests of the commonwealth" as the basis of public policy. The older system looked forward, as it were, to the establishment of a great empire. Cobdenism was not really internationalism viewed from the point of view of British policy, but nationalism in a narrow. insular sense and the policy of England under its influence was based upon the economic monopoly secured by the rapid progress of invention. The influence of the new industrialism broke the cautious continuity of British policy. Sir Robert Walpole and William Pitt revised the fiscal system by removing duties on raw material and reducing other duties with the view to increasing revenue. William Huskisson revised the fiscal system in much the same spirit. The measures throughout this period were more in accordance with the cautious and statesmanlike line of Adam Smith's *Wealth of Nations* rather than with the later economists. If this movement had not been interrupted England would probably have retained the means of conducting international negotiations for consolidating the empire and providing a mide basis for revenue without any violent changes. but under later influences the policy of free importation was carried to extremes. People pursued the logical consequences of free trade rather than the practical interests of the country. The free traders on the one hand and the protectionists on the other were in violent and direct opposition on grounds of abstract theory rather than practical policy. But there is no important economist of the free-trade school uho does not admit important exceptions to the doctrine of free importation. The idea that all economists of that school were Cobdenites is without foundation. Reference has been made above to Adam Smith and his cautious attitude, but the great classical economists fairly generally admitted cases in which duties on imported manufactures might be desirable. Allowing therefore for the very different philosophical conceptions which were the basis of economics at that time and the very different economic conditions which prevailed, there is not so much to distinguish the attitude of the writers of the early part of the 19th century from those of the early 20th century in regard to practical policy as may be thought from manifestations of feeling during the fiscal controversy. The views of economists must be distinguished from the use made of them by political and social controversialists. The Ricardian theory of rent (*see* RICARDO, DAVID). the high prices and the practical difficulties of the times gave such people magnificent opportunity for working up a crusade against landlords, and the free-trade movement, which at first had been a most reasonable and proper effort to get rid of tiresome obsolete restrictions, became in the hands of extremists an instrument of social and political revolution. It is in England especially that the free-trade movement was directed mainly against the landlord class and later on the capitalists, and it has grown by natural stages into the socialistic movement of modern times, while protectionism in all its branches has been more identified with methods of creating an industrial and commercial state of the modern type

The qualifications of the free-trade doctrine admitted by John Stuart Mill went far to undermine the whole basis of the doctrine. His famous admission in regard to infant industries of a new country could be made to cover a very large proportion of the protectionist expedients adopted in later times. The economic conditions and the rapid growth of the United States in the 19th century naturally made an immense impression. It was necessary to work out an explanation for such progress under an economic policy so different from that of England. But historically speaking, analogies to the development of the United States policy could be found the uorld over. The word "new" in regard to industry cannot be confined in its application to the historic position of a country or an industry. It must apply to the stage of organization of particular industries and if it is once admitted that a high tariff is justified from that point of view. the tariff policy of Europe during the 19th century finds much justification from the writings of the economists. But the admission could easily be extended to cover many other important steps of policy. The case may be taken of the country whose industries have been actually devastated by war or destroyed in the sense that the existing organization for production has broken up, markets lost by the diversion of great works into activities for which they were not built and where vast works of reconstruction are required to bring them back to the peace efficiency which they once had. On Mills' admission it is difficult to deny the claim for protection while reorganization is being carried out. The question becomes a matter of practical expediency. Obviously the policy to be pursued cannot be decided on purely abstract grounds.

The German Zollverein. — The most remarkable instance in modern times of the constructive use of a protective tariff in the building up of a great empire is to be found in the history of Germany. At the beginning of the 19th century Germany consisted of a number of small states each enjoying fiscal autonomy, separated from one another by customs frontiers, and. after the Napoleonic wars, German statesmen and economists saw that if national industries were to be established on a modern scale, these numerous areas would have to be unified. Standing alone and more or less isolated economically from their neighbours. they could not get the full advantages they could obtain in production by the development of their materials from their numerous population and from their mutual commercial relations. Germany had to choose between a large-state and a small-state policy, and Prussia began the work of organization by the adoption of the tariff of 1818. Internal tariffs in the provinces of Prussia were swept away. Prussia as a whole was given protection against all external competitors, and other German states were invited to enter into union with it. The result of this movement was the formation of the Prusso-Hessian *Zollverezn.* This was followed by the *Zollverezn* between Württemberg and Bavaria and other combinations These combinations were then brought into union and the first treaty of the *Zollverezn* was adopted in 1834. The larger part of Germany thus became more or less a homogeneous economic area, except for a survival of a number of internal duties which it took many years to get rid of. The treaties mere in the first instance for 12 years. By the end of the first period other states had acceded and so the process went on until the German *Zollverezn* was completed. The *Zollverein* was not corerminous with the German empire, but it was the condition and the means by which the German empire mas created.

This movement was not understood in England, mhcre it was regarded as protectionist in the narrow sense in which the word was used in English controversy. There were gloomy prophecies as to uhat would happen to Germany and what would happen to the trade of England with Germany. In fact the German movement was not dissimilar from that extending over a long period during which the economic union of England, Scotland and Ireland was effected, and many internal barriers were swept away. The formation of the *Zollverein* brought about freedom of trade over a vast area, and its trade was protected against foreign competition by a carefully devised tariff around its external frontier. It is obvious that the Internal union could not have been secured without the external protection. The German tariff and the internal organization were necessary parts of the same movement, and the tariff organization was supplemented by great schemes of reconstruction affecting every aspect of German life. The progress which followed the movement is without parallel, and the German empire became the most powerful competitor in the world with other countries. This feat of statesmanship was all the more remarkable as it was carried out in the teeth of British competition. When Great Britain entered upon an era of rapid commercial progress. it was first in the field with the inventions which revolutionized industrial processes and had the manufacturing monopoly of the world. Germany at the beginning was technically behind Great Eritain. but there was one great help to its progress. Just when Germany was applying on a vast scale the principles of policy which had made Great Britain mistress of the world, that country turned its back on its own traditions and made a free present of its market to any country which could exploit it. The rapid industrial progress of Germany was undoubtedly partly due to the fact that German exporters had free entry into the English market for their goods. Eefore World War I, it was quite common for great German factories to be planned, erected and organized on the basis that they could always dispose of their surplus production in the English markets to an advantage at any price they could fetch.

This illustration from Germany is given in order to show how misleading was and is the practice of abstract English free traders of grouping the commercial policies of the world under two categories. free trade and protection. Nor is it enough to say that the actual policies are a combination of both theories. The actual policies of countries are the expression of the living activities of great societies as they have been determined by their long history and the powers and functions which they have developed, and they never follow the lines of an abstract theory divorced from the facts of that development. Moreover, the development of large-scale production at this period tended to alter the structure of economic activity so as to remove all trace of those free and perfectly competitive conditions without which such theories cannot become a reality. Many German students for years before World War I studied very carefully the course of events in England in order to avoid the mistakes that were being made there.

The growth of the *Zollverein* brings into clear relief the mutual relations of the measures adopted in carrying out a great policy of economic nationalism, and the conditions under which such a policy can be achieved. Internal fiscal differences have to be swept away as far as possible. and that required the provision of some alternative means for furnishing the revenue which in the first instance has to be sacrificed. So a tariff against external countries is organized and the development of means of direct taxation developed. The process further involved a policy for application to the means of communication, especially the railway system and transport by sea. In all these processes there was necessary some political reorganization. The small states had to sacrifice their autonomous fiscal powers when they entered into the new union. The *Zollverein* on the German model could not be achieved without such sacrifice, a condition which could not have been realized in the British empire where the dominions would certainly not have given up their fiscal autonomy.

The German measures could not be carried through without social reorganization and mainly under the influence of the German Zentrum party and their arrangement with Bismarck a whole code of new social laws was evolved. To enlarge still further the economic borders and to bring fresh markets on the continent within their ambit, the German treaty system was developed. Later on in order to meet the economic pressure which followed from their rapid development, Germany pushed into a colonial policy; and the exigencies of diplomacy, quite apart from the necessities of defense, forced Germany into a naval policy, and the German navy was established. Thus the German empire was gradually forced to adopt in a modern form all the leading characteristics of the old English national system, and the instrument by which these changes were brought about was the German tariff. This immense constructive movement, the greatest example we have of modern economic nationalism, obviously cannot be described as simple protection. It was a great scheme of organization in which for one purpose or another the German tariff had to be used as an instrument. (W. A. S. H.)

The Modern **Attitude** Toward **Protection.**—After World War I, the trend toward protection mas pronounced all over the world. This arose not primarily from the conscious adoption of any theory of economics, but as a by-product of the rising tide of nationalism especially in evidence in the small states created as a result of the dissolution of the Austro-Hungarian empire and the defeat of Russia. Free trade seemed now to belong to a dim past, to the age when passports were unnecessary to travel and the passage of ideas across national frontiers was unimpeded by propaganda ministries.

In the 1920s new factors came into play that had the effect of changing beyond recognition the terms in which the old controversies over international trading policies had been conducted. Competitive capitalism had developed to a point at which regular alternation between world booms and world slumps began to be regarded as a feature of its normal functioning. and at which the attainment of some degree of security against these fluctuations began to be a principle preoccupation of every government in the world. The demand for economic planning became strident everywhere, and. because of the strength of nationalism, it was inevitable that the unit of planning should be the national state. It became a general practice to seek to protect domestic industries by imposing high tariffs against the dumping of cheap goods from abroad. The result was a steady and general progress toward autarchy or national economic isolation. Freedom from the contaminating influence of foreign finance, and the patriotic duty of buying in one's own country, were essential themes in all the great revolutionary and counter-revolutionary movements of the time.

At the same time, however, the ancient free-trade doctrines retained a considerable measure of prestige, beginning to emerge in a somewhat new form: although it was no longer possible to preach the virtues of absolute freedom of trade, it was still possible to condemn the practice of trade discrimination, and this condemnation was heard with particular force from the United States which, itself protected by high tariff walls, was preoccupied with the problem of getting foreign outlets for its surplus production and accordingly anxious to prevent the exclusion of its goods from any part of the world as a result of the emergence of regional economic groups based on mutual trading preferences. Controversy now raged not over the relative merits of protection and free trade but over those of discriminatory and nondiscriminatory trade. In 1932, the famous Ottawa agreements introduced a measure of reciprocal preferential trading between the member states of the British Commonwealth, aimed at protecting them from some of the worst hazards of world competition. These measures aroused bitter criticism from the advocates of nondiscriminatory trading, and attempts to emulate them elsewhere were frustrated. The choice which the exclusion of reciprocal preferences left seemed to be between high national tariff applying indifferently to all the foreign producers of the commodity taxed, and low national tariffs opening the domestic market to the full rigours of foreign competition. Since total economic isolation was not a practicable course of policy for anyone, the tendency was for states anxious to achieve economic security to pursue that end by political conquest aimed at creating economic empires large enough to be viable on a basis of isolation. Such, for example, was in part at least the explanation of Japan's aggressions in the 1930s, and later of Italy's and Germany's. Hard-pressed states also tried to bypass the tariff question altogether by instituting a direct governmental control of foreign trade. By means of official bulk purchasing and the strict control of foreign exchange operations (practices associated with the name of Hjalmar Schacht. the economic magician of Nazi Germany), it was possible for a nation to govern the direction of its foreign trade without recourse to the use of tariffs.

World War II again changed the problem fundamentally. In the first years of peace, the persistence of direct economic controls in most of the belligerent countries made tariffs largely irrelevant, because without recourse to them governments had the power to limit and direct foreign trade. At the same time, European dependence on the U.S. inclined Europe toward the acceptance of U.S. views on international trade. The U.S. (see below) continued to work for the reduction of tariffs everywhere, but it now sought to encourage planned international economic co-operation through the careful planning of production and finance. Large free-trade areas in which stability would be maintained by making finance available to counter slumps and by encouraging the planning of production under the auspices of supranational authorities but without necessarily taking ownership out of private hands was the current recipe of liberal capitalism. The extent of international. economic interdependence made the case for high protective duties increasingly difficult to sustain. The emphasis was switched from the negative idea of protecting markets against foreign competition to the positive idea of maintaining a high and stable volume of international trade. Critics of this liberal capitalist recipe demanded international planning on a basis of direct governmental control, on a basis, in short, of socialism. There remained some advocates of the preferential tariff as a means of combining stability with flexibility, but, like the classical advocates of free trade, they apparently belonged to an almost extinct tradition.

BIBLIOGRAPHY.—W. J. Ashley, *The Tariff Problem* (London, 1911); F. W. Taussig, *Some Aspects of the Tariff Question,* 3rd ed. (Cambridge, Mass., Oxford, 1931); Sir John Clapham, *An Economic History of Modern Britain,* vol. ii (Cambridge, New York, 1932), vol. iii (*ibid.,* 1938); G. Kirk, "Possible Tariff Policies of the Future," in *Financing the War, R. B.* S. Warren *et* al. (eds.) (Philadelphia, 1942), Margaret S. Gordon, *Barriers to World Trade* (New York, Toronto, 1941); *The General Agreement on Tariffs and Trade, 4* vol. (United Nations publication no. 10, New York, 1947); J. Viner, *The Customs Union Issue* (New York, London, 1950). (T. E. U.)

UNITED STATES

As the American economy developed from a colonial economy to the world's most powerful industrial machine, the factors influencing tariff policy changed substantially in importance. Revenue considerations lost much of their force as the share of customs in the general revenue of the federal government fell from about 90% as late as the 1850's to 7% by mid-20th century. The development particularly of the federal reserve system in 1913 eliminated mcnetarp and cyclical aspects of tariff policy which at times had conflicted with the protectionist aims of tariff advocates: before the creation of an efficient central banking system, the possible deflationary pressure of a budget surplus could be eliminated only by a reduction of the most important tax. the tariff. Even the protective alms proper have changed from the days when the tariff was intended to speed the development of the young economy to the protection of minor individual producer groups. Finally, as purely econoinic considerations declined, political factors increased in importance. Particularly after the end of World War II, the needs of foreign policy and of strengthening the countries of the free world through closer economic ties with each other and with the United States increasingly became paramount considerations.

Until 1816 revenue considerations dominated tariff-making. The period 1816–32 saw vigorous protection for rising young manufactures, followed by declining protective duties until 1860. From the Civil War to 1934, the United States followed a consistent protectionist policy, interrupted only by the relatively moderate Wilson and Underwood tariffs of 1894 and 1913. With the Trade Agreements act of 1934, a new period of trade liberalization started which was somewhat modified after 1948.

Before the U.S. constitution was adopted customs were a prerogative of the states. When congress met under the constitution, the first bill introduced in the house of representatives was a measure to provide revenue by means of a customs tariff. Though there clearly was also a nillingness to use the tariff to encourage domestic industries, the rates enacted were low (in general only 5%) with specific duties on certain articles selected for special encouragement. During the 20 years following. the European wars created a great foreign market for American raw products, and made shipbuilding and shipping highly profitable, particularly in New England; thus there was little growth in U.S. manufactures and no appreciable increase of protectionist sentiment, despite the strong argument for protection put forth in Alexander Hamilton's *Report on Manufactures* (1792). As more revenue was needed, tariff rates were raised, but with no special attention to their protective aspects, and down to 1816 customs duties were only remotely protective.

The Embargo and Non-Intercourse acts of 1807 and 1809, however. and the War of 1812 with England cut off a large part of exports and imports. Small manufactures sprang up to meet pressing needs. Financially weak and often ill-equipped, they were in no position to meet the competition of the more-advanced British manufactures on the return of peace. The tariff legislation of 1816 was designed to raise revenues as well as to aid manufacturers. Nevertheless, this measure embodied only moderate duties, running as high as 25% on textiles. for three years only with a provision for minimum valuation. Though bad crops in Europe kept farm prices high for a time, the farmers too found themselves in difficulties after the crisis of 1818–19, and their thoughts turned toward the possibility of a home as opposed to a foreign market. These conditions led after 1819 to an agitation for internal improvements and a vigorous protective movement which aimed to insure national self-sufficiency by encouraging young manufactures and affording the farmer a home market. This so-called "American system," popularly identified with the name of Henry Clay, its foremost spokesman, had its early strength in the middle and western states. New England at first holding aloof because of its predominant shipping and commercial interests. As industrialization proceeded. however, New England swung over, and from the latter part of the 1820s that section became a foremost advocate of the protective system, which Pennsylvania had favoured from the first.

In response to the demand for protection, congress passed the Tariff act of 1824, raising the duties on textiles, and also on iron, wool, hemp and other articles of particular interest to the middle and western states and to the farmers. Agitation was renewed after the crisis of 1825–26, culminating in the celebrated Harrisburg convention of 1827. In the following year, as a result of extraordinary political manoeuvres, the so-called "tariff of abominations" was enacted which sharply increased rates, particularly on wool, and on other goods whose protection was especially distasteful to New England. Four years later a new act put the tariff into a form satisfactory to its friends. Goods not produced domestically paid low rates while textiles, iron and other articles which it was desired to protect paid high ones. Thus woollens were taxed 50%, while the specific duty on rolled bar iron at 1832 prices was equal to 95%.

The southern states, being without manufactures, were interested chiefly in cotton exports. Realizing that protection worked to their disadvantage, they had from the beginning sharply opposed it. The opposition became so fierce that South Carolina undertook to nullify the act of 1832. The firmness of Pres. Andrew Jackson maintained the federal authority. Southern opposition, however, led to the compromise tariff of 1833, providing for a reduction of duties over a period of 10 years, until in 1842 no rate should exceed 20%. Manufactures were in fact well established by 1832 and interest in the tariff waned, while other questions, such as internal improvements and slavery, came to occupy public attention. The final low rates of the act of 1833, it so happened, were in effect only two months, since the Whig party in 1842, for political rather than economic reasons, but in part also to raise more revenue, passed a new high-tariff measure. However, with improved business conditions, revenue increased and in 1846 the moderate Walker tariff was passed which reduced rates substantially. In 1857 a redundancy of revenue led to further reductions from 30% to 20% for the most important articles. The act of 1857 marked the lowest level of protective rates since the beginning of active protection. Under the circumstances then existing, the reduction of duties commanded general approval even among the manufacturers. Farmers and manufacturers alike turned to means other than tariffs to insure their prosperity and no real or supposed national interest was successfully invoked to stay the growing movement toward freer international trade. A revenue shortage following the crisis of 1857 occasioned the enactment of the Morrill tariff of 1861, framed to attract protectionist votes to the Republican party in the campaign of 1860. Undertaking only to restore the rates of 1846, its authors yet thought to give added protection to Pennsylvania and the western states by changing ad valorem to higher specific duties and by raising rates on iron and wool. Even so, the measure belongs essentially to the period of tariff liberalization beginning in 1833.

Civil War.—The Civil War brought profound industrial changes and gave a new direction to tariff policy. Hitherto customs duties had been virtually the sole source of government revenue. The needs of war finance required an elaborate fiscal system of which the imposts on liquor and tobacco remained as a permanent and highly important part, thus affording legislators somewhat more leeway to deal with customs duties without primarily budgetary considerations. The heavy taxes imposed on many commodities by the internal revenue acts of 1862 and 1864 were naturally accompanied by corresponding increases of import duties. Since those who framed the laws were protectionists, almost any duty asked for was granted. The tariff structure, "in many ways crude and ill-considered," establishing "protective duties more extreme than had been ventured on in any previous tariff act," to quote a leading authority, was originally designed to meet the war emergency. At the end of the war, however, the structure, instead of being rebuilt, was preserved practically intact, and with relatively minor modifications continued to serve as one of the two pillars of federal finance down to 1913.

Post-Civil War Period.—After the war, the internal revenue taxes, except those on liquor and tobacco, were promptly swept away, but the protected interests successfully resisted the reduction of tariffs. The demand for tax reduction and tariff reform was met in 1870 by lowering the rates on pure revenue articles like tea and coffee, while actually raising certain protective duties, including those on steel rails and nickel. Two years later it became necessary to reduce revenue. Fearing worse things, the protectionists consented to a horizontal 10% reduction of all duties, on condition of the entire repeal of the nonprotective duties on tea and coffee. When more revenue was needed in 1875, the 10% was easily and quietly restored. The high mar rates on wool and woollens had been raised yet higher as early as 1867 at the instance of certain woollen manufacturers and sheep breeders represented in the Syracuse convention; and the elaborate scheme of classified duties on wool, together with compound specific and ad valorem compensating and protective duties on woollens introduced in the Morrill act, had been further developed. Similarly, the Lake Superior copper producers succeeded in 1869 in getting congress to raise the duties on copper ore and ingots. In 1870 the 45% duty on steel rails was changed to a slightly higher specific duty of $28 a ton. Rail costs fell rapidly, and by 1877 this amounted to almost 100%. The small number of American companies owning the Bessemer patent made enormous profits and expanded their business rapidly.

In 1883 a redundant revenue compelled a reconsideration of the entire situation. A tariff commission made up of protectionists on the whole recommended reductions, but little attention was paid to it. The protectionist forces in control of congress managed to get rates raised on goods which continued to be imported despite the existing protective duties—such as fine woollen cloths and dress goods, cotton hosiery, laces and embroideries, iron ore and various special manufactures of steel—while duties were lowered chiefly in cases in which the new rates were as prohibitory as the old, such as cheap cottons, steel rails and copper. The act made no fundamental change in the protective system. Tariff discussion continued, and Pres. S. Grover Cleveland's annual message to congress in Dec. 1887, urging general tariff reduction, particularly on raw materials, made protection the outstanding issue of the campaign of 1888. The Republicans won and proceeded accordingly to make the tariff more highly protective. The McKinley act (1890) raised the duties on wool and woollens, as well as on such cottons as continued to be imported. Linens went up sharply. and velvets and plushes of all sorts were charged high rates in an effort to establish a new industry. With the same purpose, tin plate, which had been entirely imported, was charged 2.2 cents a pound. It was, however, to be admitted duty-free after 1897 if the tariff failed to provide substantial domestic production. The duty of two cents a pound on sugar was repealed and domestic producers, who supplied only a tenth of consumption, were given a two-cent bounty instead, the two measures together taking something like $60,000,000 a year out of the treasury. The whole act was a distinct extension of the protective system.

Tariff Changes Under Democratic **Administrations.**—In the two succeeding political campaigns the Democrats, returned to power, pledged to reduce tariffs. Party quarrels over the silver question, however, together with the narrowness of the party majority in the senate and the determination of certain Democratic senators to maintain protection for particular interests, resulted in the emasculation of the tariff measure passed by the house, and the Wilson act of 1894 was allowed to become law without the president's signature. Even so, it constituted a break in the series of increasingly protective measures enacted since the Civil War. First, and most important, wool was made free, and the complicated duties on woollens were replaced by simple ad valorem duties, which, however, afforded the manufacturers as much protection as they had enjoyed under the McKinley act. Rates on the finer cottons and on iron and steel were lowered somewhat, and the rate on tin plate was cut in two. Coal and iron ore, as raw materials, were made free by the house, but the senate restored both to the dutiable list, though at reduced rates. The great battle was waged over sugar; the outcome was a duty of 40% ad valorem on raw sugar, and of 40% plus one-eighth of a cent a pound, plus an extra tenth of a cent a pound on sugar coming from any country that gave an export bounty on refined sugar. This result was commonly regarded as a victory for the "sugar trust" and a violation of party pledges. The measure as a whole was a great disappointment to the tariff reformers.

Dingley (1897) and Payne-Aldrich **(1909)** Acts.—The money question carried the Republicans back into power in 1897, but political conditions made monetary legislation impossible, and Pres. William McKinley called congress in extra session for the sole purpose of tariff revision. The Dingley act was passed without delay, restoring essentially the system of 1890. The wool and woollens duties of that year were re-established, with some changes, mostly upward. Specific duties, even higher than the previous high ad valorem ones, were laid on silks and linens. The farmer got a duty on flax, and the ranchman, for the first time in 25 years, a tax on hides. As the iron and steel industry was largely beyond reach of foreign competition, rates were left in good part where they had been put in 1894, but certain imported specialties, such as razors and cutlery, were raised by changes in classification, while tin plate was given rates little in advance of those of 1894. Rates on raw sugar were pushed above those of the Wilson act, thus at once increasing revenue and giving added protection to the beet-growing industry, and the refiners kept the one-eighth of a cent differential of 1894. The Dingley act thus gave up no part of the protective structure of 1890, and at a number of points extended it beyond its previous limits.

The rapid growth after 1898 of industrial combinations, popularly supposed to be special beneficiaries of the tariff, the rise in the cost of living, along with the restiveness of the middle-nest farmers and the growth of manufactured exports combined in putting the protectionists on the defensive. The Republican party, accordingly, in the campaign of 1908 enunciated the "true principle" of protection, that duties should equal the difference between cost of production at home and abroad. The Payne-Aldrich act of 1909, however, was written along the same lines as its predecessors, without regard to the "true principle." The house committee proposed to admit coal, lumber, iron ore and hides free. Hides were freed in fact, the other materials merely paid reduced rates. Important upward changes were made in the textile schedules, as in the rates on mercerized cotton, cheap hosiery and silks. The iron and steel duties, most of which had long since become ineffective, were generally reduced; but razors, pliers, cheap cotton gloves, asbestos fabrics and other particular articles whose claims were effectively presented by their producers to the legislators mere given added protection. Figs, prunes and lemons were protected. The act brought no substantial modification of the protective system, but the whole tone of its supporters indicated inability or unwillingness to push much further the aggressive protectionist policy of the 1890s.

The backhanded reciprocity provisions of the acts of 1890 and 1897, authorizing the president to retaliate against countries discriminating against the United States. were omitted from the act of 1909. Instead, the rates of 1909 were declared the minimum tariff and those rates plus 25% (of the value of the goods) the maximum. After March 31, 1910, the maximum rates were to go into effect automatically, except in the case of those countries where the president had satisfied himself that "no undue discrimination" was exercised against the United States. The administration managed to avoid the imposition of the maximum rates, though tariff wars with France, Germany and especially Canada were narrowly averted. The president also construed a provision of the maximum and minimum clause as authorizing him to appoint a tariff board, which proceeded to make studies on the basis of the "true principle," the moderate protectionists believing that its findings might serve as a second line of defense against the reduction of genuinely protective duties. The same moderate group, under the leadership of Pres. William Howard Taft, was eager to do something for the export manufacturers, whose interest in foreign markets had been recognized in the act of 1909 only in the ill-judged maximum and minimum provisions. A measure was accordingly driven through congress, against the bitter opposition of the extreme protectionists. approving a treaty for a moderate measure of reciprocity with Canada, and freeing wood-pulp irrespective of Canadian action. To the disappointment of the moderates, Canada rejected the treaty.

Woodrow Wilson's Administration.— The year 1913 found the Democrats in control of the presidency and of both branches of congress. Pres. Woodrow Wilson promptly called congress in special session, and a new tariff measure was enacted which was widely hailed as marking the beginning of a new era in U.S. tariff policy. Announcing the principle of a "competitive tariff," and declaring their intention to injure no "legitimate industry," the party in power yet proceeded to a downward revision looking to definitely moderate protection. Wool was admitted free; and woollens after Jan. 1, 1914, were to pay a straight ad valorem rate of 35%. Sugar, the duty on which; with the growth of the beet industry, had become a protective one, was to be free after May 1, 1916, by which time the newly enacted income tax was expected to yield income effectively. Cottons were sharply reduced; though most of the reductions were nominal the new rates meant the probability of increased imports of the finer goods. Silks were cut somewhat, though the general rate was still 45%. Coal and lumber were freed, and leather and boots and shoes followed hides to the free list. Iron ore and crude iron and steel products likewise were made free, and rates were cut to a maximum of 20% on the advanced products. To meet the farmers' wishes, agricultural implements, by a harmless gesture, were carried to the free list; but at the same time wheat, flour. cattle and meats were freed in response to the demand for a lowered cost of living, thus introducing the possibility of a less restricted border trade. The "jokers," special rates imposed at the behest of particular favoured producers, which had become so conspicuous and unpleasant a feature of protective acts, for the greater part disappeared. The act repealed the maximum and minimum provisions of 1909, and in 1916 a tariff commission mas established. While many of the reductions of the Underwood act were politically rather than economically important, it represented a genuine though cautious attempt at a wider freedom of trade.

During World War I, U.S. industries, despite reduced duties, had no European competition whatever. Various of the so-called "war babies.!' notably the chemical industry, grew enormously to meet immediate needs. With the return of peace, some of them faced sharp foreign competition. The spectacular fall of prices in 1920 plunged agriculture into distress, and the farmers turned to protection as a supposed remedy.

Fordney-McCumber (1922) and Smoot-Hawley **(1930)** Tariffs.--When the Republicans returned to power in 1921, they promptly laid high duties (quite incapable of raising prices under the circumstances) on various farm products that had been freed in 1913, notably wheat, corn and meat, as also wool and sugar. This "emergency" measure was followed by the Fordney-McCumber tariff of 1922, follou-ing the lines of the act of 1909, but surpassing it in the application of protection. Agricultural rates were higher than in 1909. Generally without economic significance, they did in fact mean the probability of higher prices for such products as California fruits, wheat on occasion, and notably sugar. Wool was given increased protection, and the elaborate system of compensating and protective duties on noollen manufacture was restored. Textiles generally fared about as in 1897 and 1909. Iron alloys and specialties subject to foreign competition, like cutlery and firearms, were raised above the rates of 1909, as were china ware jewellery, toys and laces, the last-named paying 90% ad valorem. Coal-tar products, dyestuffs and chemicals, which had sought absolute prohibition, were granted extremely high rates.

The act authorized the president, after investigation by the tariff commission, to raise or lower rates (within the limit of 50% of the prescribed duties) as might be necessary to equalize costs in the principal competing country. Under this provision the president raised rates in a number of cases, but lowered them in no important instance.

The farmers failed to share the prosperity of the 1920s, and early in his administration Pres. Herbert Hoover called congress in extraordinary session to revise the tariff for their benefit. Congressional action promptly took the form of a general upward revision of duties, giving rise to a fierce legislative struggle. Export manufacturers urged moderation, financial experts pointed out the necessity of increasing imports in view of the creditor position of the United States, protests against threatened injuries came from 40 foreign countries. and more than 1,000 economists signed a memorial advocating the defeat or veto of the measure. Nevertheless it was enacted in 1930, after a notorious process of logrolling. The act raised the average rates in every schedule, the increase being greatest on agricultural products. Sugar, cattle, dairy products, grains, lemons and other California products, wool, woollen and silk goods. manganese and tungsten bearing ores, and pig iron all went up. Lumber. brick, cement, hides, sole leather and boots and shoes, all of which had been free, were subjected to duties.

There were increases on many small manufactured products, like watch and clock movements, cheap toys and matches, unimportant to the United States, but highly important to certain foreign exporting countries.

The flexible tariff provision was retained. The raising of U.S. duties at a time when international trade was already declining caused sharp resentment abroad, and was promptly followed by higher tariffs in many countries. From 1929 to 1933 the foreign trade of the world. according to League of Nations figures, fell by 25% in quantity and 65% in value.

Reciprocal Trade Agreements Acts and **G.A.T.T.**—The failure of the Smoot-Hawley tariff of 1930 to prevent the depression of the 1930s, as well as foreign retaliation against U.S. exports, led to the realization that trade was a two-way street. With the Democrats once more returned to power, the Reciprocal Trade Agreements act of 1934, based on the earlier flexible tariff provisions, was passed, osrensibly as a measure to increase exports by bilaterally reducing tariffs. The failure of earlier reciprocity measures induced congress to delegate to the executive the power to negotiate tariff concessions bilaterally which were then to be extended to other countries with whom the United States had commercial treaties through the unconditional most-favoured-nation clause. The law. passed for three years, permitted the president to reduce tariffs up to 50%, but prohibited changes in the free list. The act was reneued in virtually unchanged form in 1937, 1940 and 1943.

In 1945 two major changes were made. In the 29 trade agreements negotiated between 1934 and 1945, the president had almost exhausted the tariff cuts permitted to him. The act of 1945 allowed him to cut rates another 50% from the level then prevailing. At the same time the administration inserted an escape clause into every trade agreement, though the law did not require this until 1948. With its renewal in 1948 by a Republican-dominated congress, the act became once more somewhat more protectionist. The escape clause, used for the first time in the Mexican trade agreement of 1942, permitted the president to withdraw unilaterally a concession made if serious injury was threatened to a domestic industry as the result of the concession. A "peril-point" amendment authorized the tariff commission to investigate how far tariffs might safely be reduced on individual commodities, though their recommendations were not binding on the president.

In 1949 the Democrats succeeded in temporarily restoring the original, less-protectionist form of the act, but from 1951 the escape- and peril-point clauses were reinserted.

Because the method of negotiating bilaterally with one country at a time has limitations in that each country is fearful of weakening its bargaining position vis-a-vis third countries as concessions are generalized through the most-favoured nation clause. simultaneous negotiations by the U.S. with 22 countries were held in 1947 in Geneva, Switz., which led to the establishment of the General Agreement on Tariffs and Trade (G.X.T.T.), which. after further negotiations at Annecy, Fr., and Torquay, Eng., in 1949 and 1950–51, 33 countries had joined by 1953. G.A.T.T. negotiated tariff concessions on about 45,000 items, making up about two-thirds of world trade.

G.A.T.T. embodied the principles of U.S. trade policy with qualifications, some of which were entered by the United States itself. The most important one was that although the United States was in principle against all quantitative restrictions as discriminatory and inconsistent with a free market economy, it would agree to them, as far as other countries were concerned, in the event of balance of payments difficulties; and the United States itself imposed quotas on agricultural imports when they conflicted with domestic agricultural programs which were frequently inconsistent with the avowed principles of foreign trade policy.

By the 1950s the escape clause had been sparingly used, the withdrawal in 1954 of lower rates originally negotiated in 1936 on Swiss watches and movements being the most important case. Undoubtedly tariffs were substantially reduced under the Trade Agreements program and G.A.T.T. An investigation by the tariff commission put the tariff level on dutiable imports in 19j3 at about 12% ad valorem, about half the level of 1934. Yet much of this reduction was also attributable to the general rise in prices which reduces the impact of specific duties, in addition to the reduction of rates. And even in 1954 there were still a substantial number of rates of 50% or more. Furthermore, other methods of protection. such as quotas, special legislation relating to sugar and wool, complicated customs procedures, arbitrary valuations, overly specialized customs classifications and other weapons in the arsenal of administrative protectionism became rapidly more important as restrictions on imports than mere tariffs. *(See* FREE TRADE; TARIFFS.)

BIBLIOGRAPHY.—F. W. Taussig, *State Papers and Speeches on the Tariff* (Cambridge, 1892), *Tariff History of the United States,* 8th ed. (New York, 1931) and *Some Aspects of the Tariff Question,* 3rd ed. (Cambridge, Mass., Oxford, 1931); T. W. Page, *Making the Tariff in the United States* (New York, 1924); P. W. Bidwell, *The Invisible Tariff* (New York. 1939); E. E. Schattschncider. *Politics, Pressures and the Tariff* (New York, 1938); A. Isaacs, *International Trade, Tariff and Commercial Policies* (Chicago, 1948); D. Gale Johnson, *Trade nnd Agriculture: A Study of Inconsistent Policies* (New York. London, 1950); H. C. Hawkins, *Commercial Treaties and Agreements, Principles and Practice* (New York, Toronto, 1951); the publications of the U.S. Tariff Commission, particularly *Reciprocity and Commercial Treaties* (Washington, 1919), *Operation of the Trade Agreements Program, 1934–1948,* Report 160, 2d series (Washington, 1948) and later annual reports. (H. R. M.; W. F. SR.)

PROTECTIVE COLORATION: *see* ANIMAL COLORATION; MIMICRY.

PROTECTORATE, a term used in international law to describe the relationship between two states, one of which exercises control over the other. The use of the term to designate such a relationship is comparatively modern; it is significant that the word does not occur in Sir George Cornewall Lewis's *Essay on the Government of Dependencies* (1841). Nevertheless the relationship is an ancient one. There have always been states which dominated their neighbours. but which did not think it politic to annex them. Edouard Engelhardt and other writers on the subject have collected a large number of instances in antiquity in which a true protectorate existed, even though such terminology was not used. Thus the hegemony of Athens. as it existed about 467 B.C., was a form of protectorate; although the subject states were called allies., they were, in all important legal matters, obliged to resort to Athens.

In dealing with dependent nations Rome used terms which veiled subjection. Thus the relationship of subject or dependent cities to the dominant power was described as that of *clientes* to *patronus.* Such cities might also be described as *civitates foederatae* (allied communities) or *civitates liberae* (free communities). Another expression of the same fact was that certain communities had come under the power (*in deditionem*) or under the trust (*in fidem*) of the Roman people. The kingdoms of Numidia. Macedonia. Syria and Pergamum were examples of protected states, their rulers being termed *inservientes* (subjects). The Romans drew a distinction between *foedera aequa* and *iniqua* (equal and unequal treaties). The latter created a form of protectorate. the protected state remaining free,

In medieval times this relation existed, and the term protection was in use, but the relationship of subordination of one state to another was invariably expressed in terms of feudal law. One state was deemed the vassal of another. and the ruler of one did homage to the other. In his work *De la République* (1576) Jean Bodin treats of "those who are under protection" or as the Latin text has it, *de patrocinio et clientela.* In Bodin's view such states retain their sovereignty (i, c, 8). Discussing the question, whether a prince who becomes a *cliens* of another loses his *majestas,* he concludes that, unlike the true vassal, the *cliens* is not deprived of sovereignty. Elsewhere he remarks. "the word protection is special and implies no subjection on the part of the party under protection." He distinguishes the relation of *seigneur* and *vassal* from that of *protecteur* and *adherent.* At times letters of protection were granted by a prince to a weak state, as, for example, by Louis XIII in 1641 to the prince of Monaco.

Reverting to the distinction in Roman law, Hugo Grotius and Samuel von Pufendorf. with many others, treat protection as an instance of unequal treaties; that is, "where either the promises are unequal, or when either of the parties is obliged to harder conditions."

In the 16th century, the rise of European national states led to increasing use of the system of protectorates as a prelude to annexation. particularly by France. This use was also developed during the 19th century as a means of colonial expansion. After the Napoleonic wars, however, establishment of protectorates by the great powers became a means of maintaining the balance of power. Thus. by the treaty of Paris (1815) the Ionian Islands became a protectorate of Great Britain in order to prevent Austria from gaining complete control of the Adriatic. The gradual elimination of the smaller European states by the unification of Italy and Germany, and the strengthening and neutralization of those that remained (*e.g.,* Switzerland and Belgium), brought to an end this development in the use of the protectorate. A curious situation arose. however, with the disintegration of the Ottoman empire. Provinces which owed allegiance to Turkey began to revolt against Turkish rule and, as a stage in their struggle for independence. were sometimes placed under the protection of a foreign power. Thus. Moldavia and Walachia, which became protectorates of Russia in 1829, were placed under international protection in 1856 and in 1878 united to form the independent state of Rumania (*q.v.*).

Definitions.— "The one common element in protectorates is the prohibition of all foreign relations except those permitted by the protecting state. What the idea of protectorate excludes, and the ideas of annexation. on the other hand, would include, is that absolute ownership which was signified by the word *dominium* in Roman law, and which, though not quite satisfactorily, is sometimes described as territorial sovereignty. The protected country remains. in regard to the protecting state, a foreign country; and this being so, the inhabitants of the protectorate. whether native-born or immigrant settlers, do not by virtue of the relationship between the protecting and the protected state become subjects of the protecting state." (Sir William Rann Kennedy, *Rex* v. *Crewe,* 1910, 2 K.B., 576.)

The term protectorate is used loosely to designate a variety of degrees of control of one state by another. from that situation in which it means no more than that the protecting state guarantees and protects the safety of the other. to a situation which is a masked form of annexation. in the manner of the German protectorates established in Czechoslovakia in March 1939. Strictly, it is distinguished from suzerainty (*q.v.*), but nevertheless both relationships display the same characteristics of the observance of such ancient forms and traditions in the protected state as are consistent nith necessary change, and the reservation of nominal freedom while securing real power to the protecting state. Protectorate is probably best regarded as a form of international guardianship and the modern emphasis is upon the responsibility and duty of the protecting state to the international community as well as to the protected state.

There are tno principal classes of protectorates, those exercised over more highly civilized countries having a stable form of government and a historical tradition of their own. and those exercised over underdeveloped peoples, the latter being sometimes called colonial or pseudo-protectorates and being especially common in Africa. Examples of the former exist in Europe in Andorra and San Marino. Strictly, there can be no protectorate over a domain nhich is uninhabited or ruled by no organized state, but the distinction has not alnays been maintained.

In its narrowest and strict meaning, the relationship established in a protectorate must be distinguished from the relationship existing between the United States and the states of Central and South America (*see* PAN-AMERICAN CONFERENCES and MONROE DOCTRINE, THE), from the former relationship between Great Britain and the Indian states (*see* INDIA) and from so-called spheres of influence (*q.v.*).

Protectorates and International Law.—"The extent of the powers of a protecting state in the territory of a protected state depend. first upon the treaties between the protecting state and the protected state establishing the protectorate, and secondly upon the conditions under which the protectorate has been recognized by third powers as against whom there is an intention to rely on the provisions of these treaties. In spite of common features possessed by protectorates under international law, they have unlimited legal characteristics resulting from the special conditions under which they were created, and the stage of their development." (*Advisory Opinion, The Nationality Decrees in Tunis and Morocco,* "Series B," no. 4, p. 21, 1923.)

The majority of protectorates have been established by treaty by the terms of which the weaker state surrenders the management of all its more important international relations, although some have been imposed by force. *e.g.,* the unilateral declaration by Great Britain concerning Egypt in 1914 (*see* EGYPT). The treaty defines the position of the protected state in the international community: with special reference to its treaty-making powers and its right to diplomatic and consular representation.

There is a conflict of opinion whether or not the protected state loses its sovereignty. Many writers have supported the view that there is no such loss, and have gone so far as to state that the arrangement is *res inter alios acto* ("a thing done between others") and concerns only the parties to it. This is not the modern view, however, and it is now generally accepted that the relationship of protectorate must be recognized by third powers. The right of the protecting state to interfere in all matters of external affairs constitutes a definite loss of sovereignty, and since in orthodox theory sovereignty is one and indivisible. such a situation must imply a loss of sovereignty on the part of the weaker state. Neither position is without its anomalies; for example, it is clear that the sovereign of the neaker state yet has jurisdictional immunity in at least the territory of the protecting state (see *Duff Development Co.* v. *Kelantan [Government] and A. G.,* 1924 A.C. 797).

On the other hand, it was equally clear that on the assumption of the status of protectorate, the weaker state ceased to qualify for membership in the United Nations.

The relationship does not affect the nationality of the members of the weaker state, although there are frequently facilities for the peoples of the protectorate to become nationals of the protector, and they one a certain ill-defined allegiance to the protecting state. Thus the British Nationality act, 1948. made provision for the naturalization of British protected persons, the requirements to be fulfilled being less onerous than those imposed upon aliens. Nor, generally speaking, does the territory of the protectorate become part of that of the protecting state. although the applicability of legislation of the dominant state can only be judged from the construction of its terms.

The older view of the position of a protectorate according to international law is contained in the decision of Stephen Lushington in "The Case of The Ionian Ships" (2 Spink 212. 164 E.R. 394 [1855]).

The Ionian Islands were at that time subject to the protectorate created by the treaty of Paris. 1815, and it was held that notwithstanding the declaration of war by Great Britain against Russia. the Ionian Islands remained neutral. It was not disputed that as the head of the protecting state the British sovereign had the right to declare war or make peace on behalf of the islands. "Such a right is inseparable from protection." But the intention to involve the protected state in the wars of the protecting power must be clearly expressed, and the state of mar does not arise *ex necessitate* on the protecting power's going to war, for there may very well be advantages to one or other of the parties to the protectorate if the protected state is not so involved. It is said that the protected state is only implicated in the wars to which the protecting state is a party where the latter has acquired a right of military occupation of the territory of the former.

See also MANDATE; SUZERAINTY; TRUSTEESHIP SYSTEM.

(E. H. LD.)

PROTEINS are highly complex substances that are universally present in living organisms. They are of great nutritional importance, have numerous industrial uses and are directly involved in the chemical processes necessary for the maintenance of life. Compounds with properties identical to those of the naturally occurring proteins had not been made in the laboratory by the second half of the 20th century. All of the proteins known and in use have therefore been synthesized by living cells. After water has been removed from the soft tissue of an animal. whether it be the human body or a one-celled animal, the major portion of the solid residue is found to be a mixture of proteins.

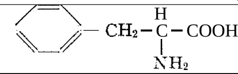
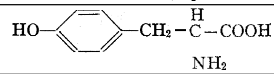
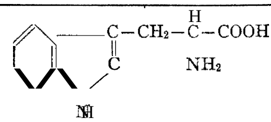
Proteins make up about 80% of the dry weight of muscle, 70% of the dry weight of skin and 90% of the dry weight of blood. The interior substance of plant cells is also composed largely of proteins.

Biological Function.—Some proteins, such as those of hair, wool. silk and bone. serve an obvious structural function for the organism that has made them. Other proteins, such as those of milk, eggs and seeds. are accumulated as storage depots of food for the young, growing organism. The proteins in the above two categories are extracellular. Another group of proteins present nithin the living cells participates very directly in the chemical processes essential for the existence of the cell. These proteins serve as specific catalysts, or enzymes (*q v*), bringing about and directing the chemical processes of metabolism. It is impossible to describe life processes at a molecular level without taking into consideration the functional role of the enzymes. There appears to be at least one kind of enzyme for each type of chemical reaction that occurs in a cell. Since there are a large number of such reactions, it follows that there are a large number of different enzymes.

The central role of proteins in biochemical processes was recognized by chemists in the early 19th century when they coined the name for these substances from the Greek word, *proteios,* meaning "holding first place."

Proteins in Nutrition.—Green plants and many microorganisms do not require protein food. For man and all animals, however, protein is an essential constituent of the diet. Without it, death is inevitable. Strictly speaking, it is not protein itself that is required, but the building blocks of protein, the amino acids (*see* below). A protein molecule is very large compared to molecules of sugar or salt, and consists of a large number of amino acids joined together to form long chains, much as beads are arranged on a string. In the digestive tract of the animal, enzymes act to degrade the protein of the food by breaking these long chains into shorter chains and free amino acids. The amino acids are absorbed across the walls of the intestinal tract and transported by

The Naturally Occurring Amino Acids

Name	Formula	Minimum daily nutritional requirement for average man
Glycine	$\mathrm{H\overset{H}{C}(NH_2)-COOH}$	None
Alanine	$\mathrm{CH_3\overset{H}{C}(NH_2)-COOH}$	None
Valine	$\mathrm{(CH_3)_2CH-\overset{H}{C}(NH_2)-COOH}$	0.8 g.
Leucine	$\mathrm{(CH_3)_2CH-CH_2-\overset{H}{C}(NH_2)-COOH}$	1.1 g.
Isoleucine	$\mathrm{(C_2H_5)(CH_3)CH-\overset{H}{C}(NH_2)-COOH}$	0.7 g.
Serine	$\mathrm{H\overset{H}{C}(OH)-\overset{H}{C}(NH_2)-COOH}$	None
Threonine	$\mathrm{CH_3-\overset{H}{C}(OH)-\overset{H}{C}(NH_2)-COOH}$	0.5 g.
Cysteine	$\mathrm{H\overset{H}{C}(SH)-\overset{H}{C}(NH_2)-COOH}$	None
Methionine	$\mathrm{H\overset{H}{C}(SCH_3)-CH_2-\overset{H}{C}(NH_2)-COOH}$	1.1 g.
Aspartic acid	$\mathrm{COOH-CH_2-\overset{H}{C}(NH_2)-COOH}$	None
Glutamic acid	$\mathrm{COOH-CH_2-CH_2-\overset{H}{C}(NH_2)-COOH}$	None
Lysine	$\mathrm{H\overset{H}{C}(NH_2)-CH_2-CH_2-CH_2-\overset{H}{C}(NH_2)-COOH}$	0.8 g.
Arginine	$\mathrm{NH_2-C(=NH)-N(H)-CH_2-CH_2-CH_2-\overset{H}{C}(NH_2)-COOH}$	None
Phenylalanine		1.1 g.
Tyrosine		None
Histidine	$\mathrm{HC{=}C-CH_2-\overset{H}{C}(NH_2)-COOH}$ (ring: N, NH, CH)	None
Tryptophan		0.25 g.
Proline	$\mathrm{CH_2-CH_2-CH_2-NH-CH-COOH}$ (ring)	None

the blood to the tissues. The cells then assemble their own proteins from these amino acid building blocks. Each species of animal or plant has a unique set of proteins different from those of other species. This difference is the reason that an animal cannot make direct use of the protein of a plant or of another species of animal, without first breaking that protein down to amino acids.

There are about 20 different amino acids that occur naturally in proteins (*see* Table). About half of these can be synthesized from other materials in the cells of the animal body. Eight of these amino acids cannot be synthesized by the human body, however. and must therefore be furnished in the diet (*see* Table). Normally, these essential amino acids are furnished in the form of protein food. The nutritional requirements of an animal for protein can actually be satisfied by feeding a mixture of essential amino acids. but since adequate amounts of such a mixture would be very expensive and not very palatable, there is little likelihood that man will substitute amino acids for good protein food such as meat, milk and eggs. It is striking that the proteins produced in nature for the nourishment of the young (for example, the milk proteins of mammals, the egg proteins of birds and the proteins laid down in seeds by plants) all provide adequate amounts of the essential amino acids. A diet that includes an inadequate supply of one or two essential amino acids, but is otherwise adequate, can be improved by adding the particular amino acids that are in short supply. It is also possible to feed an individual, who may for some reason be unable to ingest food. by intravenous injection of amino acids. The intact protein of ordinary foods cannot be used in this way.

Growth experiments have shown that all of the essential amino acids must be ingested simultaneously if they are to be utilized effectively. If the essential amino acids in the protein of the diet are balanced, then the minimum requirement of a man of average size is about 44 g of protein a day In 1943 the United Nations Conference on Food and Agriculture adopted certain dietary allowances that were regarded as the deiirable goal for all peoples of the world. These recommendations included the following average values for protein in grams per day: man, 70; woman. 60; woman in the latter half of pregnancy. 8;; woman in lactation, 100; girls 16 to 20 years, 75; and boys 16 to 20 years, 100. These goals are based on the assumption that an adequate number of calories and an adequate supply of vitamins are included in the diet. Authorities differ on these values. some setting the requirements appreciably higher.

Metabolism of Protein. — At first thought there may seem to be no reason why an adult should require protein in the diet, since an increase in the mass of body proteins occurs only during growth. Protein is continuously lost from the body, however. The proteins of dying cells, denatured protein and degradation products are broken down into amino acids by enzymes of the tissues. Some of these amino acids find their way back into new proteins. The remainder are degraded further, along with the amino acids that have been taken in the food and which are left over from protein synthesis. All of the amino acids contain nitrogen in the form of an amino group. This nitrogen is converted into urea by the liver, and the urea is excreted as a waste product in the urine. The normal adult excretes between 7 and 1j g. of nitrogen per day. The carbon compounds that remain after the removal of nitrogen are oxidized by the tissues into carbon dioxide and water. In this process the proteins may supply energy to the body. Normally, less than 20% of the energy requirements are supplied by the burning of protein. In the latter stages of starvation, however, large amounts of the tissue proteins are burned away.

The continuous breakdown and synthesis of new protein results in the renewal of all of the proteins in the body. Some tissue proteins are more susceptible to change than others. For example! the proteins of the liver. the blood plasma (but not the, red cells) and the lining of the intestine are broken down very rapidly, whereas the proteins of muscle, skin, brain and skeleton are broken down slowly. The average life of the hemoglobin in the red cells is about 120 days. but the serum albumin of the blood is renewed in a few neeks.

Proteins and **Immunity.**—When a protein of a different species is injected into the blood stream of man or an animal, an immunity to that protein may develop. Antibodies to the foreign protein appear in the blood stream. The antibody is itself a protein that has the ability to combine with the foreign protein eliciting its formation. If the foreign protein has toxic properties, these are thereby neutralized. By this mechanism the animal protects its body from invasion by bacteria. The bacterial proteins induce antibody formation that renders the bacteria harmless and incapable of invading the animal.

Industrial Use of Proteins.—Since animal tissues contain a much higher proportion of protein than plant tissues, most of the proteins of industrial importance are obtained from animal sources. Apart from the food proteins, the proteins which are utilized in the largest quantity are keratin found in wool and fibroin in silk of the textile industry (see WOOL; SILK AND SERICULTURE: *Physical* and *Chemical* Properties of **Silk;** SILK MANUFACTURE). and collagen in the processed hides of the leather industry (see LEATHER). Glues and sizes are prepared from the casein (*q.v.*) of milk. from the proteins of blood and from the crude gelatin of boiled bones (see GLUE). Bone protein, called ossein, is similar to collagen. The gelatin (*q.v.*) used in the food industry is obtained from scraps of hide, connective tissue and tendons. Waste proteins, including blood, horn, hooves, bones, etc., are used for plant fertilizer as a source of organic nitrogen.

The plant protein, zein, is a by-product of the starch industry. After starch has been extracted from corn (maize), the protein is separated from the residues by extraction with isopropyl alcohol, in which it is soluble. Zein has industrial uses similar to those of casein. Both proteins have been used to a limited extent in the manufacture of yarns. Seed proteins, such as those from the soya bean and the peanut have been converted into plastics. Wheat yields a protein, gluten, which is rich in glutamic acid and serves as a source for the condiment. monosodium glutamate. Another protein used in cookery is papain from the papaya plant. an enzyme which is applied to meat before cooking in order to make it more tender.

Properties of Proteins.—Proteins vary greatly in their properties. Some, such as the bright red hemoglobin of blood, contain pigments built into the molecule. Other proteins are colourless. Some proteins, such as hair, wool and silk, form long thin fibres completely insoluble in ordinary solvents. Others, for example the albumin of egg white. are very soluble in water but solidify on heating. Muscle cells contain fibres of protein that have the property of contracting and relaxing when the cell is stimulated. All proteins have the common property of being built from the same subunits, the amino acids, according to the same general plan. The amino acids are joined together by primary bonds, called peptide bonds, to form long chains. About 20 different kinds of amino acids are present in one protein molecule, but there may be a hundred or more amino acid subunits in the molecule. some of the amino acids recurring many times along the length of the chain. The sequence of amino acids along the chain is characteristic for each protein. It is clear that the number of possible arrangements of amino acids in the chain is very large, thus explaining why there are such an enormous number of different kinds of proteins.

Proteins, as they are found in nature, are characterized not only by the sequence of amino acids in their chains but also by the three-dimensional configuration of the chains themselves. Certain atomic groupings along the chains are able to form bonds with one another and to stick together. As a result, the chains are held in definite coiled or folded configurations. The properties and biological function of each protein depend upon the maintenance of a specific configuration. Larger aggregates are also formed. composed of several. or even a very large number, of molecules. held together more or less firmly. Since the structure of the native protein molecule is organized in a specific way. it follows from the geometry of these molecules that the structure of the aggregate is also organized into a pattern. Thus the structure of proteins is organized at three levels: (1) the sequence of the amino acids in the chains; (2) the folding of the chains into functional units; and (3) the combination of these units into larger patterns. It is this ability to form organized structures of great complexity and variety, inherent in the chemical nature of proteins, that is the basis for their function in living matter.

Differences in solubility are sometimes used for classifying proteins but as more is learned, this basis of classification loses its usefulness. Frequently the more soluble fraction of a mixture of proteins is called the albumin fraction, and the less soluble fraction is called the globulin fraction. Albumins are soluble in pure water, whereas true globulins are insoluble in water but are soluble in dilute salt solutions. Proteins insoluble in water or in salt solutions may dissolve in dilute acid or dilute alkali. High concentrations of a salt such as ammonium sulfate uill precipitate both albumins and globulins. The chemist makes use of these differences in solubility for the isolation and purification of individual proteins.

Molecular Size.—Many of the properties of proteins result from their large molecular size. They are very large compared with a molecule of water. which has a molecular weight of 18 times the neight of a hydrogen atom, or compared with a molecule of cane sugar, which has a molecular weight of 342. Though some proteins may have a molecular weight as small as 6,000. others have molecular weights greater than 100.000. Some aggregates of protein molecules, uniform in size and composition, are known to have particle weights greater than 1,000,000; *e.g.*, the virus proteins. Since protein molecules are very heavy, they can be caused to fall out of solution in a large centrifugal field. High speed centrifuges (ultracentrifuges) are used to determine the molecular weight of proteins by measuring how fast they will move to the bottom of a rotating vessel.

Compared with smaller molecules, proteins in solution diffuse very slowly from one place to another in the liquid. Those proteins with the shape of long, thin rods give viscous solutions. The large size of proteins prevents them from diffusing through natural membranes such as the walls of the blood vessels or through synthetic membranes such as cellophane. nhereas molecules as small as sugar diffuse freely. As a consequence, proteins are able to produce a permanent osmotic pressure across a membrane. That is, pressure is required to prevent water placed on one side of the membrane from penetrating into the protein solution placed on the other side of the membrane.

Denaturation.—Unlike most simple organic molecules, the physical and chemical properties of a protein are markedly altered when the substance is boiled in water. Similar changes are produced by the following reagents: dilute acid, dilute alkali, alcohol, detergents or concentrated solutions of urea The process by which these reagents alter the protein is called denaturation In general. denaturation results in lowered solubility of the protein in neutral solution. In some cases, a gel or coagulum is formed, as when egg white is heated. More significantly, denaturation usually results in the loss of the biological function of the protein. For example, enzymes lose their catalytic powers and hemoglobin loses its capacity to carry oxygen. The changes that accompany denaturation have been shonn to result from the destruction of the specific pattern in which the amino acid chains are folded in the native protein. All of the agents able to cause denaturation are able to break the secondary bonds that hold the chains in place. Once these neak bonds are broken. the molecule falls into a disorganized tangle. devoid of biological function

Conjugated Proteins.—Some proteins contain other chemical groups in addition to amino acids. Such proteins are called conjugated proteins If the nonprotein portion of the molecule is known to have a biological function. it is referred to as the prosthetic group. A large number of enzymes have prosthetic groups that participate in the catalytic activity. Some of these prosthetic groups are derived from vitamins (see VITAMINS; ENZYMES). If the prosthetic group is coloured, the conjugated protein which contains it will also be coloured. For example. hemoglobin, the main constituent of the red cells of blood, consists of the protein globin and a coloured substance called heme Four heme molecules, each of nhich contains one iron atom, are firmly attached to each globin molecule. In the lungs, an oxygen molecule is bound to each iron atom and is carried by the blood stream to the outlying tissues. Other proteins are known that contain metal atoms bound to the protein structure. The cerulo-plasmin of blood is a bright blue protein containing copper.

Proteins and Heredity.—The most important conjugated proteins are the nucleoproteins, which consist of proteins combined with nucleic acids (*q.v.*). Nucleoproteins are found not only in the nuclei of cells, but also in extranuclear particles. Chromosomes, viruses and the heads of sperm cells all consist largely of nucleoproteins. These substances serve the mechanism by which hereditary characteristics are transmitted from cell to cell, and are intimately involved in the processes of self-duplication which are basic to life.

Amino Acids.—Proteins may be broken down into their constituent amino acids by prolonged heating with acid, by heating with alkali, or by treatment with certain enzymes which cause a breaking of the bonds between the amino acids. Molecules of the natural amino acids have the common structure shown in the formula:

$$\mathrm{R-\overset{H}{\underset{NH_2}{C}}-COOH}$$

As indicated by the structure, the four covalent bonds of the *a*-carbon atom are linked to an amino group ($-NH_2$), a carboxylic acid group ($-COOH$), a hydrogen atom ($-H$), and a fourth atomic grouping which is called the side chain ($-R$). As with all organic compounds in which a carbon atom is linked to four different groups, there are two different ways in which the groups may be arranged around the central carbon atom. Only one of these arrangements is found in the amino acids isolated from proteins, and this arrangement is designated by the symbol L. Thus the subunits of proteins are described as L-α-amino acids. The amino acids obtained from proteins are distinguished by their different side chains. The table gives the names of the most important naturally occurring amino acids and their structural formulas, and indicates the importance in nutrition of each substance.

A few additional amino acids occur in proteins only rarely, and so are not listed in the table. An example is thyroxine, an iodine-containing amino acid occurring in the protein of the thyroid gland. One of the compounds listed in the table, proline, is strictly speaking an imino, rather than an amino acid. Aspartic and glutamic acids are frequently classified as acidic amino acids; histidine, lysine and arginine are classified as basic amino acids, and the remaining amino acids are described as neutral. In actual fact. since the carboxyl group is acidic, and the amino group is basic, all amino acids are both acids and bases, but the acidic and basic groups neutraiize each other, to give a molecule with the dipole structure shown:

$$\mathrm{R-\overset{H}{\underset{NH_3^+}{C}}-COO^-}$$

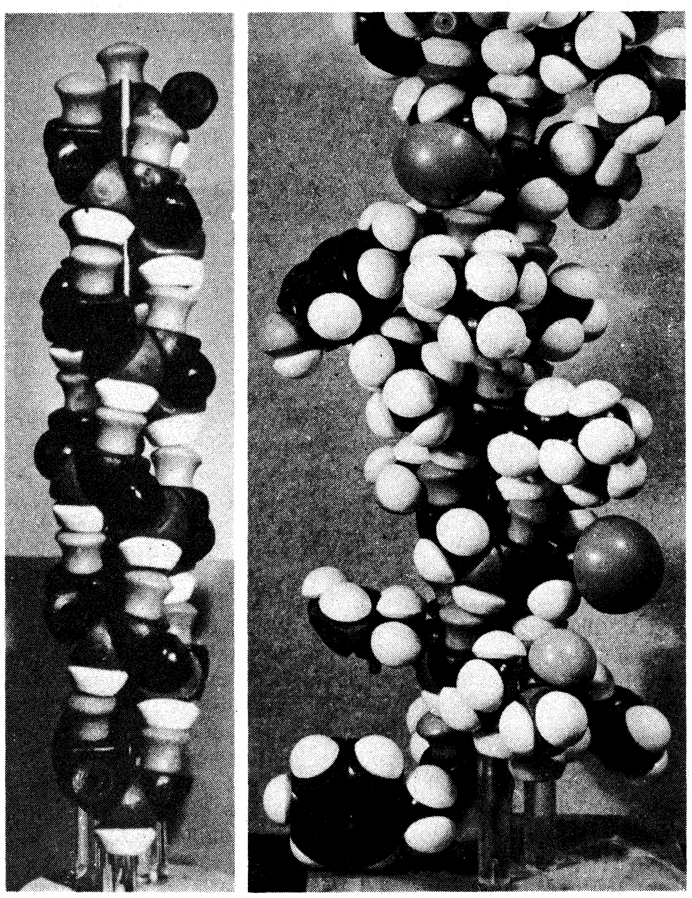
The **Peptide** Bond.—Two amino acids may be joined by condensation between the carboxylic acid group of one molecule and the amino group of the other molecule, with the splitting out of a molecule of water:

$$\underset{\text{alanine}}{\mathrm{H_2N.CH(CH_3).COOH}} + \underset{\text{serine}}{\mathrm{H_2N.CH(CH_2OH).COOH}} \xrightarrow[\text{yields}]{} \underset{\text{alanyl-serine}}{\mathrm{H_2N.CH(CH_3).CO.NH.CH(CH_2OH).COOH}} + \underset{\text{water}}{\mathrm{H_2O}}$$

The bond formed between the carbonyl group ($-CO-$) and the imino group ($-NH-$) is called a peptide bond. A dipeptide is a compound formed by the union of two amino acids through one peptide bond, such as aianyl-serine shown above. A tripeptide is formed from three amino acids joined by two peptide bonds. while a tetrapeptide is formed from four amino acids, etc. When many amino acids are linked into a chain by peptide bonds. the structure is called a polypeptide. Thus proteins may be described as molecules that are composed of polypeptide chains.

When a polypeptide chain is split into the component amino acids by the action of acid, or alkali, or certain enzymes (peptidases), the condensation reaction is reversed. A molecule of water is added to each peptide bond by a process called hydrolysis, and one carboxyi group and one amino group are reformed. If hydrolysis is not complete, the products may consist of di-, tri-, and higher peptides, besides free amino acids. The fact that proteins can be hydrolyzed to amino acids and peptides by the action of certain enzymes which are known to attack the peptide bonds of synthetic peptides provides convincing proof that the peptide bond is the principal means by which amino acids are linked in proteins. A number of simple peptides are found in nature. Among them are the pituitary hormone, oxytocin. and the tripeptide glutathione (*q.v.*). These peptides, and many others resembling them, have been synthesized in the chemical laboratory.

Structure of Protein.—If the structure of a protein is to be completely determined, one of the problems that must be solved is the sequence of the amino acids in the peptide chain. Methods whereby sequence can be determined are known, but the techniques are difficult and laborious. An event that marked a milestone in the advance of knowledge of proteins was the determination by Frederick Sanger (*q.v.*) in the early 1950s of the sequence of amino acids in the polypeptide chains of insulin. This



FROM "THE PROTEINS," EDITED BY HANS NEURATH AND KENNETH BAILEY. VOL. I, PART A, 1953, ACADEMIC PRESS, INC., PUBLISHERS: PHOTOGRAPHS BY BARBARA W. LOW

ATOMIC MODELS OF POLYPEPTIDE CHAIN (a-HELIX): (LEFT) THE CORE: (RIGHT) CORE WITH VARIOUS SIDE CHAINS ATTACHED

hormone. which counteracts diabetes, is composed of two different polypeptide chains, one 30 amino acids long and the other 21 amino acids long. Subsequent work by others resulted in the determination by the 1960s of the complete amino acid sequences of the enzyme ribonuclease and the protein subunit of the tobacco mosaic virus.

The polypeptide chains of native proteins are not free to take random configurations. They are fixed by cross-linkages between points on the same chain and between points on different chains. One type of cross-linkage is formed between the sulfur atoms of two molecules of the amino acid cysteine, giving a disulfide ($-S-S-$)bond. Another type of cross-linkage may be formed by phosphorus in the form of phosphoric acid, which may serve to link pairs of side chains.

Another type of bond prevalent in proteins is the so-called hydrogen bond formed between oxygen and nitrogen atoms. A hydrogen atom is found between the two atoms that form such a bond; *e.g.*, O—H---O and N—H---O. Although hydrogen bonds are weak compared with primary bonds, the presence of a large number of hydrogen bonds in proteins results in an accumulative effect that contributes significantly to the stability of particular structures. Investigations of proteins by means of X-rays have indicated that hydrogen bonds hold portions of the polypeptide chain in a helical (spiral) configuration. A model of the helical structure of a polypeptide chain is shown in the accompanying photograph. On the left, the side chains have been removed to show the hydrogen bonds between the carbonyl groups and the imino groups of the peptide linkages. On the right, the side chains are in place. The model demonstrates how the side chains of the different amino acids project out from a roughly cylindrical core within which the hydrogen bonds are buried. Many properties of proteins can be explained by this model.

Electrical Charge. — Although the amino acids have a dipole structure, the peptide bond is relatively uncharged. However, a protein generally contains amino acids with acidic side chains and also amino acids with basic side chains. These groups may carry electrical charges. In acidic solutions most proteins carry a positive electrical charge, while in alkaline solutions they carry a negative charge. An electrical process, called electrophoresis, is used by the chemist to analyze and separate mixtures of proteins according to the electrical charges of the molecules.

Synthesis **of Proteins.**—Polypeptide chains have been synthesized that are several hundred amino acids in length and that contain several different kinds of amino acids. Though the properties of these substances resemble the properties of proteins to a limited extent, they cannot be said to be protein in nature since the sequence of amino acids and the configuration of the chains are undetermined and random. The problem of how the living cell synthesizes protein had not been completely elucidated but by the early 1960s several laboratories had clearly achieved net synthesis of specific proteins in cell-free extracts containing enzymes, nucleic acids and subcellular particles. These events were expected to open the way for detailed analysis of this interesting and important process.

See BLOOD; NUTRITION; PEPSIN; PROTOPLASM; *see* also references under "Proteins" in the Index volume.

See M. V. Tracy, *Proteins and Life* (1948); H. Neurath and K. Bailey (eds.), *The Proteins*, vol. iA, iB (1953), iiA, iiB (1954). (B. V.)

PROTESILAUS. In Greek legend, Protesilaus was the commander of a Greek contingent from Thessaly who was the first to spring ashore on Trojan soil, although, according to the Latin author Gaius Iulius Hyginus, he knew it meant instant death. Catullus attributed Protesilaus' fate to his previous failure to make a sacrifice to the gods before building a house.

Protesilaus' wife Laodamia besought the gods below that he might be permitted to return to earth for the period of three hours. Her prayer was granted and on the expiration of the time allotted she returned with him to the nether world.

According to Hyginus, however, she made a waxen image of her husband, and a slave, having detected her in the act of embracing it and supposing it to be a lover, informed her father. He ordered her to burn the image, whereupon she threw herself with it into the flames. In another account by the Roman mythographer Conon, Protesilaus survived the fall of Troy and carried off Aethilla, the sister of Priam. During a halt on the peninsula of Pallene, Aethilla and other captive women set fire to the ships. Protesilaus, unable to continue his voyage, remained and built the city of Scione. His tomb and temple were near Eleus in the Thracian Chersonese.

Nymphs were said to have planted elm trees facing toward Troy, which withered away as soon as they had grown high enough to see the captured city.

Protesilaus was the subject of a tragedy by Euripides, of which some fragments remain, and William Wordsworth wrote a poem entitled *Laodamia*.

PROTESTANT, the generic name for an adherent of those churches which base their teaching on the principles of the Reformation.

The name is derived from the formal *Protestatio* handed in by the evangelical states of the empire, including some of the more important princes and imperial cities, against the *recess* of the diet of Spires (1529), which decreed that the religious *status quo* was to be preserved, that no innovations were to be introduced in those states which had not hitherto made them, and that the mass was everywhere to be tolerated.

The name Protestant seems to have been applied first to the protesting princes by their opponents, and it soon came to be used indiscriminately of all the adherents of the reformed religion. Its use appears to have spread more rapidly outside Germany than within Germany itself, one cause of its popularity being that it was negative and colourless, and could thus be applied by adherents of the "old religion" to those of the "new religion," without giving offense, on occasions when it was expedient to avoid abusive language.

As the designation of a church, "Protestant" was unknown during the Reformation period and for a long while after. In Germany the Reformers called themselves usually *evangelici,* and avoided special designations for their communities, which they conceived only as part of the true Catholic Church.

It was not until the period of the Thirty Years' War that the two main schools of the reformed or evangelical churches marked their definitive separation: the Calvinists describing themselves as the "Reformed Church," the Lutherans as the "Lutheran Church." In France, in England, in Holland the evangelicals continued to describe their churches as *ecclesiae reformatae,* without the *arrière pensée* which in Germany had confined the designation "Reformed" to the followers of a particular church order and doctrine.

As to the word "Protestant," it was never applied to the Church of England or to any other, save unofficially and in the wide sense above indicated, until the style "Protestant Episcopal Church" was assumed by the Anglican communion in the United States.

PROTESTANTENVEREIN is the name of a society in Germany the general object of which was to promote the union (*Verein*) and progress of the various established Protestant churches of the country in harmony with the advance of culture and on the basis of Christianity. It was founded at Frankfurt-on-the-Main in 1863 by a number of distinguished clergymen and laymen of liberal tendencies, representing the freer parties of the Lutheran and Reformed Churches of the various German states.

PROTESTANT EPISCOPAL CHURCH, THE, in the United States is spiritually the direct descendant of the Church of England, and is a part of the Anglican Communion. From the Church of England the Protestant Episcopal Church inherits its faith, its liturgy and its spiritual traditions, though it is entirely independent in its own life and government. The preface of the American Prayer Book, officially set forth in 1789, affirms the substantial identity and continuity of the two churches in the following words "This Church is far from intending to depart from the Church of England in any essential point of doctrine, discipline or worship; or further than local circumstances require." The Protestant Episcopal Church is therefore in full fellowship with the Anglican Communion, while at the same time it is wholly free and Independent in the ordering of its life and the fulfilment of its mission in the United States.

Although services were held in various parts of the country by the clergy who, as chaplains, accompanied groups engaged in exploration, the first permanent settlement of the church was at Jamestown, Va., in 1607. The church was legally established in Virginia from the start, and became established in Maryland after the Revolution of 1689. At the beginning of the American Revolution, it was established in all of the southern Colonies, and in five counties in New York. Trinity church, New York, was chartered by the crown in 1697. The Church of England obtained a foothold in Massachusetts in 1686, in Pennsylvania in 1695 and in Connecticut in 1706. By the end of the colonial period, it was represented in all of the Colonies, though its members were a small minority in some of them. Its growth during this period was fostered by the Society for the Propagation of the Gospel in Foreign Parts. Founded in 1701, through the efforts of the Rev. Thomas Bray, a missionary in Maryland, this body helped to support ministers and schoolmasters in communities where the local maintenance was inadequate. Through all this period, however, the church had no bishop in the American colonies. It was under the jurisdiction of the bishop of London, who naturally could do little for this far distant field. Without bishops, the Episcopal Church was in an anomalous position. Those desiring to be ordained to the ministry were compelled to make the long and perilous voyage to England. The people could not be brought to confirmation. Efforts to secure the consecration of bishops by the mother church in England were strongly opposed by the Nonconformist churches in the colonies, especially in New England.

Revolutionary Period.—The Revolution was a time of severe trial for the Church of England in the colonies. Many of the clergy felt called upon to give up their parishes and return to England, though others, especially in the south, remained at their posts and gave their support to the American cause. Of the laity a large majority was on the side of the Revolution, and many of them were among its most active leaders. Two-thirds of those whose names are signed to the Declaration of Independence were members of the Episcopal Church. William White, afterward the first bishop of Pennsylvania, was chaplain of the Continental congress. George Washington, himself a member of the church, went, accompanied by both houses of congress, to St. Paul's chapel. still standing on Broadway and Vesey street, New Tork city, for the religious service which completed the ceremonies of his inauguration as first president of the United States, and this service was conducted by Samuel Provoost, the first bishop of New York and rector of Trinity church.

At the close of the war, the church was left without bishops or a central organization. The first bishop was Samuel Seabury, elected by the clergy of Connecticut, who, impatient of delays in England, secured consecration from the nonjuring bishops of Scotland on Nov. 14, 1784. The development of a central organization resulted from a movement which centred in the middle states, under the leadership of the Rev. William White, rector of Christ church, Philadelphia, Pa. Stare conventions, including the clergy and representatives of the laity, were first formed, and these were united in a general convention which drew up a constitution, began a revision of the Prayer Book and secured the consecration of two bishops in England. William White of Pennsylvania and Samuel Provoost of New York. on Feb. 4, 1787.

The whole church was united in the General convention of 1789, when Bishop Seabury and delegates from New England joined the representatives from other states. This meeting revised the constitution to provide for a separate house of bishops in General convention, and completed the revision of the Prayer Book along more conservative lines than those originally proposed. Another bishop, James Madison of Virginia, was consecrated in England on Sept. 19, 1790. All four bishops united in the first consecration on American soil, that of Thomas John Claggett as bishop of Maryland in 1792.

The church was organized for its work, but the conditions which it faced were full of difficulties. As a result of the Revolutionary War there was much popular prejudice against any institution claiming connection with England, in the communities influenced by Puritanism there was strong opposition to the principles and teachings of the Episcopal Church and there were divisions within its own household. At the convention of 1811 only one of the six bishops attended: and there were few more clergy and laymen present. than in 1789.

Period of New **Vigour.**—With the coming of a new generation, the church found more vigorous leaders, whose zeal and devotion were exemplified in the careers of three men. John Henry Hobart, Alexander Viets Griswold and Richard Channing Moore, consecrated bishops respectively of New York, the eastern diocese and Virginia. In Virginia, Bishop Moore's powerful preaching and strong personality roused the church to new life. Bishop Griswold's diocese included an immense region comprising the collapsed diocese-of Massachusetts (which had already had two bishops, Edward Bass in 1797 and Samuel Parker in 1804), Maine, Rhode Island, New Hampshire and Vermont. His achievements were truly amazing; with only 16 clergy in all at the outset of his episcopate, he had the satisfaction of ending it with a five-fold increase in the number both of parishes and communicants, and with .the redivision of his cumbersome territory into five separate dioceses.

Bishops Griswold and Moore were Evangelicals. Bishop Hobart, who had brill ant success in building up the church in New York state and founded a number of important church institutions, was a high churchman who anticipated some of the positions of the Oxford movement. An awakening interest in theological education led to the foundation of General Theological seminary in New York in 1819, and of the Theological seminary in Virginia in 1824.

The church was now aroused to meet the new conditions and opportunities of its reconstituted life. The Domestic and Foreign Missionary society, founded in 1820, gave fresh impetus to the work of church extension. In 183j its membership was made co-extensive with the church. Philander Chase, the pioneer bishop of the west, did his great work in Ohio and founded Kenyon college, obtaining from churchmen in England funds for this undertaking; Jackson Kemper. the first officially designated missionary bishop, went further into the northwest where his arduous labours prepared the way for future dioceses; James Harvey Otey did noble missionary work in Tennessee and the southwest. James Lloyd Breck. priest and missionary, founded Nashotah hall, originally an associate mission. but later a theological seminary, in Wisconsin; he also started schools in Minnesota, at Faribault, and pushed on across the country. establishing new foundations as he went, until he reached the Pacific coast. During this period the Episcopal Church grew steadily from a proportion of 1 communicant to 400 of the population in 1830 to 1 communicant to 107 at the end of the century. With the growth and development of the country new dioceses and missionary districts were established. In 18j3 Bishop William I. Kip began his labours as first bishop of California; in 1854 bishops were consecrated for Oregon and Iowa; in 1859 Bishop Henry B. Whipple was sent to Minnesota to take up his work among white people and Indians. Foreign missionary work was begun with the opening of an educational mission in Greece in 1829, and expanded with the founding of missions in Liberia in 1835, China in 1840 and Japan in 1859.

The Oxford movement. whose influence began to be felt in the United States during the 1840s, though destined to enrich and broaden the life of the church, excited a bitter controversy which was interrupted but not ended by the Civil War. The hluhlenberg memorial, presented to the house of bishops in 1853, made an impassioned plea to the church to rise above partisanship and realize the full possibilities of its position. Its proposals were too daring for the time, but many of them were later adopted in modified forms. The spirit of controversy reached its peak at the General convention of 1874, but gradually subsided thereafter, through a growing realization that the church's nature was essentially comprehensive and that its Catholic and Protestant traditions could both make important contributions to its mission. The rise of the liberal movement aided in the growth of this realization.

Civil War and After.—The Civil War necessarily led to a separate administration of the church in the confederate states, but the whole body was quickly reunited at the close of the conflict. The war period saw the formation of two new seminaries, the Philadelphia Divinity school and the Episcopal Theological school at Cambridge, Mass. During the years following, the church-controlled University of the South was organized at Sewanee, Tenn.

After the period of the Civil War, the church made progress, its growth more than keeping pace with the increase in population. Its organization came to cover every part of the United States and its dependencies, and it continued to expand its missionary work in other lands, with bishops and organized missionary work in Alaska, Puerto Rico, the Panama Canal Zone, the Hawaiian Islands, the Republic of the Philippines, Cuba, Mexico, Brazil, China, Japan, Liberia, Haiti and the Dominican Republic. In 1867 and thereafter, bishops of the Episcopal Church participated periodically in conferences of the entire Anglican episcopate held at Lambeth, Eng.

Among the educational institutions of the church in the latter 1950s were Trinity college, Hartford, Conn.; the University of the South, Sewanee. Tenn.; Hobart college. Geneva. N.Y.; Kenyon college, Gambier, O.; St. Augustine's college, Raleigh, N.C.; and St. Paul's Polytechnic institute, Lawrenceville, Va. The theological schools, in addition to the General Theological seminary in New York (official institution of the whole church) and the Virginia seminary previously mentioned, were the Berkeley Divinity school, New Haven. Conn.; the Divinity school, Philadelphia; the Episcopal Theological school. Cambridge, Mass.; Nashotah house. Nashotah. Wis.; the Theological school. Sewanee. Tenn.: the Seabury-Western Theological seminary. Evanston, Ill.; the Church Divinity School of the Pacific. San Francisco, Calif.; The Episcopal Theological Seminary of the Southwest. Austin. Tex.; Bexley hall, Gambier. O. The church also had established! especially in the east; many important schools for boys and girls.

Church Development. — The life of the church continued to find expression in a great number of societies and organizations, such as the Women's auxiliary to the National council; the Brotherhood of St. Andrew; the Girls' Friendly society; the Church Association for Seamen's Work; the Social Service commissions; the church clubs of the various dioceses; the Episcopal Service for Youth; the American Church union; and the Church congress in the United States. Among the religious orders in the latter 1950s were the Society of Mission Priests of St. John the Evangelist; the Order of the Holy Cross; St. Barnabas brotherhood; the Community of St. Mary; the Community of St. John the Baptist: the Society of St. Margaret; the All Saints Sisters of the Poor; the Sisterhood of the Holy Nativity; and others. The institutions for the training of deaconesses included the New York Training School for Deaconesses; and the Central House of Deaconesses, Sycamore, Ill. St. Margaret's house, Berkeley, Calif., and Windham house, New York city, provided training for women church workers.

The governing body of the Protestant Episcopal Church is the General convention which meets every three years, and which consists of the house of bishops and the house of deputies, the two houses sitting and deliberating separately. The house of bishops has as its members all the bishops of the church. The house of deputies is composed of not more than four presbyters and four laymen elected by each diocese and not more than one presbyter and one layman elected by each missionary district. Either house may originate and propose legislation, and all acts of the convention must be adopted and authenticated by both houses. In the house of deputies the vote on any question may be taken by orders, the clerical and lay deputies voting separately and a concurrent vote of the two orders being required for the adoption of the resolution. The laity thus have their full share and responsibility in the legislative action of the church. No alteration in the Book of Common Prayer may be made unless this is proposed at one meeting of the General convention and adopted at the next succeeding triennial meeting. Each diocese holds its own annual convention, presided over by the bishop, in which both clergy and laity have their part. The diocese adopts its own constitution and canons for the regulation of its internal affairs, with the provision that these must not conflict with the constitution and canons of the General convention. A bishop is elected by the diocese, but the election must be confirmed by a majority of the bishops exercising jurisdiction within the United States, and by a majority of the standing committees of all the dioceses. Missionary bishops are elected by the house of bishops, the choice being subject to confirmation by the house of deputies if the General convention is in session. and at other times by a majority of the standing committees of the several dioceses. As regards the ministry, the Episcopal Church, in common with the Anglican Communion, holds to the historic threefold order of bishops, priests and deacons. The official pronouncements on this subject are contained in the Preface to the Ordinal. The constitution of the church (article viii) provides that no person shall be consecrated bishop, or ordained priest or deacon, until he shall have made in writing, in presence of the ordaining bishop or bishops, the following declaration: "I do believe the Holy Scriptures of the Old and New Testaments to be the Word of God and to contain all things necessary to salvation; and I do solemnly engage to conform to the Doctrine, Discipline, and Worship of the Protestant Episcopal Church in the United States of America." And every person before being baptized and received into membership in the church is required to answer affirmatively the question "Dost thou believe all the articles of the Christian Faith as contained in the Apostles' Creed?" Neither the clergy nor the laity are required to subscribe to the Thirty-Nine Articles.

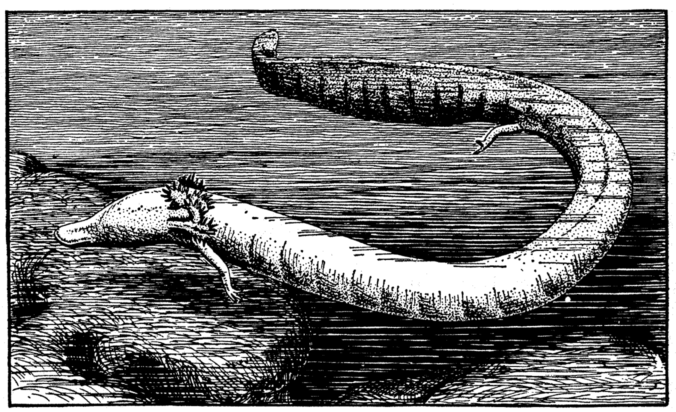
Church Activities. — An important change in the organization of the church was made in 1919 by the establishment of a national council. with the presiding bishop at its head, to act as the executive body of the General convention between its sessions, and to have charge of the general missionary, social and educational work of the church; with the provision that, for the future, the presiding bishop should be elected instead of succeeding to this office by seniority of consecration. The national council gave new impetus to the work of the church and strengthened its corporate life. The revision of the Book of Common Prayer, undertaken in 1913, was completed in 1928.

At the General convention in 1910 a movement was initiated to bring about a world conference on faith and order. After 17 years of preparation and effort, the conference was held in 1927 at Lausanne, Switz., and was attended by representatives of all the major churches of Christendom with the exception of the Roman Catholic Church. Similar conferences were held in Oxford in 1937 and in Amsterdam, Neth., in 1947. The Episcopal Church joined the Federal Council of the Churches of Christ in America (later the rational Council of Christian Churches) in 1940. Missionary work in Asia was disrupted by World War II. It was renewed with fresh vigour afterward though it was soon confronted with new problems resulting from the rise of Communism in China and the general resistance of the eastern world to western institutions. In the latter 1950s there were 102 dioceses and missionary districts, about 1,923,000 communicants and 7,900 members of the clergy.

BIBLIOGRAPHY.—See W. S. Perry, *Historical Collections Relating to the Episcopal Colonial Church* (1870), *History of the American Episcopal Church* (1885); Bishop William White, *Memoirs of the Protestant Episcopal Church* (1880); W. W. Manross, *History of the American Episcopal Church* (Milwaukee. Wis., 1935); E. C. Chorley, *Men and Movements in the American Episcopal Church* (New York, London, 1946). *See* also references under ENGLAND, THE CHURCH OF.

(W. T. M.; W. W. Ms.)

PROTEUS or OLM, a blind, water-breathing, tailed amphibian (*Proteus anguinus*) inhabiting the limestone caves to the east of the Adriatic. It is a small eel-like salamander, with minute limbs, the anterior pair having three toes on each, the posterior



CAVE SALAMANDER OF EUROPE CALLED THE "OLM" (AFTER BREHM) two; a narrow head, with flat truncate snout; minute vestigial eyes hidden under the skin which is pale flesh-coloured. with the short, plumelike external gills blood-red. Proteus forms with the American *Necturus* the family Proteidae. The second genus is more generalized in structure, with better developed limbs, with four digits, and is adapted to live in the light. Its thyroid gland is very much reduced, but, unlike the axolotl it cannot be transformed into a terrestrial form by feeding with thyroid. Exposure to white light causes the skin to become black, even over the eyes; however. in red light, no blackening occurs, and the eyes grow large and functional. See also SALAMANDER.

See H Gadow, Amphibia and *Reptiles* (Cambridge Natural *Hist.*)

PROTEUS, the prophetic old man of the sea in Greek mythology and shepherd of the sea's flocks (seals, etc.). According to Homer, his dwelling place was the island of Pharos, near the mouth of the Nile; in Virgil his home is the island of Carpathus, between Crete and Rhodes. He knew all things, past, present and future, but disliked telling uhat he knew Those who wished to consult him had first to surprise and bind him during his noonday slumber in a cave by the sea, where he spent his time during the heat of the day surrounded by his seals. Even when caught he would try to escape by assuming all sorts of shapes, that of a lion, a serpent, a leopard, a boar, a tree, fire. water. But if his captor held him fast the god at last returned to his proper shape, gave the wished-for answer and plunged into the sea. He was subject to Poseidon. In post-Homeric times the story (invented by the Greek lyric poet Stesichorus?) ran that Proteus was the son of Poseidon and a king of Egypt, to whose court Helen was taken by Hermes after she had been carried off, Paris being accompanied to Troy by a phantom substituted for her. This is the story followed by Herodotus, who got it from Egyptian priests, and by Euripides in the Helena. From his power of assuming whatever shape he pleased, Proteus came to be regarded, especially by the Orphic mystics, as a symbol of the original matter from which the world was created.

PROTHESIS, in the liturgy of the Orthodox Eastern Church, the name given to the act of "setting forth" the oblation; *i.e.,* the arranging of the bread on the paten, the signing of the cross on the bread with the sacred spear, the mixing of the chalice and the veiling of the paten and chalice (Gr. prothesis, "a setting forth"). In Eastern Orthodoxy the more common term for the preparation of these elements is "proskomide." The term is used, architecturally, for the place in which this ceremony is enacted, a chamber on the north side of the central apse in a Greek church; the term is also applied to the small table on which it is done.

During the reign of Justin II (565–574) this chamber was located in an apse and another apse was added on the south side for the diaconicon, so that from his time the Greek church was triapsal. In the churches in central Syria both prothesis and diaconia are generally rectangular, and the former constitutes a chamber for the deposit of offerings by the faithful. Consequently it was sometimes placed on the south side, if when so placed it was more accessible to the pilgrims. There is always a much wider doorway to the prothesis than to the diaconicon. There are cases where a side doorway from the central apse leads direct to the diaconicon, but never to the prothesis.

PROTIĆ, STOJAN (1857–1923), Yugoslav statesman, was born at Krusšvak Jan. 29, 1857. He entered the government service and soon came into conflict with the repressive régime of King Milan. In 1882 Protić became editor of Samouprava and a leader of the new Radical party. He was imprisoned for a press offense in 1883 and again in 1885. He held subordinate posts in the Radical cabinet of 1887. In 1899 an attempt on King Milan's life mas used by the government to rid itself of its Radical rivals. Protić was sentenced to 20 years' hard labour, although, in fact, he had no connection with the crime. Pardoned nine months later. he became director of the National library. After the revolution of 1903 he represented the Radicals in the first provisional cabinet under King Peter and remained minister of the interior in most of the succeeding cabinets down to 1907.

Protić was finance minister during the Bosnian crisis and again became minister of the interior during the period of the Balkan Wars and the European crisis of 1914. In 1914, when leaders of the secret "Black Hand" organization were implicated in the murder of Serajevo, this organization was actually at daggers drawn with the Serbian government owing to a quarrel with Protić.

Protić remained out of office during the period of coalition government from Dec. 1914 to June 1917, but continued to exercise great influence in the background. He was returned to officein 1917 and played an active part in the negotiations leading to the Corfu agreement between the Serbian government and the Yugoslav committee.

He showed more comprehension for the Croat and Slovene standpoint than his colleague Pašić, and when the conflict between Pašić and Trumbić in 1918 delayed the recognition of Yugoslavia by the Allies and created an awkward situation with Italy, Protić was appointed the first premier of the new Yugoslav state. He was keenly interested in the constitutional problem, and after his resignation in Aug. 1919 published his own draft project.

Disagreeing with the exaggerated centralism of Pašić, he declined office in 1921 and drifted steadily away from his old colleague.

Protić died in Belgrade in Nov. 1923.

His publications include The Aspirations of Bulgaria (1916) and Le *problème Albanais,* etc. (1913), issued under the pseudonym of "Balkanicus."

PROTISTA: see PROTOZOA.

PROTOCOL, in diplomacy, the name given to a variety of written instruments.

In diplomacy the name of "protocol" is given to the minutes (*procès-verbaux*) of the several sittings of a conference or congress; these, though signed by the plenipotentiaries present, have only the force of verbal engagements (see CONFERENCE, INTERNATIONAL). It is also given to certain diplomatic instruments in which, without the form of a treaty or convention being adopted, are recorded the principles or the matters of detail on which an agreement has been reached, *e.g.,* making special arrangements for carrying out the objects of previous treaties, defining these objects more clearly, interpreting the exact sense of a doubtful clause in a treaty (protocoles *interpretatifs*) and the like.

Occasionally also an agreement between two or more powers takes the form of a protocol, rather than a treaty, when the intention is to proclaim a community of views or aims without binding them to eventual common action in support of those views or aims.

Finally, "the protocol" (protocole diplomatique, protocole de chancellerie) is the body of ceremonial rules to be observed in all written or personal official intercourse between the heads of different states or their ministers. It lays down the styles and titles of states, their heads and public ministers. and indicates the forms and customary courtesies to be observed in all international acts. "It is," says M. Pradier-Fodéré, "the code of international politeness."

PROTOGENES, a Greek painter, born in Caunus, on the coast of Caria, but resident in Rhodes during the latter half of the 4th century B.C. He was celebrated for the minute and laborious finish which he bestowed on his pictures, both in drawing and in colour. Apelles, his great rival, standing amazed in the presence of one of these works, could only console himself by saying that it was wanting in charm. On one picture, the "Ialysus," Protogenes spent seven years; on another, the "Satyr," he worked continuously during the siege of Rhodes by Demetrius Poliorcetes (305–304 B.C.). notwithstanding that the garden in which he painted was in the middle of the enemy's camp. Demetrius, unsolicited, took measures for his safety; more than that, when told that the "Ialysus" just mentioned was in a part of the town exposed to assault. Demetrius changed his plan of operations. Ialysus was a local hero, the founder of the town of the same name in the island of Rhodes, and he was probably represented as a huntsman. This picture was still in Rhodes in the time of Cicero, but was afterwards removed to Rome', where it perished in the burning of the Temple of Peace.

The picture painted during the siege of Rhodes consisted of a satyr leaning idly against a pillar on which was a figure of a partridge, so lifelike that ordinary spectators saw nothing but it. Enraged on this account, the painter wiped out the partridge. The "Satyr" must have been one of his last works. He would then be about 70 years of age, and had enjoyed for about 20 years a reputation next only to that of Apelles, his friend and benefactor. Both were finished colourists so far as the fresco painting of their day permitted, and both were laborious in the practice of drawing, doubtless with the view to obtaining bold effects of perspective as well as fineness of outline. It was an illustration of this practice when Apelles, finding in the house of Protogenes a large panel ready prepared for a picture, drew upon it with a brush a very fine line which he said would tell sufficiently who had called. Protogenes on his return home took a brush with a different colour and drew a still finer line along that of Apelles, dividing it in two. Apelles called again, and thus challenged. drew with a third colour another line within that of Protogenes, who then admitted himself surpassed. This panel was seen by Pliny in Rome, where it was much admired, and where it was destroyed by fire.

In the Propylaea at Athens was a painting by Protogenes representing personifications of the coast of Attica, Paralus and Hammonias. For the council chamber at Athens he painted figures of the Thesmothetae, but in what form or character is not known. Probably these works were executed in Athens, and it may have been then that he met Aristotle, who recommended him to take for subjects the deeds of Alexander the Great. In his "Alexander and Pan" he may have followed that advice in the idealizing spirit to which he was accustomed. To this spirit must be traced also his "Cydippe" and "Tlepolemus," legendary personages of Rhodes. Among his portraits are mentioned those of the mother of Aristotle, Philiscus, the tragic poet, and King Antigonus. Protogenes was also a sculptor to some extent, and made several bronze statues of athletes, armed figures, huntsmen and persons in the act of offering sacrifices.

PROTON, a particle which is the nucleus of the hydrogen atom and a constituent of the nuclei of other atoms. It carries a positive electric charge.

Historical Background. — Lord Rutherford, in the course of experiments performed in 1919 during which he bombarded atoms of the lighter gases with alpha particles, found that the atoms disintegrated under the impact, liberating particles that he believed to be hydrogen nuclei. At the Cardiff meeting of the British Association for the Advancement of Science (1920), Rutherford suggested the name proton — Greek for "the first" — for the nucleus of the hydrogen atom, to denote that it is a primary substance. In the same year, in the Bakerian lecture at the Royal society. he offered the speculation that there might exist yet another particle, this one electrically neutral. This hypothetical particle — the neutron — was brought from the realm of speculation to reality in 1932 by a succession of discoveries by W. Bothe, Frédéric Joliot-Curie and Sir James Chadwick, who made the decisive experiments. The nuclei of all atoms except hydrogen contain neutrons as well as protons. In the case of hydrogen, the atom consists of a single proton as the nucleus, plus a single electron.

Characteristics. — The main properties of the proton are its electric charge. mass, spin, magnetic moment and statistics. The charge, e, is identical in magnitude to the charge of the electron, 4.8029×10^{-10} esu (electrostatic units), but of opposite sign; and the mass of the proton is 1.007596 esu, or 1.6729×10^{-24}g. This is 1,836.2 times as large as the mass of the electron. It is thus apparent that almost the entire mass of an atom is concentrated in the nucleus. The equality in magnitude of the charge of the proton and of the electron is shown by the fact that hydrogen atoms are neutral; hence, in order to know the charge e it makes no difference whether one measures the charge of the proton or of the electron. The latter is perhaps technically easier to measure. The mass of the proton may be determined by mass spectrograph experiments involving the deflection of a beam of protons of known velocity in a known magnetic field. In this way one obtains a measurement of the momentum mv of the proton which, once the velocity v is separately measured, gives the mass *m*.

In addition to charge and mass, the proton has an intrinsic angular momentum or spin of magnitude $\frac{1}{2}h/2\pi$ where h = 6.6252×10^{-27} erg-sec. (Planck constant). If we visualize a proton as a little sphere of matter, the spin tells us that the proton is rotating around an axis in a way similar to the rotation of the earth around the polar axis. The proton spin is revealed by a detailed study of the hydrogen atom spectrum and by many other phenomena. Connected with the spin there is a magnetic moment $\mu_p = 1.4104 \times 10^{-27}$ erg per gauss. In terms of the natural unit $he/4\pi m_p c$ (where m, is the mass of the proton and c the velocity of light), this moment has the value 2.7928. This means on our model that the small rotating sphere also has north and south magnetic poles similar to those of the earth. The magnetic moment of the proton, and its spin, can be measured spectroscopically or, with extreme precision, by magnetic methods involving the currents induced by the nuclear magnetic moments of the protons moving in a constant magnetic field. The size of the proton (or its radius, if we consider it as a sphere) is not precisely defined because its value depends on what phenomenon or method we use to measure it. For instance, we can use the exploration of the electric charge density by observing the deviation of high energy (600 Mev) electrons projected on a proton; we thus obtain a radius of 1.2×10^{-13} cm. Similar values are obtained by considering the neutron-proton collision at high energy in which only specific nuclear forces are operative.

In addition to the properties mentioned above, the proton has a very important characteristic which is expressible only in terms of quantum mechanics: it obeys Pauli's exclusion principle. This can be expressed by saying that in a system there cannot be two or more protons with the same quantum numbers, or that the wave function of a system containing several protons must be symmetrical with respect to the exchange of any two protons. This property has far reaching consequences in nuclear structures and is one of the most fundamental ones shared by proton, neutron, electron and other particles having spin $\frac{1}{2}\, h/2\pi$. A nucleus of mass number A having a positive electric charge Ze contains Z protons and has a number of neutrons N given by the number $A -$ Z. A is the integer closest to the number expressing the nuclear mass M in units equal to the 16th part of the mass of the oxygen nucleus, O^{16}.

The Proton in Theoretical and Applied Science. — The proton appears in many different aspects in a variety of chemical and physical phenomena. For example. as the hydrogen ion, it plays a very important role in chemistry, especially in all aqueous solutions (see HYDROGEN IONS). In spectroscopy it is the centre around which the electron revolves in the hydrogen atom, giving rise to the hydrogen spectrum, one of the most important subjects in atomic physics. In nuclear physics the proton is commonly used as a projectile to bombard other nuclei in modern particle accelerators such as the cyclotron or the bevatron.

In nuclear bombardments at relatively low energies, up to a few million electron volts, the general behaviour of the proton is to enter the nucleus, if it has enough energy to overcome the electrostatic repulsion of the target nucleus. Having entered the target nucleus it produces enough excitation to evaporate other particles from it. For instance if it evaporates one neutron, the target nucleus does not change its mass number, but is transformed into an element with the atomic number (Z) one unit larger.

At very high energies the proton gives rise to a host of more complicated effects connected with the structure of the nucleons (neutrons and protons are called nucleons). It is by proton bombardments that mesons, hyperons and antinucleons are most frequently produced in the large accelerators.

It is a matter of great importance that the number of protons plus the number of neutrons is conserved in all nuclear reactions. This principle of the conservation of the nucleons is at present to be considered as an empirical fact still disconnected from the other fundamental principles of physics.

P. A. M. Dirac of England pointed out in 1928 that the phenomena of nature exhibit a special kind of symmetry between the positive and negative electric charge. On this basis he predicted the possible existence of the positive electron (positron), later discovered in 1932 by C. D. Anderson. Dirac's theory predicted also the possible existence of a negatively charged proton (antiproton) mhich was discovered in 19jj by Owen Chamberlain, Emilio Segrè, Clyde Wiegand and Thomas Ypsilantis. The theory predicted the following properties for this particle: (1) it has the same mass as the proton; (2) it has equal but opposite electric charge; (3) it has the same spin as the proton; (4) it has a magnetic moment opposite to that of proton; (5) it is stable in the sense that when isolated in a vacuum it does not transform spontaneously into other particles; (6) antiprotons and nucleons annihilate each other in pairs; (7) antiprotons and protons are generated in pairs.

Property (4) means that a proton and an antiproton having their spin equally oriented have opposite magnetic moments, or that if the two small rotating spheres representing them rotate in the same way, their magnetic north and south poles are interchanged.

Properties (6) and (7) are not in contradiction with the principle of conservation of nucleons. On the contrary, if we consider an antiproton as "minus one proton," the condition that generation and annihilation occur only in pairs becomes a direct consequence of the conservation of nucleons. The fact that one antiproton and one proton must be generated together determines a high energy threshold for this process. Thus, for instance, the production by proton-proton collision can occur only at a projectile energy higher than 5.6×10^9 ev (electron volts) in the laboratory system; hence, huge accelerating machines are necessary. Antineutrons are characterized by a set of properties which bear a relation to those of the neutron similar to those listed above for the antiproton in relation to the proton. In particular properties 1, 2, 4, 6, 7 are the same provided the word neutron is substituted for proton and antineutron for antiproton. Neutron and antineutron are both electrically neutral and both spontaneously undergo a beta decay the neutron emitting electrons, the antineutron positrons.

Antineutrons have been generated from antiprotons by causing the antiproton to collide with a proton. In this process most frequently the proton and antiproton annihilate each other, generating pi mesons, but in about 1% of the cases they disappear, generating a neutron-antineutron pair. The antineutron is best detected in the subsequent annihilation process with a nucleon.

The symmetry between positive and negative electricity manifested by the electron and positron, and nucleon and antinucleon, opens the possibility of the existence of "antimatter." This would be formed by atoms in which every nucleon is replaced by the corresponding antinucleon and every electron by a positron. In many ways this antimatter would be indistinguishable from ordinary matter. For example, no ordinary astronomical observation including the study of the spectra and of the Zeeman effect, could distinguish between matter and antimatter in a star. However, a collision of matter and antimatter would result in annihilation with the immediate production of pi mesons which would in turn decay, leaving as their ultimate residue gamma rays, neutrinos and, if the system is not initially electrically neutral, electrons.

As of the late 1950s there was no experimental evidence in favour of or against the existence of antimatter in the cosmos. From a cosmic point of view the existence of antimatter would allow the creation of the universe from energy without the violation of the principle of the conservation of nucleons.

See also ACCELERATORS (PARTICLE); ATOM; ELECTRON; NEUTRON; PARTICLES, ELEMENTARY.

BIBLIOGRAPHY.—E. Segrè (ed.), *Experimental Nuclear Physics* (1951–59); H. Bethe, P. Morrison, *Elementary Nuclear Theory*, 2nd ed. (1956); M. Born, *Atomic Physics*, 6th ed. (1957). (EO. S.)

PROTOPHYTA. The designation Protophyta ("primitive plants") is applied to all simple one- or many-celled organisms that obtain their carbohydrates by means of photosynthesis. The Protophyta are not a natural division of the plant kingdom since they include organisms from various divisions of an algal nature.

There is diversity of opinion concerning what should be considered a "primitive plant." Many restrict them to those algae in which the vegetative cells are flagellated and motile. According to such an interpretation the Protophyta would include the motile members of the Chlorophyta, Chrysophyta and Pyrrophyta (see ALGAE). (G. M. S.)

PROTOPLASM is the actual living substance of the cells of animals and plants. It is a highly organized system endowed with properties, the sum total of which is life. The term was introduced long after the discovery of the microscope and not until investigators began to be aware of a visible substance enclosed within what had been known as cells of plants and animals. It was probably first coined in 1839 by Johannes Evangelista Purkinje (1787–1869) of Prague, who adopted it from Protoplastus, a liturgical term having reference to Adam. Shortly thereafter Hugo von Mohl (1805–72), a German botanist, applied the same term, as meaning "first plasma," to the slimelike, granule-filled material which he observed undergoing circulatory movements within plant cells. In 1835 Felix Dujardin (1801–60), a French protozoologist, had introduced the term sarcode for the material he saw in protozoa which had been called a living jelly. He described it as "a substance, viscid, translucent, homogeneous, elastic and contractile." In 1861 Max Schulze (1825–74) called attention to the similarity of the protoplasm of plants and animals and of the sarcode of protozoa and proposed the term protoplasm for the physical basis of all life. Thus, the unification of biological science was begun by the recognition of the cell and of its protoplasm as the physical basis of all living beings.

The multifarious activities of protoplasm within the dimensions of a living cell require a complexity of constitution and structure. The earlier investigators sought for this in the fibrils (Walter Flemming, 1843–1905), granules (Richard Altmann, 1852–1901) and alveoles (Otto Biitschli. 1843–1920) familiar to the cytologist (see CYTOLOGY). William B. Hardy (1864–1933) emphasized the colloidal state as being essential for the manifestations of life (see COLLOID).

According to the present concept, protoplasm possesses an ultramicroscopic, labile system of structural proteins offering large internal surfaces for the promotion of heterogeneous catalyses, the interstices of the system being filled with a liquid. This interstitial liquid is generally regarded as aqueous, and the protein fabric as capable of imbibing water.

The characteristic properties of protoplasm are irritability, motility, metabolism, growth and reproduction. Adaptability must also be included to account for the evolutionary changes. The ovum, from which an organism springs, possesses potentialities for changes. but these changes ordinarily lie within the limits of the organization of a particular species. Occasionally mutations occur spontaneously and have even been induced experimentally. The surprising feature is that, with the complexity of the protoplasmic constitution and the variety of environmental conditions, there should be such an extraordinary stability of protoplasm as we find it in nature.

The properties of protoplasm which are most readily observable through a microscope are motility, irritability, reproduction and growth. Motility is expressed in two types of motion, the amoeboid locomotion of entire cells and the currents of flow within the protoplasm of a cell. Both vary greatly in rate. It is of interest to note that the apparent inertia of most plants and the constant activity of animals are in striking contrast to what is observed within their cells. The protoplasm of most plant cells generally exhibits a marked streaming which is barely perceptible in most animal cells. The property of irritability may be easily observed by the cessation or, conversely, the acceleration of protoplasmic flow when mechanical or electrical stimuli are applied. The phenomena of reproduction and growth can be observed readily in young root hairs, in yeast and in cells of tissue culture by the cleavage of parent into daughter cells and the increase in size of the latter. (See ANIMAL CELL [TISSUE] CULTURE; PLANT CELL [TISSUE] CULTURE.)

The three most prominent constituents of the protoplasmic unit of a cell are the nucleus. the cytoplasm and the protoplasmic surface film. This surface film, called plasma membrane by Wilhelm Pfeffer (1845–1920) who first recognized its existence, maintains the integrity of the protoplasmic unit. If. in the normal, aqueous medium of cells, it is torn and does not repair itself quickly. the protoplasm undergoes progressive disintegration or cytolysis. The nucleus is usually a spheroidal body first described in plant cells by Robert Brown (1773–1858). It contains specific nuclear structures, chromosomes and the so-called nucleoplasm. The cytoplasm constitutes the remainder of the protoplasmic unit and usually contains granules and vacuoles of various sizes, mitochondria, etc.

The discovery of the virus, which is beyond the visibility of the light microscope, has posed a question as to the size limits of a viable unit of structure. Some viruses, *e.g.*, the tobacco mosaic virus, are regarded as consisting of no more than one or a few thousand molecules of nucleoprotein. This is much smaller than the structural elements or particles generally seen in protoplasm. Structural elements of protoplasm may have a higher degree of autonomy than is generally assumed, and their survival, when removed from protoplasm. may become possible when a medium is found mhich is compatible with their environment. There is no evidence of spontaneous generation, but a beginning must be inferred. There must have been a time when existing conditions brought about syntheses of compounds containing asymmetric carbons which led to the formation of proteins as prerequisites for the creation of living matter. The present era seems to be one in which protoplasm persists and perpetuates its properties of individuality, adaptability, growth and reproduction.

METHODS OF STUDY

Cytochemical Methods.—The technique involves primarily the analysis of extracts of disintegrated cells and tissues. Our knowledge of the chemistry of protoplasm has been greatly enhanced by developments of physicochemical techniques and improved methods of extraction and isolation of various constituents of these extracts; *e.g.*, by electrophoresis and by ultracentrifugation. Specific proteins have thus been isolated and studied. In particular, various important enzymes have been isolated, and a study in *vitro* of their activities, separately and combined. is helping to explain many of the mechanisms by means of which living cells maintain and perform their functions (see BIOCHEMISTRY).

An important corollary to the above is the mechanical isolation of morphologically visible cell components from freshly disintegrated cells. Cell nuclei, cytoplasmic granules. mitochondria and even nuclear chromosomes can be separated by virtue of their different size and density and isolated by micro-needles or by differential high-speed centrifugation or by exposure to certain salt solutions which dissolve some and not others. Chemical analyses and enzyme-activity tests are then performed on the separated fractions. A limitation to this type of study, mhich involves crushing of protoplasm, is the injury inflicted on many of the components.

In some cytochemical techniques the cells are not destroyed but are subjected to various physical and chemical treatments while intact. In the incineration method. thin layers of cells and of cellular tissues are placed on transparent sheets of mica and exposed rapidly to high temperatures. The morphological contours of the ashed cells persist and, through the microscope, the distribution of mineral constituents may be mapped by chemical and electron-optical means.

Other cytochemical methods employ specific colour reactions to demonstrate the distribution; *e.g.*, of enzymes, of nucleic acids and of arginine-rich proteins. Use has also been made of purified enzymes to determine the structural importance of substances such as lipids, proteins and nucleic acids in the framework of certain cell constituents (chromosomes, etc.).

Information on important biocatalysts has been gathered by studying the effect on living cells of specific enzyme inhibitors (carbon monoxide, cyanide, azide, etc). Thus, the hemin nature of the respiratory ferment and of the Pasteur enzyme has been elucidated by determining the effect of monochromatic light of different wave lengths on the carbon monoxide inhibition of cell respiration or the Pasteur reaction (Warburg's photochemical method).

Still another method is to explore living tissues with the aid of heavy and radioactive isotopes; e g., deuterium, heavy nitrogen, radioactive carbon. etc. These become incorporated and serve as "tracer" atoms to determine the origin and fate of protoplasmic constituents, *e.g.*, proteins, also the movements of certain chemical elements into and out of living cells.

Physical Methods.—The light microscope (see MICROSCOPE) is of prime necessity for observing protoplasmic structures. The unaided eye, at a distance of 10 in.. can discern objects 0 1 mm. (1/250 in.) apart. This is the resolving power of the unaided eye. The light microscope increases the resolving power 400 times; in other words, it can discriminate objects 0.00025 mm. or 0.25μ apart. The resolution is limited by the wave length of the light illuminating the object. An increase of resolving po er can be obtained by utilizing radiations of wave lengths shorter than those of visible light. This has been achieved by means of the ultraviolet microscope. with which objects 0.1μ apart may be photographically recorded. Visibility to the eye is made possible by the use of fluorescent screens and fluorescent dyes The usefulness of this instrument is not so much in its resolving power, which is only about twice that of visible light. but more as a means for detecting cell components which specifically absorb ultraviolet radiations; *e.g.*, nucleoproteins. The phase-contrast microscope accentuates minute, refractive index differences with the aid of artificially created interference phenomena. Photoelasticity, form and flow birefringence may be studied with the polarizing microscope. When the exact shape of particles is less important than their detection or behaviour (*e.g.*, Brownian motion), the dark field and the so-called ultramicroscope are used. Particles, down to 5 millimicra (0.000005 mm.) appear as luminous diffraction disks (see LIGHT: The Scattering of Light).

A further extension of the range of observability is accomplished by the electron microscope. This is essentially a vacuum tube with accessories for utilizing electrons in the same manner that light waves are utilized in a light microscope. A stream of electrons, after passing through an object, is focused in magnetic or electrostatic fields which act as condenser lenses analogous to the glass lenses of a light microscope. The resulting magnified image of the object is projected on a photographic plate, or on a fluorescent screen for direct observation. Electron-optical magnifications as high as 50,000 diameters have become possible; the resolving power of the present electron microscopes under optimum conditions is estimated at 15Å or 1.5 millimicrons. By means of this microscope, viruses and even single protein molecules have been photographed. A limitation to its use is the necessity of working with dried films of extreme thinness and in a high vacuum. The visibility of the dried objects, *e.g.*, tendon fibrils, has been enhanced by impregnating them with multivalent, heavy metal acids (electron stains), also by coating objects, such as viruses and protein molecules, with noble metal films placed under oblique angles of incidence (shadow casting). The centrifuge microscope permits observation of the effect of intense gravitational fields on living cells. This and the centrifuge method, in general, has been used to determine the relative mass and density of particles, also to study differences in rigidity of certain regions in protoplasm.

Electromagnets, mounted on the microscope stage, have been used to measure protoplasmic viscosity by observing the rate of travel of minute particles of iron or nickel introduced into cells. Hydraulic pressure chambers mounted on the microscope stage have been devised for directly observing the reversible liquefaction of gelated protoplasm under high pressure. The microspectroscope is an attachment to an ordinary microscope which facilitates the identification, through their absorption spectra, of pigments contained in living cells.

The thickness of films, such as cell envelopes and nuclear membranes, may be determined with the aid of the leptoscope, which enables comparison of the intensity of the light reflected from the object with that reflected from a barium stearate film of known dimensions. The fine structure of living systems, *i.e.*, their molecular organization, can be studied by the X-ray and the electron diffraction method. The application of X-ray analysis to fibrils, virus-protein crystals, and similar objects has thrown light on their molecular pattern and has yielded quantitative information on backbone and side-chain spacings of regularly built units and molecules. The irradiation of living cells with intense monochromatic ultraviolet radiation or with X-rays, as well as their bombardment with gamma rays (from radium) and with neutrons (by the use of the cyclotron), produces lesions and mutations which have been of value in the study of chromosome structure, mitosis and gene action. Electrophoresis (migration of particles in electrical fields), produced by the application of electric currents, has been used for determining the electrical charge on cell granules and on intact cells. Microrespirometers of the constant volume (manometric) and constant pressure (volumetric) type, *e.g.*, the Warburg manometric apparatus and the Cartesian diver, are used for making quantitative measurements of the rate of energy-yielding reactions of intact cells, of cell extracts and of formed elements isolated from cells. Micrurgy. or the micromanipulation technique, employs mechanical devices for operating on living cells in the field of the compound microscope (see MICROMANIPULATION). The varied techniques used in micrurgy make possible microscopic observations on differences in the relative stiffness or viscosity of visible constituents of protoplasm. effects of mechanical injury in various regions of single cells and the reparability of these regions under experimental conditions, etc. The tensile strength and torsional resistance of protoplasmic strands have also been studied.

The microinjection of various chemical solutions and the application to the surface and to the interior of protoplasm, of oil drops differing in interfacial tensions have afforded new insight into the physical and chemical state of living protoplasm. The importance of this technique is appreciated since protoplasm exists only within microscopic dimensions. There is no way of securing a sizable mass of protoplasm for gross handling. In most instances it exists as microscopic units. In macroscopic cells, *e.g.*, some plant cells, plasmodia of myxomycetes and the avian yolk cell the contained protoplasm is microscopic in at least one of its dimensions.

Maintenance of Environmental Conditions for Living Cells.—A usual way of observing or operating on protoplasm is to secure cells which either occur singly or can be isolated from tissues. Examples of such cells are the relatively yolk-free, microscopic egg cells of many marine organisms, protozoa, plant hairs, teased out or finely sectioned layers of plant and animal tissues, and cells present in blood and body fluids.

Marine eggs and protozoa are best studied in their natural aqueous environment, while tissues and single cells from higher organisms are usually suspended in body fluids (serum) or in synthetic media—such as Ringer's solution—which contain salts in the concentration of their normal medium. An important adjunct is the use of the tissue-culture technique by means of which fragments of tissue from plants or animals are grown in suitable media outside the organism (see ANIMAL CELL [TISSUE] CULTURE; PLANT CELL [TISSUE] CULTCRE).

Constitution of a Physiological Medium.—The natural environment of all living cells, plant and animal, is aqueous and contains electrolytes, the indispensable ions of which are sodium, potassium and calcium. Of evolutionary significance is the fact that these electrolytes are present in body fluids in the same relative proportions as in the ocean. The total concentration of these salts, within well-defined groups of living organisms, is constant but varies greatly among different groups.

Water freely penetrates most cells. and special provisions exist to prevent what otherwise would result in an excessive osmotic swelling of the protoplasmic unit and an eventual bursting of the cell. Among plant cells the provision is partly mechanical through the presence of rigid cell walls. Many unicellular fresh-water organisms are similarly protected. while others have devices for the periodic elimination of excess water. Unicellular organisms which live in the sea are in osmotic equilibrium with their environment. The cells of the more highly organized animals are in osmotic equilibrium with their body fluids; this equilibrium is maintained independently of external variations.

Temperature.—Raising the temperature only a few degrees above the optimum destroys protoplasm. This may be explained by the effect of the temperature on the rate of enzymatic reactions and on the native configuration of proteins which undergo irreversible denaturation. On the other hand, lowering the temperature slows down chemical reactions and thus tends to prolong vital activities without irreversibly affecting them. Many cells survive subcooling to several degrees below 0° C. Even when the extracellular fluids are frozen solid, the fine capillarity of the fluid spaces within living cells prevents internal freezing. Death may eventually occur through irreversible dehydration. Furthermore, death occurs if, at any time, ice crystals form intracellularly. This can be induced either by sudden agitation of the cooled tissue or by introducing an ice crystal into the cell by means of a micropipette.

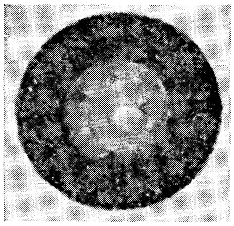
Hydrogen-ion Concentvation.—The maintenance of an acid base equilibrium of the medium is essential for most cells. Physiologically, the hydrogen-ion concentration is chiefly regulated by bicarbonate in equilibrium with gaseous carbon dioxide. This may occur with the participation of proteins in the body fluids of higher animals.

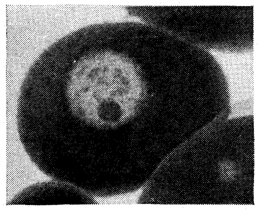
THE NATURE OF PROTOPLASM

Physical State and Morphology of Protoplasm.—To appreciate the implications involved in a study of protoplasm it is advisable to begin with results obtained on its physical state and that of its structural components. Protoplasm is to be regarded as a microheterogeneous system in which particles and molecules of varying solubility are dispersed in an aqueous phase. The state of the protoplasm of many cells is such that the cells round up into spheres when freed of their extraneous envelopes. This is also true for the protoplasts of plant cells removed from their rigid cell walls.

The protoplasmic surface film is a tenuous structure usually interposed between an external envelope of varying rigidity and an internal layer of gellike, cortical material of the protoplasm. The external material which serves as a supporting envelope is an excretion product of the protoplasmic body. It is extraneous to the protoplasm, since it can be removed without interfering with the viable properties of the latter. This envelope depends for its rigidity upon the presence of calcium in the surrounding medium. In multicellular tissues the envelope of contiguous cells serves as intercellular cement for binding the cells together. When calcium is deficient or absent from the medium the cement loses its cohesiveness and the cells become separated. The protoplasmic surface film beneath the extraneous envelope also depends for its maintenance on the electrolytes of the medium but. in this case, the chief ions responsible are sodium and potassium. Thus, of the three electrolytes, sodium, potassium and calcium present in the aqueous environment of living cells, calcium is essential for the external cell envelopes and hence for the intercellular cement of multicellular forms, while sodium and potassium are required for the protoplasmic surface film. The older literature which stressed the importance of calcium, to the extent of introducing the phrase "calcium is essential for life:" arises chiefly from observations on multicellular organisms. Plant and animal tissues: immersed in nutrient media lacking calcium. break down into isolated cells but, as long as sodium and potassium are present, maintain their individual vitality.

Theoretical considerations. supported by certain experimental observations. lead to the concept that the surface layer of protoplasm consists of a palisadelike arrangement of lipoproteins, the more water-soluble groups of which are directed outward. It is ,suggested that the extraneous envelopes of animal cells are produced by the continual casting off of denatured. proteinaceous material. Experimental tearing of the protoplasmic surface results in the outflow of the fluid parts of the interior, provided that calcium has been removed from the environment. Otherwise, irreversible clotting of the exuding material occurs and spreads into the interior. The protoplasmic surface layer disappears in a wave spreading from the torn region, as if the palisade arrangement





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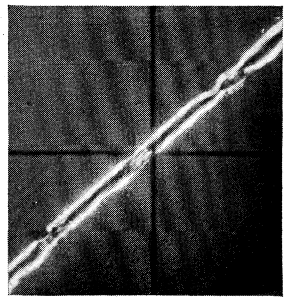

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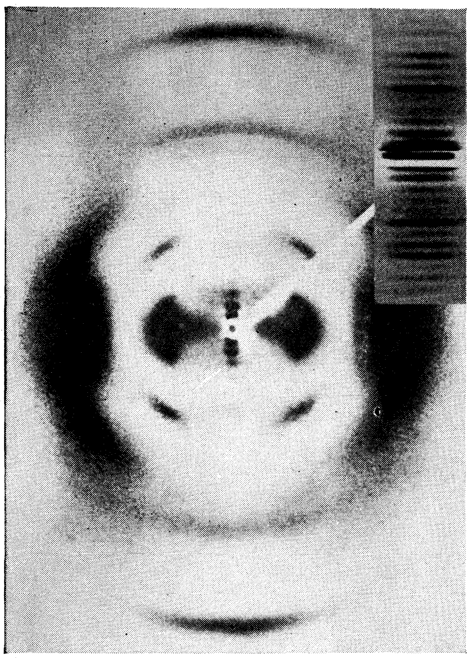

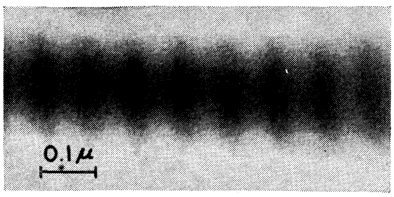

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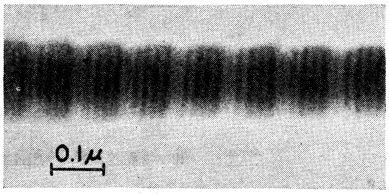

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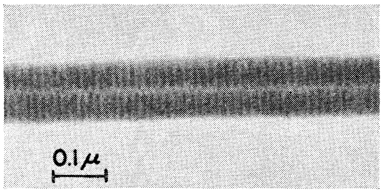

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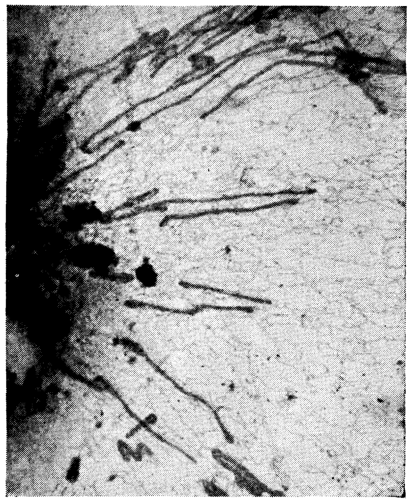

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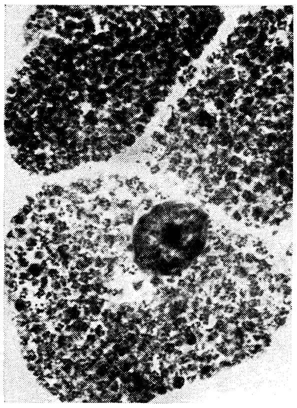

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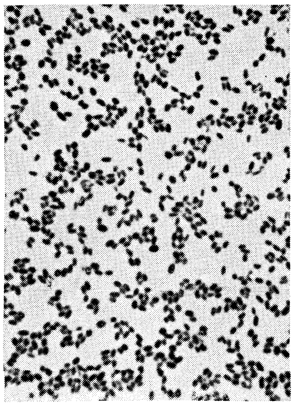

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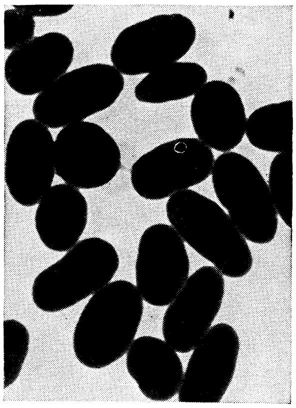

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BY COURTESY Of (1) E. B. HARVEY, PRINCETON UNIVERSITY, (2) G I LAVIN, (3, S 71 F. O. SCHMIDT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY (4) R S BEAR (8) K R PORTER, (9 11) ALBERT CLAUDE, ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

PHOTOMICROGRAPHS OF VARIOUS BIOLOGICAL SPECIMENS EXAMINED WITH DIFFERENT TYPES OF RADIATION

1. *Light microscope.* Living, immature egg (70 microns in diameter) of sea urchin, magnified 300 x. Cytoplasm, with dispersed, brown pigment-granules which appear dark, and nucleus which is translucent and contains a hyaline nucleolus

2. *Ultra-violet* light microscope. Similar specimen, same magnification, exhibiting opaque regions because of the presence of nucleic acids which strongly absorb ultra-violet light of 2,600 Ångstrom units

3. Polarizing *microscope.* Side view of a myelinated nerve fibre freshly removed from the sciatic nerve (frog), magnified 460 x and viewed between crossed nicol-prisms showing the bi-refringent bright myelin-sheath against a dark background

4. X-ray *diffraction pattern* of a tendon (kangaroo) taken with a pin-hole camera. Fibre axis is vertical to the X-ray beam. Inset, to right, shows the central portion of a pattern more highly magnified and taken with a slit camera. It indicates a repeating period of 145 Ångstrom units along the fibre axis

5. Electron microscope. Side view of a fibril from a guinea pig tendon (aried in vacuo). Width of fibril is slightly greater than 0.1 of a micron, therefore, barely within limit of resolution by the light microscope. Here it appears as a relativviv broad structure with cross-bands of alternating light and dark material

6. *Electron microscope.* Fibril of fig. 5, impregnated with phosphotungstic acid. This eiectron stain enhances the resolution of the finer, cross-band elements within spacings of 0.01-0.02 of a micron

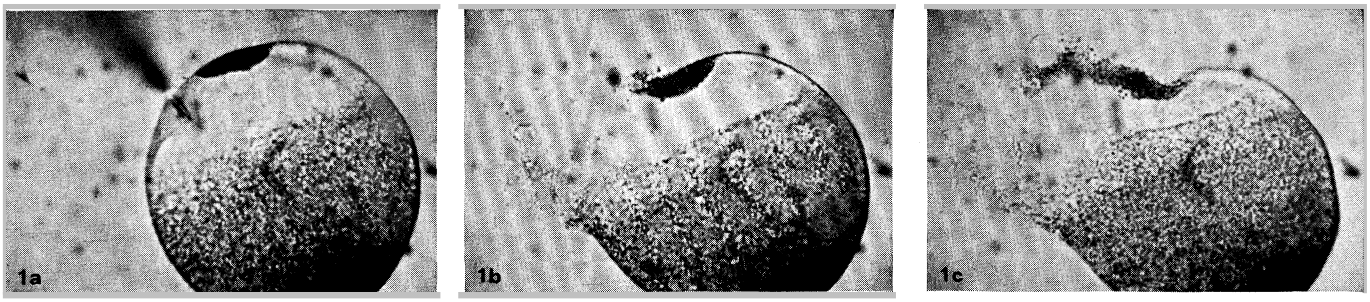
7. *Electron* microscope. Paramyosin fibril (from a clam), impregnated with phosphotungstic acid. The resolving power is so great that cross-bands of 145 Ångstrom units (0.0145 microns) apart can be distinguished

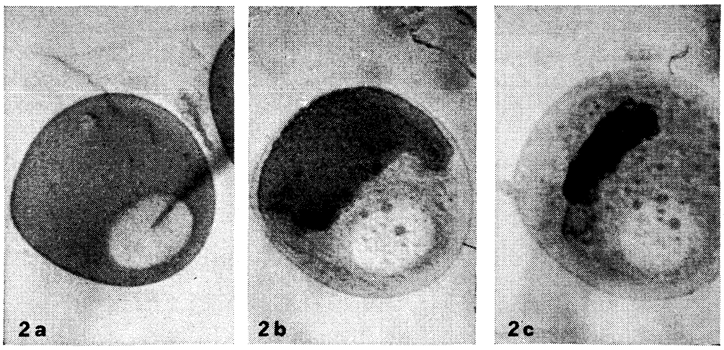
8. *Electron microscope.* Detail of much flattened part of a cell (macrophage) in tissue culture, showing filamentous mitochondria (fixed with osmic acid, magnification 4,000 x)

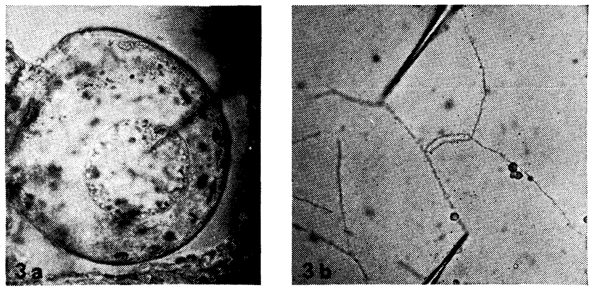
9, 10, 11. Photomicrographs to compare magnifications obtained with the visible light and those with the eiectron microscope. 9. *Light microscope.* Section of liver (Amphiuma) fixed and stained. Three liver cells are shown in which the nucleus of one is evident. The cytoplasm contains many granules, among which the melanin granules (0.5 microns in diameter) are clearly seen as small, black dots (magnification 1,000 x). 10. *Light* microscope. A cluster of melanin granules from the *Amphiuma* liver, obtained by crushing the cells and collecting the melanin granules by centrifugation (magnification 2,000 x). 11. Electron microscope. The same melanin aranules maanified 20.000 times

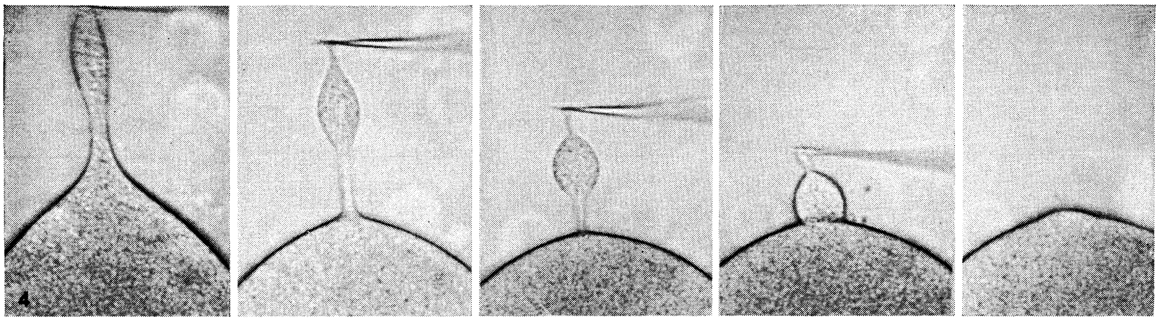
PLATE II

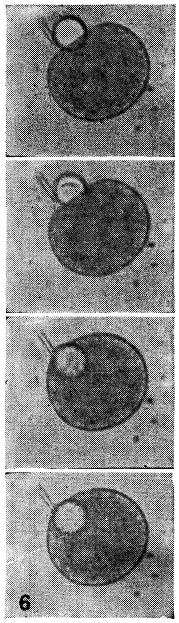
PROTOPLASM

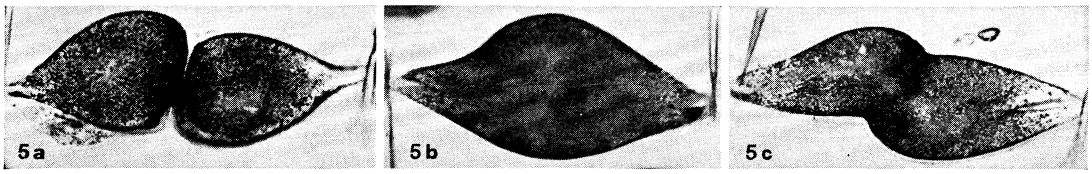












BY COURTESY OF (3) DR. WM. R. DURYEE, CARNEGIE INSTITUTION, WASHINGTON, D.C.

ALL THE FIGURES ARE FROM PHOTOMICROGRAPHS OF MICRURGICAL OPERATIONS ON LIVING OVA UNDER THE LIGHT MICROSCOPE TO DEMONSTRATE FEATURES OF THE PHYSICAL STATE AND STRUCTURE OF PROTOPLASM

1a. Living sea-urchin egg (70 microns in diameter) after having been centrifuged so as to sediment its visible components into several zones according to their relative weights. The tip of a microneedle has been inserted into the fluid, hyaline zone, above which is a dark mass of fat droplets. Just below can be seen a clear spherical body, the nucleus. Below the hyaline is a granular zone, the lowest layer of which consists of dark-brown pigment-granules

1b, c. Two successive micrographs, one and two seconds after tearing the surface layer of the egg. They show the escape of fluid and the outward dispersal of the various granules. In 1c the extruded nucleus can be barely seen in advance of the out-streaming fat globules

2a, b, c. Three successive micrographs of a starfish egg after tearing the nuclear membrane. They show the destructive effect of suddenly mixing nuclear and cytoplasmic material

3a. Ovarian egg of an amphibian with centrally located nucleus

3b. Highly magnified view of a filamentous chromosome being stretched after it had been removed from the nucleus. The chromosome appears to consist of an elastic thread of cohering granules

4. A strand of protoplasm drawn out with a microneedle from the surface of a starfish egg. The strand behaves as a viscous fluid since. on causing the needle-tip to approach the egg's surface, the release of tension results in a shortening and beading of the strand until finally the strand flows back and disappears in the protoplasm of the egg

5a. A sea-urchin egg which underwent successful cleavage after it had been stretched along the polar axis into the shape of a ribbon. b. A sea-urchin egg which did not cleave after being stretched at right angles to its polar axis. c. A sea-urchin egg which cleaved after having been stretched diagonally to its polar axis. The cleavage persisted in the plane at right angles to the original, polar axis. On each side of the cleavage furrow can be seen bulges which are not to be expected if the consistency of the stretched mass of the egg were uniform. The bulges are caused by the gelated regions which resist the pull exerted by the microneedles

6. Four photomicrographs of a sea-urchin egg, taken at Intervals of one-twentieth of a second, showing the rapid penetration of an oil drop applied to the surface of the egg with no evidence of rupturing the surface

forming the boundary were disrupting or breaking down. Repairs from such injuries. if not too extensive, have been observed. Minute vacuoles appear in the cytoplasm of the torn region. These break open and the linings of the vacuoles spread out and join until a sufficient area of film separates the disintegrating from the intact cytoplasm underneath.

The formed elements of protoplasm are of two general types: well-defined inclusion bodies and regions of gelation. the latter being transitory and serving special purposes. Of the inclusion bodies: some in highly differentiated cells, are specific organellae such as the elastic. contractile trichocysts of paramecia (see PROTOZOA; PARAMECIUM). Other inclusion bodies are fat and yolk globules, pigment-containing and colourless vacuoles some of which may he very large (especially in plant cells), rod-shaped or spherical mitochondria and microsomes. the last being barely within the limits of vision. These bodies mostly float freely in the cytoplasm, and their constant movements reveal the existence of currents flowing in various directions in the cell. The function of many of these bodies is unknown. Some are doubtless reservoirs of foodstuffs. while for others there is suggestive evidence that they carry enzymes and are concerned with oxidation-reduction activities and various anabolic and catabolic processes.

The so-called ground substance of protoplasm exhibits at one time the properties of a fluid (solj and at another, those of a deformable solid (gel).

It is known that many colloidal substances, *e.g.,* certain proteins. bentonite or vanadium pentoxide, in solution readily pass from the sol to the gel state and vice versa. This phenomenon, called thixotropy, is exhibited by these systems upon shaking: application of pressure, temperature changes or the action of chemical agents. Protoplasm thus may be regarded as a thixotropic colloid.

The nucleoplasm of the cell nucleus varies widely in viscosity. In some cells it behaves like a stiff gel. In others it is so fluid that the nucleolus suspended in it is readily affected by gravity. Within the nucleoplasm are siender chromatin strands of an elastic consistency. During cell division these filaments shorten into the chromosomes. which are considered to be the carriers of hereditary characters (genes).

It is well recognized that the life of the cell depends upon its nucleus. A case in point is given in fig. 1, which illustrates a binucleated cell in tissue culture. It shows the damage caused by puncturing one of the nuclei and the subsequent repair because of the presence of the second, unharmed nucleus. If the cell had been mononucleated. the initial damage would have destroyed the cell.

A micro-needle (*see* MICROMANIPULATION), when inserted into a gland cell or a starfish egg and rapidly agitated. generally produces cytolytic reactions involving rhe liberation of acid and the progressive breakdown of the vacuoles, mitochondria, etc. A cloud of microsomes is generated which tends to convert the translucent protoplasm into an opaque mass. On the other hand, the gradual insertion and cautious manipulation of the needle in the cytoplasm produces no appreciable effect.

Theories on Ultrastructure of Protoplasm.—According to A. Frey-Wyssling. the cytoplasm forms a network of fibrils having the dimensions of a single polypeptide chain of a protein molecule. These chains are considered to be angular in shape and periodically branched. The side chains interact through points of attachment which may be of various types. This creates a finely meshed. three-dimensional net or molecular sponge the interstices of which are occupied by aqueous solutions of salts and also by lipids. The entire assembly is n-ell ordered through the hydrophilic and lipophilic groups present in the protein network. Such a spongy fine structure would explain many properties of protoplasm. such as reversible swelling by imbibition of fluid or dehydration by constriction of the interstitial spaces. The salient feature of this concept is the presence of an organization of the materials constituting a scaffold, so as to ensure an orderly progression of the reactions over the surfaces of the structure, presumably through the alternate adsorption and desorption of substrate molecules on the stationary centres of enzymatic, active proteins. Obviously, any detailed picture of protoplasmic fine structure must be based largely on our knowledge of the structure of proteins.

Work on proteins has indicated the inadequacy of the original concept by Emil Fischer of their molecular structure. namely of long, straight polypeptide chains of different amino acids A more complex structure is required to explain such important features as specificity, biological activity, and the phenomena encountered in the denaturation of proteins. Some (*e.g.,* W. T. Astbury) assume that the polypeptide chains in the globular and fibrous protein molecules are folded or contracted in varying degrees and are kept so by hydrogen bonds and similar forces According to this view, protein denaturation would consist in the unfolding of compact units similar to the opening up of the bellows of an accordion or to the unraveling of a spool of thread. Others (*e.g.,* D. M. Wrinch) postulate more elaborate structures such as the so-called cyclol fabric involving the formation of six-membered carbon rings through secondary valencies. Whatever the true picture of a protein molecule may be, it can no longer be doubted that these large molecules possess a high degree of geometrical symmetry. This is already indicated by the nell-defined X-ray diffraction patterns exhibited by a variety of proteins (Astbury, J. D. Bernal, I. Fankuchen and D. Crawfoot).

A striking phenomenon is the streaming of the cytoplasm. This is accompanied by a greater or smaller degree of flow birefringence to be explained by the alignment, through shearing stresses, of asymmetric. rod- or platelike particles. When observed in the Tyndall beam of the slit ultramicroscope or with dark-field illumination. the cytoplasm reveals the presence of immense numbers of particles, as small as jo Å. which are in active Brownian motion. These may represent the basic building blocks of protoplasm of which the larger particles. ranging up to 5,000 Å, are aggregates.

There appears to be a close correlation between the submicroscopic and the visible structure of cellular components. A fibril, for instance, has its special form and properties, *e.g.,* elasticity, because the protein molecules which it contains are themselves fibrous and contractile. Experimental observations have also indicated that cilia. flagellums, sperm tails and linear chromosomes consist of interlinked bundles of submicroscopic fibrous protein particles which are oriented with their long axes parallel to the fibre axis. Likewise, membranes and films seem to be built up of submicroscopic iayers or lamellae of single molecules. It is of interest to note that the plasma or protoplasmic surface film appears to contain also lipid molecules. with their long axes perpendicular to the surface. On the other hand, the nuclear membrane

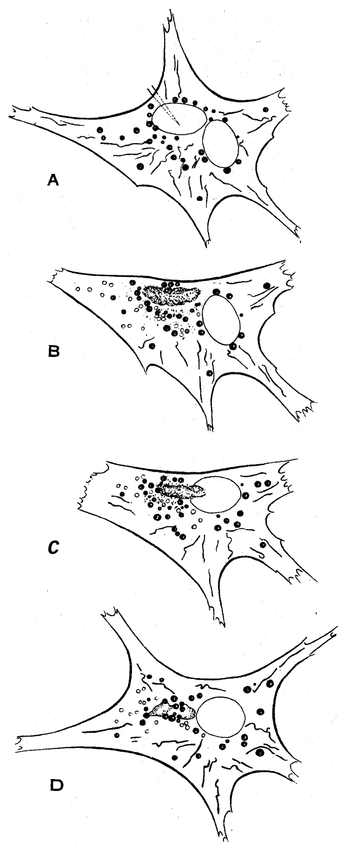


FIG. 1.—SUCCESSIVE STAGES OF A CELL WITH TWO NUCLEI (FIBROCYTE) IN TISSUE CULTURE. SHOWING THE EFFECT OF PUNCTURING ONE OF THE NUCLEI

(A) The cell showing extended pseudopodia before the microoperation. The tip of a micro-needle is about to puncture one of the nuclei. In the cytoplasm can be seen the mitochondria as slender filaments and the fat droplets as highly refractive spheres. (B) The same cell, four seconds after the nuclear puncture. The punctured nucleus has been changed into an opaque mass of material. The cytoplasm near the damaged nucleus is abnormally granular and the mitochondria in the vicinity have changed into pale, spherical bodies. The fat droplets are unaffected. (C) Six seconds later. The damaged nucleus is fading and the cytoplasm surrounding it is becoming less granular. (D) Twenty seconds later.. The cell has recovered because of the presence of the second, undamaged nucleus seems to contain little or no oriented lipid material. The most highly organized protein-lipid system thus far encountered is the myelin sheath of nerve fibres. The sheath appears to consist of concentric lipid-protein layers, each layer about 180 Å thick, containing one or two thin protein leaflets of about 2 j A lying between two double molecular sheets of mixed lipids. Water molecules seem to be distributed over the polar interfaces of this highly organized structure which is irreversibly destroyed by dehydration.

These complex, fine structures of protoplasmic organization constitute a reversible, dynamic system, continually being built up and broken down during the course of normal cell metabolism. This has been demonstrated through the use of isotopic tracer elements, carbon, nitrogen, etc.. which, when fed to animals or cells, rapidly replace the corresponding elements forming essential parts of the molecular structure (R. Schönheimer).

Chemistry of Protoplasm. — From a quantitative point of view, water represents the major component: animal tissues contain up to about 80% water while the plasmodia of myxomycetes (slime molds) may contain as much as 94%. The water may be a basic constituent additional to serving as the solvent or suspension medium of many components of protoplasm.

The chemical composition of the protoplasmic solids may be deduced from the analysis of such animal tissues as lung, muscle, brain or liver. They contain about 20% solids. The protein content is, on the average, about 10%, that of muscle about 16.5%. The total lipid content of brain and liver is about 456, that of lung 2.7%. The mineral content of tissues in general is approximately 1 5%. In addition to these there is a series of minor substances, such as reserve carbohydrates (glycogen), organic acids, creatine and creatinine, free amino acids, pigments, urea, etc. Some of these minor constituents vary in amount, depending on the functional state of the tissue; they may be classified as metabolites and excretion products rather than as essential constituents of protoplasm.

The compounds classed under the general terms of "protein" or "lipid" may be subdivided into conjugated and straight proteins, or neutral fats, cholesterol, cephalin, etc. The conjugated proteins comprise such different complexes as nucleoproteins, lipoproteins, mucoproteins, iron proteins, etc.

The nucleoproteins are of signal importance: those containing desoxyribose (thymonucleoproteins) appear to occur exclusively in the nucleus, while those containing pentose (yeast or ribose nucleoproteins) are found predominantly in the cytoplasm and in the nucleolus The desoxyribose nucleoproteins are integral components of the chromosomes and are considered by many to be the carriers of the inherited characters of the organism (genes). The ribose nucleoproteins of the cytoplasm appear to be related functionally to the mitotic cycle. which involves the chromosomal nucleoproteins. and to the synthesis of proteins and protoplasmic substance of the cell in general. The functional aspects of the nucleoprotein problem, of great importance for the genesis and maintenance of protoplasmic structures. was still largely inferential and speculative. Nucleoproteins within the cell may be detected and quantitatively estimated with the aid of ultraviolet microscopy and microphotometry. This method utilizes the strong absorption of nucleic acids in the ultraviolet region (near 2.600 Å) nhere ordinary proteins and other cellular constituents are fairly transparent. It should be pointed out, however, that this technique does not differentiate between the two basic types of nucleic acids which can be detected by certain staining and colour reactions (Feulgen and Dische reactions).

The lipoproteins constitute an Important group of conjugated proteins. They appear to be secondary valence complexes in which various proteins and lipids, e.g , lecithin. cephalin or sphingomyelin. are held together by forces of the van der Waals type. The lipoproteins appear to be contained chiefly in the cell or plasma membrane. in the mitochondria, microsomes and other cytoplasmic inclusions. The lipoprotein "mosaic," present in the plasma membrane, plays an Important role in determining its permeability

The components just enumerated represent either building blocks or metabolites of protoplasm. There are also many catalysts; *i.e.,* substances capable of accelerating and promoting reactions which, in their absence, would take place only at negligible rates (see CATALYSIS and ENZYMES). The catalysts are either enzymatic or nonenzymatic. The enzymes (or thermolabile, colloidal catalysts) are classified as hydrolytic or as oxidative, according to their action on suitable substrates. The hydrolytic enzymes split lipids and proteins by introducing the elements of water. The oxidative enzymes are the oxidases which cause substrates to combine with molecular oxygen and the dehydrogenases which serve as hydrogen acceptors, thereby removing hydrogen atoms from the substrate. The action of many of these enzymes has been shown to be reversible, thus indicating that they not only promote the breakdown but also the synthesis of protoplasmic constituents. Another important group of intracellular enzymes are the phosphorylases which store energy by forming energy-rich phosphate bonds and also, by splitting the same phosphate esters, *e.g.,* adenosine triphosphate, yield readily available energy for vital processes. Examples of intracellular enzymes are catalase, which splits hydrogen peroxide into oxygen and water; cathepsin, a proteinase which attacks the peptide bonds in native proteins at the hydrogen-ion concentrations prevailing in the cell; and cytochrome oxidase (or respiratory ferment), which through the intermediary catalyst, cytochrome, induces molecular oxygen to oxidize suitable substrates, such as paraphenylene diamine. Cytochrome is an example of a nonenzymatic or intermediary catalyst. The oxidative enzymes, together with nonenzymatic catalysts, play an important role in the energy metabolism (respiration and fermentation) of the cell, while the hydrolytic enzymes are mainly concerned with the breakdown of foodstuffs and the rebuilding of protoplasm from the split products. The distribution of the various enzymes and other catalysts between the different formed elements of the cell and the cytoplasm has as yet not been completely elucidated. However, it would seem as if all important enzymes occur both in the nucleus and in the cytoplasm. It would appear that the mitochondria are particularly rich in enzyme content. The control of the orderly flow of the reactions in protoplasm is accomplished by various devices, such as the mechanical separation of catalysts and substrates and the regulation of the hydrogen-ion concentration which, in turn, affects the rate of enzymatic processes. The orderly progress of reactions of these various catalysts and their substrates, all within the confines of a single protoplasmic unit, postulates the existence of regulatory mechanisms. For example, the rate of enzymatic processes is markedly affected by changes in the hydrogen-ion concentration of the medium. Spatial separation may also be assumed to play a role since there is evidence that some of the enzymes concerned with the terminal oxidation of metabolites are anchored, in a definite pattern, to the surface of macromolecular particles within the living cell.

Protoplasmic Reactions. — Cell Respiration *and* Energy *Production.*—Perhaps the most valid criterion of life is metabolism, a term which covers the intricate processes concerned in the breakdown of foodstuffs (substrates or metabolites) and the utilization of the reactions to release energy required for the proper functioning as well as for the repair and growth of protoplasm. Energy-yielding reactions are of two types: respiration and fermentation. Respiration utilizes the molecular oxygen of the air. Fermentation. on the other hand, proceeds in the absence of air and, in many instances, is adversely affected by the presence of oxygen (Pasteur effect). In the metabolism of the most primitive types of cells, represented by certain strictly anaerobic microorganisms, the primary requisite of life appears to be the ability to ferment carbohydrate, yielding end products such as lactic acid, butyric acid, carbon dioxide or hydrogen. From an energetic point of view. fermentation is not very economical since it releases only a small fraction of the energy available in foodstuffs. In contrast to this the respiratory or oxidative process releases all the available energy from a given substrate by burning it to carbon dioxide and water. Aerobic cells possess both types of mechanism. Fermentation is an indispensable prerequisite for respiration, since the latter utilizes chiefly products made available by anaerobic splitting of foodstuffs. The Pasteur effect allows only that portion of fermentation to persist in the presence of air which is required for the production of the substrates needed by the respiratory system.

It had been assumed that the ability to respire was restricted to intact and complete cells. It is now known that neither the cell membrane nor the nucleus is indispensable for this process and that the ability to utilize oxygen for the combustion of suitable substrates resides in the smallest particles which can be obtained from the protoplasm by mechanical means. Cell-free extracts retain the ability to ferment sugar but lose the ability to respire normally. It appears that the mechanical methods which break up the architecture of the protoplasm destroy the intricate correlations which are necessary for normal cell respiration. The same is true for the Pasteur reaction. However, it has been possible to demonstrate in cell-free solutions the presence of many of the enzymatic components of the respiratory system. This shows that the steps catalyzed by single enzymes do not depend upon the coordinated, vital activities of protoplasm (see ENZYMES).

Chemical energy is required for all of the so-called "vital" functions of the cell, such as the maintenance of membrane potentials, selective permeability, the maintenance of optimal hydrogen-ion concentration, of oxidation-reduction potentials, as well as cell division and protoplasmic movements. While primarily this energy can be made available only by fermentation or respiration processes, it is becoming increasingly clear that the immediate source of readily available energy for these diverse functions is to be found in energy-rich phosphate bonds. The energy released from the foodstuffs by the metabolic activity may be stored up by the synthesis of compounds of the type of adenosine triphosphate and creatine phosphate. The energy can then be released for such processes as the cpntraction of a muscle fibre or the excitation of a nerve fibre with the aid of specific enzymes which split the energy-rich phosphate bonds.

Oxidation-Reduction Potentials in Living Cells.—Oxidation-reduction systems are classified as reversible or irreversible. However, there exist many intermediate types such as the fully electroactive, the sluggish and the semireversible systems, depending on the ease with which the state of oxidation of the system may be reversed or with which electrons may be exchanged with other systems. A cell cannot be regarded as a system endowed with a uniform degree of oxidation-reduction intensity. It is possible that certain materials of a suitable reduction intensity are being continuously depleted by irreversible oxidation and are as continuously being replenished by the formation of fresh amounts. The physiological function of the reversible systems would then lie in their continual oscillation between the oxidized and reduced state, thus enabling the systems to play the role of nonenzymatic, intermediary catalysts. Systems composed of certain oxidative enzymes and their substrates, in the presence of suitable, electroactive dyestuffs (mediators) have been shown to constitute truly reversible oxidation-reduction systems, the potential of which is determined by the ratio of the oxidized and the reduced form of the substrate. In the living cell, we do not encounter such a state of thermodynamic equilibrium but rather a steady state resulting from the incessant and simultaneous flow of oxidative and reductive reactions in both directions; this balance has been designated as "aerobic" and "anaerobic" potential. It is evident that any disturbance of this steady state by changing the oxygen tension of the medium or by the addition of strongly reducing or oxidizing agents will profoundly affect the physiological activity of the cell, provided they break through the defensive mechanism which may be described as the oxidation-reduction buffering capacity of protoplasm.

Hydrogen-ion Concentration.—Attempts at determining the intracellular hydrogen-ion concentration or pH (see HYDROGEN IONS) have been made in various ways. The earliest was to crush a mass of cellular tissue and determine the pH of the extract electrometrically and also by means of colorimetric pH indicator-solutions. Considerable variations were found to occur, not only with different tissues but with the same tissue at different times. It was later observed that the damage produced in crushing the protoplasm of cells causes the appearance of what has been termed an "acid of injury" which upsets the evaluations. The only method to prevent this kind of injury is to obtain values in single cells while the cells are known to be still alive. Such a method has been made possible by means of microinjection (see MICROMANIPULATION). Colorimetric indicators in aqueous solution can be injected into living cells and have produced results on which this section is based. In the determinations it is necessary to realize that the values obtained refer to the aqueous portion of the protoplasm.

The two chief constituents of protoplasm are protein and water. The water is continuous throughout the protoplasmic matrix and serves as a dispersing medium for granules of various sorts, fatty droplets and vacuoles, also as a solvent for electrolytes and the ionizable portions of the other main constituent, namely protein. The nature and degree of the ionization depend upon the hydrogen-ion concentration, which is a conditioning factor for the metabolic activities of protoplasm. For the cytoplasm the pH value has been found to be 6.9 ± 0.2 where pH 7.0 represents neutrality. For the nucleus the value is 7.7 ± 0.2 indicating that the aqueous phase or portion of the nucleus is definitely more alkaline than that of the cytoplasm. It is significant that these values have been found to be constant in a large variety of animal and plant cells, both of unicellular and multicellular organisms. This constancy is maintained by the so-called buffers; *e.g.*, the bicarbonate-carbonic acid system and the amphoteric proteins. Otherwise, the normal functional state of the protoplasm would be seriously disturbed by the acids which are produced during the various metabolic reactions occurring in the cell. For example, such metabolic end products as lactic and carbonic acid are immediately neutralized. The resulting neutral compounds are carried to the surface of the cell where their acid components are released to the outside.

The cytoplasmic vacuoles are liquid-filled sacs. Their enveloping membranes consist of a nonaqueous material and serve as mechanical and selectively permeable barriers to keep the vacuolar contents separated from the surrounding cytoplasm. The membranes of the vacuoles map allow certain solutes to enter but not to leave. In other words, these membranes exhibit the remarkable property of a one-way permeability, a property which has caused considerable speculation as to their physicochemical structure. The vacuolar contents are usually more acid and, in some instances, more alkaline than the cytoplasm. They are only slightly if at all buffered. Because of this the pH of the vacuoles may vary considerably with the nature of the environment. On the other hand, the pH of the cytoplasm and of the nucleus is independent of the environment as long as the cell is alive. This constancy of the protoplasmic pH is of great significance for the maintenance of the normal physiological state of the protoplasm and of its metabolic activities. Therefore, when one speaks of intracellular pH, it is necessary to discriminate between the pH of the protoplasm and of the contained vacuoles.

Gel-Sol Reversal.—The peculiar property of protoplasm to maintain or to change its physical state occurs generally in such a way that one part of the protoplasm is gelated while another remains in the sol state. These changes, together with protoplasmic streaming, are related to various protoplasmic activities such as amoeboid movement, cell division and possibly the periodic torsion observed in extended strands of myxomycete plasmodia. The gelated regions are more or less transient in character and revert to the sol state either spontaneously or when subjected to certain experimental conditions.

Amoeboid Movements.—An amoeba or a leucocyte is unable to advance were it not for the ability of its protoplasm to undergo gel-sol reversals. While at rest, most of the body of the amoeba is extended into several. long-tapering pseudopodia. Its protoplasm is in the state of a gel except for the innermost region which is in the sol state and exhibits a slow, shifting flow of the granules suspended in it. When an amoeba begins to advance. the action is initiated by a return. at some spot on its periphery, of the gel into the sol state. There follows a streaming from within the amoeba into this region, which bulges outward. The streaming progressively develops into a "fountain flow"; *i.e.,* an axial forward and a peripheral return flow (fig. 2). When the peripherally returning fluid reaches the base of the bulge, it gelates. A pseudopodium thus develops by the formation of a progressive lengthening of a cylinder, the walls of which are in the gel and the interior in the sol state. The interior is flowing forward to the tip where the "fountain flow" continues. Retrogression of the pseudopodium occurs by a change in direction of the flow, accompanied by a liquefaction of the walls of the cylinder progressing backward from the tip. Mechanical agitation accelerates the reversal to the state of a sol.

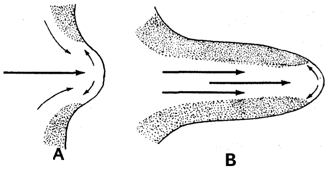


FIG. 2.— FORMATION OF AN AMOEBOID PSEUDOPODIUM

(A) Initial solation of the peripheral gelated protoplasm accompanied by a "fountain flow" in that region. (B) Extension of the pseudopodium by means of forward, axial streaming of the protoplasm in the sol state and a progressively lengthening, hollow column of gelated protoplasm being added to by peripheral back flow at the tip

Cell Division.—This process als~ exhibits sol-gel reversal. The first sten in cell division is the disappearance of the nuclear membrane. followed by a mixing of the nucleoplasm with the cytoplasm. At this time the mitotic spindle appears and the chroinosomes collect at its equator (see CYTOLOGY). During this period two regions of the protoplasm, one at each pole of the cell. progressively undergo gelation. This phenomenon is accompanied at the equator by a streaming which is directed toward the centre of the cell. The stream, as it approaches the centre, separates into two currents to the two opposite poles of the cell. The inward streaming produces a depression at the surface around the equator of the cell. This depression forms an ever-deepening furrow which ultimately divides the cell in two. As it advances, the walls of the furrow become gelated. In brief, there are two principal phenomena which accompany the process of cell division. One is a specifically directed protoplasmic flow and the other is a localized sol-gel reversal.

Selective Permeability of Protoplasm.— Ever since the cell was discovered as the structural unit of protoplasm, it has been abundantly proven that protoplasm exhibits a unique selectivity in the incorporation of certain materials and not of others from the surrounding medium. Water and dissolved gases readily pass in and out; so do certain ions, but not others. Nonionized molecules, *e.g.,* of weak acids and bases, appear to penetrate readily. while water-insoluble fatty acids do not. The penetration of particles in suspension and of nonelectrolytes appear to be a matter of size.

Electric charges play an important role with ion-valency as a determining factor. Most cells appear to be readily permeable to monovalent and distinctly less so to polyvalent cations. Some types, *e.g.,* blood cells, have been found to be permeable to anions and not to cations; but this is not true for all species of red cells. The fact that, in general, weak acids and weak bases penetrate more readily the less they are dissociated, has been used as an argument for a predominantly lipoid nature of the protoplasmic surface.

Paul Ehrlich (*q.v.*) and Charles E. Overton (1865–1933) made extensive use of a great variety of dyestuffs, especially coal-tar products, dissolved in the normal. aqueous environment of living cells. They found that the predominating condition for penetration is that the dye be the salt of a basic dye, the colour base of which is fat-soluble. Overton used this fact as the chief argument for his theory that the superficial layer of protoplasm is a lipoid membrane. Later. H. A. Bethe pointed out that the normal environment of cells is relatively alkaline and that protein, which is the chief constituent of protoplasm, should exist on the alkaline side of its isoelectric point and, therefore, react as an acid. Bethe opposed the Overton theory by concluding that the observed staining with basic dyes is explained more simply on the basis of chemical -affinity, namely the basic dye-radical combining with the acid-radical of the intracellular protein. Uniortunately for Bethe's assumption. chemical combinations of foreign compounds with the proteins in living cells are often toxic.

The following three types of processes may be mentioned, using dyestuffs as examples.

Penetration *of* Particles by *Virtue* of Size.——Most of the vital acid dyes are salts of weak acids which. at the pH of the normal cell environment, tend to be dispersed either molecularly or in aggregates of molecules. The diffusibility of many of these dyes into living cells has been shown to be a property of particle size, the size varying between j or 6 Å to 10 or 11 Å for different types of cells.

Penetration *of* Solubility.— Vital basic dyes. such as neutral red (an amino-azin), are salts of a weak. coloured base. It tends to be both fat-and-water soluble and is also more soluble in acid, aqueous media while it becomes increasingly nonionized and tends to precipitate in more alkaline media. The environment of cells is usually more basic than the aqueous phase of the protoplasmic interior. The dye diffuses readily into the cell where its accumulation predominates in the still more acidic, cytoplasmic vacuoles giving them a bright red colour. Moreover. by virtue of its lipid solubility. neutral-red also colours lipid granules.

Penetration Depending *Upon Metabolic* Activities.— This phenomenon. recognized as a so-called secretory process, may be illustrated by referring to the cells of the wall of the kidney tubule. It can be demonstrated on living fragments of kidney tubules immersed in solutions of highly dissociated salts of coloured acids, such as phenolsulphonphthalein, which do not penetrate cells generally.

There is evidence that this type of penetration is caused by some type of a metabolic process. Optimum temperature and oxidation-reduction conditions are obligatory, conditions which are not needed with the usual vital dyes, such as neutral red.

A significant feature to be pointed out is that the cells do not exhibit this phenomenon during the period when they are undergoing reproduction by division. Evidently, the metabolic functions for the performance of "secretion" and of division do not occur simultaneously.

There is no generally accepted opinion regarding the nature of the protoplasmic surface to explain its selective permeability. Some have claimed the surface layer to be a mosaic of water and lipoid soluble regions, both of which may be present simultaneously or may alternate in appearance with time. Others adhere to Overton's theory, according to which the passage of ions is explained by their conversion into lipoid soluble compounds at the time of their passage. Still others lay stress on the role played by electric charges on the surface. The selective permeability of the protoplasmic surface layer also may be conditioned by the interstices of the molecules constituting it, and by the chemical affinity for cations or for anions, according to whether carboxyl or amino groups predominate in the surface layer.

CONCLUSION

Protoplasm is an organized entity in which structure and chemical reactions are closely integrated. It possesses the physical properties of a plastic. deformable material. Although a major part of its substance is water. dispersed through it as a continuous phase, protoplasm contrives to maintain its structural integrity in an aqueous environment. It follows that water-insoluble materials, such as lipids and fibrous proteins, must predominate at its surface.

The physicochemical nature of this surface film largely conditions the interchange of materials with the environment. The mechanical rigidity of a living cell is a function of the nature of its envelope. of the water-imbibing property of its protoplasm. and of the ability of protoplasm to undergo reversible sol-gel transformations.

The kinetics of the catalytic and other chemical reactions of protoplasm are aided by the ultrastructure of its ground substance with its large multiplicity of surfaces. blechanisms which regulate these reactions involve the control of hydrogen-ion concentration and of levels of oxidation-reduction intensities. Of particular importance are the enzymes which, by means of reversible. coupled reactions, make energy available for the functioning of the cell. It is an interesting iact that cells are built up of the same kind of materials that are used as substrates for their energy-yielding reactions.

In summary, protoplasm, as the physical basis of life, is a dynamic system of organized matter constantly absorbing and expending energy. Its uniqueness is due to the fact that part of the absorbed energy it utilizes for its own regeneration and growth, the remainder being largely expended as work and heat.

BIBLIOGRAPHY.—*Methods:* T. Svedberg and K. O. Pedersen, *The Ultracentrifuge* (1940); H. A. Abramson, L. S. Moyer and M. H. Gorin, *Electrophoresis of Proteins* (1942); M. Dixon, *Manometric Methods* (1943); A. Köhler in *Z. Wiss. Mikr.*, 21, 129, 273 (1904); G. I. Lavin in *Rev. Sci. Instr.* 14, 375 (1943); A. Köhler and W. Loos in *Naturwissenschaften*, 29, 49 (1941); O. W. Richards in *Nature*, 154, 672 (1944); O. Glasser (ed.), *Medical Physics* (1944); R. E. Burk and O. Grummitt (eds.), *Major Instruments of Science* (1945); V. K. Zworykin *et al.*, *Electron Optics and the Electron Microscope* (1945).

General: W. Seifriz, *Protoplasm* (1936); A. Frey-Wyssling, *Submicroscopic Morphology of Protoplasm*, 2nd Eng. ed. (1953); L. V. Heilbrunn, *General Physiology*, 2nd ed. (1938); H. H. Pfeffer, *Experimental Cytology*, (1940); R. Schönheimer, *The Dynamic State of Body Constituents* (1940); R. Höber, *et al.*, *Physical Chemistry of Cells and Tissues* (1945); Erwin Schrödinger, *What is Life? The Physical Aspect of the Living Cell* (1945).

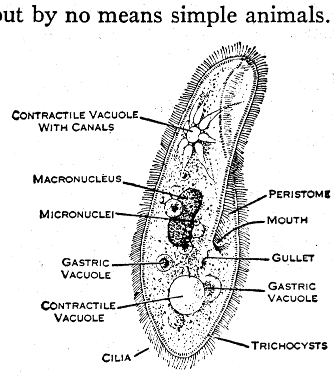
Special: L. Michaelis, *Oxidation-Reduction Potentials* (1930; 2nd ed., 1933); W. J. Schmidt, *Die Doppelbrechung von Karyoplasma, Zytoplasma und Metaplasma* (1937); F. O. Schmitt, "The Ultrastructure of Protoplasmic Constituents," *Physiol. Rev.*, 19, 270 (1939); C. Oppenheimer and K. G. Stern, *Biological Oxidation* (1939); A. Guilliermond, *The Cytoplasm of the Plant Cell* (1941); S. C. Brooks and M. M. Brooks, *Permeability*, Protoplasma Monograph no. 19 (reprinted 1944); J. Cattell (ed.), Biological Symposia, *Frontiers in Cytochemistry*, vol. 10 (1943); *Cold Spring Harbor Symposia on Quantitative Biology*, vol. 1 (1933), vol. 6 (1938), vol. 7 (1939), vol. 8 (1940), vol. 9 (1941), vol. 10 (1944); J. Alexander (ed.), *Colloid Chemistry, Theoretical and Applied, Biology and Medicine*, vol. 2 (1928), vol. 5 (1944); Publications of American Association for the Advancement of Science, *The Cell and Protoplasm*, no. 14 (1940).

(R. CH.; K. G. ST.)

PROTOPOPOV, ALEXANDER DMITRIEVICH (1864–1918), Russian statesman, was born in 1864 and educated in a military school. He served for some time in the army before going into business. As a big landowner of the Simbirsk province, he took an active part in the Zemstvo life, and was elected member of the executive board of the Simbirsk Zemstvo and marshal of the nobility of the Simbirsk province. He was elected member of the third (1907) and of the fourth State Duma, where he joined the left wing of the Octobrist (Moderate Liberal) party. Later he became vice-president of the State Duma. In March 1916 he visited the capitals of western Europe as one of the leaders of the Russian parliamentary delegation. At the beginning of Oct. 1916 he was appointed minister of the interior in the Stürmer cabinet, proving to be now the strongest upholder of reaction. He enforced the censorship, and interfered dangerously with the food-supply work of the Zemstvos and Towns union. At a stormy meeting held at the Duma he was asked to resign his post, and when he refused his name was struck off the list of members of the party. Hated by the Liberal circles and by the Duma, Protopopov not only supported the reactionary policy of Stürmer and Prince Galitzin, but he is said also to have been one of the secret organizers of the disturbances of Feb. 1917, which he proposed to suppress by military force, and which, unexpectedly for him, resulted in the overthrow of the empire and of himself. He was arrested by the provisional government and committed for trial. He remained for many months in the Peter and Paul fortress and was executed by order of the extraordinary commission in Sept. 1918.

PROTOZOA. The Protozoa are usually defined as unicellular animals in contrast with the higher animals, or Metazoa, in which the body is composed of many structural and physiological units, or cells, differentiated to perform the various functions of life. Under the influence of the "cell theory," this interpretation was definitely suggested in 1843 by M. Barry and formally made in 1845 by T. H. von Siebold, the latter establishing the term Protozoa, previously used in a general sense for primitive animals, for the basic phylum of the animal kingdom. However, in view of the fact that each protozoon is a complete independently-living organism, a few zoologists, under the impetus of C. Dobell (1911), prefer to regard the Protozoa as "noncellular" and to restrict the term cell to the units of the tissues of the Metazoa. But this unduly minimizes, for instance, the significance of the fundamentally similar structure and method of division of the Protozoa and the cells of Metazoa and also the highly probable, and generally accepted, view that the Metazoa have evolved from the Protozoa by the aggregation and specialization of these units to allow tissue differentiation. The Protozoa apparently have accomplished all that is possible within the confines of a cell, and have endowed the Metazoa with potentialities that are essentially unlimited. (Fig. 1.)

The Protozoa are the simplest but by no means simple animals. Most species are too small to be seen with the naked eye, so their discovery awaited the advent of microscopes in biological studies during the 17th century. In 1674 the Dutch microscopist, Antony van Leeuwenhoek, focused his lenses on pond water, vegetable infusions, etc., to reveal a new and prolific microcosm of "animalcules," and became the founder of protozoology and bacteriology.



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)
FIG. 1.—PARAMECIUM AURELIA. MAGNIFIED ABOUT 350 TIMES

Significance of Protozoology.—When the Protozoa were discovered they naturally provoked amazement by their small size, stupendous numbers and enormous powers of multiplication, and were seized upon as support for the current views on spontaneous generation which were being undermined, in particular by the work of Francesco Redi on the propagation of flies in 1668. The spontaneous origin of "animalcules" appeared highly plausible, but it was believed by Leeuwenhoek to be fallacious. This was definitely indicated as early as 1718 by the experiments of Louis Joblot, who found that boiled infusions, thoroughly sealed, remained devoid of life.

Although the problem of the origin of the tiny animals long persisted, interest gradually centred on their description and classification. Thus, John Hill in 1752 formally assigned to them the basic position in the animal kingdom, under the title Animalcules, but the first great contributions to their taxonomy were made by O. F. Mueller, chiefly in his monograph published in 1786. This broad survey naturally led to intensive studies on protozoan structure. Is it essentially a tiny replica of the body of higher animals with somewhat similar organs and organ systems, or is it unique? C. G. Ehrenberg presented the culmination of the former view in 1838 and F. Dujardin of the latter in 1841. Dujardin's ideas prevailed during the ensuing decade with the recognition that the protozoan body is relatively simple, being composed of a unit mass of sarcode, now called protoplasm, which is the physical basis of life common to all animals and plants. Then came the realization, as already indicated, that the individual protozoon is comparable to the cellular unit of structure and function in higher organisms. So it appeared that the Protozoa present animal life in primitive form—isolated cells in which the answers to some of the fundamental life problems can be sought more readily than in multicellular animals with tissue differentiation. This viewpoint led to a wealth of important investigations begun shortly after the middle of the 19th century and still continuing unabated, but now with the full realization that the intricacies of protozoan morphology and physiology within the cell—the *multum in parvo* plan of structure—does not necessarily spell simplicity. Indeed, one wonders whether the performance of all the functions of an individual's life within the confines of one cell, instead of in myriads of differentiated cells, is the more simple. Be that as it may, the fact remains that these primitive animals have served as an important approach to many basic questions such as the structure of protoplasm, the intricacies of growth and regeneration, the significance of fertilization, and the factors underlying senility—to cite only a few of many. All told, these studies have contributed greatly to the grasp of general biological problems, even though it may be admitted that the little animals have divulged their secrets somewhat more grudgingly than the earlier workers anticipated in their enthusiasm.

It should be emphasized that much of our information in regard to the Protozoa has been derived from investigations conducted with no immediate object in view other than to broaden the horizon of knowledge. But the facts secured have proved a necessary foundation for other studies of medical and economic importance. It has become increasingly apparent that many Protozoa are disease-producing parasites of man and beast. Although Leeuwenhoek observed some protozoon parasites, it was not until about the start of the 20th century that the causal relation of Protozoa to certain diseases, notably malaria, amoebic dysentery and African sleeping sickness, attracted wide attention. This aspect of protozoology came to form a large and important part of parasitology, and so from the practical as well as the theoretical standpoint studies on the Protozoa afford invaluable information.

Types of Protozoa.—Broadly speaking, all Protozoa are aquatic organisms since they demand a fluid environment for active life. They abound in pools and puddles, lakes and seas, and the soil, as well as in the bodies of higher animals and plants—essentially everywhere that moisture is available and elsewhere when they are in a dormant state. Nearly every animal that has been carefully studied has revealed one or more species especially adapted to live in its body, and therefore it seems probable that there are actually more kinds of Protozoa than there are of all the rest of the animal world, although by 1945 only about 20,000 species had been described.

Active phases of the Protozoa are provided with suitable locomotor organs, and it is on the type of these organs that three of the four great classes of the phylum are chiefly based. The Mastigophora or Flagellata (*e.g., Euglena*) move by flagella, the Sarcodina or Rhizopoda (*e.g., Amoeba*) by pseudopodia and the Ciliophora or Ciliata (*e.g., Paramecium*) by cilia. The remaining class, the Sporozoa (*e.g., Plasmodium*), comprises solely parasites which possess no diagnostic locomotor organs though all species are motile at some stage in their life history. It might appear, then, that the separation of the Protozoa into clearly defined classes should be relatively easy, but since some species exhibit, for example, both flagella and pseudopodia at different phases in their life history as well as other intermediate characters, their relationships must be appraised on the ensemble of characters presented. Comparable difficulties arise in the taxonomy of the various subdivisions of the classes. (Figs. 1–4.)

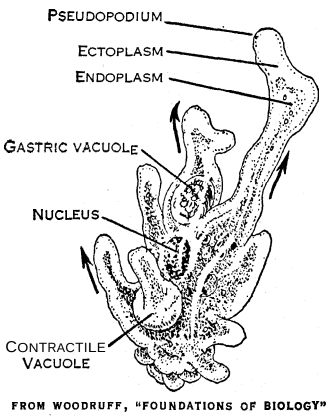
Although the class Mastigophora comprises the most primitive animals, no hard and fast line can be drawn between the plant and animal kingdoms—one merges into the other when their simplest forms are approached. In fact botanists claim, with considerable justice, some of the flagellates, chiefly because they possess chlorophyll and are able to synthesize food by the energy of sunlight as do typical green plants. But in the absence of light, many of these forms with chloroplasts or chromatophores, such as *Euglena,* are able to use relatively complex food material in solution, and are similar in structure to other species without chlorophyll that are typically holozoic, *i.e.,* engulf solid food. Accordingly, it is to a considerable extent a matter of emphasis on one or another of the various aspects of flagellate physiology and structure which determines whether certain species are regarded as unicellular Algae or Protozoa—a condition recognized by zoologists who stress the animal nature of the flagellates but divide the class into two major divisions, the Phytomastigophora and Zoomastigophora.

Form.—Protozoa in general exhibit a definite "adult" form characteristic of the species, although many of the rhizopods, in particular, readily change their shape by protoplasmic flowing, known as amoeboid movement from the name of the common genus, *Amoeba.* Furthermore, many species have complicated life cycles in which the individual cells at various stages are quite different in appearance so that more than one and often many stages are necessary for identification. Indeed, polymorphic life cycles in which a series of forms follow one another in a definite sequence complicate the concept of "individuality" in the Protozoa just as they do in many higher animals and plants. (Fig. 4.)

The protozoan body form is so exceedingly diverse that nearly every possibility seems to be realized. For instance, the range is from homaxonic or spherical types, typically seen in various floating rhizopods such as most of the fresh-water Heliozoa and marine Radiolaria, to monoaxonic types in which a mouth, or cytostome, is at or near the anterior end of the long axis, resulting usually in imperfect bilateral symmetry as in many flagellates and ciliates. Some of the latter in particular show a marked dorsoventral differentiation with the cytostome on the ventral aspect.

Although the vast majority of the Protozoa are microscopic in size, the lower limit being about 2/1000 of a millimetre, there are giants among the rhizopods; a few of the Foraminifera approximate 15 cm. in diameter and are exceeded by the plasmodia of some Mycetozoa. Well-known species such as *Amoeba proteus* and *Paramecium aurelia* are barely visible to the naked eye under the most favourable conditions. While a fairly definite size characterizes each species, as well as the various stages of polymorphic species, many are composed of races showing size differences, and all are especially susceptible to nutritional and other changes in their environment. Accordingly, size alone is a precarious specific character. (Figs. 1, 2.)

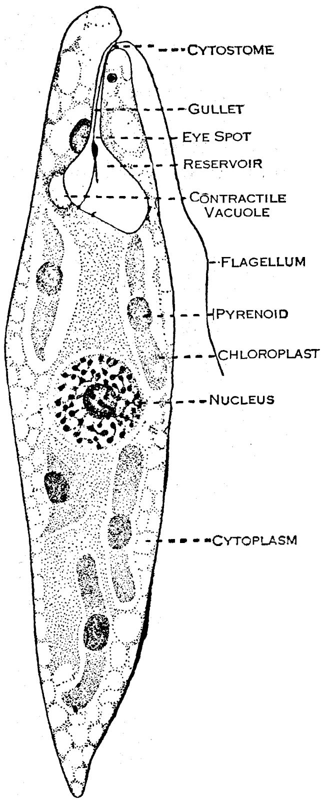
Shells and Skeletons.—External and internal protective and supporting structures, usually permanent but sometimes temporary and restricted to certain stages, are widespread. In some instances the secreted substance is solely organic in nature, such as gelatinous material, tectin or cellulose. In other types there are added to this basis various inorganic elements, in particular calcium and silicon, and also foreign bodies, such as diatom tests and sand grains. The protective covering may be closely applied to the cell surface or separated by a space. In many of the Foraminifera elaborate shells of calcium carbonate are largely internal structures, becoming permeated and surrounded by the protoplasm of the animal. In other species the cell may be supported by a skeleton, often both external and internal, reaching the climax of complexity in many of the Radiolaria. So again, as in the case of form to which they contribute, nearly every shape of protective and supporting structure that can be imagined in a unicellular animal has been attained, and even the most elaborate of these are necessarily formed anew during reproduction and often repaired after mutilation. An example of the complexity of the process of shell-building is afforded by certain common freshwater rhizopods. Thus in *Difflugia*, with a simple shell composed of siliceous particles embedded in an organic matrix, the foreign material is gathered before fission and passed to the offspring during the process; while in the closely related *Euglypha,* plates and spines are secreted by the parent cell and later become arranged on the surface of the young animal. (Fig. 5.)



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 2.—AMOEBA PROTEUS. MAGNIFIED ABOUT 100 TIMES

Cell Body.—The cytoplasm of the protozoan body usually exhibits two general regions: an outer, clear, relatively homogeneous layer, or ectoplasm, and an inner, granular mass, or endoplasm, forming the bulk of the cell. The ectoplasm proper is physiologically delimited from its surrounding by an altered surface, or plasma membrane, which by virtue of selective permeability controls the diffusion of materials into and from the cell. Usually there is also a definite skin, or pellicle, that may either appear structureless or show striations, grooves, ridges or sculpturing in various ways,



FROM MACDOUGALL & HEGNER, "BIOLOGY: THE SCIENCE OF LIFE" (MCGRAW-HILL BOOK CO.), AFTER BAKER

FIG. 3.— EUGLENA AGILIS, A GREEN FLAGELLATE. MAGNIFIED ABOUT 1,500 TIMES

sometimes in relation to the protrusion of cilia or flagella. Also in the ectoplasm there may be skeletogenous material in the form of rods, plates and fibrils, and contractile fibres or myonemes, as well as specialized organelles serving other functions, particularly those which are in direct relation to the environment of the cell.

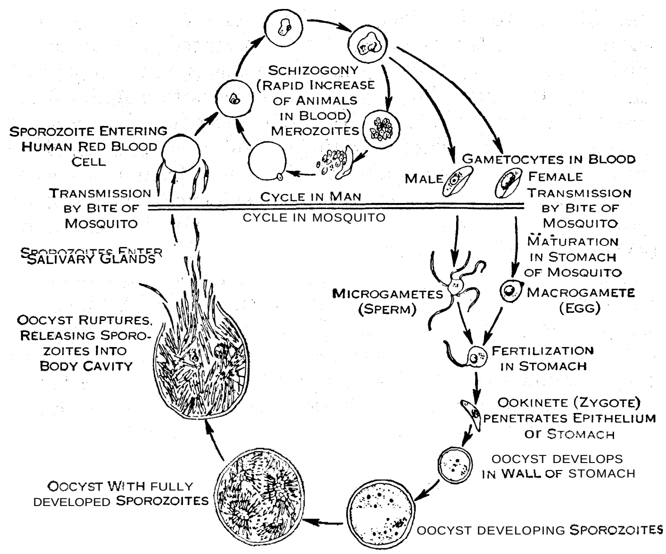
The endoplasm, in contrast with the ectoplasm, is relatively fluid, markedly granular and vacuolated; the last character giving the impetus to O. Buetschli's well-known "alveolar theory" (1878, 1892) of the finer structure of protoplasm. Within the endoplasm is the nuclear apparatus, comprising one or more nuclei, and most of the organelles, such as gastric vacuoles, contractile vacuoles and chromatophores, as well as stored proteins, carbohydrates and fats, and crystals and other metaplasmic bodies. Chondriosomes and Golgi bodies have been described in many species and probably are always present.

Motor Organelles. — Motor organelles—pseudopodia, flagella and cilia—have served from the time of Felix Dujardin (1841) to demark three of the great groups of Protozoa. Pseudopodia are temporary extensions of the body which range in complexity from mere outflowings of the protoplasm of the cell, as seen in Amoeba *proteus* and its allies, to more definitely formed structures as found in the Heliozoa and many Radiolaria. All pseudopodia function to some extent in locomotion and prehension of food, but the latter use predominates in many species. Four general types of pseudopodia may be distinguished, each of which is characteristic of certain species, though subject to considerable modification under varying surroundings. Lobopodia are relatively broad and usually blunt outflowings of both ectoplasm and endoplasm (*e.g.,* in common Amoebae); filopodia are long, slender, pointed threads of ectoplasm (*e.g.,* in *Euglypha*); myxopodia are threadlike and tend to branch and fuse to form large meshworks (*e.g.,* in the Foraminifera); and axopodia are relatively stiff raylike processes, each consisting of an axial filament arising from a basal body in the cell and enclosed by a layer of flowing protoplasm (*e.g.,* in the Heliozoa). Axopodia in certain species approach the structure of flagella and have been regarded as evidence of a close relationship between the Heliozoa and Mastigophora. (Figs. 2, 6.)

Flagella are long, vibratile threads of protoplasm which extend from the surface of the cell and function chiefly as locomotor organs, but also may serve to waft food-bearing currents toward the animal or to explore the immediate surroundings in a sensory capacity. The number of flagella varies in different species from one to hundreds, but usually does not exceed four. Typically they arise at the anterior end of the cell and project forward, but in many common species with two flagella (*e.g.,* Bodo sp.) one flagellum trails posteriorly, acting as a gliding organ or rudder. There may be considerable variations in length and also in form of the flagella in the same and different species. Most flagella are circular in cross section, but some are flattened or form the edge of an undulating membrane as in certain parasitic flagellates (*e.g.,* Trypanosomes). The finer structure of flagella is extremely difficult to determine, but from the study of favourable examples it evidently consists of two parts—an elastic sheath which envelopes an axial vibratile filament, the latter being an outgrowth of a basal body, or blepharoplast. The mechanism of flagellar movement is apparently inherent in the flagellum itself because it retains activity when isolated with its basal body. The basal body is a centriole, or a derivative of a centriole, which is usually situated just under the cell surface near the point of exit of the axial filament but may lie deeper and be closely associated with the nucleus. In many species the kinetic system is complicated by multiple basal bodies, parabasal bodies, axostyles, rhizoplasts and other elements of unknown function too diverse to be briefly summarized. (Figs. 3, 16, 19.)

Cilia are relatively short protoplasmic threads which arise from basal bodies in the ectoplasm of all species of the Ciliophora. They are usually exceedingly numerous and form longitudinal rows that may be evenly distributed over the surface of the cell or restricted to certain regions and differentiated for special functions. Thus the union of the cilia in a row or the union of rows of cilia, or both, form such complexes as undulating membranes and membranelles in the oral region for wafting food into the peristome, while the fusion of tufts of cilia constitutes bristlelike cirri for crawling and tactile purposes. The basic structure and mechanism of movement of cilia appear to be similar to that of flagella, but the effectiveness of ciliary action is caused by waves of contraction passing along the rows, each composed of a multitude of cilia coordinated by underlying fibres that connect the basal bodies. (Figs. 1, 14.)

Nucleus. — The nuclei of the Protozoa have the same basic structure and function as in metazoan cells: a nuclear membrane encloses the karyolymph in which are embedded achromatic and chromatic elements; the latter constitutes the definitive chromosomes. However, the nuclei show much more variation in general structure than do those of the 'Metazoa, and in many cases kinetic bodies are intranuclear. All attempts to arrange a satisfactory evolutionary series of nuclear types have failed, largely because diverse types may occur in obviously closely related species. It is customary to classify protozoan nuclei in a broad way as either vesicular or massive. In the former type



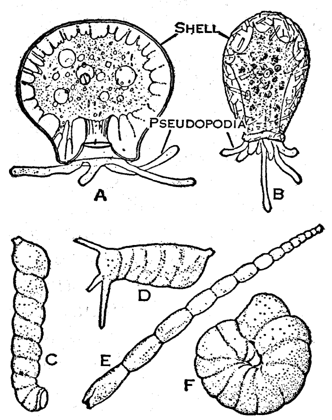
FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 4.—GENERAL SCHEME OF THE LIFE HISTORY OF A HUMAN MALARIAL PARASITE. PLASMODIUM

the chromatin is concentrated in a centrally located body, the endosome, surrounded by a zone of clear karyolymph; but there are many gradations between this condition and the massive type in which the chromatin is distributed evenly throughout so that the nucleus presents a comparatively homogeneous appearance. Both nuclear types may be found in the same genus: the micronuclei are typically vesicular in some species of Paramecium and approach the massive in others.

The majority of Protozoa contain a single nucleus, but there are many species with two or more nuclei, and some with hundreds. Common forms with many nuclei are represented by the large freshwater rhizopod, *Pelomyxa,* certain stages of the Mycetozoa and some of the parasitic ciliates of the frog, such as *Opalina.* Multiple nuclei may be present during nearly the whole life of a species, or only in stages preparatory to reproduction by multiple division.

A unique and characteristic condition prevails in nearly all of the ciliates, where the typical nuclear apparatus comprises two structurally differentiated parts: usually one relatively large macronucleus and one or more micronuclei. Both types divide during cell division, but the macronucleus is apparently a composite nucleus which as a whole divides amitotically in distributing its component elements which may individually divide mitotically. The micronuclei divide by typical mitosis and on them depends the origin of gametic nuclei, and the formation of a new macronucleus after fertilization as well as in a nuclear reorganization process known as endomixis (&. ').



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN), AFTER SEVERAL AUTHORS.

FIG. 5.— (A) ARCELLA SHOWING THE PROTOPLASM THROUGH THE TRANSPARENT SHELL AND ALSO PROTRUDING AS PSEUDOPODIA, (B.) DIFFLUGIA SHOWING THE SAME; (C-F) SHELLS OF FOUR SPECIES OF FORAMINIFERA. VARIOUSLY MAGNIFIED

In addition to the formed nuclei, sometimes there are granules distributed in the cytoplasm that have been released from the nucleus. Many of these take nuclear stains and are undoubtedly chromatin, but the chromatin nature of others is highly questionable. The chromatin granules, or chromidia, gave rise to elaborate theories, by R. Hertwig and his school, in regard to their cell function, particularly in reference to the nucleo-cytoplasmic relationship and to the origin of the nuclei of gametes. It is generally accepted that a delicately balanced proportionality normally exists between the volume of nucleus and cytoplasm of a cell, a relationship which, however, varies within limits during different phases of cellular activity. Granting this, it is assumed that the nucleo-cytoplasmic ratio is under certain conditions maintained by the elimination of chromatin from the nucleus. This may well be true, though crucial evidence that chromidia function in this way is lacking. But the aspect of the "chromidial hypothesis" which is of most interest assumes that formed nuclei, especially of the gametes, arise from chromidia in certain species. A number of categorical descriptions of such an origin have been given, but more recent observations demonstrate beyond peradventure in all cases that have been critically re-examined (*e.g.,* in the Foraminifera) that the nuclei of the gametes are formed by a continuous series of mitotic divisions involving definite chromosome distribution.

It is clear then that nuclear division, long believed to be amitotic in many Protozoa, is really mitotic since it involves the exact distribution of chromosomes or elements comparable with chromosomes in metazoan cells. This has been demonstrated by observations on dividing nuclei in certain species, and also by the results derived from genetic studies that can be interpreted only from the standpoint of a segregating mechanism as in Metazoa. It is true that the macronucleus of ciliates divides as a whole amitotically but, significantly, is replaced periodically from mitotically dividing micronuclei. Although in many species of Protozoa definitive chromosomes have not, actually been seen, in others specific chromosomes have been unequivocally identified in both the haploid and diploid state; *e.g.,* the diploid number in the sporozoan, *Aggregata eberthi,* is 12, and in the foraminifer, *Patellina corrugata,* is 24. In most cases the chromosome nurnber is within the usual range of that found in metazoan cells, say less than 50, although polyploidy may greatly increase the number, as in certain races of *Paramecium bursaria.* Again the number may mount to more than a thousand, as in the so-called polyenergid nuclei of some of the Radiolaria that may be essentially aggregates of nuclei.

In contrast with metazoan nuclei, the protozoan nuclear membrane usually persists during mitosis, and the centrioles or comparable kinetic agents, as well as the spindle, are intranuclear. However, variations are very numerous and range from cases where part of the mitotic apparatus is outside the membrane to those in which the whole mitotic figure arises in the adjacent cytoplasm (figs. 8, 9).

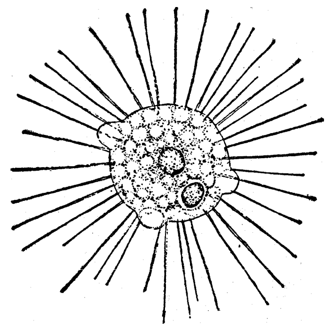
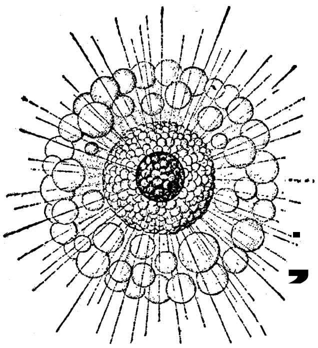

FROM KUDO'S "PROTOZOOLOGY," 3RD ED., P. 357, FIG 163 (1946) COURTESY CHARLES C THOMAS, PUBLISHER, SPRINGFIELD, ILL.

FIG. 6.—A HELIOZOAN, ACTINOPHRYS SOL. MAGNIFIED ABOUT 400 TIMES

Nutrition. — Various methods of nutrition occur in the Protozoa and, in general, these are characteristic of particular groups. Autotrophic, or holophytic, nutrition is found in the chlorophyll-bearing species, particularly in the phytoflagellates, and involves photosynthesis as in green plants, but some of these species, even in the light, require nitrogen in organic combinations, such as amino acids. In the absence of light most. autotrophic forms (*e.g., Euglena*) can absorb organic substances dissolved in the medium and so live by the saprozoic method, whereas many of the free-living flagellates without chlorophyll and nearly all parasitic Protozoa are solely saprozoic. But variations in details of nutrition are legion. For example, it appears that some of the free-living, colourless flagellates can be cultivated on a remarkably simple inorganic medium to which acetate has been added as a carbon source. Indeed, it is becoming increasingly clear from extensive studies on pure cultures of various species and races of flagellates, rhizopods and ciliates in controlled media, where the significance of vitamins, trace elements, and so on may be determined, that there are many intermediate gradations between typical autotrophic and saprozoic nutrition and between the latter and holozoic nutrition in which particulate food is required. To define this nutritional versatility a highly elaborate but unsettled terminology has been developed.

The majority of the free-living species are holozoic, ingesting solid food. usually micro-organisms, such as bacteria and yeasts, and other Protozoa. This involves the development of a wide variety of methods for securing and ingesting the food. In most rhizopods the mere contact of the nutrient material with nearly any point on the exposed surface of the protoplasm is followed by its gradual engulfment by pseudopodial action; in other species a special receptive point for ingestion is provided. This may consist, as in some flagellates, merely of an exposed region at the anterior end near the base of the flagellum, or, as in many ciliates, of a definite cytostome leading into the endoplasm. The cytostome may be terminal but more often in the ciliates it is situated laterally and ventrally in a funnel-like depression of the surface, the peristome, and opens into a tubular gullet extending into the endoplasm. Ciliary action in the peristome wafts the food particles in a vortex toward the mouth and accordingly it is in this region that special groups of cilia, such as undulating membranes and membranelles, are present. Species so provided feed continually if food is available because the mouth is permanently open. It has been conservatively estimated that a *Paramecium* may ingest as many as 5,000,000 bacteria in 24 hours. In various other species the mouth is open only when occasion demands. This is particularly true in the case of carnivorous forms which capture prey when chance brings it within reach, as is well illustrated by ciliates such as *Didinium,* whose sole diet consists of *Paramecium,* and *Spathidium,* which feeds on *Colpidium* and closely similar small ciliates. In such cases the food is "selected" by limitations imposed by the character of the oral apparatus. Thus the seizing organ of *Didinium* is in some way adapted so that it adheres to the pellicle of Paramecium and not to that of other organisms with which it happens to come in contact. Quite a different method of food capture is employed by the free-living Suctoria, which in the adult state are devoid of cilia but are provided with tentacles. Prey, such as a small ciliate, coming in contact with the tentacles is paralyzed, presumably by some poisonous secretion, and thereupon its endoplasm is sucked out until there is merely a collapsed remnant. (Figs. 10, 11).

In some species the ingested food appears to lie directly in contact with the endoplasm, but more often it is in a droplet of water, taken in at the same time, that constitutes a gastric vacuole. In most ciliates, such as Paramecium, the vacuole passes from the gullet into the endoplasm, where it is carried along a more or less definite course through the cell by cyclosis. During this passage digestive enzymes, etc., are secreted into the vacuole. The reaction of the vacuolar content varies from acid to alkaline, and the presence of proteinases and amylases has been demonstrated, but in very few Protozoa is there definite evidence of the digestion of fats. although this undoubtedly occurs. However, the details of digestion are largely undetermined, not only because of the delicacy of the technique involved in the study but also because the process varies in different species and in the same species with the nature of the available food. In any event the digestible contents of the vacuole gradually disappear as it circulates through the endoplasm and then the useless residue passes out of the cell, usually at a definite point, the cytoproct. It appears that gastric vacuoles containing material of no food value are rejected after a relatively short course in the cell. (Fig. 1.)



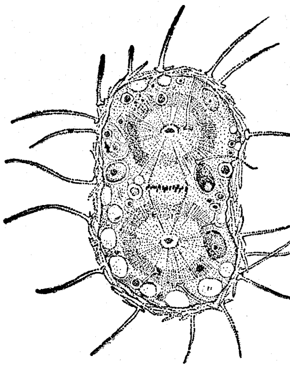
FROM KUDO'S "PROTOZOOLOGY," 3RD ED., P. 372, FIG. 169B (1946), COURTESY CHARLES C. THOMAS, PUBLISHER, SPRINGFIELD, ILL., AFTER HUTH

FIG. 7.—A RADIOLARIAN, THALASSICOLLA NUCLEATA. MAGNIFIED ABOUT 15 TIMES

Respiration. — With the wide distribution of Protozoa in nearly every ecological niche of nature, it is not strange that their respiratory processes show considerable variation. The majority of species are strictly aerobic, demanding free oxygen for their normal metabolic processes. This is secured with the intake of water with food and also by diffusion through the whole surface of the body, since structurally differentiated respiratory organs are not present. Similarly the outgo of CO_2 is apparently accomplished by the cellular membrane, probably incidentally aided to some extent by the contractile vacuolar system when it is present. The oxygen uptake and the CO_2 output varies greatly in different species and in the same species under altered internal and external conditions. Experiments indicate that the hourly rate of oxygen consumption of Paramecium *calkinsi* at 20° C. is of the order of magnitude of 28 cu.mm. per 100,000 animals.

Some typically aerobic forms are able to exist for a considerable time as facultative anaerobes and obtain energy from processes that do not require free oxygen, such as the breakdown of glycogen into lactic acid. Paramecium can survive for about 12 hours in the absence of free oxygen. But there are many species that are largely or entirely anaerobic, in particular various endoparasitic forms and those inhabiting mud and highly polluted sewage water. Indeed, free oxygen is lethal for certain species.

Contractile Vacuole.—One of the most interesting among the organelles of the Protozoa is the contractile vacuole that occurs in the majority of fresh-water species, but is usually absent in marine and parasitic forms other than the ciliates. The vacuole appears and disappears rhythmically from view as it gradually accumulates and then expels fluid from the cell. In most forms the vacuole occupies a definite position in the cell, but in Amoebae the general location changes as the animal flows along. Commonly there is only one vacuole, but some species possess two or several. Furthermore, the definitive vacuole, especially in the ciliates, may be the focus of a vacuolar system comprising accessory canals that radiate from the vacuole (*e.g.*, in Paramecium) or ramify widely through the endoplasm (*e.g.*, in Frontonia). In most cases the vacuole is supplied by the migration of tiny droplets of fluid and accessory vacuoles which coalesce at the contractile vacuolar locus or with some part of the canal system when such is present. Many observations indicate that at least some of the droplets of fluid originate in association with osmophilic material, probably representing the so-called Golgi apparatus.

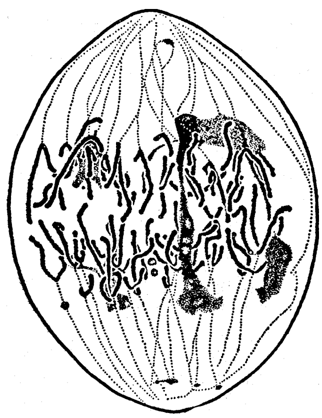


FROM STERN, "ARCHIV F. PROTISTENKUNDE" (FISCHER)

FIG. 8.—MITOSIS (METAPHASE) DURING DIVISION OF A HELIOZOAN, ACANTHOCYSTIS ACULEATA. MAGNIFIED VERY HIGHLY

Although it is difficult to determine the nature of the deliminating surface of the vacuole, it seems clear that some types are surrounded by a structural membrane in addition to the theoretically necessary physiological membrane. Again in some cases the vacuole discharges through a definitive excretory pore, while in others the pore is temporary. The rate of vacuolar contraction varies in different species and also in the same species with changes in the osmotic pressure of the surrounding medium, temperature, and other factors, but in general the vacuolar cycle ranges in duration from a few seconds to a minute.

The first significant suggestion relative to the function of the contractile vacuolar system was made in 1776 by Lazzaro Spallanzani, who regarded it as respiratory, but it is now believed, as first emphasized by M. Hartog in 1888, to be chiefly associated with the maintenance of the proper osmotic relations between the cell and its surroundings by regulating the water content of the protoplasm. A *Paramecium* with two contractile vacuoles may eliminate its own body volume of water in less than 20 minutes. That this system also acts in an excretory capacity to eliminate CO_2 and nitrogenous wastes has not been satisfactorily determined, though undoubtedly such material must incidentally, at least, pass out in the vacuolar fluid. However, the fact that many Protozoa are without contractile vacuoles makes it clear that these organelles are not invariably necessary for such indispensable functions.



FROM CHEN, PROCEEDINGS NATIONAL ACADEMY SCIENCES

FIG. 9.— NUCLEUS OF A CILIATE. ZELLERIELLA INTERMEDIA, IN MITOTIC DIVISION (ANAPHASE) SHOWING TWO DAUGHTER SETS OF 24 CHROMOSOMES. MAGNIFIED ABOUT 2,000 TIMES

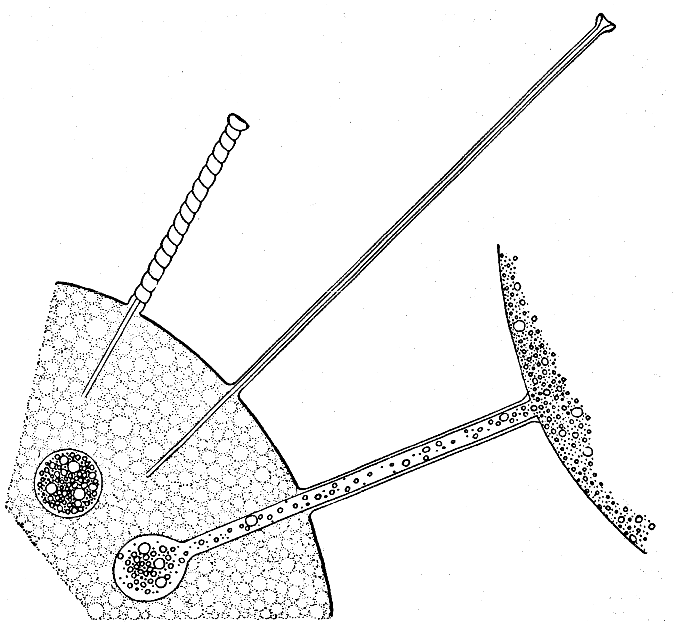
Reproduction. — Although reproduction in all animals and plants is basically dependent upon cell division, this is most evident in unicellular forms where the parent individual divides into daughter cells and so loses its individuality. The important types of cell multiplication in the Protozoa are commonly referred to as binary fission, budding and sporulation — all intrinsically asexual processes though in certain instances leading to the formation of gametes. Binary fission involves the division of the cell, both nucleus and cytoplasm, into two essentially equal daughter cells that grow into replicas of the parent. So stated the process seems simple, but obviously it involves making each half into a whole. Dedifferentiation of various structures in the parent cell must be followed by differentiation in the daughter cells. Although some organelles are taken over intact, in general the daughter cells are essentially "new" organisms. For instance, in many of the specialized ciliates it has been possible to show that the highly modified groups of cilia, or cirri, are resorbed and new ones arise in, or migrate to, the proper relative positions on the daughter cells.

Many gradations occur between binary fission and budding, or gemmation, in which the parent cell retains its identity while producing by division one or many daughter cells. Sometimes a bud is essentially as large as the parent, so the result is nearly the same as binary fission except that parent and offspring can be distinguished; but usually the bud is much smaller, less differentiated, and gradually assumes the parent form after it has become free. This condition is well seen in the sessile Suctoria, where the buds become detached as free-swimming, ciliated embryos which finally settle down and develop tentacles and other adult characters. In some species the buds arise on the surface of the parent and in others within deeply invaginated "brood chambers" from which they escape at "birth." The former is referred to as exogenous and the latter as endogenous budding.

Multiple budding leads by various transitions to sporulation, in which the nucleus of the parent cell divides a number of times, followed by the division of the cell body into as many cells as there are nuclei, so that the parent cell becomes resolved into many progeny. Sporulation is obviously a method of very rapid multiplication and is especially characteristic of parasitic forms, such as the Sporozoa with complicated life cycles including asexual and sexual phases. Thus in many species an asexual phase. known as schizogony, is followed by the development of sex cells and zygote formation. This in turn leads to spore formation, or sporogony, and so completes the life cycle. But other variations in reproduction are legion. For instance, so-called plasmotomy sometimes occurs in multinucleate species such as some of the Opalinid ciliates; the cytoplasm divides into two parts, each retaining the nuclei that are in it at the time. A continuation of this process may produce uninucleate cells. (Fig. 4).

Colonies.---Reproduction in the vast majority of the Frotozoa results in individuals that move apart and live a completely separate existence, but in certain species the cells formed by division remain associated so that colonies result. Protozoan colonies vary widely in form ranging from essentially amorphous groups of individuals, or zooids, embedded in a gelatinous substance, to those in which the zooids assume definite spatial relations with each other so as to constitute linear, platelike, spherical or arboroid colonics. All of the individuals composing a colony are, with few exceptions, structurally the same and physiologically independent, though the colony may swim by the combined action of the flagella of its component zooids (*e* g., *Gonium*) or contract as a whole by virtue of a common stalk (*e.g.*, certain arboroid colonies among the ciliates).

Colony formation in some of the phptoflagellates of the family Volvocidae is of special interest because there are various gradations from small groups of individuals, in structure quite similar to those of closely related noncolonial species. to complex colonies of thousands of cells. Representatives of the simpler types are the several species of *Gonium* that ere square, platelike colonies of from 4 to 16 zooids, usually in a gelatinous matrix; and of *Pandorina* and *Eudorina* that consist of spherical groups of 16 or 32 zooids similarly embedded. All of the zooids have the same structure and are capable of asexual and sexual reproduction. But a differentiation of somatic and reproductive zooids appears in various species of *Pleodorina,* comprising up to 128 zooids, and *Volvox,* often consisting of many thousands of zooids connected by protoplasmic strands and forming the surface of a gelatinous sphere. So there is a demarcation of somatic and germinal regions of the colony that is prophetic of the further individualization and attendant physiological division of labour characteristic of the true multicellular organisms. In the case of *Volvox,* particularly, the fact that it is difficult to draw a hard and fast line between a colony and a metazoan individual is evident, and probably such a colony would be regarded as an individual mere there not gradations between it and closely related noncolonial species. Students of phylogeny consider most acceptable the view that the Metazoa were derived from a spherical colony of flagel-



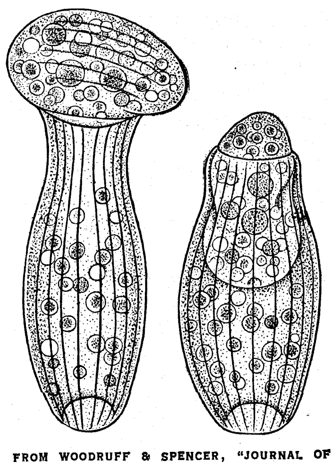
FROM NOBLE, UNIV. OF CALIF. PUBL. ZOOL., VOL. 37, P L 35, FIG. 4

FIG. 10.— SECTION OF THE SURFACE OF A SUCTORIAN, TOKOPHRYA LEMNARUM, SHOWING TENTACLES CONTRACTED, FULLY EXTENDED AND IN THE ACT OF FEEDING. MAGNIFIED ABOUT 2.000 TIMES

lates, not greatly dissimilar to *Volvox.* This view receives support from similarities in the method of development of *Volvox* and some calcareous sponges. (Fig. 12.)

Sex.—Sexual phenomena are wide-spread in the Protozoa but evidently are not universal, as was formerly assumed, because intensive studies of many species have given no supporting evidence. Sex in the Protozoa is expressed in the same basic way as in the rest of the animal kingdom. involving intrinsically the formation of male and female sex cells, or gametes, whose nuclei unite in the zygote to form a composite nucleus! or synkaryon. In some species mature sexual individuals, which are not recognizably differentiated except by their behaviour, unite in pairs and melt together, cytoplasm with cytoplasm and nucleus with nucleus, to form a zygote. In various other species the gametes show nearly all possible gradations in differentiation, both of size and behaviour, finally resulting in minute active sperm and large passive eggs as in most Metazoa. Furthermore, in the ciliates (*e.g.*, in *Paramecium*) a unique process known as conjugation prevails, in which two similar individuals come in contact and temporarily unite about the oral region. Then in each of the conjugants two gametic nuclei of micronuclear origin are formed. one of which migrates into the other conjugant and fuses with its "stationary" nucleus to form a synkaryon. Accordingly this exchange results in mutual fertilization of the conjugating animals which thereupon separate, re-establish the typical nuclear apparatus from the synkaryon, and proceed to reproduce by binary fission. However, in some ciliates, represented by the sessile Vorticellids, mutual fertilization does not occur; the conjugants are differentiated in size and behaviour so that free-swimming microconjugants unite with and fertilize sessile macroconjugants. (Fig. 13.)

In most instances the uniting, gametes are produced by distantly related cells, but sometimes the reverse is true. They may be separated merely by a cell division or two from a common parent, as in some heliozoans, *e.g.*, *Actinophrys* and *Actinosphaerium,* so that very close inbreeding, known as paedogamy, occurs; while in extreme cases the gametic nuclei arise and fuse in the



FROM WOODRUFF & SPENCER, "JOURNAL OF EXPERIMENTAL ZOOLOGY," (WISTAR INST. OF ANATOMY AND BIOLOGY)

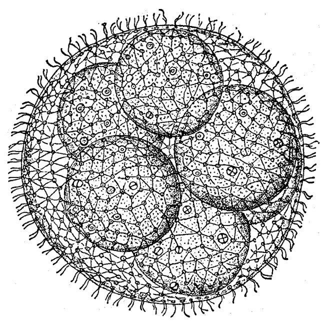
FIG. 11.—A CILIATE, SPATHIDIUM SPATHULA, CAPTURING AND SWALLOWING A COLPIDIUM. HIGHLY MAGNIFIED

same cell. that produced them and so-called autogamy results. The latter takes place under certain conditions in Paramecium and some other ciliates, as also does endomixis in which a synkaryon is not formed although a new nuclear apparatus arises from a micronucleus. Endomixis simulates many of the nuclear phenomena of autogamy but without the attendant genetic possibilities involved in fertilization.

Furthermore, so-called mating types exist in various ciliates. Thus in Paramecium aurelia six such types have been described, each type conjugating with its companion mating type but not with any of the others. When many animals of two companion mating types are mixed together, usually they soon become clumped in large groups which gradually are dispersed as the conjugating pairs swim away. The types are typically established at the reorganization of the exconjugants and are recognizable solely by their mating behaviour, which obviously differentiates the members of the species into physiologically incompatible genetical varieties from the standpoint of fertilization. Variations in mating types occur in other ciliates, involving both the number of types and of companion types for each. The significance of these types in regard to sex phenomena in general is not as yet clear, some authorities interpreting them as evidence of multiple sex systems.

The nuclei throughout the trophic life of most Protozoa contain the diploid number of chromosomes characteristic of the species. Reduction to the haploid condition occurs, as typically in the Metazoa, during the formation of the gametic nuclei, and their union restores the diploid number in the zygote. However, some instances are know, especially among the phytoflagellates and sporozoans, where reduction takes place immediately after fertilization so that only the zygote is diploid. (Fig. 9.)

Genetics.— Reproduction by division unaccompanied by fertilization, *i.e.*, uniparental reproduction, results as a rule in offspring with all their characteristics the same; collectively they constitute a clone. But there are some exceptions of great interest because the clone becomes differentiated into lines of descent with divergent characters. Some of these changes are physiological, such as acclimatization to various temperatures and chemicals, whereas others are morphological, such as size and shape. Some are adaptive and some are not. In certain cases the changes directly attributable to the influence of environmental conditions are inherited for hundreds of generations after the conditions leading to their establishment no longer are present, but in most instances, perhaps all, they gradually disappear. This supports the view that such so-called enduring modifications are chiefly cytoplasmic and are not established in the basic genetic system, as also does the fact that most of them are altered or disappear after sexual reproduction. But some of the heri'table variations within a clone occur without obvious environmental influence, and long-continued selective breeding may isolate and establish different strains. Presumably these are the result of mutations, but how any of the changes during asexual reproduction actually arise is not as yet clear, although the fact remains that they form divergent lines of descent, some of which may be important in the differentiation of species.



FROM DOFLEIN, "PROTOZOENKUNDE" (FISCHER), AFTER KLEIN

FIG. 12.—VOLVOX SP. WITH FIVE DAUGHTER COLONIES PRODUCED ASEXUALLY. MAGNIFIED ABOUT 150 TIMES

However, the chief immediate source of variation arises, as would be expected, from sexual reproduction. In all of the diploid species, as well as in the relatively few haploid forms, inheritance, so far as known, follows the typical Mendelian principles and their extensions, involving segregation, independent assortment, dominance, linkage, crossing-over, etc. But, of course, there are no recessives in haploid species; the offspring manifest combinations of all the characters evident in the parents.

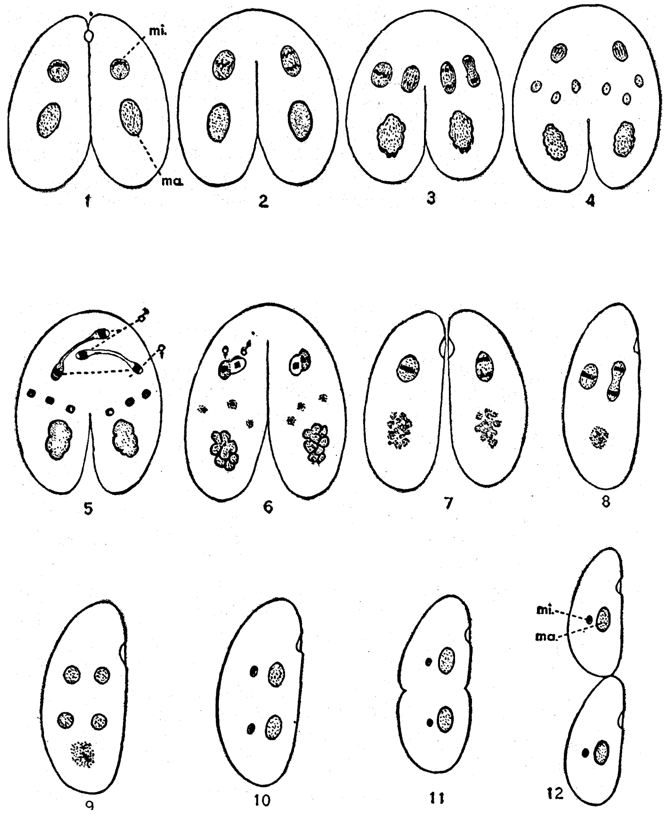
Furthermore, recent work with pedigreed cultures of Paramecium aurelia reveals definite proof of the interaction of specific dominant genes and cytoplasmic factors, both of which must be present if the character involved is to be expressed in the individual, or phenotype. The cytoplasmic element cannot be perpetuated in the absence of the dominant gene in the macronucleus, and the gene cannot initiate the synthesis of the cytoplasmic element. The latter has been referred to as a "primer" of the gene. Obviously this result offers highly significant data for the interpretation of so-called cytoplasmic inheritance in general.

In brief, fertilization in the Protozoa, as elsewhere in animals and plants, produces hereditarily diverse strains from the two uniting gametes and thus is a source of variation that is of crucial importance in adaptation and evolution. And from the standpoint of evolution it is of great significance that the intrinsic genetic mechanism involved is the same from the Protozoa to the highest organisms, including man.

"Cycles."—In addition to its genetic results, fertilization contributes a dynamic effect that arises from the profound reorganization process involved. This aspect of fertilization has been widely studied in pedigreed races of many species of Protozoa ever since it was emphasized by the work of E. Maupas in 1888 and 1889, and elaborated by G. N. Calkins in a series of investigations begun in 1902. In general these studies on ciliates indicated that at conjugation there is initiated a cycle of reproductive activity. Thus after conjugation the rate of division rises for a considerable number of generations and then gradually wanes until death ensues unless the line is "rejuvenated" again by conjugation. This conclusion, if generally true, is of fundamental significance. But other work by various investigators has not only demonstrated that many species of Protozoa, in which fertilization normally occurs, can live under favourable environmental conditions in pedigreed cultures for many years and thousands of generations— apparently indefinitely— when fertilization is excluded, but also has revealed that there are others in which fertilization evidently does not occur at all in the life history. Therefore it is clear that basically fertilization is not a necessary phenomenon to counteract a general inherent tendency to degeneration and death in the Protozoa; and this is in agreement with the apparently limitless vegetative propagation of many plants and the greatly extended life of body cells of higher animals when cultivated in vitro.

Granting that fertilization in the Protozoa is not intrinsically indispensable, extensive experiments nevertheless have shown, particularly in the ciliates *Uroleptus* and *Spathidium*, that when conjugation does occur it actually produces a stimulation of the cell, especially evident in its rate of reproduction. Accordingly the dynamic aspect of conjugation may be of crucial importance— indeed have a survival value—when the organisms are exposed to unfavourable conditions. And the same result probably follows self-fertilization (autogamy), and also endomixis which involves nuclear reorganization without synkaryon formation.

Regeneration.— The power of replacing portions of the cell and specific organelles not carried over at the time of binary fission is, of course, universal in the Protozoa, but nearly equally so is the capacity to regenerate parts lost by mutilations of various kinds at other times in the life of the organism. Both processes are basically similar, involving dedifferentiation, growth, differentiation and reorganization. The animal may retain and remodel old structures, or discard and replace them in a great variety of ways. In some instances a very small amount of cytoplasm with a nucleus suffices for a complete restoration of form. Indeed, under favourable conditions in some of the ciliates, *e.g., Spathidium,* a complete individual capable of division may regenerate from a nucleated piece comprising less than 10% of the original volume of the individual, while much less than this amount may



FROM TURNER, "FERTILIZATION IN PROTOZOA," IN CALKINS AND SUMMERS, EDS., PROTOZOA IN BIOLOGICAL RESEARCH (COLUMBIA UNIV. PRESS)

FIG. 13.—GENERAL PLAN OF CONJUGATION IN CILIATES

1, two individuals joined ventrally, micronuclei in early mitosis; 2, first meiotic (equation) division; 3, second meiotic (reduction) division, macronucleus beginning to degenerate; 4, third division of one of the nuclei in each animal to form the gametic nuclei; 5, exchange of the male (♂) gametic nuclei; 6, fusion of gametic nuclei to form synkaryon and restore diploid condition; 7, conjugants separate, first division of synkaryon; 8, second division of synkaryon; 9, four nuclei produced by the two divisions of the synkaryon, the old macronucleus disintegrates; 10, two of the four nuclei develop into new micronuclei, two into new macronuclei; 11 and 12, first fission of the exconjugant distributes one micronucleus and one macronucleus to each daughter cell, re-establishing the vegetative condition.

suffice for restoration of form without the ability to reproduce. But many other factors besides size and the presence or absence of the nucleus influence the result; among them being the part of the cell involved, the relative amount of ectoplasm and endoplasm present, the phase in the life history, etc. Although a nucleus is necessary in all cases for complete regeneration followed by normal fission, enucleated fragments may survive many hours or until destructive metabolic processes gain ascendancy. In the ciliates either a micronucleus or part of the macronucleus must remain if complete regeneration and reproduction are to occur. Amicronucleate races which are commonly found in some species possess the same power of regeneration as do typical micronucleate individuals.

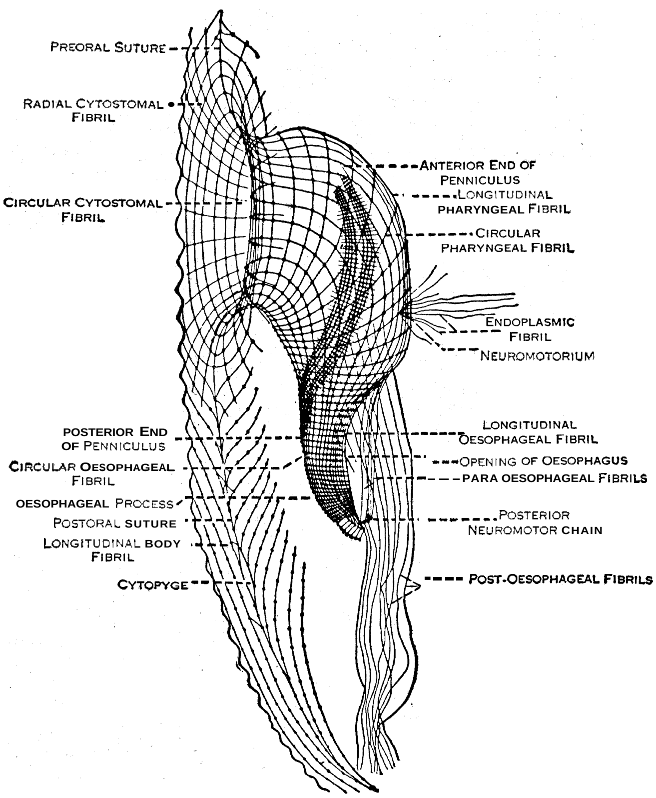
Behaviour.—All Protozoa, of course, respond to many environmental factors. The reception of stimuli occurs in general over the entire surface of the cell, but sometimes special receptors are also present. Apparently pseudopodia, flagella, cilia, cirri, etc., act as tactile organs and probably as chemical receptors, but the most specialized sensory structures are photoreceptors such as the stigma. or eye spot, of many chlorophyll-bearing flagellates, represented by the various species of *Euglena* and *Volvox.* In the latter the organelle consists of a cup of pigment surrounding a photosensitive substance, and a lenslike structure near the opening of the cup. Evidence indicates that the lens brings certain light waves to a focus on the photosensitive material. More remarkable still is the eyelike apparatus of certain Dinoflagellates which is provided with a large spherical lens.

The effect of stimulation in most cases is conducted by the entire cell, but at least in certain ciliates, such as *Epidinium* (*Diplodinium*), *Euplotes* and *Paramecium,* a so-called neuromotor system of conducting fibres is found. This system is integrated with the general supporting ectoplasmic fibrillar network and specifically comprises a complex of fibres that ramify from a focus, or motorium, near the gullet and terminate at the basal bodies of the cilia or cirri. Experiments indicate that the system has a conductile function, because severance of the relationship of the fibres with the motor organs results in the loss of co-ordinated movement by the latter. (Fig. 14.)

Motor responses to particular agents are referred to as chemotaxis, thermotaxis, phototaxis, galvanotaxis, etc., in accordance with the nature of stimulus involved. Apparently in actively motile forms the reactions to stimuli are of two general but related types, one involving the trial and error method and the other directive action. In the former type of motor reaction an animal when stimulated stops and retreats, then turns at an angle to its previous course and proceeds again. And this avoiding reaction, or shock reaction, is repeated until, if possible, the animal is removed from the stimulating agent. In general, unfavourable stimuli induce responses whereas favourable ones do not, and accordingly the animals tend to collect where optimal conditions prevail; the reactions, though negative, are in the long run adaptive. In contrast to such responses, directive reactions are relatively rare and, indeed, intrinsically may involve shock reactions although the organism moves toward or away from the stimulus. They are best exhibited in the response of some chlorophyll-bearing flagellates to light, and of various species to electric currents. Changes in the intensity or direction of light rays so affect the stigma that by a series of responses the organism becomes oriented with its long axis parallel with the beam of light. If the anterior end of the cell is oriented toward the source of light, progression is in that direction. Such positive phototaxis is usual in the green flagellates, but is subject to modification by various factors, such as abrupt changes in the intensity of the light or the chemical condition of the environment: as indeed are all reactions of the Protozoa. Most Protozoa exhibit galvanotaxis by directive responses to the passage of an electric current. Amoebae extend pseudopodia toward the cathode and move in that direction. Flagellates usually proceed toward the anode and ciliates toward the cathode, largely as a result of the direct action of the current on the locomotor organs. Accordingly, when certain flagellates and ciliates are intermingled on a slide under the microscope, they can be separated by the passage of a constant current —anodically galvanotactic flagellates moving to one pole and cathodically galvanotactic ciliates to the other. Then if the current is reversed the two groups rush toward each other, pass and again assemble at opposite poles.

But the behaviour of the Protozoa is not so stereotyped as might appear from the relatively simple reactions just mentioned. In certain cases these may be integrated so that the animals exhibit potentialities beyond those of mere automata. This condition may be glimpsed if a ciliate, *Stentor roeseli,* while sessile is stimulated by a tiny stream of carmine grains. In general, when the useless carmine first reaches the peristome no reaction occurs, but as the carmine continues, the animal bends over to one side. If this behaviour does not remove the stimulus, the ciliary beat is temporarily reversed so that the carmine momentarily does not reach the oral apparatus. And, if the stimulus still continues, the organism contracts more or less violently and, finally, becomes detached and swims away. Furthermore, when a *Stentor* which has reached the contraction stage in the series of reactions is stimulated again within a few minutes, it does not run the gamut of responses but immediately contracts. Obviously a series of different physiological states has been initiated, since the animal successively responds in a different manner to the same stimulus. Behaviour is modifiable.

Explosive Organelles. — Prominent among the various specialized organelles that contribute to the versatility of the protozoan cell are trichocysts and similar explosive structure. Trichocysts occur in many ciliates and have been most intensively studied in *Paramecium*, where they are quite evenly distributed



FROM LUND (UNIV. OF CALIF. PUBL. ZOOL., VOL. 39, P. 48, FIG. A)

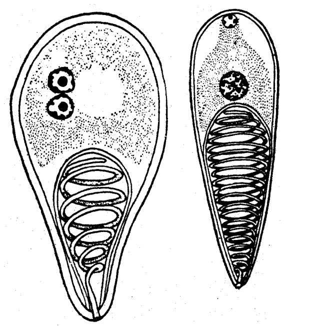
FIG. 14—DIAGRAM OF THE NEUROMOTOR SYSTEM IN THE PERISTOMIAL REGION OF PARAMECIUM MULTIMICRONUCLEATUM VERY HIGHLY MAGNIFIED

just beneath the surface of the cell. Each trichocyst is a minute, spindle-shaped body which, on mechanical or chemical stimulation, ejects material that instantaneously forms a relatively long filament projecting from the cell. The function of the threads has not been determined but probably is protective. Exploded trichocysts may be replaced by new ones. More complex trichocysts, called cnidotrichocysts, occur in other species, for example the ciliate *Prorodon,* where they consist of a capsule containing a coiled tube which on discharge is everted and apparently passes material to the exterior. Indeed in some species it is evident that toxic material is secreted because free-swimming prey is paralyzed upon contact with the oral region to which the trichocysts are confined. Cnidotrichocysts closely approach in structure the nematocysts of coelenterates, as is evidenced by the fact that especially complex examples found in two genera of dinoflagellates were formerly regarded as ingested nematocysts. Again, an immense group of the Sporozoa is known as the Cnidosporidia because the highly specialized spores are characterized by so-called polar capsules, each containing a spirally-wound thread that evaginates and apparently serves as an anchor when the proper position is attained in a new host. The diversity of structure and function of explosive organelles makes it obvious that they have evolved independently in different groups of Protozoa. (Fig. 15.)

Encystment.—Many species of Protozoa have the ability to seal themselves in essentially impermeable cases, or cysts, to meet various exigencies of the environment or to carry on digestion and reproduction. So-called protective cysts enable the organism to withstand desiccation, lack of food and other conditions inimical to active life and are most common in fresh-water and parasitic forms. The general procedure of encystment in free-living species, such as many ciliates, involves a complex series of events. The animal becomes quiescent while cilia, flagella, and other organelles not absolutely essential for life are resorbed, and food and inert material are ejected. Contractile vacuoles function more and more slowly and finally disappear as water is eliminated and the body becomes a relatively small sphere. While this dedifferentiation is proceeding, the cyst wall is secreted which commonly consists of an outer gelatinous layer, or ectocyst, and an inner delicate membrane, or endocyst, but there is great variation in composition and structure. The ectocyst rapidly hardens and frequently has characteristic spines, warts, etc. Within this resistant case the dormant animal, with all life processes reduced to a minimum, can survive unfavourable conditions for long periods of time. Thus cysts in samples of dry soils, tightly bottled, have yielded the ciliate *Colpoda* after 38 years, and small amoebae and flagellates after 49 years, when supplied with culture fluid; but the evidence indicates that most ciliates encysted on dry hay rarely survive more than five years. The process of excystment is broadly the reverse of encystment and is initiated by the presence of moisture or, if the cysts are already in water, by the return of favourable temperature, chemical conditions and the presence of food. The endocyst is dissolved by enzyme action induced by the animal, which thereupon ruptures the ectocyst and escapes to assume its typical form.

The world-wide distribution of many of the Protozoa is probably dependent to a large extent upon their ability to encyst, which enables them to be transported in numerous ways, such as by adhering to the feet of birds or to dry grass, and by being wafted by air currents. However, results obtained from the exposure of sterile culture media to the atmosphere indicates that only a relatively few species are usually disseminated in the air: chiefly tiny amoebae and flagellates and the ciliate *Colpoda.* And, incidentally, there is no completely satisfying evidence that the cosmopolitan *Paramecium* encysts, in spite of the prevalent notion that a culture can be established by the infusion of dry hay in sterile water.

In many parasitic forms, notably the Sporozoa, cysts are crucial in order that the parasite may weather the outside world during chance transfer to a new host. Indeed, the absence of protected stages during a parasite's life history usually indicates that it is directly transferred by an intermediate host. Many of the highly specialized protective cysts of parasites are also reproduction cysts because spore formation and other types of multiplication occur in them. Encystment in such cases does not involve a dedifferentiation of the animal but rather its specialization for the reproductive process. Furthermore, various free-living species encyst for reproduction, fertilization or simply to digest a heavy meal. In the life history of the foraminiferan *Patellina corrugata* growth cysts, fission cysts and fertilization cysts occur in sequence. Obviously, then, protozoan cysts serve such various functions, sometimes several simultaneously, that it is often impossible to distinguish sharply among the many types.



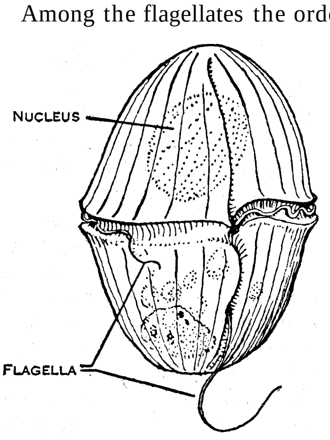
FROM CALKINS, "BIOLOGY OF THE PROTOZOA" (LEA & FEBIGER), AFTER KUDO

FIG. 15.—CNIDOSPORIDIAN SPORES WITH POLAR CAPSULES. VERY HIGHLY MAGNIFIED

DISTRIBUTION

Protozoa are essentially ubiquitous wherever moisture is available, but certain species are, of course, adapted to special habitats so that characteristic faunas develop. Excluding for the moment parasitic species that constitute highly specialized groups within nearly all higher animals and some plants, a few representative examples of marine and fresh-water faunas will serve as examples, but it must be borne in mind that each of these major faunas is, in turn, formed of numerous relatively local faunal groups.

Among the flagellates the order Dinoflagellata stands pre-eminent in its contribution to the microscopic life of the sea. Typical dinoflagellates possess two flagella, usually lodged in grooves, one encircling the body and the other trailing posteriorly. Nutrition is commonly autotrophic through the presence of chromatophores, but many holozoic and parasitic species occur, and some ,of the zooxanthellae in the Radiolaria and Foraminifera are apparently symbiotic dinoflagellates. Although some species abound in fresh waters and are troublesome in municipal reservoirs, they are inconsequential in comparison with those constituting the marine fauna which plays an important part in the nutrition of oceanic life as a whole. This is chiefly because of photosynthetic activity that makes many species a first link in the nutritional chain and so an integral part of the so-called ocean pastures; but some species exist in such prodigious numbers that they directly constitute a significant part of the food of tiny invertebrates and so indirectly of higher animals. Vast areas of the sea may be discoloured by their presence; thus not infrequently the water appears orange like "tomato soup" from the presence of incalculable numbers of the cosmopolitan *Noctiluca miliaris,* and the same organism is responsible for much of the luminescence of marine waters. (Figs. 16, 17.)



FROM WOODRUFF, "FOUNDATIONS OF BIOLOGY" (MACMILLAN)

FIG. 16.— A DINOFLAGELLATE, GYMNODINIUM SP. MAGNIFIED ABOUT 500 TIMES

The great contributions of the rhizopods to the microfauna of the sea are made by the Foraminifera and the Radiolaria. Most species of the former are bottom-dwellers that creep on the surface of the mud and ooze or attach themselves loosely to foreign material, but pelagic species are represented by enormous numbers of individuals. The shells, composed chiefly of calcium carbonate, sink to the bottom and contribute to the Globigerina ooze, so called because of the predominance of members of the Globigerinidae and closely related forms. This and similar deposits cover vast areas—perhaps one third of all the ocean floor down to approximately 5,000 yd.—and have been computed to be accumulating in certain regions at the rate of about 12 mm. in 1,000 years. At greater depths other species with arenaceous shells persist. Deposits during the geologic past are represented today by' limestone, as seen in the chalk cliffs of England. Various types have rather definite geologic and geographic ranges and therefore are of significance in determining the age and characters of sediments and the general conditions under which they were laid down. Such knowledge is of great value in checking well-drillings and accordingly in locating oil-bearing strata. (Fig. 5.)

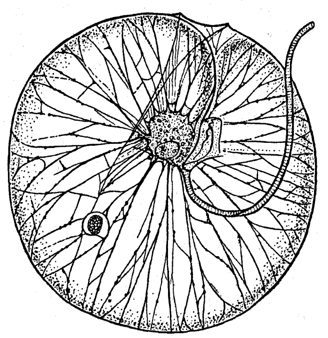

FROM PRATJE, "ARCHIV F. PROTISTENKUNDE" (FISCHER)

FIG. 17.—NOCTILUCA MILIARIS. MAGNIFIED ABOUT 50 TIMES

Although a few species of the Foraminifera inhabit fresh and brackish water, the Radiolaria are solely marine and adapted to a pelagic life. The body is typically spherical or conical and is usually supported by a silicious skeleton in a bewildering array of beautiful patterns. The distribution of the group as a whole is very extensive, both horizontally and vertically, and the skeletons accumulate in the great depths of the sea where calcareous shells of other forms become dissolved. Here in association with sponge spicules, diatom tests, and so on, they form the chief element of the Radiolarian ooze. And in the geologic past their skeletons have made large contributions to silicious rock. (Fig. 7.)

The ciliate fauna of ocean waters is by no means inconsequential, but it is not comparable in importance with those of the flagellates and rhizopods. Most typical is the wealth of marine species and individuals of the Tintinnidae, pelagic heterotrichous forms provided with vaselike protective cases consisting chiefly of a secreted organic material moulded into widely divergent but specific patterns.

As to the more varied conditions afforded by bodies of fresh water, it is impossible even to summarize the distribution of large groups of Protozoa in such broad terms. Members of the three free-living classes flourish everywhere in puddle, pond and lake, and some occur in hot springs and Arctic waters. Most of the common species abound in similar places the world over. Many species are remarkably adaptable, being equally at home in fresh or brackish water or even in the sea. Although this is true, very slight variations in conditions, particularly the type of available food and the chemical constituents of the environment, determine the presence or absence of certain species. For instance, *Paramecium* feeds chiefly on bacteria, and *Didinium* solely on .*Paramecium,* so that depletion of the bacteria eventuates in the encystment of *Didinium.* This interdependence seems relatively clear-cut, but it involves various other factors not immediately apparent.

The practical impossibility of analyzing many of the elements involved in the "web of life," even in a relatively restricted environment, is well exhibited by the general development of an infusion of a few wisps of hay and water. Here the obvious components merely supply the matter and energy for the interplay of various micro-organisms present in a dormant or active state on the hay or in the water. A microscopical examination of a newly-made infusion shows very few active organisms, but if the temperature is favourable countless bacteria arise in a day or so from the relatively small number originally present. Then during the period of bacterial ascendancy another factor intrudes itself: microscopic animals, chiefly Protozoa that have been multiplying with increasing rapidity as conditions became more favourable, soon become the dominant life phase in the infusion. Usually first to appear are various species of minute flagellates, some saprozoic and others holozoic, that employ the products of organic disintegration supplied by the activity of the bacteria and the bacteria themselves. Then tiny ciliates, such as *Colpidium* and *Colpoda* appear in countless numbers and feed on the bacteria. This dominance of small ciliates is terminated after a time by the ascendancy of larger ciliates which, though feeding to some extent on the now greatly depleted bacterial population, employ chiefly the smaller Protozoa as food. And so the general nutritional cycle in the infusion continues with attendant chemical changes; saprozoic species are gradually replaced in dominance by herbivorous types, and these in turn by others that are carnivorous. But clearly this sequence of events must sooner or later terminate; extermination faces the population unless chlorophyll-bearing organisms are present to entrap and store the energy of sunlight—to form food photosynthetically. If such occurs, the hay infusion world is, indeed, a microcosm in which the various Protozoa and other organisms are reciprocally adjusted so that essentially a stable equilibrium results. (Fig. 11.)

Most free-living Protozoa find larger and relatively stable bodies of water conducive to their welfare, but specialized conditions do not always exclude them. Thus various species inhabit the fluid in the traps of carnivorous plants, such as the bladders of *Utricularia* and the pitchers of *Sarracenia,* and others flourish in the water in holes in trees. Most of these species are incidental sojourners but some apparently are especially adapted to the microclimatic factors in such unique environments. Indeed, the examination of blades of grass moist with dew usually reveals certain species making the most of a brief opportunity for activity before returning to the encysted state. And within the soil an immense fauna of Protozoa contributes to soil microbiology in association with bacteria and other fungi, algae, and various lower animals. It appears that the majority of the Protozoa present are essentially cosmopolitan in distribution from the arctic regions to the tropics, though there are certain dominant types in nearly every soil. Most protozoan forms are found in the upper six inches of soil, but large numbers may be several feet below the surface. In general the number of species and individuals present is in direct proportion to the number of bacteria, being most numerous in rich, moist soils. Some idea of the size of the population may be gained from the fact that in one study it was estimated that at the maximum there were more than a million amoebae and flagellates per gram of soil. The view has been urged that the Protozoa may be inimical to soil fertility by destroying types of bacteria important for crop growth. This remains to be proved; but that the Protozoa form an important, active element in the soil microcosm is certainly true, even though many are in the encysted condition for considerable periods. Again here it seems clear that among the various species present some are mere casual inhabitants, while others constitute an endemic soil fauna. And in passing it should be noted that various Protozoa play a part in the so-called self-purification of streams by depleting the bacterial population, whereas others add to the contamination of municipal water supplies chiefly by liberating oily products of metabolism which impart odours to the water that may render it unpalatable. In brief, the adaptability of the Protozoa is so great that they have left hardly a niche in nature untenanted—not even in the bodies of other organisms.

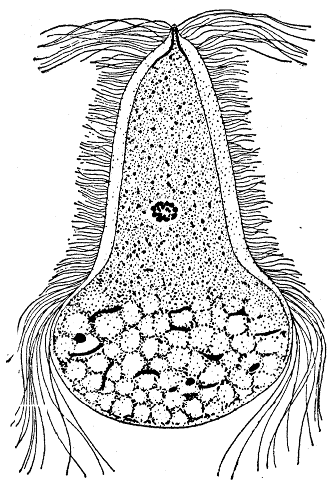
PARASITISM

The intimate association of Protozoa with other animals as commensals, symbionts, or parasites is widespread, but often it is difficult to distinguish between these types of relationship because one may grade into the other, or the same species may act in different capacities under varying conditions. Commensal associations incur no injury to either species involved, the protozoon merely gleaning food as a result of its position on the surface or in the interior of its host. Common ectocommensals among the ciliates are various vorticellids and suctorians attached to hydroids, and *Kerona* and *Trichodina* that crawl on *Hydra*. Endocommensals are more numerous, being widely distributed especially in the digestive tract of higher animals. Among them are most of the bizarre faunas of ciliates that inhabit the stomach or intestine of various herbivorous mammals, such as sheep, cattle and horses; and some of the flagellates and amoebae present in the human intestinal tract.

Symbiotic species, in which the relationship is mutually beneficial, are relatively few but include interesting examples. Thus the common *'Paramecium bursaria* harbours unicellular green forms, or zoochlorellae, in its endoplasm where they multiply and, in return for a relatively safe abode and waste products of metabolism, supply the products of photosynthesis when light is available. Again an immense number of highly specialized flagellates, such as the various species of *Trichonympha* and their allies, dwell in the intestines of certain termites and wood-feeding roaches where they secrete enzymes that digest cellulose and thus make the products available to their hosts. If the flagellates are removed the insects die of starvation. And at least a few of the ciliates mentioned above that inhabit the digestive tract of cattle apparently perform a similar function, although here digestion of cellulose is dependent chiefly upon bacteria. Furthermore, in these and other cases where the protozoan fauna is enormous it may well be that it directly affords an appreciable increment to the nitrogenous food supply of the host. (Fig. 18.)

Associations in which one organism, the parasite, secures the sole advantage at the expense of the hapless host are by far the most numerous. As already mentioned, protozoan parasites have been found in nearly all higher animals that have been investigated, and they also occur in some plants. Even the Protozoa themselves are not immune. Thus a species of amoeba infests the endoplasm of certain opalinid ciliates which, in turn, live in the frog—an example of hyperparasitism.

The most intensively studied protozoan parasites are naturally those which produce serious maladies in man, in particular the malarial organisms, trypanosomes, and endamoebae. The human malarial parasites are members of a large group of the Sporozoa that are known as Haemosporidia because a part of the life history is spent in the blood of vertebrates. Very closely related to the malarial forms in man are those that parasitize birds, and their study has contributed largely to the knowledge of malaria in general. Four species of human malarial parasites had been recognized by 1945, three of them being outstanding in importance: *Plasmodium vivax*, the cause of so-called benign tertian malaria, P. *falciparum* of malignant tertian malaria, and *P. malariae* of quartan malaria. P. *ovale* also produces a benign type of tertian malaria. The life histories of all four species follow a similar general basic plan with a mosquito of the genus *Anopheles* as the invertebrate host. Asexual stages (sporozoites) inoculated by a mosquito into the human blood stream multiply in the red blood cells and probably also in the reticulo-endothelial tissues. Eventually gamete-forming stages (gametocytes) arise which demand transfer from the peripheral blood to a mosquito for further development. If this hazard is met, gametes develop and fertilization occurs in the stomach of the mosquito and then the motile zygote enters the stomach wall and forms a large oocyst within which myriads of sporozoites are formed. Rupturing of the oocyst releases the sporozoites into the body cavity from whence they reach the salivary glands of the mosquito, ready to be inoculated into man. (Fig. 4.)



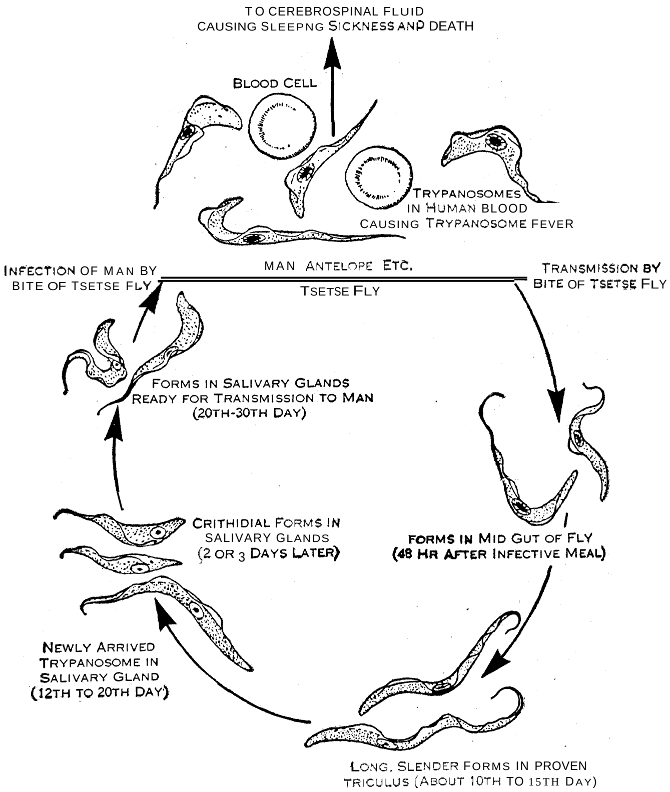
FROM CALKINS "BIOLOGY OF THE PROTOZOA" (LEA & FEBIGER), AFTER KOFOID & SWEZY

FIG. 18.—TRICHONYMPHA CAMPANULA. MAGNIFIED ABOUT 300 TIMES

The most important parasitic flagellates are members of the genus *Trypanosoma* that infest chiefly the blood stream of various vertebrates, including man, usually after a cycle of development in blood-sucking invertebrates. Trypanosomes show considerable change in form during the life history, but the typical "adult" phase found in the vertebrate circulatory system is an elongated bladelike organism, with the flagellum arising from a basal body near the posterior end of the animal and then passing forward as the edge of a delicate undulating membrane to emerge at the anterior end as a free flagellum.

The most important pathogenic forms in man are *Trypanosoma gambiensi*, the causative agent of typical African sleeping sickness, and T. *rhodesiensi*, which produces a similar but still more virulent effect. Both species are morphologically indistinguishable from each other and from *T. brucei*, which does not infect man but is the cause of "nagana" in domestic cattle of tropical Africa. All three are transmitted by tsetse flies and apparently are nonpathogenic in their natural reservoirs, certain antelopes and other wild mammals, and are essentially physiological races of one species. Another human trypanosome of high significance is *T. cruzi*, the cause of Chagas' disease, which is chiefly prevalent in Central and South America. The parasite is transmitted by triatomid bugs and multiplies in various organs of the human body. Most trypanosomes cause little disturbance in their natural hosts; for example, *T. theileri*, transmitted to cattle by tabinid flies and *T. lewisi*, to rats by fleas. The vectors of the trypanosomes of aquatic vertebrates are usually leeches, as in the case of *T. rotatorium* of the frog. (Fig. 19.)

Among the rhizopods that infest man the only true parasite is *Endamoeba histolytica*, formerly believed to be confined to tropical regions but now known to be cosmopolitan in distribution. The other five species are harmless commensals, although E. *gingivalis* of the mouth may take advantage of otherwise infected gums, and is apparently transmitted by contact because cysts are unknown. In the case of E. *histolytica*, encysted stages reach the human intestine, usually in contaminated water or food, where excystment occurs, and the amoebae multiply in lesions they produce in the wall of the colon. In many cases no observable pathological symptoms follow while the amoebae produce a continuous supply of cysts which pass to the outer world, ready to infect another host. The evacuation by the host of more than 40,000 cysts in one day has been recorded. But sometimes this



ADAPTED BY PERMISSION FROM "PARASITOLOGY" BY A. C. CHANDLER, PUBLISHED BY JOHN WILEY & SONS, INC.

FIG. 19.— GENERAL SCHEME OF THE LIFE HISTORY OF TRYPANOSOMA GAMBIENSI

relatively innocuous host-parasite relationship does not prevail, either because of the particular sensitivity of the host or the special virulence of the race of amoeba involved. Then the latter become highly destructive parasites that produce serious lesions in the tissues of the colon, resulting in "amoebic dysentery." In addition the parasites pass to other organs of the body, most often forming abscesses in the liver. Incidentally, this procedure is equally unfortunate for the amoebae, since the progeny are rarely able to encyst and make a getaway to another host. (Fig. 20.)

TAXONOMY

Classification of the Protozoa offers especial difficulties, chiefly because all the variations occur within the confines of a single cell or a series of cells comprising a life cycle, whereas in other animal phyla the numerous characters of multicellular bodies combine to afford more easily discernible diagnostic features. Accordingly, taxonomic systems are to a considerable extent more tentative in the Protozoa than elsewhere in the animal kingdom. However, it is believed that the following brief classification approximates the consensus of opinion of protozoologists and will serve to give a synoptic view of the phylum. It must be emphasized, however, that the versatility of the Protozoa is so great that only the most salient characters of representative types can be cited.

PHYLUM PROTOZOA. Typically unicellular animals that stand in contrast with the rest of the animal kingdom, the multicellular animals, or Metazoa. Four classes are recognized:

Class I. MASTIGOPHORA or FLAGELLATA. The most primitive of the four great classes of Protozoa, comprising animals with one to many flagella in the principal phase of the life history. The typical form is ovate or elongate with a cortex which maintains a definite shape, but there is immense variation and some species are even temporarily amoeboid. Division is almost always longitudinal, Habitats and methods of nutrition are highly diverse; most species are free-living, but many are parasitic.

Subclass PHYTOMASTIGOPHORA. A large assemblage of the most primitive members of the class, some of which can, with reason, be classified as plants. Many species assume a so-called palmella phase in which the cells lose their flagella, round up, and secrete a gelatinous matrix in which they reproduce. Nutrition is usually autotrophic, but many species are saprozoic and some are holozoic at various phases of their life history. They are widely distributed in fresh and salt water.

Order *Chrysomonadida.* Usually small, simple forms, with one or two apical flagella, yellow or brown chromatophores, and often a red stigma. Many are remarkably protean, readily assuming amoeboid and palmella phases. In some species the palmella state is dominant. Nutrition is usually autotrophic, but may be saprozoic or holozoic. Coverings of cellulose and silica are common. So-called coccoliths, common in ocean sediments, are plates of calcium carbonate from the tests of one widely distributed family of this order. Unique silicious cysts are characteristic of the group. Representative genera are *Chromulina, Mallomonas,* and *Dinobryon,* the last usually colonial, and *Synura* and *Uroglena,* both colonial.

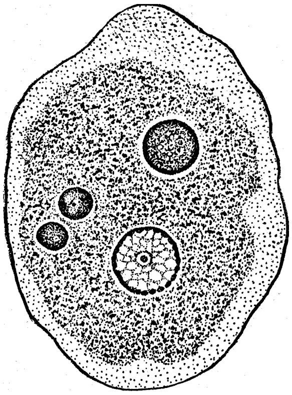
Order *Cryptomonadida.* Tiny flagellates with a relatively constant body form and one or two flagella, usually inserted at the anterior end of a furrow which in some species leads into a cytopharynx, Chromatophores may be yellow, brown, blue or green; but there are many colourless species that are either saprozoic or holozoic. Palmella stages occur. Some cryptomonads live as symbiotic zooxanthellae in other protozoons and in metazoons. Typical genera are *Cryptomonas* (with yellow chromatophores) and *Chilomonas* (colourless).

Order *Dinoflagellida.* A large but relatively circumscribed group; the characteristic type possesses two flagella, disposed in grooves, one of which forms a girdle while the other trails. Most species are provided with tests composed of one or numerous cellulose plates impregnated with inorganic material, but many are naked. Chromatophores are usually yellow or brown. Nutrition is autotrophic, saprozoic or holozoic. Departures from the typical body-plan are numerous, while symbiotic and parasitic species may lose all characteristic structure but form flagellated "dinospores." Representative genera are *Gymnodinium, Glenodinium, Peridinium, Ceratium* and *Blastodinium* (parasitic). The well-known *Noctzluca miliaris,* attaining about 1.5 mm. in diam., is an aberrant, floating, marine species with one small flagellum and a so-called tentacle. It was formerly assigned to a special group, the Cystoflagellata. (Figs. 16, 17.)

Order *Euglenida. A* wealth of common species, usually spindle-shaped, with one or two flagella emerging from a pit or pharynx into which a contractile vacuole discharges.. A red stigma is present in the chlorophyll-bearing forms. Some species are very plastic and exhibit "euglenoid movements." Nutrition is autotrophic, saprozoic or holozoic. Encystment commonly occurs, and palmellá phases are present in some species. Well-known genera include *Euglena* (green, one flagellum), *Astasia* (colourless, one flagellum), *Heteronema* and *Peranema* (colourless, two flagella). (Fig. 3.)

Order *Chloromonadida.* A largely artificial group comprising relatively rare and little-known species, usually with two flagella and small pale green chromatophores. Representative genera are *Gonyostomum* and *Vacuolaria.*

Order *Plzytomonadida.* Typically small, ovate or spindle-shaped cells usually with two flagella, a red stigma and green chromatophores. Many of the phytomonads are colonial. Sexual reproduction is general with isogamous or anisogamous gametes. Common representatives of the noncolonial forms are the many species of *Chlamydomonas,* in a few of which haematochrome develops abundantly under certain conditions so that the organisms impart a reddish tinge to melting snow, rain pools, etc. Some genera, such as *Polytoma,* comprise colourless, saprozoic forms. The family Volvocidae includes the highly interesting colonial types, represented, for example by various species of *Gonium, Pandorina, Eudorina, Pleodorinu* and *Volvox.* The individual zooids are, in general, Chlamydomonas-like in form and vary in number from 4 in *Gontum* to many thousands in *Volvox.* (Fig. 12.)



FROM DOBELL, THE AMOEBAE LIVING IN MAN" (WILLIAM WOOD & CO , 1919)

FIG. 20 —ENDAMOEBA HISTOLYTICA, SHOWING NUCLEUS AND THREE INGESTED RED BLOOD CELLS. MAGNIFIED VERY HIGHLY

Subclass ZOOMASTIGOPHORA. Flagellates without chlorophyll and unequivocally animal in nature, showing an immense structural range from simple to complex. Nutrition is holozoic or saprozoic. Many species are parasitic.

Order *Protomastigida.* Some of the simpler representatives, often referred to as monads, are tiny ovate forms, usually with one or two flagella, but with some amoeboid tendencies. Free, attached, and colonial species occur. Common genera include *Monas, Oicomonas* and *Anthophysa* (colonial). Members of the genus *Bodo,* with one flagellum directed anteriorly and the other trailing, are examples of somewhat more complex iorms, usually possessing a cytostome, multiple basal bodies and a parabasal body near the flagellar insertion. In the genus *Cercomonas* the trailing flagellum passes along the cell surface and becomes free merely at the posterior end, whereas in *Cryptobia* (*Trypanoplasma*) it forms the edge of an undulating membrane so that these parasites superficially resemble Trypanosomes. In one group, the Choanoflagellates, the animals have a delicate cytoplasmic collar about the base of the single flagellum that aids in catching food. The remarkable similarity of these flagellates to the collar cells of sponges and the fact that a colonial representative, *Proterospongia,* forms a gelatinous mass with both collar and amoeboid zooids suggest a possible point of origin of the Porifera, or sponges.

But by far the most significant members of the Protomastigida from the standpoint of human welfare are members of the family Trypanosomidae which comprises a remarkable series of parasitic species. In general they are fusiform or bladelike cells with or without an undulating membrane connecting a part of the single flagellum with the cell surface, but all are highly polymorphic. Three genera, *Leptomonas, Phytomonas* and *Leishmania,* are very similar in the flagellate phase, uith the flagellum arising from a kinetic complex at the anterior end. The leptomonads are confined to invertebrates and chiefly to insect hosts, but the phytomonads are transmitted by insects to the latex of certain plants and the leishmanias to vertebrates. In the vertebrate host leishmania loses the flagellum and rounds up as an intracellular parasite that gives rise to characteristic pathological symptoms; for example, one species produces in man the disease known as "kala azar," and another "Oriental sore." The members of the genera *Crithidia* and *Herpetomonas* are restricted to invertebrates and are similar in structure to the genera mentioned above, but with the flagellum arising further posteriorly and extending forward as the edge of a smal! undulating membrane. Finally, in the genus *Trypanosoma* the flagellum arises near the posterior end and proceeds forward as the edge of an extensive undulating membrane. Trypanosomes are blood-inhabiting parasites of man and other vertebrates, with an invertebrate, usually an insect or leech, as the intermediate host. The trend of evolution in the family is indicated by the progressive polymorphism exhibited by the several genera that reaches a climax in the trypanosomes whose life history recapitulates, as it were, the phases that are dominant in the other genera. (Fig, 19.)

Order *Polymastigida.* An assemblage of diverse forms usually with from three to eight flagella but sometimes with many. The majority of the species are parasites or commensals in the intestinal tract of animals. Among the simpler genera commonly represented by species in man are: *Trichomonas* with one nucleus and four anterior flagella and another flagellum which forms the edge of an undulating membrane; *Chilomastix,* with a single nucleus and four flagella, one of which undulates in a cytostomal cleft; and *Giardia,* with two nuclei and eight flagella arising from three parts of a bilaterally symmetrical body. It is not clear that any of the species are primarily pathogenic, though when present in large numbers they may aggravate abnormal conditions. The most complex polymastigotes live as commensals or symbionts in the intestine of termites and exhibit a reduplication of certain structures of the simpler species so that there may be many nuclei, each associated with several flagella, a parabasal body and other kinetic elements. Examples are *Calonympha* and *Stephanonympha.*

Order *Hypermastigida.* The acme of flagellate complexity is attained in this order, which includes a wealth of commensal and symbiotic forms chiefly in termites and cockroaches. They possess numerous flagella, either widely distributed or in tufts, and a multiplication of kinetic structures but only one nucleus. Regional differentiation of the cytoplasm is remarkable. The origin of the diversity and high specialization of the unique populations of hypermastigote and polymastigote flagellates in a restricted environment is of considerable evolutionary. interest. Common examples are *Lophomonas blattarum,* found in domestic cockroaches, and various species of *Trichonympha,* present in termites and wood roaches. (Fig. 18.)

Order *Rhizomastigida.* A heterogeneous group of species that may almost equally well be included under the class Sarcodina because they are essentially amoebae with one or more permanent flagella. The best-known genus is *Mastigamoeba.*

Class SARCODINA or RHIZOPODA. A huge assemblage of amoeboid animals formerly regarded as the most primitive class of the phylum. The chief general characteristic is the presence of pseudopodia for locomotion and obtaining food, though some temporarily develop flagella, and others produce flagellated gametes. Nutrition is usually holozoic.

Order *Amoebida.* The typical shell-less amoebae with pseudopodia varying from lobose to broad. Some of the simplest forms exhibit interchangeable amoeboid and flagellated phases. Among the larger fresh-water amoebae the best known is *Amoeba proteus* with lobose pseudopodia showing surface ridges, truncate bipyramidal crystals in the endoplasm, and a discoidal nucleus. Reproduction is apparently solely by binary fission. This species sometimes attains a length of more than 600 micra as it creeps along, but members of the genus *Pelomyxa* are very much larger and have many nuclei. One of the latter possibly was the amoeba observed by Rösel von Rosenhof as early as 1755 and named *Chaos chaos* by Linnaeus in 1767. In addition to the many free-living amoeba, large and small, there are numerous parasitic species, the one of outstanding importance being the widely distributed *Endamoeba histolytica,* the sole pathogenic amoeba inhabiting man. (Figs. 2, 20.)

Order *Testacea.* Amoebae with simple one-chambered tests of tectinous material in which foreign particles or secreted silicious plates are usually incorporated. The pseudopodia apparently consist solely of ectoplasm and are often threadlike. Reproduction is usually by the protrusion of a bud from the orifice of the test but, in certain cases, multiple division results in the liberation of many amoebulae that gradually assume the characters of the parent. Common representatives in fresh-water ponds and bogs are the many species of *Arcella* with yellowish, bowl-like tests, and *Difflugia* and *Euglypha* with pyriform tests. (Fig. 5.)

Order *Foraminifera.* An immense array of ,almost exclusively marine, shelled rhizopods of considerable importance. The shells may be tectinous, arenaceous, or silicious, but the majority are calcareous. They may consist of one or many chambers, and be imperforate or perforated by numerous tiny pores that afford, in addition to the mouth of the shell, exits for numerous fine branching and anastomosing pseudopodia. The multichambered (polythalamous) forms result from the addition to the initial chamber of one new chamber after another and, in general, their shape and the spatial relations they assume determine the various types of shells as linear, spiral, etc. The life history typically involves an alternation of asexual and sexual generations with characteristic differences in the shells, nuclear apparatus, etc. The asexual generation produces amoeboid spores that develop into sexual individuals, while the latter give rise to amoeboid or flagellated gametes and the resulting zygotes develop into asexual individuals. Nearly 50 families had been recognized by 1945. Well-known genera include *Globigerina, Elphidium* (*Polystomella*), *Peneroplis, Patellina,* and *Camerina (Nummulites),* the last solely fossil. (Fig. 5.)

Order *Proteomyxa.* A relatively small heterogeneous assemblage of indefinite relationships, usually with raylike pseudopodia that frequently branch or tend to anastomose. Most species are parasites on the lower algae, such as *Spirogyra.* Representative genera include *Nuclearia, Arachnula* and *Vampyrella.*

Order *Mycetozoa.* An immense group sometimes classified among the Fungi as Myxomycetes, or "slime moulds," chiefly because, in the typical free-living species, specialized structures are developed for the production and dissemination of air-borne spores. Although this characteristic may be regarded with some assurance as an indication of convergence rather than of relationship with plants, the Mycetozoa are evidently a borderline group where formal classification is difficult or fails entirely. The most prominent phase in the life history consists of a multinucleate sheet of flowing protoplasm, the plasmodium, with great networks of anastomosing pseudopodia. Eventually spores are developed and these produce tiny amoeboid forms, each with a flagellum, that multiply and form gametes. The zygote is an amoeboid cell which increases in size by growth and union with other similar plasmodia, in some cases becoming several centimetres in diameter and containing thousands of nuclei. Nutrition is saprozoic and holozoic as the plasmodium creeps over decaying wood, leaves, etc. Common genera include *Lycogala, Physarum* and *Fuligo.* In addition to the typical Mycetozoa there are usually included in the group various forms which may be only distantly related because they exhibit wide departures in structure and life history. One of the most common is *Plasmodiophora brassicae,* an intracellular parasite which produces the disease known as clubroot in cabbages and closely related plants.

Order *Heliozoa.* A rather circumscribed group of typically spherical fresh-water forms with raylike axopodia. Protective coverings of gelatinous material, silicious spicules, etc., are often present. Most so-called sun animalcules are free-floating but some are sessile. Nutrition is holozoic. Common genera include *Actinophrys* (uninucleate) and *Actinosphaerium* (multinucleate). (Fig. 6.)

Order *Radiolaria.* An enormous assemblage of marine species adapted for pelagic life, including some of the largest Protozoa. Most are spherical and are provided with complex skeletons of remarkable and beautiful designs. The skeletons are usually silicious, but in one group they are apparently composed of strontium sulphate. The most highly characteristic feature is the definite segregation of the body into intracapsular and extracapsular regions by a perforated membrane, the central capsule. The intracapsular protoplasm is relatively homogeneous and includes from one to many nuclei, oil droplets, etc., while the extracapsular region is differentiated into several zones. The outermost consists largely of axopodia and myxopodia which have their origin within or just outside the central capsule in the surrounding "matrix" and traverse the broad "calymma": a gelatinous zone apparently secreted by the protoplasm and characterized by fluid-filled vacuoles that give the animal a frothy appearance. So-called yellow cells (zooxanthellae) are usually present in the calymma and in certain cases, at least, are modified dinoflagellates and chrysomonads living as symbionts or parasites. Reproduction by division includes the central capsule and, when possible, the skeleton. Multiple division of the nucleus and centrai capsule without division of the extracapsular protoplasm may give rise to temporary forms with several capsules, a condition that is permanent in some colonial species. Reproduction by tiny flagellated spores also occurs, but the formation of gametes remains to be proved. Representative genera are *Collozoum* (without a skeleton, colonial), *Thalassicolla* (without a skeleton), *Acanthometron* (with a skeleton). (Fig. 7.)

Class SPOROZOA. A very large and heterogeneous assemblage of endoparasitic forms with hosts representing all animal phyla. Reproduction at some stage in the life history is by "spores," but these are not homologous throughout the class. In general, each species is limited to a specific host or to two hosts in each of which a part of the life history is spent. Transmission may be contaminative by resistant spores, or by inoculation of unprotected stages. Reproduction is usually by multiple fission (schizogony) followed by gamete formation and finally by sporulation (sporogony) to complete the life cycle. The alternation between the asexual and sexual phases is often associated with the change of hosts.

The class is sometimes divided into two subclasses, the Telosporidia and Neosporidia, with, in general, the following chief differences. In the former the production of spores terminates the life cycle, the sporozoites are vermicule in form, and the spores are without polar capsules; while in the latter, sporulation proceeds during the trophic phases of the life cycle, the sporozoites are amoeboid, and polar capsules are usually present in the spores. Though this division, suggested by Fritz Schaudinn in 1900, recognizes the natural assemblage of gregarines, coccidians and haemosporidians as Telosporidia, it fails to discriminate between the widely divergent forms included in the Neosporidia and, accordingly, it is customary to substitute for the latter group two subclasses: the Cnidosporidia with polar capsules, and the Acnidosporidia without such structures. But it is generally agreed that this is to some extent a temporary expedient awaiting further knowledge.

Subclass TELOSPORIDIA. The general characteristics are as stated above.

Order *Gregarinida.* A relatively homogeneous group of common parasites of invertebrates. For a brief period after the invasion of a host, development of the gregarine is intracellular, but most of the life history is extracellular with the parasites living in the intestine or various body cavities. Here the mature, wormlike forms (trophozoites) are either attached or move about by contortions of the body and by a characteristic gliding motion. Some gregarines are large enough to be readily visible to the naked eye. In general the body shows considerable differentiation and in some species is highly complex. In the cephaline type the body is divided into two parts (protomerite and deutomerite) by a transverse septum, and the protomerite itself may be capped by a special structure (epimerite) for attachment. The ectoplasm usually consists of several layers, including a region of myonemes which comprises both longitudinal and circular fibres, some of which may extend into the dense, granular endoplasm. Asexual reproduction by schizogony does not occur, the trophozoite proceeding directly to sexual phenomena and spore formation. The resistant spores usually pass from one host to another of the same species, but in some cases an alternate host is involved. Common examples of acephaline gregarines are the various species of *Monocystis* found in the seminal vesicles of earthworms. The more complex cephaline forms, chiefly inhabitants of the intestine of arthropods, are illustrated by members of the genus *Gregarina* that often parasitize meal beetles and cockroaches.

In addition to the eugregarines considered above, there is a small group of schizogregarines, so called because the life history includes a schizogonous cycle. The best known genera are *Ophryocystis* and *Schizocystis,* both with representative species that parasitize insects.

Order *Coccidia.* Intracellular parasites of many invertebrates and vertebrates, infesting chiefly the epithelial lining of the intestine and its derivatives, though some species invade the blood vascular system. The typical life history includes asexual multiplication by repeated schizogony followed by sexual phenomena and then sporogony involving the formation of resistant spores. Most members of the order are confined to a single host, but the blood-dwelling haemogregarines alternate between the circulatory system and other organs of vertebrates and the intestine of invertebrates such as mites and leeches, and are without resistant spores. Representative coccidians are the various species of *Eimeria* that infest in particular mammals and birds, *Adelea ovata* living in centipedes, and *Haemogregarina stepanowi* alternating between turtles and leeches. *Isospora hominis* occurs rarely in man.

Order *Haemosporidia.* Intracellular coccidialike forms that typically undergo schizogony chiefly in the red blood cells and reticulo-endothelial tissue of vertebrates, and fertilization and sporogony in the digestive tract of blood-sucking arthropods, particularly insects. Resistant spores are not formed. The most important genus is *Plasmodium,* which comprises the malarial parasites of man carried by anopheline mosquitoes, as well as parasites of various lower vertebrates, including birds. Other representative genera are *Haemoproteus* and *Leucocytozoon,* transmitted especially to birds by biting flies. Differing somewhat from the typical haemosporidians are the piroplasms carried by ticks and often the cause of serious diseases in domestic mammals. Of especial interest is *Babesia (Piroplasma) bigemina,* the cause of Texas cattle fever. This was shown by the work of T. Smith and F. L. Kilborne in 1893, which was the first demonstration of the transmission of a protozoan parasite by an arthropod vector. Closely related to the various species of *Babesia* are members of the genus *Theileria,* such as *T. parva* that produces East Coast fever in African cattle. (Fig. 4.)

Subclass Cnidosporidia. An assemblage of species characterized by resistant spores with polar capsules. The products of the spores are amoeboid forms that start early in the life history to produce spores by internal budding. Accordingly an alternation of asexual and sexual cycles is absent, sexual phenomena occurring in the trophic stages. Species with intermediate hosts are unknown. (Fig. 15.)

Order *Myxosporidia.* Almost exclusively parasites of fishes, in which they sometimes cause severe epidemic disease. Some species develop as free forms in cavities, such as the gall and urinary bladders, while others are actual tissue parasites that produce more serious pathological effects. Common genera with many species, some infecting economically important fishes, are *Ceratomyxa, Myxidium* and *Myxobolus.*

Order *Actinomyxidia.* A small group of little-known species which inhabit the coelom and intestinal epithelium of aquatic annelids. The spores are usually triradiate and have three polar capsules. Representative genera are *Triactinomyxon* and *Hexactinomyxon.*

Order *Microsporidia.* Minute intracellular parasites that chiefly infest various tissues of arthropods and fishes. The best known species are *Nosema bombycis* of the silkworm moth and *N. apis* of bees, the former producing the pébrine disease of silkworms investigated by Louis Pasteur in 1865.

Subclass Acnidosporidia. A provisional group comprising little-known forms with simple spores lacking polar capsules.

Order *Sarcosporidia.* This order includes one important genus, *Sarcocystis,* with several species that infest the muscles of vertebrates, chiefly mammals, including mice, pigs, cattle and rarely man. The parasites form large "sarcocysts" in which crescentic spores are formed and produce a toxin that may prove fatal when injected into small mammals.

Order *Haplosporidia.* Largely an artificial assemblage of diverse forms, with affinities still to be determined, though certain species are probably closely related to the Microsporidia. They inhabit body cavities and tissues of invertebrates and lower vertebrates. Representative genera are *Haplosporidium,* present in aquatic annelids and mollusks, and *Ichthyosporidium* in fishes. A species of *Coelosporidium* occurs in cockroaches.

Class Ciliophora or Ciliata. An immense and clearly differentiated class, often called the Infusoria, characterized chiefly by the presence of cilia, and by two types of nuclei except in the subclass Protociliata. Division is typically transverse. Most species are monomorphic and are free-swimming in fresh and marine waters, though some are temporarily or permanently attached. Colony formation occurs.

Subclass Protociliata. A small subclass comprising the so-called opalinids which are endocommensals or parasites almost exclusively of frogs and toads. The body is uniformly coated with cilia but otherwise shows little similarity to other members of the class. The nuclei, from two to many in number, are not differentiated into micronuclei and macronuclei and there is no cytostome or contractile vacuole. Fertilization is by anisogamous gametes. Four genera are recognized: *Protoopalina, Zelleriella, Cepedea* and *Opalina.*

Subclass Euciliata. A very large subclass that includes all of the typical ciliates. Micronuclei and macronuclei are present and fertilization is by conjugation. Most species are free-living but some are commensals or parasites. The classification of this highly organized group of the Protozoa is based chiefly on the plan of distribution and the specialization of the cilia.

Order *Holotrichida.* The holotrichs are usually provided with unspecialized cilia, either over the entire surface or restricted to certain regions of the body. The best known genus is *Paramecium,* represented by about ten clearly-defined species, some of which are among the most widely studied animals. Among other common genera are *Chilodonella, Colpoda, Colpidium, Spathidium* and *Didinium.* Most holotrichs are free-living, but many are commensal or endoparasitic, including a unique group of astomatous species. *Ichthyopthirius multifilius* is an ectoparasite of fresh-water fishes which sometimes causes serious epidemics in aquaria. (Figs. 1, 11.)

Order *Spirotrichida.* Species with a complex adoral zone of cilia united to form membranelles, and usually an undulating membrane, in addition to other ciliation. Included are the *heterotrichous* forms with relatively short cilia over the rest of the body, represented, for example, by the various species of *Stentor, Spirostomum, Blepharisma, Bursaria* and *Balantidium;* the *oligotrichous* forms with general body ciliation reduced or wanting, as in the genera *Halteria, Tintinnidium,* and *Epidinium;* and finally the *hypotrichous* forms with markedly flattened bodies provided with cirri on the ventral surface for creeping, etc., including such common genera as *Oxytricha, Stylonychia* and *Euplotes.*

Order *Peritrichida.* Members of this order are typically bell-shaped and attached by a stalk, and accordingly are commonly called bell animalcules. Ciliation is practically restricted to the rim of the bell and peristome, and includes an adoral zone. Representatives are the many species of *Vorticella* and the closely related colonial genera *Epistylis, Zoothamnium* and *Carchesium.*

Order *Chonotrichida.* A very small group of ciliates superficially similar but clearly unrelated to the peritrichs. All live attached to aquatic arthropods. The common genus is *Spirochona.*

Subclass Suctoria. A unique but widely distributed group of fresh-water and marine species in which the cilia are confined to the young, free-swimming stages which arise as buds. The adults are typically sessile and are provided with tentacles by means of which they adhere to the prey and withdraw its contents. Many species live attached to the surface of aquatic organisms, usually as commensals but sometimes as parasites, while others are highly modified endoparasites. Some species infest *Paramecium* and other ciliates. Common genera are *Tokophrya, Acineta* and *Ephelota.* (Fig. 10.)

Bibliography.—Standard treatises affording a survey of the Protozoa and an introduction to the immense literature in the field of protozoology include: Otto Buetschli, "Protozoen," in Bronn's *Klassen und Ordnungen des Tier-Reichs,* 3 vols. (Leipzig, 1880–89); C. M. Wenyon, *Protozoology* (London and New York, 1926); F. J. Cole, *History of Protozoology* (London, 1926); F. Doflein and E. Reichenow, *Lehrbuch der Protozoenkunde,* 5th Auflage (Jena, 1927–28); G. N Calkins; *Biology of the Protozoa,* 2nd ed. (1933); A. Kahl, "Ciliata," in *Die Tierwelt Deutschlands* (Jena, 1935); R. R. Kudo, *Protozoology,* 3rd ed. (1946); L. H. Hpman, *The Invertebrates: Protozoa through Ctenophora* (1940); G. N. Calkins and F. M. Summers (editors) *Protozoa in Biological Research* (1941).

(See Protophyta; Algae.) (L. L. W.)

PROUD, JOSEPH (1745–1826), English clergyman, was born in Beaconsfield, Buckinghamshire on March 22, 1745. He served as minister of the general baptist congregation at Knipton, Leicestershire beginning about 1772. and in 1775 accepted a similar position at Fleet, Lincolnshire, where he was ordained in 1780. In 1791 he mas ordained minister in the "new church" and opened the Birmingham "temple" in the same year. He continued to preach in various churches in Manchester and London where his oratory attracted large audiences. He wrote nearly 300 hymns and published numerous books, some of which went through several editions. He died at Handsnorth, near Birmingham on Aug. 3. 1826.

PROUD, ROBERT (1728–1813). U.S. educator and historian, was born near Yarm, Yorkshire on May 10, 1728. After attending a Friends' school he went to London in 1750 and continued his studies under the guidance of Dr. Fothergill. In 1759 he came to the United States and opened a boys' school in Philadelphia. In 1761 he became master of a Friends' school. a position he held until 1770, and later, from 1780 to 1790. His important work, *The History of Pennsylvania* (2 vols., 1797–98), contained much valuable material on the early history of the area. Proud died at Philadelphia on July 5, 1813.

PROUDHON, PIERRE JOSEPH (1809–1865), French moralist and advocate of social reform. was born on Jan. 15, 1809, at Besançon, in the traditionally rebellious Jura mountain district of France. He came of a poor family and at 19 became a working compositor; later, as a proofreader, he acquired knowledge of theology; Latin and Greek, as well as Hebrew. Although he subsequently won academic scholarships, he spurned formal training and remained a self-educated man. His interests turning to economics and politics. he published. in 1840. *Qu'est-ce que la propriété?* His answer. "Property is theft," does not, however, mark him a socialist. Proudhon voices, instead, the typical middle-class objection to concentrated economic power and the consequent difficulty that small businessmen have long experienced in raising capital even when the security offered was perfectly sound. So far from demanding the abolition of private property in means of production, Proudhon urged that productive property be widely dispersed among owner-producers who operate as individuals or band together in mutual benefit associations. Proudhon argued that the government should preserve an open door for investment in small and locally or mutually owned businesses. To this end the government should establish a semipublic exchange and capital bank to take the place of the Bank of France and the stock exchange. This "people's bank" would furnish currency and credit at a low rate of interest, or none at all, against: (1) written orders for payment drawn by sellers of goods on the purchasers (acceptance bills); (2) payment bills issued to wage-earners by their employers; (3) credit bills presented by buyers of residential housing. industrial or agricultural property, who have been judged eligible for home loans or business loans. Thus Proudhon aimed to universalize the bill of exchange: an instrument of credit whose familiar use was in connection with the shipment of finished goods in commerce rather than in relation to home ownership or business-property transactions. Proudhon wished to divorce money and credit from any basis of gold or specie, so that the economy would constitute a universal credit union, with productivity rather than specie as the basis of credit. Labour and every product of labour would in effect be ready and exchangeable money. Because money in the form of goods or services cannot be hoarded, the aggregate supply of goods and services creates its own sufficient aggregate demand, hence unemployment caused by overproduction would be banished. With money based on productivity rather than specie, market competition would regulate prices so that consumers might buy goods at nearly their real costs of production; prices would not be burdened by surcharges of interest, rents and capital gains realized by absentee capitalists, landlords and speculators. Nor can the government create money or manipulate its supply to favour politically powerful special-interest groups. For in Proudhon's scheme, money is only th'e reflection of productive transactions whose terms are negotiated by private producers without the intervention of government.

Besides his monetary reform proposals, Proudhon projected the concept of associations of owner-producers. Each association forms its internal rules; the members surrender individual advantages for the common good of the organization. A spirit of give-and-take also characterizes, in Proudhon's vision, the relations among the separate organizations of businessmen. workers and farmers. Thus mutualism nithin groups joins with mutuality between groups to yield an economy of justice—economic justice not stipulated by the government but justice emanating from the ranks of the producers.

Proudhon's economic reform program was early attacked by Karl Marx (*q.v.*), in 1847. on the ground that finance capitalism. which Proudhon sought to abolish, and industrial capitalism, which Proudhon wished to strengthen, are inextricably intertwined. In the Marxist view, the unplanned nature of capitalist production sets the stage for economic instability under which speculation thrives. as well as for concentration of economic power and exploitation of labour, so that Proudhon's desired working harmony among producers cannot be realized. This controversy—with Proudhon writing *The Philosophy of Misery* and Marx countering with *The Misery of Philosophy*—is of current interest. It exhibits the roots of the continuing difference between middle-class reformers and the would-be socialist transformers of capitalism.

A prolific and passionate writer. Proudhon analyzed in the manner of an unprofessional philosopher. and his writings frequently lapse into merely perceptive journalism, especially those in the field of national and international political affairs. Proudhon portentously combined a rebellious peasant provincialism with a global grandiosity—thus he presaged in his thoughts and deeds the persistently conflicting tendencies of French capitalist democracy, toward anarchy on the one hand and despotism on the other.

Proudhon's works in English translation include: *What Is Property? System of Economic Contradictions: or the Philosophy of Misery; General Idea of Revolution in the Nineteenth Century.* His complete works were published in Paris (1923–52). See also ANARCHISM; SOCIALISM.

BIBLIOGRAPHY.—George Woodcock, *Pierre-Joseph Proudhon* (1956); Dudley Dillard, "Keynes and Proudhon," *J. Econ. Hist.* (May 1942); J. Salwyin Shapiro, "Pierre-Joseph Proudhon, Harbinger of Fascism," *Amer. Hist.* **Rev.** (July 1945). (G. W. Z.)

PROUST, JOSEPH LOUIS (1754–1826), French chemist, whose great contribution to chemistry was his experimental establishment of the principle of the constant composition of compounds. Born at Angers on Sept. 26, 1754, he mas the son of an apothecary. He studied chemistry under the direction of G. F. Rouelle, and became chief apothecary at the Salpêtrière hospital in Paris. In his lifetime he attained eminence in chemistry in both France and Spain. In France he lectured at the Palais Royal, and in Spain he taught at the Academy of Artillery at Segovia, at the seminary at Vergara and at the newly established Royal laboratory at Madrid. The latter had notably excellent facilities, which enabled him to conduct (1799–1806) skilled researches on the composition of many substances, finally proving—beyond doubt that then existed—that pure compounds were strictly definite in composition by elements, no matter what their source. Thus his celebrated controversy with Claude Louis Berthollet (1748–1822) was resolved in Proust's favour. Proust did not formulate the law of definite proportions (John Dalton, 1808), but his work furnished the necessary experimental evidence for its acceptance. After his election in 1816 to the French Academy of Sciences he returned to Angers where he died July 5, 1826. Proust, a Frenchman, is frequently confused with William Prout (1785–1850), an Englishman. The latter was the proponent of the hypothesis in 1815 that the atomic weights of the elements are exact multiples of the atomic weight of hydrogen.

(R. K. SG.)

PROUST, MARCEL (1871–1922), French man of letters, was born in Paris on July 10, 1871. His father was a professor of medicine, and his mother was of Jewish extraction. He was educated at the *lycée* Condorcet, and about 1892 he was for some time associated with Léon Blum, Louis Mirhlfeld and Tristan Bernard on the *Revue Blanche,* a periodical conducted by a select group of intellectuals, mostly Jewish. Becoming a favourite in the salons—especially those of Mme. de Caillavet and Madeleine Lemaire—he wrote a number of society love stories (collected in 1896 under the title Les *plaisirs* et *les jours*) distinguished by their psychological subtlety. He also attained reputation as a clever writer of pastiches. He became an enthusiastic admirer of John Ruskin and translated several of his works into French, including the Bible of Amiens, to which he contributed a valuable preface.

In 1902 Proust's health began to fail. Thenceforward he was reluctantly obliged to lead an extremely retired and careful life, and for many years it looked as if he had altogether abandoned literature, in which his name hitherto had not been known outside a small circle of friends. He was reading and writing a great deal, however. The interminable discursiveness of Ruskin, which French readers do not suffer gladly, was to him a constant source of delight, and Saint-Simon, ever one of his favourite authors, exerted a powerful influence upon him at this time. Thus it came about that, having unlimited time at his disposal, he embarked upon a long and leisurely work, full of minute detail, in which was imprisoned, as in a net, his whole experience of life; in which the salon life he loved was revived in all its details and observances like the court life in Saint-Simon's memoirs; in which the people he had known provided the materials for new, fuller and richer characters (M. de Charlus, for example, is a blending of three different people of Proust's acquaintance), and in which the author sought out and lived the past over again. Hence the general title given to the 15 volumes of the series, A la recherche du temps perdu (1913, etc.).

This lengthy work had almost been completed when Proust published the first part, *Du côté* de *chez Swann,* in 1913. The freshness and minuteness of the recollections of childhood attracted some attention, but nonetheless Proust, who had had to publish the first part at his own expense, had difficulty in finding a publisher for the second, *A* l'ombre des *jeunes filles* en *fleurs.* When it did appear its qualities were at once appreciated by Léon Daudet, whose enthusiastic articles, followed by the award of the Prix Goncourt in 1918, brought Proust's name prominently before the public, and he was read, discussed and criticised everywhere. Two more parts appeared during Proust's lifetime—Le *côté* de *Guermantes* and *Sodome* et Gomorrhe, both in 1921. When he died in Paris. Nov. 18, 1922. he left three parts still in manuscript—La *prisonnière,* published in 1924, Albertine *Disparue* (1926) and Le temps *retrouvé* (1926).

Proust's influence, especially after his death, has been considerable. He introduced into the novel an analytic method which has a superficial resemblance to that of Meredith, but is more properly comparable with that of Freud. That the name and notion of time should appear in the general title of his great work is not without significance. By a curious coincidence he was related by marriage to Bergson, the philosopher of "creative time," and the term "creative time" aptly describes the psychological time which Proust explores, seeks and recovers. His people are never given as "characters" in the fashion of La Bruyère or Balzac; they are always in process of development, change and continual creation.

Part of Proust's success was due to the very thing that is likely to tell against his lasting reputation. viz. the fact that his characters, beginning with the "I" of the book, are exceptional, an erotic and mysterious group having little in common with, the generality of mankind. This is true not only of *Sodome* et Gomorrhe and Proust's emphasis upon homosexuality, but also of the idle life and ultimate nothingness of the people of his world, their lack of all interests other than those of social life, and the indifference that the ordinary reader must always feel as to their fate. On the other hand, there will be a taste for Proust so long as there is a taste for psychology as an end in itself, and so long as the play of memory, the searching and brooding that pertain to the conquest of the past, afford to some men a sufficient reason for living or a romantic manner of not living. The authorized translation by C. K. Scott Moncrieff appeared with the series title Remembrance of Things Pest (1922–1930), the final part. Past Recaptured (1932), being translated by F. A. Blossom, the whole appearing in 4 vol. in 1934. (A. T.; X.)

BIBLIOGRAPHY.—*Marcel* Proust, an English tribute, collected by C. K. Scott Moncrieff (1923); Jacques Rivière, Marcel Proust (1924); L. Pierre-Quint, Marcel Proust, sa vie, son oeuvre (1925; Eng. trans., 1927); Benoist-Méchin, La *Musique* et *l'immortalité dans l'oeuvre* de Marcel Proust (1926); R. Dreyfus, Marcel Proust *à dix-sept* ans (1926), Souvenirs sur Marcel Proust (1926); G. Gabory, Essai sur Marcel Proust (1926); Marcel Proust, by various writers, with bibliography (1926); P. Souday, Marcel Proust (1927); R. Fernandez, Les Cahiers de Marcel Proust (1927); Clive Bell, Proust (1928). His Lettres inddites were published with a preface by Camille Vettard in 1926. Chroniques, a selection of his articles chiefly from Le Figaro, was edited by R. Proust (1927).

PROUSTITE, a mineral consisting of silver sulfarsenite, known also as light red silver ore, and an important source of the metal. It is closely allied to the corresponding sulfantimonite, pyrargyrite (*q.v.*), or dark red silver ore, from which it was distinguished by the chemical analyses of J. L. Proust in 1804, after whom the mineral received its name. The composition is Ag_3AsS_3. The colour is scarlet-vermilion and the lustre adamantine; crystals are transparent and very brilliant, but on exposure to light they soon become dull black and opaque. The streak is scarlet, the hardness 2.5, and the specific gravity 5.57.

The mode of occurrence is the same as that of pyrargyrite, although proustite is less common, and the two minerals are sometimes found together. Magnificent groups of large crystals have been found at Chafiarcillo in Chile; other localities which have yielded fine specimens are south Lorrain, Ont., and Freiberg and Marienberg in Saxony. It is mined as an ore in Mexico and is found in small amounts in the United States in California, Colorado, Idaho and Nevada.

PROUT, SAMUEL (1783–1852), English water colourist, born at Plymouth, Devon, Sept. 17, 1783. was educated at Plymouth grammar school. He went on sketching expeditions with B. R. Haydon, at whose father's house he met John Britton, publisher of The Beauties of England and Wales. He worked for Britton in London, and exhibited at the 1803 Royal Academy. He also painted marine pieces for T. Palser, received pupils, and in 1813 published The Rudiments of Landscape, With Progressive Studies, the first of his several handbooks for art students. From 1815 he exhibited regularly at the Water-Colour society, becoming a member four years later. A visit to France in 1819 distinguished him from previous English topographers by his choice of foreign townscapes as subjects, and that same year he attempted the recently discovered process of lithography. His Illustrations of the Rhine (1824) comprised the first of many lithographs resulting from frequent visits to France, Germany, the Netherlands and Italy. He died at Camberwell, Feb. 10, 1852. Prout's success was due to his fine draftsmanship, skillful composition and ability to seize upon some strikingly picturesque quality.

See Jane Quigley, *Prout* and Roberts (1926). (D. L. Fr.)

PROUTY, CHARLES AZRO (1853–1921), U.S. lawyer, was born in Newport, Vt., on Oct. 9, 1853. He graduated at Dartmouth college, Hanover, N.H., in 1875 and subsequently became principal of Newport academy. He was admitted to the bar in 1882 and practised law in Newport until 1896. In 1888 he was a member of the Vermont house of representatives and from 1888 to 1896 served as a reporter of decisions of the state supreme court. He was appointed to the U.S. Interstate Commerce commission in 1896, holding office until 1914 and serving as chairman in 1912–13.

In 1914 Prouty was made director of valuation for the commission and from 1918 to 1920 was director of public service and accounting in the U.S. Railroad administration. He died at Newport on July 8. 1921.

PROVENCAL LANGUAGE is one of the Romance languages (*q.v.*). In its narrow meaning the term refers to the speech, or the dialects, of the region called Provence. But more often it is the collective term for all southern dialects of France. Similarly the alternative name *langue* d'oc (oc "yes." as compared with northern oil, modern oui) refers generally to all idioms of the Midi (the south), although Languedoc as a politico-geographic term signifies only part of the region. In literary history, however, Provencal is the name given to the artificially homogeneous standard language employed by the troubadours (*q.v.*) of the 12th, 13th and 14th centuries.

The boundary separating Provencal (in the widest sense) from northern French runs from the estuary of the Gironde eastward along the northern edge of the Massif Central, crosses the Rhone between Vienne and Valence, and moves toward the Alps; but in the middle ages the frontier lay much farther to the north, being anchored in the west at the mouth of the Loire and in the east in the southern Vosges mountains.

This linguistic boundary. which is so trenchant as to be one between languages rather than dialects, resulted from differing historic and cultural developments. The Midi, or at least part of it, mas conquered by the Romans in 122 B.C., about 70 years before the rest of Gaul. A flourishing and rich province, it was quickly and profoundly romanized. Moreover. the Germanic invasions of the middle ages were culturally less effective than they were in the north; even that of the Franks (so decisive elsewhere as to give their name to the whole country) exerted. little influence. The southern dialects in comparison with the northern, are therefore more conservative in their retention of Latin traits and less affected by the Germanic superstratum.

The medieval history of the Midi is that of many small feudal holdings, in constant dispute among themselves and with outsiders. The country never attained national independence, but it was officially united with the rest of France in 1486. The greatest single catastrophe to befall the south was the crusade against the Albigenses (*q.v.*) early in the 13th century. What began as a religious expedition under the aegis of the church against the Xlbigensian heresy ended as political suppression of the south and its feudal lords by northern competitors. This calamity brought about the end of the independent flourishing of the Midi's native culture, particularly of its troubadour literature; it was assuredly responsible for the end of Provenqal as an interregional standard idiom. for the re-emergence of local dialects, and for the spread. albeit slow, of standard northern French, in particular Francien, the dialect of the Île-de-France, as the literary and official language of the whole region.

Henceforth the southern dialects. bereft of a southern standard language in competition with Francien, sank to the level of patois of strictly local and familiar currency. The present dialects may be classified as follows: (1) Provencal (in the narrow sense as idioms of the Provence proper); (2) Xuvergnat and Limousin; (3) Gascon (see below). Each of these larger divisions can of course be subdivided into smaller dialects, in the past as much as, or even more than. now.

This dialectal fragmentation of the south raises the question of which of the southern dialects was employed in troubadour poetry, or which formed the core of their fairly homogeneous language. The main obstacle to a satisfying answer, apart from the insufficient knowledge of the medieval dialects of the Midi. is that Provenqal, even in the works of the oldest troubadours (Guilhem IX. Marcabrun. Cercamon), is already fully developed and standardized, so that the history of its formation escapes linguistic scrutiny. On the whole. it seems to represent a central rather than a peripheral southern speech area. The history of the Provençal language largely deals nith the language of the troubadours

Late spoken Latin	Old Provençal	Old French	Modern French
Vowels			
amare	*amar*	*amer*	*aimer*
pede(m)	*pe*	*pie(d)*	*pied*
solu(m)	*sol*	*suel*	*seul*
flore(m)	*flor*	*flour*	*fleur*
fide(m)	*fe*	*jei*	*foi*
auru(m)	*aur*	*or*	*or*
Consonants			
caballu(m)	*caval*	*cheval*	*cheval*
gallina(m)	*galina*	*geline*	*geline*
scribere	*escriztre*	*escrire*	*écrire*
castellu(m)	*castels*	*chastels*	*château*
causas	*cauzas*	*choses*	*choses*
securu(m)	*segur*	*seür*	*sûr*
matura(m)	*madura*	*meür*	*mûr*
laudare	*lauzar*	*lower*	*louer*

since little else is known until recent times. It is convenient to compare it with the northern Francien standard in order to show its peculiarities. See also FRENCH LANGUAGE and, especially for earliest developments from Latin, ROMANCE LANGUAGES.

Where northern dialects nasalize a vowel before a following *m* or *n,* nith eventual absorption of the consonant (*pontem* > *põ*), Provencal may not nasalize at all, or may nasalize the vowel with retention of the consonant (*pontem* > pon, *põn*).

Gascon has certain peculiarities which set it apart from other southern dialects. For example, Latin medial -11- appears as *-r-* (*appellare* > *apera[r]*), final *-l* as *-t* (*bell[um]* > bet), initial *r-* as *arr-* (*ramu[m]* > *arram*), initial f- as h- (*femina* > *hemna, henno*). For these and other reasons some do not include Gascon among the Provencal dialects (in the wider sense). But then the only alternative is to establish it as a separate Romance language, as some linguists do with Catalan or Franco-Provencal or both.

In morphology, the declension of Old Provencal retains, as does Old French, a two-case system. one for the subject and one for the nonsubject case. In the modern dialects, a one-case (that is, no-case) system prevails.

The Provenqal verb partakes of all the changes from Latin to Romance in general; but the typically Provençal features relate it more to Ibero-Romance (Spanish, Portuguese, Catalan; *q.v.*) than to French.

A renascence of southern speech ways was unsuccessfully attempted during the 19th century, mainly through the efforts of Frédéric Mistral (q *v.*), who attempted to create a new literary standard language for the Midi, based chiefly on several patois of the Bouches-du-Rhône district.

BIBLIOGRAPHY.—C. H. Grandgent, *An Outline of Phonology and Morphology of Old Provençal (1905)*; D C. Haskell, *Provençal Language and Literature (1925)*; R T Hill and T. G. Bergin, *Anthology of Provençal Troubadours (1941)*; Frédéric Mistral, *Lou tresor dou Felibrige: Dictionnaire Provençal-Français,* new ed. *(1932)*; J. Ronjat, *Grammaire istorique [sic] des parlers provençaux modernes (1930–41)*. (E. PM.)

PROVENCAL LITERATURE. Provenqal literature is much more easily defined than is the Provencal language (*q.v.*). Starting in the 11th and 12th centuries in several centres, it gradually spread out, first over the greater portion, though not the whole, of southern France, then into the north of Italy and Spain. It never felt the influence of the neighbouring literatures. At the time of its highest development (12th century) the art of composing in the vulgar tongue did not exist, or mas only beginning to exist, to the south of the Alps and the Pyrenees. In the north, in the country of French speech, vernacular poetry nas in full bloom; but between the districts in which it had developed—Champagne, Île-de-France. Picardy and Normandy—and the region in which Provencal literature had sprung up. there seems to have been an intermediate zone formed by Burgundy. Bourbonnais. Berry. Touraine and Anjou which, far on in the middle ages, appears to have remained almost barren of vernacular literature. In its rise Provenqal literature stands completely by itself. It presents at several points genuine analogies with the sister literature of northern France; but these analogies are due principally to certain primary elements common to both and only in a slight degree to interaction.

Provencal literature can be clearly divided into three periods: the first covers the middle ages from the 11th to the 13th century; the second extends from its first renaissance over the classical age. covering the 17th and 18th centuries; and the third begins mith its second renaissance in the 19th century, the age of the Félibrige and their successors.

FIRST PERIOD

Origin.—The new vernacular literature took a poetic form, and its oldest monuments show a virtuosity and a variety that indicate that poetry had already been practised for some time. The oldest piece of Provencal verse extant is said to belong to the 10th century: it is a refrain attached to a Latin poem in a Vatican ms. (text in the *Zeitschrift* fzir deutsche *Philologie,* 1881, p. 335). More important, however, is a 257-line fragment of didactic verse preserved in an Orléans ms. and frequently edited since F. J. Raynouard first printed it in his *Choix* des *poésies* originales des troubadours. It is the beginning of an adaptation of A. Boethius' treatise De Consolatione Philosophiae by an anonymous clerk, whose use of the poetic form in the vulgar tongue shows that his illiterate contemporaries must at least have been already accustomed to such poetry. The handwriting of the manuscript is that of the period A.D. 1000–50, the language seems to belong most probably to the Limousin or to La Marche. Boethius' ideas are developed with a Christian colouring of which there is no trace in the Latin original; for instance, from some verses in which Boethius contrasts his happy youth with his afflicted old age. the clerkly author draws a lengthy homily on the necessity of laying up from early years a treasure of good works. A little later on, at the close of the 11th century, we have the poems of William IX, duke of Aquitaine (Guilhem VII of Poitiers). They consist of 11 very diverse strophic pieces and were meant to be sung. Several are love songs; one relates a *bonne* fortune in very free terms; and the most important of all—the only one which can be approximately dated, being composed at the time when William was setting out for Spain to fight the Saracens (about 1119)—expresses in touching and often noble words the writer's regret for the frivolity of his past life and the apprehensions which oppressed him as he bade farewell, perhaps forever, to his country and his young son.

There is no reason to believe that William created the type of poetry of which he is to us the oldest representative: it may have been his high rank that saved some of his work from oblivion while that of his predecessors and contemporaries disappeared. The contrast in form and subject between the Boethius poem and the stanzas of William IX is an indication that by the 11th century Provençal poetry was being rapidly developed in various directions. Whence came this poetry? How and by whose work was it formed? That it has no connection whatever nith Latin poetry is generally admitted. The view which seems to meet with general acceptance (even if a slight influence from Arabic poetry can nom be admitted) is that Romance poetry sprang out of a popular poetry quietly holding its place from Roman times Yet, as regards the substance, the poetic material, we find nothing in the earliest Provencal which is strictly popular. the extremely personal compositions of William IX have nothing in common with folklore. At least the poets must have found themselves obliged to compound with the refinement of an aristocracy that had become. from century to century, more and more delicate, not to say learned.

From what class of persons did this poetry proceed? Latin chroniclers of the middle ages mention ioculares, *ioculatores,* men of a class not very highly esteemed whose profession consisted in amusing their audience either by what we still call jugglers' tricks, by exhibiting performing animals, or by recitation and song. They are called joglars in Provencal, jonglers or jongleurs in French; and they were the first authors of poetry in the vernacular both in the south and in the north of France. In the north, where manners mere not so refined and where the taste for warlike adventure prevailed, those of the jongleurs who composed verses produced chansons *de* geste full of tales of battle and combat. In the courts of the southern nobles, where wealth was more abundant and life more civilized, they produced love songs.

The Provençal love songs reflect the social conditions obtaining in the Midi under feudalism. The daughters of territorial lords, who might well become rich heiresses, were married for political reasons, not to satisfy their own inclinations; but, once married, they seem to have enjoyed a very generous measure of personal liberty. Consequently, they welcomed the attentions of their husbands' dependents, who, as courtiers, would address flattering songs of love to them. As the poets were usually far beneath the ladies in social status. they wrote in a most guarded and respectful style, as though they had very little hope of having their love requited. This profession of "courtly" or "chivalrous" love became a matter of convention; but it would be a mistake to assume that the real sentiments or experiences of the poets were invariably as platonic as the expression given to them.

The Troubadours.—By the end of the 11th century, then, a clear distinction had been drawn between the lower sort of *joglars* and the refined poets; and it is to the poets as such that the name troubadour (*q.v.*) belongs, comprising as it does not only accomplished poets of the lower ranks of society but also some of the great nobles who wrote poetry. In the Limousin lived a viscount of Ventadour, Eble. who early in the 12th century seems to have been brought into relation with William IX of Aquitaine and, according to a contemporary historian, Geffrei, prior of Vigeois, erat valde *gratiosus* in cantilenis. We possess none of his compositions; but under his influence Bernart de Ventadour was trained to poetry. Bernart gained the love of the lady of Ventadour and. when on the discovery of their amour he had to depart elsewhere. received a gracious welcome from William IX's granddaughter Eleanor of Aquitaine, consort (from 1152) of Henry II of England. Of Bernart's compositions we possess about 50 songs of elegant simplicity; some of which may be taken as the most perfect specimens of Provencal love poetry. At the same period, or earlier, flourished Cercamon, a Gascon, who composed, says his old biographer, "pastorals according to the ancient custom" (*pastorelas* a la *uzansa* antiga). Among the earliest troubadours is hfarcabrun, a pupil of Cercamon's, from whose pen we have about 40 pieces, those ahich can be approximately dated ranging from 1135 to 1148 or thereabout. His songs, several of which are historical. are free from the commonplaces of their class, and contain curious strictures on the corruptions of the time. Jaufre Rudel of Blaye, the singer of the *amor* de lonh (far-away love), is scarcely less famous.

Only a few of the troubadours can be cited here. They include Peire d'Alvernha (Peter of Auvergne), who in certain respects must be classed with Marcabrun; Arnaut Daniel, remarkable for his complicated versification, the inventor of the sestina; Arnaut de Mareuil (Marueil or Maroill) who, while less famous than Arnaut Daniel, surpasses him in elegant simplicity of form and delicacy of sentiment; Bertran de Born. famous for the part that he is said to have played both with his sword and with his *sirventess* in the struggle between Henry II of England and his rebel sons; Peire Vidal, of Toulouse. a poet of varied inspiration who grew rich with gifts bestowed on him by the greatest nobles; Giraut de Borneil (Guiraut de Bornelh), lo *maestre* dels trobadors and at any rate master in the art of the so-called "close" style (*trobar clus*), though he has also left us some songs of charming simplicity; Gaucelm Faidit, from whom we have a touching lament (*planh*) on the death of Richard Coeur de Lion; Folquet de Marseilla, a ponerful thinker who from being a troubadour became first a monk, then an abbot and finally bishop of Toulouse (d. 1231); the chivalrous Raimbaut de Vaqueyras (Provence); the truculent monk of Montaudon (Auvergne); the satirical Peire Cardenal (Velay); and "the last troubadour," Guiraut Riquier.

The troubadours who nere not themselves great feudatories could hardly expect to obtain a livelihood from any other quarter than the generosity of the great. It will consequently be well to mention the most important at least of those princes who are known to have been patrons and some of them practisers of the poetic art. They are arranged approximately in geographical order, and after each are inserted the names of those troubadours with whom they were connected.

France.—ELEANOR OF AQCITAINE, Bernart de Ventadour (Ventadorn); HENRY CURTMANTLE, son of Henry II of England, Bertran de Born(?); RICHARD COEUR DE LION. Arnaut Daniel, Peire Vidal, Folquet de Marseilla, Gaucelm Faidit; ERMENGARDE OF NARBONNE (1143–92), Bernart de Ventadour, Peire Rogier, Peire d'Alvernha; RAYMUND V. count of Toulouse (1143–94), Bernart de Ventadour, Peire Rogier, Peire Raimon, Uc Brunet, Peire Vidal, Folquet de Marseilla, Bernart de Durfort; RAYMUND VI, count of Toulouse (1194–1222), Raimon de Miraval, Aimeric de Pegulhan. Aimeric de Belenoi, Ademar lo Negre; ALPHONSO II, count of Provence (1196–1209), Elias de Barjols; RAYMUND BERENGAR IV, count of Provence (1209–45), Sordel; BARRAL DE BAUX, viscount of Marseilles (d. *c.* 1192), Peire Vidal, Folquet de Marseilla; WILLIAM VIII, lord of hfontpellier (1172–1204), Peire Raimon, Arnaut de Mareuil, Folquet de Marseilla, Guiraut de Calanson, Aimeric de Sarlat; ROBERT, dauphin of Auvergne

(1169–1234), Peirol, Perdigon, Pierre de Maensac, Gaucelm Faidit; GUILLAUME DE BAUX, prince of Orange (1182–1218), Raimbaut de Vaqueyras, Perdigon; SAVARIC DE MAULÉON (1200–30), Gaucelm de Puicibot, Uc de Saint-Circ; BLACATZ, a Provençal noble (1200?–36), Cadenet, Joan d'Albuzon, Sordel, Guilhem Figueira; HENRY I, count of Rodez (1208–22?), Uc de Saint Circ; perhaps HUGH IV, count of Rodez (1222?–74) and HENRY II, count of Rodez (1274–1302), Guiraut Riquier, Folquet de Lunel, Serveri de Girone, Bertran Carbonel; NUÑO SANCHEZ, count of Roussillon (d. 1241), Aimeric de Belenoi; BERNARD IV, count of Astarac (1249–91), Guiraut Riquier, Xmanieu de Sescas.

Spain.—ALPHONSO II, king of Aragon (1162–96), Peire Rogier. Peire Raimon, Peire Vidal, Cadenet, Guiraut de Cabreira, Elias de Barjols, the monk of Montaudon, Uc Brunet; PETER II, king of Aragon (1196–1213), Raimon de Miraval, Aimeric de Pegulhan. Perdigon, Ademar lo Negre, Uc de Saint Circ; JAMES I, king of Aragon (1213–76), Peire Cardenal, Bernart Sicart de Marvejols, Guiraut Riquier. At de Mons; PETER III. king of Aragon (1276–85), Paulet de Marseilla, Guiraut Riquier, Serveri de Girone; ALPHONSO VIII or IX, king of Castile (1158–1214), Peire Rogier, Giraut de Borneil, Aimeric de Pegulhan, Uc de Saint Circ; ALPHONSO X, king of Castile (1252–84), Bertran de Lamanon, Bonifaci Calvo, Guiraut Riquier, Folquet de Lunel, Xrnaut Plages, Bertran Carbonel.

Italy.—BONIFACE I, marquis of Montferrat (1192–1207), Peire Vidal, Raimbaut de Vaqueyras, Elias Cairel, Gaucelm Faidit (?); FREDERICK II, emperor (121s–so), Joan d'Albuzon, Afmeric.de Pegulhan, Guilhem Figueira; Azzo VI, marquis of Este (1196–1212), Aimeric de Pegulhan, Rambertin de Buvalelli; Azzo VIII, marquis of Este (1215–64), Aimeric de Pegulhan.

The decline and fall of troubadour poetry was due mainly to political causes. When in the first decades of the 13th century the Albigensian War had ruined a large number of the nobles and reduced to lasting poverty a part of the Midi, the profession of troubadour ceased to be lucrative. It was then that many of these poets went to spend their last days in the north of Spain and Italy, where Provencal poetry had for more than one generation been highly esteemed. Following their example, other poets who were not natives of the Midi began to compose in Provencal; but from the middle of the 13th century, they began to abandon the foreien tongue and took to singing the same airs in the local dialects. About the same time in the Midi itself the flame of poetry had died out save in a few places — Narbonne, Rodez, Foix and Astarac — where it kept burning feebly for a little longer. In the 14th century composition in the language of the country was still practised; but the productions of this period are mainly works for instruction and edification. The poetry of the troubadours was dead.

For a further account of the art of the troubadours, with lives of individual exponents and a bibliography, *see* TROUBADOURS.

Chansons de Geste and Historical Poems. — Northern France is *par excellence* the country of the *chanson de geste* (*q.v.*); but Provençal literature has some highly important specimens of the class. The first place belongs to *Girart de Rossillon,* a poem of 10,000 lines, which relates the struggles of Charles Martel with his powerful vassal Gerard oi Roussillon. The existing recension seems to have originated on the borders of Limousin and Poitou; but it is a recast of an older poem no longer extant, probably either of French or at least Burgundian origin. To Limousin also seems to belong the poem *Aigar e Maurin* (end of the 12th century). Of less heroic character is the poem *Daurel e Beton* (first half of the 13th century).

Midway between legend and history may be classified the Provenqal *chanson* on the siege of Antioch, a mere fragment of which, 700 verses in extent, has been recovered in Madrid and published in *Archives de l'Orient latin,* vol. ii. This poem (*see* G. Paris, in *Romania,* xxii, 358) is one of the sources of the Spanish compilation La *Gran Conquista de Ultramar.* To history proper belongs the *chanson* of the crusade against the Albigensians, which, in its present state, is composed of two poems, one tacked to the other: the first, containing the events from the beginning of the crusade till 1213, is the work of a cleric named Guilhem de Tudela, a moderate supporter of the crusades; the second, from 1213 to 1218, is by a vehement opponent of the enterprise. The language and style of the two parts are no less different than the opinions. The second part is certainly one of the masterpieces of Provenqal literature. Finally, about 1280, Guilhem Anelier, a native of Toulouse, composed a poem on the war carried on in Navarre by the French in 1276 and 1277, a historical work of little literary merit. All these poems are in the form of *chansons de geste;* viz., in stanzas of indefinite length, with a single rhyme. *Girart de Rossillon, Aigar e Maurin* and *Daurel e Beton* are in lines of ten, the others in lines of 12 syllables. The peculiarity of the versification in *Girart* is that the pause in the line occurs after the sixth syllable and not, as is usual. after the fourth.

Narrative Poems.—We possess but three Provencal romances of adventure: *Jaufre* (composed in the middle of the 13th century and dedicated to a king of Aragon, possibly James I), *Blandin de Cornoalha* and *Guillem de la Barra.* Connected with the romance of adventure is the novel (in Provençal *novas,* always in the plural), which is originally an account of an event "newly" happened. Some of the extant novels may be ranked with the most graceful works in Provençal literature. Two are from the pen of the Catalan author Raimon Vidal de Besalu: one, the *Castia-gilos,* is an elegant treatment of the story of the husband who disguises himself as his wife's lover in order to trap her and receives with satisfaction blows intended, as he thinks, for him whose part he is playing; the other is the recital of a question of the law of love, departing considerably from the subjects usually treated in the novels. Mention may also be made of *Novas del Papagai* by Arnaut de Carcasses, in which the principal character is an eloquent parrot, who assists the amorous enterprises of his master. Novels came to be extended to the proportions of a long romance. *Flamenca,* which belongs to the novel type, still runs to more than 8,000 lines, though the only ms. of it has lost some leaves both at the beginning and at the end. This poem, composed in all probability in 1234, is the story of a lady who by very ingenious devices, not unlike those employed in the *Miles gloriosus* of Plautus, eludes the vigilance of her jealous husband. No book in mediaeval literature betokens so much quickness of intellect or is so instructive in regard to the manners and usages of polite society in the 13th century. From the south of France the novel spread into Catalonia, where we find in the 14th century a number of novels in verse' very similar to the Provenqal ones, and into Italy, where in general the prose form has been adopted.

Didactic and Religious Poetry. — The more important works are: the Boethius poem (unfortunately a mere fragmentj, already mentioned as one of the oldest documents oi the language; an early (12th-century?) metrical translation of the *Disticha de moribus* of Dionysius Cato (*Romania,* xxv, 98, and xxix, 445): Daude de Prades (early 13th century), *Auzels cassadors,* one of the best sources for the study of falconry; and a translation by Raimon d'Avignon (*c.* 1200) of Rogier de Parme's "Surgery" (*Romania,* x, 63 and 496). More original are some compositions of an educational character known under the name of *ensenhamenz* and comparable in some respects to the English nurture books. The most interesting are those of Garin le Brun (12th century), Arnaut de Mareuil, Arnaut Guilhem de Marsan, Amanieu de Sescas. Their general object is the education of ladies of rank. Of metrical lives of saints we possess about a dozen, among which two or three deserve a particular attention: the life of St. Fides (ed. by A. Thomas and by E. Hoepffner), written early in the 12th century; the life of St. Enimia (13th century), by Bertran of Marseilles (ed. by C. Brunel) and that of St. Honorat of Lerins by Raimon Feraut (about 1300), which is distinguished by variety and elegance of versification but is almost entirely a translation from Latin. Lives of saints (St. Andrew, St. Thomas the Apostle, St. John the Evangelist) form a part of a poem, strictly didactic, which stands out by reason oi its great extent (nearly 35,000 verses) and the somewhat original conception of its scheme — the *Breviari d'antor,* a vast encyclopaedia on a theological basis, composed *c.* 1288–1300 by the Minorite friar Matfre Ermengaut of Béziers.

Drama. — The dramatic literature of the Midi consists of mysteries and miracle plays seldom exceeding 2,000 or 3,000 lines, which never developed into the enormous dramas of northern France, whose acting required several consecutive days. Generally those plays belong to the 15th century or to the 16th. Still, a few are more ancient and may be ascribed to the 14th century or even to the end of the 13th. The oldest appears to be the *Mystery of St. Agnes* (edited by K. Bartsch, 1869), written in Arles. Somewhat more recent, but not later than the beginning of the 14th century, are a mystery on the Passion of Christ and another on the Marriage of the Virgin; the latter is partly adapted from a French poem of the 13th century (see *Ronzania,* xvi, 71). A manuscript printed by A. Jeanroy and H. Teulié 1893, contains not less than 16 short mysteries, 3 founded on the Old Testament, 13 on the New. They were written in Rouergue and are partly imitated from French mysteries. At Manosque (Basses Alpes) was found a fragment of a *Ludus sancti Jacobi,* inserted in *a* register of notarial deeds (printed by C. Arnaud, Marseilles, 1858). The region comprised between the Rhône and the Var seems to have been particularly fond of representations of this sort, to judge by the entries in the local records (see *Romania,* xxvii, 400). At the close of the 15th and the beginning of the 16th centuries many mysteries were played in that part of Dauphine which corresponds to the present *département* of Hautes-Alpes. Five mysteries of this district, composed and played about 1500 (the mysteries of St. Eustace, of St. Andrew, of St. Pons, of SS. Peter and Paul and of St. Anthony of Vienne) have come down to us. The influence of the contemporary French sacred drama may to some extent be traced in them.

Prose. — In the 12th century we find in Languedoc sermons whose importance is more linguistic than literary (*Sermons du XII^{e} siecle en vieux provençal,* ed. by F. Armitage, Heilbronn, 1884). About the same time, in Limousin, were translated ch. xiii–xvii of St. John's Gospel (K. Bartsch. *Chrestomathie provençale*). Various translations of the New Testament and of some parts of the Old were made in Languedoc and Provence during the 13th and 14th centuries (see S. Berger, "Les Bibles provençales et vaudoises," *Romania,* xviii, 353;

and "Nouvelles recherches sur les Bibles provençales et catalanes," ibid., xix, 505). The Provencal prose rendering of some lives of saints made in the early part of the 13th century (*Revue* des *langues romanes,* 1890) is more interesting from a purely linguistic than from a literary point of view. To the 13th century belong certain lives of the troubadours intended to be prefixed to, and to explain, their poems. Many of them were written before 1250, when the first anthologies of troubadour poetry were compiled; and some are the work of the troubadour Uc de Saint Circ. Some were composed in the north of Italy, at a time when the troubadours found more favour east of the Alps than in their own country. Considered as historical documents these biographies are of a very doubtful value. To the same period must be assigned Las *Razos* de trobar of the troubadour Raimon Vidal de Besalu (an elegant little treatise touching on various points of grammar and the poetic art), the *Donatz proensals* of Uc Faidit and the "life" of St. Douceline, who died in 1274, near Marseilles, and founded an order of Beguines.

The leading prose work of this period is the treatise on grammar, poetry and rhetoric known by the name of Leys *d'amors,* composed in Toulouse c. 1350. The decay of Provencal literature, caused by political circumstances, arrived too soon to allow of a full development of prose. Nor did anything remain, in the second quarter of the 14th century, of what had been the first Provençal classicism, except the stale School of the Gai Savoir.

SECOND PERIOD

Yet Provenqal literature never died out entirely. The Academy of Toulouse, founded in 1324, was flourishing, mith the School of the Gai Savoir, at the end of the Hundred Years' War and, after many vicissitudes, is flourishing still. The poets crowned by this body between 1324 and 1498 stand in the same relation to the troubadours as the Meistersinger do to the Minnesanger: academic correctness takes the place of inspiration. The institution flourished, even to the extent of establishing branches in Catalonia and Majorca; and in 1484, when its prosperity was threatened, a seinifabulous person, Clémence Isaure, is said to have brought about a revival by instituting fresh prizes. The town of Toulouse never ceased to supply funds of some kind. In 1513 French poems were first admitted in the competitions, and under Louis XIV (from 1679) these were alone held eligible. This arrangement held good till 1893, when the town very properly transferred its patronaqe to a new Escolo *moundino;* but it soon restored its support to the older institution, on learning that Provençal poetry was again to be encouraged. In the two centuries that followed the glorious mediaeval period we have a succession of works, chiefly of a didactic and edifying character, which served to keep alive some kind of literary tradition. Religious mystery plays, which, though dull to us, probably gave keen enjoyment to the people, represent a more popular genre; the latest that have come down to us may be placed between the years 1450 and 1515.

In the 16th century there are not only signs of a revival, but a strong movement toward what might be called a Provenqal Renaissance. The Gascon Pey de Garros (d. 1585), author of the famous Eglogues, raised his native dialect to the rank of a literary language with his translation of the Psalms of David (1565) and inserted in his Poesias *gasconas* (1567) a maniiesto that might be compared to the Declaration of Font-Ségugne, launched four centuries later by the Felibres (see below, Third Period). As early as 1579, G. de Salluste du Bartas, in his trilingual *Salut,* followed the example of Pey de Garros. The Rabastens wheelwright, Augié Gaillard (1530–95), started the movement in Languedoc, and Louis Bellaud de la Bellaudière (1532–88) in Provence proper.

After Garros, in Gascony, came Guillaume Ader (Lou Catounet gascoun, 1605; Lou *Gentilome gascoun,* 1610), Louis Baron (b. 1612), who celebrated with great tenderness his native village of Pouyloubrin, Geraud Bedout (Lou Parterre gascoun, 1642), and J. G. d'Astros who, about the same time, with his remarkable Trinfe de la lengouo gascouo proved a most elegant and witty verse writer. But the most conspicuous among the poets of the Midi between Pey de Garros and Jacques Jasmin is certainly Pierre Goudelin (Goudouli; 1579–1649) of Toulouse, called "the hlalherbe of Oc." who, had he written in French, would have been given rank with the best of the times. Nicolas Sabolv (1614–75) excelled in the popular form known as the noel.

Other 17th-century writers worth mentioning, outside Gascony, are Claude Brueys (1570–1650), remarkable chiefly for comedies dealing with duped husbands (*Jardin deys musos* provensalos, 1628); Gaspar Zerbin (La *Perlo* deys *musos* et *coumedies provensalos,* 1655); Jean Michel de Nimes who wrote the picturesque *Embarras* de la *Fieiro* de Beaucaire; Daniel Sage of Montpellier (Las Foulies, 1650); the *avocat* Bonnet, author of the best among the open-air plays that mere annually performed at Béziers on Ascension Day (a number of these, dated 1616–57, were eubscquently collected, but none can compare with the opening one, Bonnet's *Jugement* de Paris); Nicolas Fizes, of Frontignan, whose vaudeville, the *Opéra* de *Frontignan* (1670), dealing with a slight love intrigue, and an idyllic poem on the fountain of Frontignan, show a real poetic gift. A number of Toulouse poets, mostly *laureats* of the academy, may be termed followers of Goudelin: of these, Franqois Boudet. who composed an ode, Le Trinfe del *Moundi* (1678), in honour of his native dialect, deserves mention. The classical revival that may be noted about this time is also generally ascribed to Goudelin's influence. Its most distinguished representative was Jean de Valks, of Montech, who made excellent translations from Virgil and Persius and wrote a brilliant burlesque of the former in the manner of Scarron (Virgile deguisat, 1648).

The best of the pastoral poets was François de Cortkte (1571–1655), of Prades, whose comedies, Rnnzounet and *Miramoundo* (published, unfortunately with alterations, by his son in 1684), are written with such true feeling and in so pure a style that they can be read with real pleasure. A comedy of his dealing with Sancho Panza in the palace of the duke has been edited. Arnaud Daubasse (1664–1727), of Qnercy, who belonged to the working classes, was patronized by the nobility in exchange for panegyrics.

In the 18th century the number of authors is much larger, but the bulk of good work produced is not equally great in proportion. The priests are mainly responsible for the literary output of Languedoc. The chief of the band is the abbe' J. B. Favre (1727–83), whose *Sermoun* de *Moussu* Sistre, delivered by a drunken priest against intemperance, is a masterpiece. He also wrote a successful mock-heroic poem (Sidge de Cadaroussa), travesties of Homer and Virgil, a prose novel depicting the country manners oi the time (*Histouèro* de *Jean-l'an-prés*) and two comedies which likewise give a vivid picture of the village life that he knew so well. Two genuine poets are the brothers Rigaud of Montpellier: Auguste (1760–1835) was the author of a deservedly famous description of a vintage; and Cyrille (1750–1824) produced an equally delightful poem in the Amours de Mounpeie'. Pierre Hellies of Toulouse (d. 1724), a poet of the people, whose vicious life finds an echo in his works, has a certain rude charm, at times distantly recalling Villon. In Provence, Toussaint Gros (1698–1748), of Lyons, holds undisputed sway. His style and language are admirable, but unfortunately he wasted his giits largely on trivial *pièces* d'occasion. J. B. Coye's (1711–77) comedy, *Lou* Novy para, is bright and still popular, while J. B. Germain's description of a visit paid by the ancient gods to Marseilles (Bourrido dei Dious, 1760) has considerable humour. In Gascony the greatest poet is Cyrien Despourrins (1698–1755).

THIRD PERIOD

The Revolution produced a large body of literature, but nothing of lasting interest. When it was over, scholars like F. J. Raynouard (1761–1863), of Aix, occupied themselves with the brilliant literary traditions of the middle ages; newspapers sprang up (the Provençal *Bouil-Abaïsso,* started by Joseph Désanat, and the bilingual Lou *Tambourin* et le menestrel, edited by Pierre Bellot, both in 1841); poets handed together and collected their pieces in volume iorm (*e.g.,* the nine *troubaire* who published Lou Bouquet *prouvençaou* in 1823). Much has been written about the "iorerunners of the Felibrigr," and critics are sorely at variance as to the writers that most deserve this appellation. We shall not go far wrong if we include in the list Hyacinthe Morel (1756–1829); Louis Aubanel (1758–1824); Auguste Tandon, "the troubadour of Montpellier"; Antoine Fabre d'Olivet (1767–1825); J. J. M. Diouloufet (1771–1840); Jacques Azaïs (1778–1856); Léon d'Astros (1780–1863); F. H. J. Castil-Blaze (1784–1857); the marquis de Fare-Alais (1791–1846). While these writers were all more or less academic and appealed to the cultured iew, four poets of the people addressed a far wider public: Antoine Verdié (1779–1820), of Bordeaux, who wrote comic and satirical picces; Jean Reboul (1796–1864), the baker of Nimes, who never surpassed his first effort, *L'Ange* et l'enfant (1828); Victor Gelu (1806–85), relentless and brutal but undeniably powerful of his kind (*Fenian* et *Grouman;* dix chansons *provençales,* 1840); and, greatest of them all, the true and acknowledged forerunner of the Felibres, Jacques Jasmin (*q.v.*).

The Advent of the **Felibrige.**—In 184j Joseph Roumanille (1818–91) of Saint Remy became usher in a small school at Avignon, which was attended by Frédéric Mistral (*q.v.*). Roumanille had composed some pieces in French; but, finding that his old mother could not understand them, he determined thenceforth to write in his native dialect only. These poems revealed a new world to young Mistral and spurred him on to the resolute that became the one purpose of his life: de *remettre* en *lumière* et conscience de sa gloire cette noble race *qu'en plein '89 Mirabeau nomme* encore la nation *provençale.* There is no doubt that Mistral's is the more puissant personality or that his finest work towers above that of his fellows; but in studying the Provençal renaissance, Roumanille must not be overlooked: his claims, indeed, were put forward with great force by Mistral himself (in the preface of Lis Isclo d'or). Roumanille's secular verse (Li Margaritedo, 1836–47; *Li Sounjarello,* 1852; Li Flour de Sauvi, 1850–59, etc.) moves the reader with the sincerity of its poetry, his *noëls* are second only to those of Saboly, his prose works (such as Lou Mege de *Cucugnan,* 1863) sparkle with delightful humour. He it was who in 1852 collected and published *Li Prouvençalo,* an anthology in which all the names yet to become famous and most of those famous already (such as Jasmin) are represented. In 1853 he was one of the enthusiastic circle that had gathered round J. B. Gaut at Aix and whose literary output is contained in the *Roumavagi deis* troubaires and in the shortlived journal Lou Gay Saber (1854). At the same time the first attempt at regulating the orthography of Provenqal was made by him (in the introduction to his play, La Part *dou* bon *Dieu,* 1853). In 1854 he was one of the seven poets who, on May 21, foregathered at the castle of Font-Ségugne, near Avignon, and founded the Felibrige.

The other six were Mistral, Aubanel, A. Mathieu (a schoolfellow of Mistral's at Avignon), E. Garcin, A. Tavan and P. Giera (owner of the castle). Of these, Théodore Aubanel (1829–86; of Avignon, son of a printer and following the same calling) alone proved himself worthy to rank with Mistral and Roumanille. "Zani," the girl of his youthful and passionate love, took the veil; and this event cast a shadow over his whole life and determined the character of all his poetry (*La Miougrano entredubaerto,* 1860; *Li Fiho d'Avignoun,* 1883). His is, without a doubt, the deepest nature and temperament among the Felibres, and his lyrics are the most poignant. His powerful love drama *Lou Pan dou pecat* was received with enthusiasm at Montpellier in 1878.

The Felibrige after Roumanille, Aubanel and Mistral.—The Felibrige increased considerably in Mistral's time and the subsequent period. The names of A. B. Crousillat, J. Brunet, L. Roumieux and of the "Muse" Antoinette de Beaucaire should be added to those of the signatories of the Font-Ségugne declaration. In Catalonia, V. Balaguer (1824–1901) lent his glory to the development of the Felibrean movement, before joining it. Among the poets of the next generation the most illustrious is certainly Félix Gras (1844–91) who settled down at Avignon as a young man. His rustic epic, *Li Carbounié* (1876) is full of elemental passion and abounds in fine description and scenery. Among his other works are *Li Roumancero Provençal* (1887) and a collection of prose tales, *Li Papalino* (1891). Gascony, which had been less closely associated with the Felibrige, then admitted the Landais writer Isidore Salles among the heirs of Despourrins and of the earlier 19th-century author Xavier Navarrot. Quite independent were Auguste Fourès in Languedoc and Clovis Hugues and Auguste Marin at Marseilles. The Latin Felibrean movement developed in Montpellier with A. Roque-Ferrier (1844–1907) and the Federalist movement with T. Amouretti (1863–1903) and Marius André (*La Glòri d'Esclarmoundo,* 1894; *Eme d'arantge un cargamen,* 1924). We should also mention, among the wider heritage of the first Felibres, the Irishman Bonaparte Wyse (*Li Piado de la Princesso,* Plymouth, 1882), the popular songwriter Charles Rieu, or Charloun (1845–1924), and, coming with a number of poets, born in Gascony, Rouergue and Languedoc, the somewhat artificial Joseph Roux (*La Chansou lemousina,* 1889) and the Auvergnat Arsène Vermenouze who proved with *Flour de brousso* (1895) and *Jous la cluchado* (1909) one of the poets most evocative of his homeland. Among those who attained fame during the first half of the 20th century, we should note the names of Valère Bernard (1860–1936) of Marseilles, author of *La Legenda d'Esclarmonda,* a masterpiece comparable to Mistral's best work, Antonin Perbosc (1861–1944), the Languedocian poet of *Lo Got occitan* and of *Lo Libre dels ausels,* Michel Camelat of Bigorre, Simin Palay of Béarn, and the Pyrenean *trobairitz* Philadelphe de Gerde. Contemporary with them were the *meynadiers* of the Camargue in Provence proper: Joseph d'Arbaud (1872–1950), who is less famous as the poet of *Lou Lausié d'Arle* than as the author of short stories such as *La Bestiou dou Vacarès,* written in an epic vein; Folco de Baroncelli (1869–1943) and Marius Jouveau (1878–1949). A curious case is that of S. A. Peyre, writing in Provençal, in French and in English. If Paul Froment (1875–98) had not died so young, he would doubtless have been the great poet of Quercy. P. L. Grenier (1879) was a notable artist who revived the classical language of Limousin. Albert Pestour, also a native of Limousin, with a fine command of the vernacular language, was the inspired poet of the *Rebats sus l'Autura* and of *L'Autura enviblada.* Among authors writing in the 1950s, mention should be made also of J. S. Pons (Roussillon), Louise Paulin (Languedoc) and of P. Eyssavel (Provence). They had, moreover, a regiment of young followers who bore witness to the permanent vitality, not so much of the Felibrige (a notion that was by that time somewhat out-of-date) as of Occitanian poetry.

Bibliography.—For a general bibliography, *see* D. C. Haskell, *Provençal Literature and Language* (New York, 1925), a list of references in the New York public library. On the whole of Provençal literature there is only one work: C. Camproux, *Histoire de la littérature occitane* (Paris, 1953). On the first and second period, viewed as a whole, *see* A. Jeanroy, *Histoire sommaire de la poésie occitane, des origines à la fin du XVIIIe siècle* (Toulouse, 1945).

On the first period, for general surveys, *see* J. B. de La Curne de Sainte-Palaye, *Histoire littéraire des troubadours,* 3 vol. (Paris, 1774); A. Restori, *Letteratura provenzale* (Milan, 1891); J. B. Beck, *Die Melodien der Troubadours* (Strasbourg, 1908); J. J. Salverda de Graves, *De Troubadours* (Leyden, 1917); J. Anglade, *Pour étudier les troubadours,* 2nd ed. (Paris, 1930); A. Pillet, *Bibliographie der Troubadours* (Halle, 1933); A. Jeanroy, *La Poésie lyrique des troubadours* (Paris, 1935); P. Belperron, *La Joie d'amour: contribution à l'étude des troubadours* (Paris, 1948). For general surveys with selections, *see* F. J. Raynouard, *Choix des poésies originales des troubadours,* 6 vol. (Paris, 1816–21); K. Bartsch, *Chrestomathie provençale,* 4th ed. (Elberfeld, 1880); C. Appel, *Provenzalische Chrestomathie,* 3rd ed. (Leipzig, 1903); V. Crescini, *Manualetto provenzale,* 2nd ed. (Verona, 1905); A. Kolsen, *Dichtungen der Trobadors* (Halle, 1916–19); J. Beck, *Les Chansonniers des troubadours et des trouvères, publiés en facsimilé et transcrits en notation moderne* (Philadelphia, 1927); A. Jeanroy, *Anthologie des troubadours* (translations only; Paris, 1907); J. Anglade, *Anthologie des troubadours* (Paris, 1927); J. Audiau and R. Lavaud, *Nouvelle anthologie des troubadours* (Paris, 1929); A. Berry, *Florilège des troubadours* (Paris, 1930); M. de Riquer, *La Lirica de los trovadores* (Barcelona, 1948). For special studies and selections, *see* Manuel Mila y Fontanals, *Los Trovadores en España* (Barcelona, 1861, 1889); P. Meyer, *Les Derniers Troubadours de la Provence,* 2 vol. (Paris, 1869–71); C. Chabaneau, *Poésies inédites des troubadours du Périgord* (Paris, 1885); F. de la Salle de Rochemaure and R. Lavaud, *Les Troubadours cantaliens* (Aurillac, 1910); A. Jeanroy, *Jongleurs et troubadours gascons des XIIe et XIIIe siècles* (Paris, 1923); H. J. Chaytor, *The Troubadours and England* (Cambridge, 1923); J. Audiau, *Les Troubadours et l'Angleterre* (Paris, 1927); J. Anglade, *Les Troubadours de Toulouse* (Paris, 1928) and *Actualité des troubadours de l'Aude* (Toulouse, 1941); A. Basset, *Les Troubadours limousins* (Limoges, 1949). For individual troubadours, *see* Troubadour: *Bibliography.* There are modern editions of *Girart de Roussillon* by P. Meyer (Paris, 1878), of *La Chanson de la croisade contre les Albigeois* by P. Meyer (Paris, 1875–79), of *Flamenca* by P. Meyer, 2nd ed. (Paris, 1901) and of *Las Leys d'Amors* by J. Anglade (Paris, 1919–20); there is also an important study of *Flamenca* by G. Millardet (Paris, 1936). The ancient *Biographies des troubadours* have been republished by J. Boutière and A. Schutz (Toulouse, 1950). *See* also A. Jeanroy, *Les Joies du Gay Savoir* (Paris-Toulouse, 1914); J. Anglade, *Les Origines du Gay Savoir* (Paris, 1919); and *Las Flors del Gay Saber* (Barcelona, 1926).

On the second period *see* J. B. Noulet, *Essai sur l'histoire littéraire des patois du Midi de la France aux XVIe et XVIIe siècles* (Paris, 1859) and *Histoire littéraire des patois du Midi de la France au XVIIIe siècle* (Montpellier, 1874–77).

On the third period, *see* P. Mariéton, *Les Félibres* (Paris, 1885); G. Jourdanne, *Histoire du Félibrige* (Avignon, 1897); E. Ripert, *La Renaissance provençale, 1800–60* (Paris, 1918) and *Le Félibrige* (Paris, 1924), the latter with an excellent bibliography; J. Salvat, *Le Félibrige* (Castelnaudary, 1940).

On Gascon literature, viewed separately, *see* G. Millardet, *Le Domaine gascon* (Brussels, 1909), for bibliography; G. Bastit, *La Gascogne littéraire depuis le moyen-âge jusqu'à nos jours* (Bordeaux, 1894); F. Sarran, *Poètes gascons du Gers* (Auch, 1904); G. Guillaumie, *Anthologie de la littérature et du folk-lore gascons,* 7 vol. (Bordeaux, 1941–45); I. Girard, *Anthologie des poètes gascons* (Toulouse, 1942).

(A. A. F. B.)

PROVENCE, a province in the southeast of ancient France, bounded on the north by the Dauphiné, on the east by the Alps and Italy, on the west by the Rhône and on the south by the Mediterranean sea. About 600 B.C., according to tradition, some traders from Phocaea founded the Greek colony of Massalia (Marseilles). Other colonies in the neighbourhood, such as Antibes, Agde and Nice, originated in this settlement. During the wars which followed, the inhabitants of Massalia asked assistance from the Romans, who thus made their first entry into Gaul (125 B.C.) and conquered the territories between the Alps, the sea and the Rhône (with the province of Narbonne on the right bank of this river). These lands formed the Provincia Romana, and the name was retained by Provence. The town of Aix (Aquae Sextiae) was founded to form the capital of this conquered land. Under the empire the territory of the former Provincia was divided into the new provinces of Narbonensis II, of the Maritime Alps and of Viennensis and formed an important centre of Roman learning and civilization. Arles was made the chief town of the province, becoming after the capture of Trier by the barbarians (A.D. 418) the capital of Gaul. By the 5th century bishoprics had been founded in all the cities of Provence.

At the beginning of that century Provence was attacked by the Visigoths. In 476 Arles was captured by Euric I, and the country south of the Durance thus came definitely under Visigothic rule. The more northern cities, such as Orange, Apt and Trois-Châteaux, were joined to the kingdom of Burgundy. About 510 Visigothic Provence was ceded to Theodoric, king of the Italian Ostrogoths; and soon afterward the Ostrogoths extended their lands in the north as far as Gap and Embrun. Witigis, king of the Ostrogoths, ceded Provence to the kings of the Franks about 537, when the northern cities and those on the coast (Arles, Marseilles, Toulon, Antibes, Nice) were given back to Burgundy, while a narrow strip of territory, with Avignon, Apt, Cavaillon, Riez, etc., extending from the west to the east as far as the Alps, was added to the kingdom of Austrasia.

In the 8th century western Provence was for a time conquered by Arabs from Spain. In 739 they were expelled by Charles Martel, who brought the country definitely under Frankish rule. Under Charlemagne and Louis the Pious the history of Provence was incorporated with that of the rest of the empire and became more and more subject to the incursions of the Saracens. **After** the partition of Verdun (843) it fell to the portion of the emperor Lothair. Later it went to his son, the emperor Louis II; and finally in 875 it passed to Charles the Bald, who handed it over to his brother-in-law Boso (879). The latter bore the title of king, and thus arose the kingdom of Provence (Provence, Viennois, Lyonnais and Vivarais), sometimes called Cisjuran Burgundy.

After some years of trouble the kingdom was given, in the 10th century, to Rudolph II of Burgundy, so that the kingdom of Burgundy now extended from the Aar to the Mediterranean. But under Rudolph's successors control became weaker and weaker, until Provence passed to the German kings, who then took the title of king of Arles (see ARLES, KINGDOM OF).

Local Countships. — At the beginning of the 10th century Provence was in a state of complete disorganization. All the real power was in the hands of local counts. It is probable that from the 9th century' several of the Provençal countships were united under one count and that the count of Arles had the title of duke, or marquis, and exercised authority over the others. In the middle of the 10th century this position was held by another Boso, of unknown origin, who left it to his two sons William and Roubaud (Rotbold).

From the end of the 10th century the descendants of the two brothers, without making any partition, ruled over the different countships of Provence; only one of them, however, bore the title of marquis. The counts of Provence had, from about the middle of the 11th century, a tendency to add the name of their usual residence after their title, and thus the lordships, known later under the names of the countships of Provence, of Nice and of Venaissin grew up. At last, by the marriage of Douce, the heiress, in 1112 to Raymund-Berengar III (Ramón Berenguer), count of Barcelona, the marquisate of Provence with the overlordship of this region passed to the house of Barcelona. The definite establishment of the countships of Provence, Venaissin and Forcalquier belongs to this period.

After the death of Raymund-Berengar IV (II of Provence) in 1162, his son Alphonso II, king of Aragon, took the title of count of Provence. His succession was disputed by the count of Toulouse, Raymund V. Most of the lay and ecclesiastical lords of Provence recognized Alphonso, who in 1176 signed a treaty with his competitor, by which Raymund V sold his rights to the king of Aragon.

Alphonso was represented in Provence by his brothers Raymund-Berengar III (of Provence) and Sancho, in turn, and in 1193 by his son Alphonso, who inherited Provence but not Aragon on his father's death in 1196. This Alphonso gave Aragon and Catalonia to his brother Peter (Pedro) and kept only Provence for himself; but on the death of his father-in-law, Count William II, in 1208, whose son had been disinherited, he added to it the county of Forcalquier. It was not until after his death (1209), during the minority of his son Raymund-Berengar IV, that Provence was involved in the struggle of the count of Toulouse against Simon de Montfort, when the part played by the city of Avignon in the Albigensian movement finally led to the expedition of Louis VIII of France against the town (see ALBIGENSES).

Raymund-Berengar had also to fight against Raymund VII, count of Toulouse, who had received from the emperor in 1230 the countship of Forcalquier. The intervention of St. Louis, who in 1234 had married Margaret, the eldest daughter of the count of Provence (the second, Eleanor, married Henry III of England in 1236), put an end to the designs of the count of Toulouse. Raymund-Berengar died in 1245, leaving a will by which he named as his heiress his fourth daughter, Beatrice, who shortly afterward, in 1246, married the celebrated Charles of Anjou (see CHARLES I, king of Kaples), brother of the king of France. After her death, in 1267, Charles still maintained his rights in Provence. The countship of Venaissin was left to him by his sister-in-law, Joan, countess of Toulouse. but in 1272 King Philip III took possession of it, giving it up in 1274 to Pope Gregory X, who had claimed it for the Roman Church in pursuance of the treaty of 1229 between Raymund VII of Toulouse and St. Louis.

Charles of Anjou was continually occupied with his kingdom of Naples. His government of Provence was marked by his struggles with the towns. In the first part of the 12th century the towns of Provence began to form municipal administrations and consulates, independent of the viscounts, who in theory represented the authority of the count in the towns. Marseilles, Arles, Tarascon, Avignon (whose consulate laws ddte from the 12th century), Brignoles and Grasse had become self-governing and elected their magistrates, sometimes negotiating with the count, as a power with a power, and concluding political or commercial treaties without consulting him. The city of Nice, which was joined to Provence in 1176. had retained its freedom. This state of affairs was in direct opposition to the arbitrary policy of Charles of Anjou. In 1251 he seized Arles and Avignon and placed them under a viguier (vicar) nominated by himself. In 1257 Marseilles was also subdued, and ministers nominated by the court performed their duties side by side with the municipal officials.

Annexation to France. — The successors of Charles of Anjou were chiefly interested in maintaining their rights over the kingdom of Naples. Charles II (-ruled 1285–1309) lived in Provence during the latter years of his reign and tried to introduce reforms into the administration of justice and finance. Robert of Calabria (1309–43), his son, was succeeded by his granddaughter Joanna I, widow of Andrew of Hungary, who sold her rights over the city of Avignon (where the popes settled from 1309 to 1377 and subsequently during the great schism) to Clement VI in 1348 to raise money to continue the struggle against the house of Aragon in Naples. The emperor Charles IV visited Avignon and had himself crowned king of Arles in 1365. He gave up his claims to Louis I, duke of Anjou, brother of Charles V of France. but the expedition which this prince made to take possession of Provence only resulted in the seizure of Tarascon and failed before Arles (1368).

Joanna had first nominated as her heir Charles of Anjou-Gravina, duke of Durazzo, her nephew by marriage: but when he took sides against her claim to the kingdom of Kaples she nominated instead Louis of Anjou as her eventual successor (1380). Louis took possession of Provence, while Charles of Durazzo made the queen prisoner at Naples and gave orders for her to be put to death (1382). Louis of Anjou also made an expedition to Naples, but did not arrive till after her death; he died in 1384. His son Louis II (ruled 1384–1417), only resident in Provence toward the end of his life, established a *parlement* in 1415. The wars carried on by his successor, Louis III (ruled 1417–34), against the kings of Aragon, his rivals at Naples, were the cause of the temporary ruin of Marseilles by the Aragonese fleet. René I (*q.v.*), duke of Anjou and Lorraine, Louis's brother and successor, after an unsuccessful attack on Naples (1460–61) retired to France, but after 1471 generally resided in Provence, where he built the castle of Tarascon and interested himself in art, literature and pastoral amusements. In 1474 he left his territories by will to his nephew Charles, count of Maine, who on his death in 1481 bequeathed Provence to Louis XI, king of France. Under Louis's successor, Charles VIII, Provence was definitely annexed to France. though even then it preserved a certain individuality. In laws relating to this country the sovereigns added to their title of king of France "and count of Provence and of Forcalquier," and Provence preserved a separate administrative organization.

Religious Troubles. — In the 16th century Protestantism made its appearance in Provence. A sentence passed in 1540 by the parlement of Provence against the heretics was carried out with great severity in 1545 by the president Jean de Maynier, baron d'Oppède, and the baron de la Garde. The movement drew a fair number of followers from the ranks of the lesser nobles. Charles IX's journey in Provence in 1567, followed by the establishment in the *parlement* at Aix of a court (*chambre*) in which Catholics and Protestants had an equal number of seats; led to a momentary cessation of hostilities. These were resumed between the Carcistes (Roman Catholics) and Razats (Protestants) but were again interrupted by the peace of 1576, which gave some guarantees to the Protestants, with La Seyne as a place of security, and also by the plague of 1579, which affected the whole country. The

League, on the other hand, made rapid progress in Provence. and the governor Bernard de Nogaret de La Valette and his brother Jean-Louis, duc d'Epernon (afterward governor also), vainly tried to pacify the country. La Valette and the party of the *Politiques* or Bigarrats mere finally more or leas reconciled to the Protestants; and at the time of the death of Henry III, the struggle was no more than a question of local politics. In 1596 the religious wars in Provence were definitely ended by the capitulation of Marseilles.

Under Rrchelieu the restriction of local freedom led to a rising which Condé suppressed in 1630–31. At the time of the Fronde additional taxes were levied by the *parlement* at Aix, and a period of local unrest began which culminated in an insurrection at Marseilles in 1660 followed by the abohtion of the last remaining municipal liberties of the town.

Provence was severely tried by the imperial invasions of 1706 and 1746 and the great plague of 1720.

Economic Development. — Throughout the middle ages, Provence was continually changing from the economic point of view. At the end of the ancient period and in Merovingian times it was a busy region with an important transit trade, the port of Marseilles being a commercial focus that connected Provence with the Italian ports and with the east. From the 7th century, however. trade undernent a serious crisis, caused in part by Arab expansion along the Mediterranean and by plundering of the Saracens, who blockaded the port and often attacked the coast of Provence But as early as the 12th century trade came to life again and the inland towns became local fairs. These fairs, however, did not enjoy so much prosperity as did those of other regions, because the important commercial roads — from Italy to Champagne and Flanders — did not cross this region. Nevertheless, Marseilles and Aigues-Mortes were ports in relation with Italy and the Latin east. At the beginning of the Angevin period (the end of the 13th century) the ports were busiest. Moreover, the tonns acquired a considerable pohtical importance dnd became great commercial and banking centres as well; such was the case with Avignon, where the papacy settled in the 14th century, and with Beaucaire, famous for its fairs. But later internal disturbances brought about a considerable falling off of these activities.

Administration.—Provence, with its own language and its law so closely related to Roman law, was quite separate from the other French provinces. Until 1639 it retained its provincial estates, the origin of nhich has been traced back to the 12th century They met annually and included representatives of three orders for the clergy, the archbishop of Aix, president ex officio of the tstates, the other bishops of Provence and the abbots of St Victor at hlarseilles, of Montmajour and ot Thoronet; for the nobility, all the men of noble birth until 1623. when this privilege was restricted to actual holders of fiefs; for the third estate, the members of the 22 chief towns of the *vigueries* (divisions corresponding to the *prévôtés* of the rest of France) and 15 other privileged places, among which were Arles and Marseilles. There nere theoretically no taxes, but only supplies given freely by the estates and assessed by them. The administrative divisions of Provence were constantly changing. At the end of the *ancien régime* tire government (*gouvernement*) of Provence, which corresponded to the *généralité* of Aix, was made up of eight *sénéchaussées:* those of lower Provence—Aix, Arles, Marseilles Brignoles, Hyères, Grasse, Draguignan, Toulon; and four of upper Provence—Digne, Sisteron, Forcalquier, Castellane. For judicial purposes the *parlement* of Aix had replaced the former *conseil e nment* or *cour souveraine*. There was a *chambre des comptes* at Aix and also a *cour des aides*. A decree dated Dec 22, 1790 divided Provence into the three departments of Bouches-du-Rhône, Basses-Alpes and Var; and in 1793 Vaucluse, the former county of Venaissin, which belonged to the pope, was added to these

The boundaries of Var were modified in 1860 after the annexation of the county of Nice when the department of the Alpes Maritimes was formed.

Bibliography —V L Bourilly and R Busquet, *Histoire de Provence* (Paris, 1944); *R.* Busquet, *Etudes sur l'ancienne Provence* (Paris, 1930); R. Poupardin, *Le Royaume de Provence sous les Carolingiens* (Paris, 1901); *G.* de Manteyer, La *Provence du Ier au XIIe siècle* (Paris. 1906); G. Lambert, *Essai sur le régime municipal et l'affranchissement des communes en Provence* (Toulon, 1882); *R.* Busquet and R. Pernoud, *Histoire du commerce de Marseille* (Paris, 1949).

(R. P.; M. Pac.)

PROVERBS, BOOK OF. This Old Testament book falls into nine sections. Each of these has its special stylistic and other characteristics. some of them containing evident traces of compilation from earlier collections, one (as has only lately been recognized) being almost completely paralleled in an extant Egyptian hook, while individual proverbs are found to bear traces of the "international" character of their origin and are variously related to the culture of Egypt, Babylonia, Greece, etc. *(see* Wisdom Literature).

Moreover, the tradition preserved in the book itself which ascribed certain parts of the book to Solomon (x. 1, xxv. 1), the "sages" (xxii. 17, xxiv. 23), Agur (xxx. 2), King Lemuel's mother (xxxi. 2) militates against the view that any one author was responsible for the composition of these various sections of the book: the ascription to Solomon in i. 1 probably referred originally to chapters i.–ix.—though this was probably the last section to be compiled.

Wellnigh the only characteristics common to all sections of the book may be summed up under three heads and these are not confined to the Book of Proverbs but are to be found in nearly all the extant gnomic literature of the Hebrews—the presuppositions that "wisdom" comes from Jehovah, that wisdom is, or should be, the guiding principle of life, and that cardinal social virtues such as industry, thrift, discretion, truthfulness, honesty, chastity, thought for others, including the lower animals, should be inculcated. Consequently in its present form the book represents the last stage in a long compilatory history and provides many useful examples of Hebrew proverbial and gnomic thought at various stages of its development. The date of each section and subsection must be alternately determined by the character of its contents, the relation in which the latter stands to the extant gnomic literature of other peoples, and the stage or stages of moral and theological development reflected in it.

Chapters i.–ix.—The first section serves as an introduction to the whole book, but in origin it is of late date and its contents suggest that, like the book as a whole, it was compiied from more than one source. At times, for instance, the motive advanced for good conduct is moral and religious (*e.g.*, ii. 5–8): at times it is frankly utilitarian (*e.g.*, vi. 1–5). Instead of a series of unrelated proverbial couplets, such as those in the following section, comparatively long discourses follow on each other. The sage addresses his remarks to young men. Though not confining his warnings to these two offenses, he warns them more especially against highway robbery and adultery — unless indeed the latter is an only too thinly veiled warning against Hellenism (*cf.* "Madam Folly" in ch. ix. 13–18) conceived of as a prostitute enticing the uninstructed ("ye simple ones") from their allegiance to their true love, the "wisdom" which comes from Jehovah, incarnate, as it were, in His religion, Judaism. Somewhat similar warnings against woman's wiles are given by Egyptian sages such as Amenophis and Ptah-hoteph, and by the Mesopotamian author of the Wisdom of Ahikar. The section is chiefly remarkable for the developed thought contained in viii. 1–31 as to "wisdom," its relation to God, the universe and man. It is perhaps more developed than, not only Eccles. xxiv. 1–19, but also the descriptions of it in the Book of Wisdom. "Wisdom" claims to have existed prior to the universe *(cf.* "in the beginning" with the first words of Gen. i. 1 and Jolin i. 1) as a possession of God (viii. 22 sff.), to have witnessed the creation of the universe, and even to have acted as a clerk of the works or architect in the process of the creation, unless, as the parallelism of the verse makes probable, the vocalization of the Hebrew word translated "master workman" should be altered to justify the rendering "nursling." But it is questionable whether even here the Hebrew author does more than poetically *Personify the principle* of wisdom: he scarcely gives it a real *hypostasis* and does not go so far in this direction as did Philo in his description of the Logos as "a second god."

It is not, however, outside the bounds of possibility that the author of the prologue to the Fourth Gospel was considerably influenced by this description of wisdom rather than by Philo's descriptions of his Logos, even though he substituted the latter term for "wisdom." This advanced thought as to wisdom is not confined to ch. viii., but seems to be more or less presupposed throughout the section. The author's philosophy of life otherwise shows little of a pronouncedly modern character. Righteousness and wickedness are rewarded in this life (*e.g.,* ii. 21) ; the sacrificial worship is inculcated (ii. 9, iii. 9); the words "law" and "commandment" are used now of the Mosaic system, now of parental injunctions, now of the sage's advice. It is the language and philosophy of life characteristic of Deuteronomy which are most prominent; suffering is divine chastisement administered, however, in love (iii. 12).

Chapters **x.–xxii.**—The second section illustrates earlier stages in the literary productions and ideals of the exponents of wisdom. Each proverb is confined to two lines, antithetical in form if we except a few in which synonymous parallelism occurs. The utilitarianism of the compiler of this section is often overemphasized: it contains, on the contrary, sentiments which anticipate some of the highest ideals expressed in the New Testament and to which the latter owe their literary form (*e.g.,* x. 12 cf. I Cor. xiii. 7, I Pet. iv. 3, James v. 20; xiv. 31; xvii. 5, cf. Matt. xxv. 40, 45; xx. 11, cf. Matt. vii. 16; xx. 22, *cf.* Matt. v. 39, Rom. xii. 17, 19, etc.). It reflects, moreover at times the "prophetic" revolt against the hollowness of merely external sacrificial worship (xv. 8, xxi. 3) cf. the emphasis on the national virtue demanded by Amos (xiv. 34) and on inner purity (xx. 9) and on the omniscience of Jehovah (xv. 3, 11). Thus, in date, the section shows no trace of the developments of religious, theological and philosophical thought for which the latter post-exilic Judaism was responsible; on the other hand, along with much which might be the product of any period, it presupposes, at least in the above respects, the very latest products of pre-exilic piety.

Chapters **xxii. (17) to xxiv.** (22) — The third section bears the title "words of the wise." Its contents are presented to the reader in a strophic form, forming a miniature discourse, and having four lines to a strophe, as in the newly deciphered Egyptian "Teaching of Amenophis." It is the remarkable similarity of the section to this latter book which has especially concentrated attention upon it since 1924. The similarity between the two continues, with certain exceptions, throughout a considerable portion of the section and creates a problem which is scarcely solved by the theory that both reflect gnomic sayings which were common to all nations of the orient. Indeed so close is the relationship that it is possible to emend with a fair degree of certainty, on the basis of the Egyptian tradition, passages in which the Hebrew text is manifestly corrupt: thus "excellent things" (xxii. 20) without any change in the consonantal text, should be read as "thirty (sayings)," the exact number of the "chapters" into which *The* Teaching of Amenophis is divided. It would appear unlikely that the Egyptian sage borrowed from the Hebrew, and we are therefore compelled to suppose that either a copy of the Egyptian book penetrated into Palestine and its contents gradually became "Hebraised," its Egyptian theology slowly yielding to that of the Hebrews and proverbs from. other sources gradually attaching themselves to it; or a Hebrew sage, visiting or living in Egypt, became acquainted with it, expurgated its Egyptian polytheism and made it acceptable to those who saw in Jehovah the only God who ruled every department of life. Either of these alternatives can best be visualised as happening in pre-exilic rather than late post-exilic days, but to dogmatise as to the exact date, whether the reign of Hezekiah, the early years of the exile or otherwise is to substitute guesswork for reason. An outstanding one among the many sayings common to the Hebrew and Egyptian gnomic writers occurs in the next section (xxiv. 23–34, an appendix to the present one) as well as already in the preceding one (xx. 22) : it is the earliest extant form of "the golden rule," later extolled by Hillel and Jesus, which is thus proved to be in its origins Egyptian rather than Hebrew or Jewish.

Chapters **xxv.–xxix. (27).**—The fifth section, attributed traditionally to Hezekiah's scribes (xxv. 1), contains, like the second section, chiefly short independent proverbial aphorisms; but it has some of two or more verses in length, and advances from the consideration of worldly matters in chs. xxv.–xxvii. to matters of more specifically religious import in chs. xxviii., xxix.. where the observance of "the law" in particular is emphasized, and prophecy is specified as a sine qua non of popular self-restraint (xxix. 18). In spite of the presence in this section of proverbs which occur elsewhere, it contains several of considerable interest. It reflects a somewhat hostile attitude to the monarchical form of government, but attempts to deflect criticism from the person of the king to his courtiers. Whether "the king" is a native Jewish ruler, Davidic or Maccabaean, or a Ptolemaic or Seleucid overlord, or merely figures impersonally in a set of proverbs of international vogue cannot be decided: consequently it gives no real help in fixing the date of the section. In at least two respects this collection provided the inspiration for practical and ethical advice too often supposed to have originated in Christian circles namely xxv. 7 which evidently inspired Luke xiv. 8–11, and xxv. 21 which is quoted in Rom. xii. 20.

Chapter **xxx. (1–16).**—The sixth section has the cryptic and not very convincing title "The words of Agur, the son of Jakeh, of Massa (R. V. mg.)," followed by a line which has defied all efforts to translate it. This, like xxxi. 1, though a frank confession by the Jewish sages that they were prepared to welcome aphorisms of foreign origin, and having done so, openly to ascribe them to a foreign author, really throws no light upon the origins and background of the present section. It would appear to date from a period when problems of theology and philosophy were being discussed ad nauseam and to emanate from an author who found little comfort, but much disturbance of faith in speculations of this nature. Consequently confessing his own limitations of intellect (v. 2 seq.), he plaintively asks who in point of fact has ever penetrated into the supra-mundane sphere to return with a knowledge adequate to justify him in propounding such riddles (v. 4). And so he takes refuge in the revealed "word" of God and utters a warning against human endeavours to supplement it or detract from it in self-confidence or insolence. He ends by pointing out the shortcomings of his generation (vv. 5–14). It is the answer of a religious obscurantist rather than, as is too commonly supposed, of a pious agnostic.

Final Section. — The seventh section, chap. xxx. 15–33, consists of miscellaneous dicta introduced by an unintelligible line and bound together by their "numerical" form of introduction In these few words is concentrated a wealth of insight into the normal and abnormal, the obvious and mysterious in life and nature, which, as it were in a nut-shell, illustrates the keenness and the breadth of observation to which the "wisdom" writers, the humanists of Israel, trained themselves.

The eighth section, chap. xxxi. 1–9, purports to be a further instance of foreign wisdom, again from "Massa," and indeed an illustration of a king's instruction by his mother. The vices against which he is warned include impurity, drink and maladministration of justice. These vices were prevalent in most oriental courts of the period during which the section could have been written, and do not necessarily presuppose the vices which Hellenism in particular communicated to the petty kings of oriental states into which it penetrated.

The ninth and last section, chap. xxxi. 10–31, is perhaps the masterpiece of this remarkable collection of the literary output of the humanists of Israel. Incidentally it is an "alphabetical" poem, each verse beginning with a letter of the Hebrew alphabet, and each letter appearing in its correct sequence. The lie is here given to the depressing picture, though one too often fully justified, which is mostly drawn in the Old Testament, of woman's personal and economic position among the Hebrews as the slave and chattel of her husband who was legally free to possess not one but many wives. But practice reinforced by economic necessity. probably rose in this respect above precept. At any rate, in the wealthy and prosperous household here depicted monogamy is presupposed and the poet depicts the wife as its master-mind as well as its mainstay. To what extent such a régime pressed heavily on the female slaves and other underlings we do not know since no literature emanating from them has survived.

Next to their passion for the highest morality of their day. and their unswerving loyalty to their ancestral faith, certain of the Hebrew gnomic writers whose work has survived in the Book of Proverbs will be held in honour most of all for their ability, which, as stated at the outset, is only now beginning to be realized, to master the gnomic literature of Egypt and of Mesopotamia, of Edom and of Massa, to expurgate from it what was unworthy, and to transform it into an instrument for the instruction of successive generations of the worshippers of Jehovah. Only a study of the Book of Proverbs in the light of the comparative study of gnomic literature can make the reader realize this; for instance in addition to close relationship with the Egyptian Teaching of Amenophis, there are more than 70 dicta in the Wisdom of Ahikar and of these more than half find an echo in this book.

BIBLIOGRAPHY.—For the literature, which is considerable, *see* the commentaries of Toy (1898), and especially W. O. E. Oesterley, *The Book of Proverbs* (1928) in the *Westminster Commentaries*, who gives striking parallels and references to the latest literature. *See* also Cheyne, *Job and Solomon* (1887) ; id., in *Sem. Studies* (ed. Kohut, 1897) ; id., *Jew. Relig. Life* (1898) ; Montefiore in *Jew. Quart. Review* (1898–1890) ; Cohen, *Ancient Jewish Proverbs;* Elmslie, *Studies in Life from Jewish Proverbs:* Goldman, *Proverbs of the Sages* (1911). For materials for the comparative study of Hebrew proverbial literature and that of other ancient nations, *see* D. C. Simpson, *The Hebrew Book of Proverbs and The Teaching of Amenophis* in *Journal of Egyptian Archaeology* (1926) ; Oesterley, *The Wisdom of Egypt and the Old Testament* (1927) ; Langdon, *Babylonian Wisdom* (1923) ; Hindu: Monier-Williams, *Indian Wisdom* (1875) ; Arabic: Jacob, *Altarab. Parallelen z. A. T.* (1897). (D. C. S.)

PROVIDENCE, the capital of Rhode Island, U.S., is located at the head of Narragansett bay on the Providence river, about 43 mi. S.W. of Boston and 180 mi. N.E. of New York city. It is an active seaport as well as an important industrial and commercial centre.

Providence is built on three hills College hill, on which Brown university is located, rises most sharply to the east of the central business district; it was at the foot of this rise and on its slope that the first houses and shops were built. The total land area of the city is only 17.9 sq.mi. and the density of population is high (1.159 in 1960). Most of the city is closely built-up with many sections where multiple-dwellings are common. The population remained nearly stationary at around 250,000 persons from 1930 to 1950, declining to 207,498 in 1960. Meanwhile. moderate growth took place in the Providence-Pawtucket standard metropolitan statistical area. This area increased 9% from 1940 to 1950 and 7.4% from 1950 to 1960, its total population in 1960 being 816,148. The metropolitan area as defined by the census bureau includes, in Rhode Island, all of Bristol county; Warwick city, East Greenwich and West Warwick towns in Kent county; Central Falls, Cranston, Pawtucket. Providence and Woonsocket cities and Cumberland, East Providence, Johnston, Lincoln, North Providence, North Smithfield and Smithfield towns in Providence county; North Kingstown town in Washington county; and in Massachusetts, Attleboro and North Attleboro, Seekonk, Bellingham, Franklin, Plainville, Wrentham, Blackstone and Millville towns. Important manufacturing centres in the metropolitan area, in addition to Providence, include Pawtucket, Central Falls, Cranston, Bristol, Woonsocket and East Providence. The remaining communities are primarily residential and, except for the city of Warwick, are smaller in size. (For comparative population figures see table in RHODE ISLAND: Population and MASSACHUSETTS: *Population.)*

Among these communities only Woonsocket and Pawtucket have well-developed separate business centres and all are dependent on Providence for many services, retail, wholesale and financial. Local bus lines operate to most of the suburbs and a network of major highways centres on Providence from all directions. Besides the English and the Irish, the major ethnic groups represented are the Italians, followed by Canadians (both English- and French-speaking) and Russians.

History. — After his banishment from Plymouth colony for his unorthodox religious beliefs, Roger Williams made his way slowly to the banks of the Seekonk river and thence by canoe to a point at the foot of what is now known as College hill, where he and his five dissenter companions found a spring with abundant water. On the way he is said to have been hailed by a friendly Indian with the words, "What cheer?" — perpetuated in the names of several businesses. From the Narragansett chieftains Canonicus and Miantonomi, Williams secured a grant of land which he named in gratitude for "God's merciful providence" and which he dedicated as "a shelter for persons distressed for conscience."

The site was a favourable one and the promised freedom of conscience appealed to many. By 1675 about 1,000 persons made up the population. Further growth was only momentarily halted by King Philip's War when 29 homes were burned by the Indians. More important in the long run was the erection of the city's first wharf in 1680 by Pardon Tillinghast; in the years which followed Providence developed into a major commercial centre. Its sailing ships to the West Indies, Africa, India, China and coastal ports carried home molasses, slaves, rum and other items in exchange for colonial exports; this trade was the basis for the development of several wealthy and powerful families whose great mansions filled with expensive furniture and art objects rose along College hill.

Providence took a leading part in the rebellion against Great Britain which led to the colonies' independence. In 1772 a British revenue vessel, the "Gaspee," was ^burned off Warwick while aground. In 1775 occurred a Providence Tea Party as an attack upon the idea of taxation without representation. Revolutionary forts were built and manned and French troops were quartered in what is now University hall at Brown university. The city was the scene of the signing of the Rhode Island Independence act on May 4, 1776, two months in advance of the country's Declaration of Independence.

In the post-Revolutionary period, Providence's crippled trade and commerce gradually recovered. The city's prosperity was augmented by new industrial development, starting with the establishment in adjacent Pawtucket in 1790 of Samuel Slater's textile mill, the first in the U.S. The town grew in size and status during the first half of the 19th century, incorporating as a city in 1832. Several notable buildings were erected, including the Arcade, an imposing covered building of many separate shops built in 1828 and designed after an Athenian temple, and the Providence Athenaeum (1836), a private library on College hill.

In the second half of the 19th century the city's industrial activities became of prime importance, supplanting but not diminishing its commerce and trade. The first important industry in Providence was the textile industry, starting with cotton factories and later expanding to include a woolen and worsted industry. Next came the jewelry industry, beginning with the little shop in which Seril Dodge made silver shoe buckles in 1786 and expanding after 1850 into a major industry. By 1880 the state was first in the nation in jewelry manufacture; 142 of its 148 plants were in Providence.

In addition to textiles and jewelry, other industries have developed to places of importance in the city and its metropolitan area, especially the machine tool and metal, rubber and electronics industries. In the second half of the 20th century Providence continued to be of major importance as the centre of the nation's most highly industrialized state.

Historic Sites. — One of the oldest cities in the U.S., Providence contains much of historic interest. The names of many streets are reminders of its trade and commerce and its early search for religious toleration; Benefit, Benevolent, Hope, Friendship, Dubloon, India and Ship streets and many others remain. Other points of historic interest in the city include the First Baptist meetinghouse, oldest of the denomination in the U.S.; First Unitarian church, its bell the largest cast by Paul Revere; the Old State house; the present capitol; and the Rhode Island Historical society, with extensive collections on Rhode Island history. The city contains dozens of old and historic homes and public buildings, many of which are open. The Old Slater mill in adjacent Pawtucket is a museum.

Education and Cultural Activities. — Despite its emphasis on industrial activity, Providence is an educational, cultural and recreational centre. The oldest of its several colleges is Brown university, founded in Warren in 1764 as Rhode Island college, moved to Providence in 1770 and renamed Brown university in 1804 in honour of Nicholas Brown, a treasurer of the college and a principal benefactor. Its women's college is Pembroke, organized in 1891.

John Hay library, erected as a memorial to John Hay secretary of state under Presidents McKinley and Theodore Roosevelt and a Brown graduate in the class of 1858, and other college libraries contain about 850,000 volumes and many special collections. On the campus are the John Carter Brown library, containing the world's foremost collection of Americana printed prior to 1801, and the Annmary Brown memorial, with a world-famous collection of incunabula from the period 1460 to 1500 Brown's Haffenreffer museum, located at Bristol. has a growing collection of Indian and other anthropological materials.

The Rhode Island School of Design is a private, coeducational college, founded in 1877 and providing four-year degree programs in the fine arts, architecture, design and related fields. The school's museum is notable for its collections of early furniture and early American crafts. There are comprehensive collections of paintings and sculpture of various periods and an oriental collection.

Other institutions of higher learning in Providence include the Rhode Island college, a state college chartered in 1854 and now offering teacher training on a handsome 48-ac campus opened in 1958; Providence college, a liberal arts college for men under the auspices of the Dominican Order, founded in 1917; and Roger William: Junior college, incorporated in 1956.

The Providence Public library facilities were approximately doubled in 1954 by the opening of a new wing to the main building, erected in 1900. There are several branch libraries and one or more libraries in each of the towns in the metropolitan area

Recreational Facilities. — The city maintains several parks and playgrounds and a municipal golf course. The largest park is Roger Williams park, with 453 ac. of lakes, flower gardens, walks, animal and bird houses, a museum of natural history, Betsey Williams cottage and a small amusement area for children.

Several state parks and picnic grounds are located in the metropolitan area. Yacht clubs and marinas are found in several waterfront communities and sailing and other forms of boating are common on Narragansett bay and adjacent waters. A ski slope and tow are operated by the state in Cumberland in winter. Dozens of ocean resorts lie just beyond the metropolitan area on the bay and the Atlantic ocean. (V. H. Wh.)

PROVINCE, a term applied in ancient Rome (Lat. *provincia*) to the sphere of duty assigned to one of the higher magistrates, the consuls and praetors (*qq.v.*). Only those magistrates who had military power (*imperium*) had a province. When the province of a quaestor is mentioned it refers to the province of the consul or praetor to whom the quaestor is subordinate.

When the government of conquered countries grew to be one of the most important duties of the higher magistrates, the term province, from designating the government of a conquered country as one particular duty of a Roman magistrate, came to be used generally as a designation of the country itself.

The provinces paid tribute to Rome, for it was a recognized principle that they were the estates of the Roman people and were to be managed for its benefit. The constitution of a province was drawn up by the victorious Roman general, assisted by ten commissioners appointed by the senate, and the province was governed on the lines laid down in this constitution or charter (*lex provinciae*). For administrative purposes the province was divided into districts, each with its capital, for judicial purposes into circuits (conventus) and in the chief town of each circuit the governor of the province held assizes.

The lands of cities captured by force of arms were turned into Roman domains, and were let out by the censors to private persons. Royal domains, such as those of Macedonia and Cyrene, were also confiscated. Communities which surrendered were usually allowed to retain their personal freedom and private property; but all the lands were subjected to a tax, consisting either of a payment in kind (*vectigal*) or of a fixed sum of money (tributum, stipendium). It is to this class of communities (the *civitates* vectigales or stipendiariae) that the majority of the provincial states belonged. In a better position were those states whose freedom was guaranteed by Rome on the ground of old alliances or special loyalty. Their freedom was recognized either by a treaty or by a decree of the Roman people or senate. As a decree of the people or senate could at any time be recalled, the position of the free states without a treaty was more precarious than that of the treaty states (*civitates foederatae*). The latter enjoyed internal freedom, retained their lands, paid no taxes, and were bound to render those services only which were expressly stipulated for in the original treaty. Amongst such treaty states were Massilia (Marseille), Athens, Rhodes and Tyre. The privileges of the free states without a treaty were somewhat similar. All political distinctions, save that between slave and freeman. disappeared when Caracalla bestowed the Roman franchise on the whole empire (A D. 212).

Provincial Diets. — Every province had, under the empire, a provincial assembly or diet of its own (concilium or *commune*), and these diets are interesting as the first attempts at representative assemblies. The diet met annually, and was composed of deputies (legati), from the provincial districts. It arranged for the celebration of religious rites and games, especially for the worship of the emperor. The celebration was under the conduct of the high priest of the province. The diet also passed votes of thanks to the outgoing governor, or forwarded complaints against him to Rome; and it had the right of sending embassies direct to the senate or the emperor.

The Provincial Governor.—The provinces were administered by governors from Rome, who held office for a year. From the formation of the first provinces in 227 B.C. down to the time of Sulla (82 B.C.) the governors were praetors (*see* PRAETOR); from the time of Sulla to that of Augustus the praetors remained in Rome during their year of office, and at the end of it assumed the government of a province with the title of propraetor. A province which was the seat of war, or was in a disturbed state, was committed to the care either of one of the consuls for the year, or of a commander specially appointed for the purpose, with the title of proconsul. The senate determined which provinces were to be governed by consuls and which by praetors and the consuls arranged between themselves which of the provinces each should have, and similarly with the praetors. The Sempronian law of 123 B.C. provided that the senate should nominate the two consular provinces before the election of the consuls, and that the consuls should, before their entry on office, arrange which of the two provinces each should have. The Pompeian law of 53 B.C. enacted that no one should hold the governorship of a province till at least five years after his consulship or praetorship. This law was repealed by Caesar, but was re-enacted under Augustus; it setered the connection between an urban magistracy and the governorship of a province, and turned the latter into an independent office. A provincial governorship was regularly held for one year; but it could be prolonged by a vote of the people or a decree of the senate. The necessary supplies of men and money were voted to the governor by the senate. His staff included one or more lieutenants (legati) and a quaestor (*q.v.*). Besides these the governor took with him young men of the upper classes to assist him in the government. These were known as the companions (*comites*) or suite of the governor They were chosen by the governor himself, but they were maintained at the expense of the state, and under the empire, received regular pay. In addition there was a crowd of subordinates. Before setting out for his province the governor, clad in the purple military robe of his office, offered sacrifice on the Capitol; then immediately after receiving the *imperium* or military command he marched out of the city (for the *imperium* could only be exercised outside of Rome and was forfeited by staying in the city), preceded by his lictors and accompanied by his suite. His year of office began from the day he set foot in his province. In the hands of the governor all powers military and civil were united. He commanded all the troops in the province, and had power to raise levies of Roman citizens as well as of provmcials. and to make requisitions of war material. He possessed both criminal and civil jurisdiction; as criminal judge he had the power of life and death, and from his sentence none but Roman citizens could appeal; as civil judge he was guided partly by the charter of the province (*lex* provinciae), partly by the edict which it was customary far him to issue before his entrance on office (see PRAETOR).

Condition of the Provinces under the Republic. — The Roman people regarded the provinces as so many estates from which they were to derive revenue. Hence agriculture and commerce were encouraged, settlements were made, roads and aqueducts were constructed; in short, the Roman aimed at exploiting his empire by a system of prudent economy. But the Roman governors were apt to look on their provinces as their own peculiar prey; they had usually bought their way to office at vast expense, and they now sought in the provinces the means of reimbursing themselves for the expenditure they had incurred at Rome. Redress was to be had by a complaint to the senate; after 149 B.C. there was a court established at Rome for the trial of cases of extortion (*repetundae*) by provincial governors. But, even when the provincials had arraigned their oppressor, it was difficult to secure his condemnation at the hands of juries composed of men who had a fellow-feeling for the offender because they had themselves committed, or hoped for means of committing. similar offences Besides the governor, two classes joined in wringing the uttermost farthing from the unhappy provincials. These were the publicani (*q* v.) or farmers of the taxes, and the money-lenders (negotiatores). Both these classes were recruited from the *equites* (*q.v.*) and, since from 122 B.C. the juries were drawn at first exclusively and after 70 B.C. partially from that order, the provincial governor could not check their excesses without risking a condemnation at the hands of their brethren. Accordingly he generally made common cause with them.

The Provinces under the Empire. — Under the empire the provinces fared better. Romans and provincials were reduced to a common level of subjection to the emperor, who meted out equal justice. The first centuries of the Christian era were for some of the countries included in the Roman empire the happiest of their history.

Augustus, in 27 B.C., divided the provinces into imperial and senatorial. Those which required the presence of an army were placed under the direct control of the emperor; those which needed no troops were left to the senate. (1) The senatorial provinces were ruled by annual governors called proconsuls. Their poners were much the same as they had been under the republic, except that they had now no troops. or only a handful to maintain order. (2) The imperial provinces were governed by imperial lieutenants (legati *Caesaris*), who were nominated by the emperor and held office at his pleasure; all of them had the power of the sword (*ius* gladii). For the administration of the finances these lieutenants had procurators under them, while the governors of the senatorial provinces continued to have quaestors. Certain other possessions were regarded as domains of the emperor, and were managed by a procurator or praefect (see PREFECT (ROMAN), responsible to the emperor.

PROVINCETOWN, a town of Massachusetts. U.S., situated among extensive sand dunes within a fishhook-shaped harbour at the northern end of Cape Cod, is a noted artists' colony. fishing port and tourist centre. Discovered by explorers Bartholomew Gosnold and Henry Hudson in 1602 and 1609, it was the first landing place of the Pilgrims before they founded Plymouth. The birth of Peregrine White. the first white person born in New England, and the signing of the Mayflower Compact both occurred on shipboard in Provincetown harbour. Settled by lawless traders and fishermen before 1700 on lands owned by the Province of Massachusetts Bay (hence its name), the village was first a precinct of the town of Truro and in 1727 became a separate township. Its exposed position, subject to repeated attacks by sea, forced its abandonment during the French wars and the American Revolution. Its magnificent harbour was used as a naval base by British blockading squadrons in the Revolution and the War of 1812. In the 19th century it was an active maritime and whaling port, and its Portuguese descendants still maintain there the most prosperous fishing industry on Cape Cod. Until 1900 its communications with the mainland were mostly by boat because of the wind-blown loose sand that swept across its highways.

Modern Provincetown was for some time the home of Eugene O'Neill, whose first produced play, Bound East for Cardiff, was staged there in 1916 by the Provincetown Players. The top of the great Pilgrim monument, 350 ft. above the sea, affords a superb view of the cape and Massachusetts bay. Drives along the sand dunes, buried forests and shipwreck-littered beaches are popular with tourists. The close-packed streets and wharves of the old maritime town are annually explored by thousands of visitors. The resident population is about 3,500. (H. F. Ho.)

PROVINCETOWN PLAYERS, an experimental theatrical group, was organized in 1915 at Provincetown, an artists' colony in Massachusetts. Its program, the creation of a vital American drama, derived philosophical support from the hypotheses of Jane Ellen Harrison and Gilbert Murray (*qq.v.*). In 1916 they staged *Bound East* for *Cardiff*, the first of Eugene O'Neill's plays to be produced. That minter they moved to New York's Greenwich Village where, calling themselves the Playwrights' theatre, they encouraged playwrights, actors and stage technicians to "work out their ideas in freedom." The result was to provide an impetus to the individual artists and playwrights (particularly O'Neill), who were responsible for the renaissance of the American theatre after 1920, and to demonstrate to the commercial theatre that its patrons were as ready for provocative treatment of contemporary themes as patrons of museums or novel readers. The group disbanded in 1929. (A. S. DR.)

PROVING GROUND, an area set aside and usually specially modified and equipped to "proof test" military devices and military and commercial vehicles. The purpose of such testing is to show up, by excessive or distorted operation, the weaknesses of an item or any of its components; to determine whether the item's operation fits into a standard pattern; or to determine the life expectancy of any product. In many instances, items are tested to destruction; in the case of ammunition the test is actually an expenditure of sample quantities from each lot made. In all cases, data are collected, evaluated and used in further development or in making engineering or production improvements.

Vehicle proving grounds, whether military or commercial, have a wide variety of roads and road surfaces to cause the vehicle under test to be strained or overworked in one manner or another. Corduroy tracks twist the car frame to determine its stamina; steep slopes shon whether the engine can develop sustained power under unusual demand; braking power is tested when a stop is made on the slope. Tires are tested on many types of cobbles and broken stones and in sand and deep mud. Engines and brakes are proof tested by running the vehicle through deep water; brakes and tire traction are put to the test by passing through deep mud.

Military proving grounds also have special facilities and instruments for proofing guns of all sizes, from small arms to the largest cannon. Rifles or machine guns may be fired from stands in indoor ranges to test the gun barrel's resistance to wear when fired at excessive rates, to determine its ability to operate at extreme ranges of temperature or in dust or rain, or to allow studies of bullet flight by flash photography. Some artillery weapons are also fired indoors, but more often the firing is in the open against various types of targets, including different thicknesses of armour plate. Prominent on the artillery test range are tall towers supporting large metal rings. These rings are solenoids ('electrical coils affected magnetically by the presence of moving steel objects) through which shells are fired to study their behaviour.

Guided missile proving grounds are distinctive primarily because of the much greater ranges involved. They are usually located in sparsely settled areas where missiles may be fired distances of 100 mi. or more; sometimes they are on coasts so that firing may be out to sea.

Notable proving grounds in the United States are several commercial vehicle test areas maintained by manufacturers of motor vehicles near Detroit, Mich.; the U.S. army ordnance corps' Aberdeen proving ground near Baltimore, Md., for guns, ammunition and combat and transport vehicles; and the U.S. army's

White Sands missile range in New Mexico, for rockets and missiles. Aberdeen's area is more than 70.000 ac., but shells may be fired as far as 30 mi. out over Chesapeake bay. White Sands is a desert valley 40 mi. wide and about 100 mi. long. Very long range missiles for the army and the air force are fired southeastward into the Atlantic ocean from the Atlantic missile range at Cape Canaveral, Fla.

Germany's great proving ground at Hillersleben before and during World War II resembled Aberdeen proving ground in that it permitted the proof testing of many types of weapons ana other material at one place. The United Kingdom, hoaever, spreads the proof testing or try-out operations to different areas. For example, tanks are tested at Castle Douglas in Scotland; artiliery at Holyhead in Anglesey and at Lark Hill in Wiltshire; infantry weapons and ammunition at the small arms school at Hythe. Kent. Long-range rockets and missiles developed within the British Commonwealth are tested at the Woomera range in Australia.

(F. D. McH.)

PROVINS, a town of northern France, capital of an arrondissement of the *département* of Seine-et-Marne, at the junction of the Durtain with the Voulzie (an affluent of the Seine), 59 mi. E.S.E. of Paris by rail. Pop. (1954) 8.288. Provins began to figure in history in the 9th century. Passing from the counts of Vermandois to the counts of Champagne, it quickly became prosperous. Cloth and leather were its staple manufactures, and its fairs were attended by traders from all parts of Europe, throughout which its money had currency. Plague and famine reduced the population in the 14th century and the Hundred Years' War completed its ruin. During the religious wars it sided with the Catholic party and the League, and Henry IV obtained possession of it in 1592 only after thirteen days' siege. The town has mineral waters and a trade in roses. Provins is divided into two quarters —the ville-haute and the less ancient *ville-basse*—which in the 13th century were surrounded by fortifications. In the *ville-haute* stands the large tower known as the king's, Caesar's or the prisoner's tower. The tower serves as belfry to the church of St. Quiriace, which dates from the 12th century. The old tithe-barn is a building of the 13th century with two fine vaulted chambers, one of which is below ground. The church of St. Xyoul dates from the 12th to the 16th centuries. St. Croix belongs partly to the 13th century. There is an active trade in grain, livestock and wool, and the industries include nursery-gardening, brickmaking and the manufacture of porcelain, gas and petrol engines, agricultural implements and sugar.

PROVISION, in ecclesiastical law, signifies the conferring of an office or benefice. With King John's submission to the pope in 1213, presentations of this sort previously made by English patrons were gradually appropriated by Rome to finance the increasingly costly centralized church administration. To secure papal aid in international affairs, English kings tolerated this system, resented by commons because so many foreigners were granted English benefices by the pope, until the coincidence of the Hundred Years' War with France and the Avignon papacy led to the enactment of the Statutes of Provisors (1351) and of Praemunire (1353) which outlawed the practice. Nevertheless, despite this and subsequent legislation, papal provision continued. abetted by the king, who eventually managed to secure virtual control over the pope's nominations. Provision was finally eliminated with the death of Mary Tudor. Though papal provision was legally sound, its abuses, condemned alike by satirists and saints, provoked such mass indifference toward the church that it must be considered one of the prime causes of the collapse of Catholicism in the 16th century.

Bibliography.—H. M. Gwatkin, *Church and State in England to the Death of Queen Anne* (1917); P. Hughes, *A History of the Church*, vol. iii (1947) ; F. W. Maitland, *Roman Canon Law in the Church of England* (1898) ; J. R. H. Moorman, *Church Life in England in the Thirteenth Century* (1955). (P. A. Be.)

PROVISIONAL ORDER, in Great Britain, a direction by a government department sanctioning some project otherwise unattainable without private bill legislation. The procedure generally involves: (1) preliminary local enquiry and report by a departmental inspector; (2) departmental decision as to the framing of the order; and (3) inclusion of the order in a provisional order conformation bill introduced into parliament by the minister concerned. Such bills, if opposed, are referred to a select committee; they also go before examiners who see that the contents comply with standing orders. An early instance is the Inclosures act of 1845 whereby commissioners could provisionally order the enclosure and regulation of commons. Gradually the system was extended to the varied purposes of local government. The early enactments were later superseded and the process of devolution progressively developed.

Two railway acts in 1864 initiated the provisional certificate which embodied schemes for railway construction or working agreements, and, unless the schemes were opposed, required no express parliamentary sanction. Later a special order procedure was evolved whereby a draft of the proposed order was published and (on objection) a local enquiry was held, but a confirmatory act of parliament was not required. The National Health Insurance act of 1928 authorized a "provisional special order." Under this variant the appropriate minister, instead of waiting for criticisms of his draft orders, could bring them into force forthwith provided that he certified the expediency of such action. (C. T. C.)

PROVO, a city of Utah, U.S., the seat of Utah county, is situated 45 mi. S. of Salt Lake City between Utah lake and Wasatch peaks, at an altitude of 4,549 ft. An amalgam of weathered gray adobes and modern structures of frame or brick set amid trees and gardens, Provo has a dual modern identity as college town and steel centre.

The city takes its name from the Provo river, named for the trapper Étienne Provost (c. 1782–1850), who penetrated to Utah from New Mexico in 1824. Brigham Young sent a Mormon colonizing mission to the site in 1849 and the next year what had been Ft. Utah by legislative fiat became Provo. Incorporated in 1851, Provo was Utah's second city until the Pacific Railroad gave Ogden predominance in 1869.

Decisive in Provo's early fortunes was the founding in 1875 of Brigham Young academy, a Mormon institution which in 1903 became Brigham Young university. After 1923, steel plants were built in northern and southern suburbs; the Geneva plant, erected during World War II, became the largest integrated steel plant in the western U.S. and Utah's largest single manufacturing enterprise. The city has some other industry and is the trading centre for a rich agricultural area. It has a council-manager form of government, in effect since 1956.

The population of the Provo-Orem standard metropolitan statistical area (Utah county) in 1960 was 106,991. For comparative population figures see table in Utah: Population.

(D. L. M.)

PROVOOST, SAMUEL (1742–1815), first bishop of the Protestant Episcopal Church in New York, was born in New York city on Feb. 26, 1742. After graduating from King's college (later Columbia university) in 1758, he went to England for further study, becoming a fellow-commoner of St. Peter's college, Cambridge, in 1761. Though of Reformed background, he united with the Church of England in his college days, if not earlier. He was ordained deacon on Feb. 23, 1766, and priest on March 25, 1766. Returning to America, he was elected assistant minister of Trinity church, New York, in Dec. 1766, resigning in 1771 because of ecclesiastical and political differences with the vestry. Though strongly sympathetic to the American cause in the Revolution, he took no active part in the dispute, living in retirement on a farm in Dutchess county until the end of the war. After the British evacuated New York, the Whig party gained control of the parish of Trinity church and elected Provoost rector. He was appointed a regent of the University of the State of New York in 1784 and served as chaplain to congress in 1785. He took an active part in the organization of the Protestant Episcopal Church after the Revolution and was elected bishop of New York on June 13, 1786. With Bishop William White of Pennsylvania he was consecrated in England on Feb. 4, 1787. They were the first two Americans to be consecrated by English bishops. Provoost was elected chaplain of the U.S. senate in 1789. Ill-health compelled him to retire from all active duty in 1801. He died on Sept. 6, 1815.

(W. W. Ms.)

PROVOST, a title attached to various ecclesiastical and secular offices. In ecclesiastical usage the word *praepositus* was at first applied by the church fathers to any ecclesiastical ruler or dignitary. It early, however. gained a more specific sense as applied to the official next in dignity to the abbot of a monastery, or to the superior of a single cell. In England the title provost has thus everywhere given way to that of "dean"; in Germany, on the other hand, "*Probst*" is still the style of the heads of certain chapters. The name *praepositus* was also sometimes used for the secular *advocatus* of a monastery. With the ecclesiastical use of the title is connected its English application to the heads of colleges; "provost" is still the style of the principals of Queen's, Oriel and Worcester colleges at Oxford. of King's college at Cambridge, of Trinity college at Dublin and of Eton college.

As a secular title *praepositus* is also very old; we need only instance the *praepositus sacri cubiculi* of the late Roman empire, and the *praepositus palatii* of the Carolingian court. The important developments of the title in France are dealt with below. From France the title found its way into Scotland, where it survives in the style (provost) of the principal magistrates of the royal boroughs. and into England, where it is applied to certain officers charged with the maintenance of military discipline. A provost marshal is an officer of the army appointed when troops are on service abroad for the prompt repression of all offences. He may at any time arrest and detain for trial persons subject to military law committing offences! and may also carry into execution any punishments to be inflicted in pursuance of a court-martial (Army act, 1881, *s.* 74). A provost sergeant is an officer responsible for the maintenance of order when soldiers are in Great Britain.

The Provost in France. — The word *prévôt* (provost) in old French law had many applications. In conformity with its etymology (*praepositus*) it could be applied to any person placed at the head of a branch of the public service, a position which, according to the old principles, habitually carried with it a right of jurisdiction. It is thus that there was at Paris the provost of Paris, who was a royal judge, and the provost of the merchants (*prévôt des marchands)*, the head of the Paris municipality. There were besides — to mention only the principal provosts — the provosts of the marshals of France (*prévôts des maréchaux de France*), of whom more below; the provost of the royal palace (*prévôt de l'hôtel du roi)* or grand provost of France *(grand prévôt de France)*, and the provost general (*prévôt général*) or grand provost of the mint (*grand prévôt des monnaies*). But the most important and best known provosts, who formed part of a general and comprehensive organization, were the royal provosts (*prévôts royaux*), the lower category of the royal judges. It must be borne in mind, however, that the magistrates belonging to the inferior category of royal judges (*juges subalternes*) had different designations in many parts of France. In Normandy and Burgundy they were called *châtelains,* and elsewhere—especially in the *south — viguiers.*

Some time in the 11th century the provosts replaced the viscounts wherever the viscounty had not become a fief, and it is possible that in creating them the crown was imitating the ecclesiastical organization in which the provost figured, notably in the chapters. The royal provosts had at first a double character. In the first place they fulfilled all the functions which answered locally to the royal power. They collected all the revenues of the domain and all the taxes and dues payable to the king within the limits of their jurisdiction. Doubtless, too, they had certain military functions, being charged with the duty of calling out certain contingents for the royal service; there survived until the end of the *ancien régime* certain military provosts *prévôts d'épée* (provosts of the sword)·who were replaced in the administration of justice by a lieutenant. Finally, the provosts administered justice, though certainly their competence in this matter was restricted. Their second characteristic was that their office was farmed for a time to the highest bidder. It was simply an application of the system of farming the taxes. The provost thus received the speculative right to collect the revenues of the royal domain in the district under his jurisdiction; this was his principal concern, and his judicial functions were merely accessory. By these short appointments the Crown guaranteed itself against another danger: the possible conversion by the functionary of the function into a property. Very early,. however, certain provostships were bestowed *en garde; i.e.,* the provost had to account to the king for all he collected. The *prévôtés en ferme* were naturally a source of abuses and oppression, the former seeking to make the most of the concession he had bought. They disappeared in the 16th century, by which time the provosts became regular officials, their office being purchasable.

Other transformations had previously taken place. The creation of the royal *baillis* reduced the provosts to a subaltern rank. Each *bailli* had in his district a certain number of provosts, who became his inferiors in the official hierarchy. When appeals were instituted (and this was one of the earliest instances of their introduction) the provost, the sphere of whose competency was limited, was subject to an appeal to the *bailli,* though his judgment had hitherto been without appeal.

Moreover, in the 14th century they had ceased to collect the revenues of the royal domain, except where the *prévôté* was *en ferme,* and royal collectors (*receveurs royaux*) had been appointed for this purpose The summoning of the feudal contingents. the *ban* and *arrière-ban*, had passed into the hands of the *baillis*. Thus the provosts were left for their sole function as inferior judges for non-nobles.

The "provosts of the marshals of France," mentioned above, were non-legal officials (*officiers de la robe courte)* forming part of the body of the *maréchaussée* which was under the *ancien régime* what the *gendarmerie* was after the Revolution. Their original function was to judge offences committed by persons following the army, but in the course of the 14th and 15th centuries they acquired the right of judging certain crimes and misdemeanours, by whomsoever committed. They became stationary, with fixed spheres of authority, and the oifences falling within their competency came to be called *cas prévôtaux.* These were the worst crimes of violence, and all crimes and misdemeanours committed by old offenders (*repris de justice)*, who were familiarly known as the *gibier des prévôts des maréchaux* (gaol-birds).

(J. P. E.)

PROXY (short for "procuracy"), a term denoting either (1) a person who is authorized to stand in place of another; (2) the legal instrument by which the authority is conferred. Proxies are now principally employed for certain voting purposes. A proxy may in law be either general or special. A general proxy authorizes the person to whom it is entrusted to exercise a general discretion throughout the matter in hand, while a special proxy limits the authority to some special proposal or resolution. Formerly a peer could give his vote in the British parliament by proxy, by getting another peer to vote for him in his absence, temporal peers only voting for temporal and spiritual peers for spiritual. However, on March 31, 1868, on the recommendation of a committee, a new standing order was adopted by which the practice of calling for proxies on a division was discontinued. In English and American bankruptcy proceedings creditors may vote by proxy, and every instrument of proxy, which may be either general or special, is issued either by the official receiver or trustee. Under the English Bankruptcy Act of 1914 and the American Bankruptcy Act of 1898 a creditor may still vote by proxy in the manner prescribed. A shareholder in a limited liability company may vote by proxy, and regulations to that effect prescribing the requirements are usually embodied in the articles of association. In England a proxy to vote at a meeting must bear a revenue stamp.

PRUDENTIUS, AURELIUS CLEMENS (348–*c.* 410), the most remarkable of the earlier Christian poets in the West, was probably born at Tarraco. The meagre autobiographical preface, which he affixed to the complete edition of his works when he was fifty-seven years old, makes it clear that he received a liberal education — being of noble family — practised as a lawyer and entered official life, and finally held some high office under Theodosius. At the age of fifty-seven he retired to a monastery, but died shortly afterwards.

Bentley calls Prudentius "the Horace and Virgil of the Christians," but his diction is stilted and his metre often faulty. The list of his works given in the preface mentions the hymns, poems against the Priscillianists and against Symmachus and *Peristephanon.* The *Diptychon* or *Dittochaeon* is not mentioned. The twelve hymns of the *Cathemerinon liber* ("Daily Round") consist of six for daily use, five for festivals, and one intended for every hour of the day. Prudentius shows Ambrose as his master here, but gives to Ambrose's mystic symbolism much clearer expression. The *Apotheosis* and *Hamartigenia* are polemic, the first against the disclaimers of the divinity of Christ. the latter against the gnostic dualism of Marcion and his followers. In them Tertullian is the source of inspiration. Of more historical interest are the two books *Contra Symmachum,* of 658 and 1.131 hexameter verses respectively, the first attacking the pagan gods, the second directed against the petition of Symmachus to the emperor for the restoration of the statue of Victory which Gratian had cast down.

The *Peristephanon* consists of fourteen hymns to martyrs. These were mostly Spanish, but some were suggested to Prudentius by sacred images in churches or by the inscriptions of Damasus. This book, with the *Cathemerinon liber* and the *Psychomachia,* mas among the most widely read books of the middle ages. Its influence on the iconography of mediaeval art was great. The *Psychornachia* is aesthetically inferior, but had the greatest influence of all of Prudentius's writings. In it he depicts the struggle of Christendom with paganism under the allegory of a struggle between the Christian virtues and the pagan vices. The *Dittochaeon* is a series of quatrains, probably intended to explain forty-nine pictures of a basilica. The work is more interesting for archaeology than for literature.

PRUD'HON, PIERRE PAUL (PIERRE PRUDON) (1758–1823), French painter, born at Cluny on April 4, 1758, was the 13th child of a mason. By the aid of the bishop of Mâcon he was placed with Devosge, director of the art school at Dijon. In 1778 Prud'hon went to Paris armed with a letter to Willie, the celebrated engraver, and three years later he obtained the triennial prize of the states of Burgundy, which enabled him to go to Rome, where he became intimate with Canova. He studied the work of Correggio and the affinity of his style with that of the great Italian gave him the title of the French Correggio. He returned to Paris in 187. The illustrations which he executed for the *Daphnis and Chloe* published by Didot brought him into notice, and his reputation was extended by the success of his decorations in the Hôtel de Landry (now Rothschild), his ceiling painting of "Truth and Wisdom" for Versailles (Louvre), and of "Diana and Jupiter" for the Gallery of Antiquities in the Louvre. In 1808 he exhibited "Crime Pursued by Vengeance and Justice" (Louvre), which had been commissioned for the assize courts, and "Psyche Carried off by Zephyrs." These two compositions brought Prud'hon the Legion of Honour; and in 1816 he entered the Institute. Consoled for the misery of his marriage by the devoted care of his pupil, Mlle. Mayer, Prud'hon's situation seemed enviable; but Mlle. Mayer's tragic suicide in 1821 brought ruin to his home, and Prud'hon died two years later on Feb. 16, 1823.

PRUNE: *see* PLUM.

PRUNING: *see* ARBORICULTURE: *Pruning;* FRUIT FARMING: *Basic Problems and Practices of Fruit Farming: Training and Pruning;* GRAPE: *Cultivation: Pruning.*

PRUNUS, a highly important genus of more than 150 species comprising the well-known stone fruits of the Rosaceae family. *See* ALMOND; APRICOT; CHERRY; NECTARINE; PEACH; PLUM.

PRURITUS: *see* ITCHING.

PRUSSIA, a former German kingdom, became the largest and most important *Land* of the Third German Reich. It included the whole of Germany north of Saxony, Thuringia, Bavaria and Hesse, except Mecklenburg and Oldenburg, and some small enclaves, such as Brunswick. In 1938 the *Land* of Prussia comprised the provinces of East Prussia, Berlin, Brandenburg, Pomerania, Grenzmark, Silesia, province of Saxony, Schleswig-Holstein, Hanover, Westphalia, Hesse-Nassau, Rhine province and Hohenzollern. In 1945 East Prussia passed in part to the U.S.S.R. and the remainder to Poland. Poland also absorbed all Prussian territory as far as the Oder-Neisse line, expelling the German population and replacing it by Poles. The main part of the rest of Prussia was subdivided into the new *Lander* of Brandenburg and Saxony-Anhalt in eastern Germany, and Schleswig-Holstein, Lower Saxony and North Rhine-Westphalia in western Germany. Berlin was divided between the two republics. Lesser areas of Prussia were included in the *Länder* of Mecklenburg in eastern Germany, and of the Rhineland-Palatinate, Hesse and Baden-Württemberg in western Germany. Though the boundaries of the new *Lander* usually followed the former political pattern, some regard was also paid to their economic character. Prussia was formally liquidated by a law of the Allied Control council on Feb. 25. 1947.

Physical Features. — The greater part of Prussia belongs to the Great European plain, though its surface is more varied than that bare statement suggests. The plain is narrowest in the west, being only 75 mi. wide between the Weser uplands and the North sea. It includes three divisions, markedly different in character: (1) west of the lower Elbe, a region of reclaimed *Marschen* along the coast, of *Moor* or ill-drained peat bogland behind it, and of dry, sandy *Geest* lands further inland; (2) east of the Elbe, with the low Baltic heights next the coast and the belt of *Urstromtaler,* wide marshy valleys, to the south; (3) the fertile *Borde* strip along the edge of the uplands and with wide "bays" (Cologne, Miinster, Leipzig and Silesia) reaching south into the mountainous country. In the southwest, most of the Rhine plateau country, the Harz and Weser uplands and part of the Triassic hill country (with the volcanic Vogelsberg and Rhon) fall within the Prussian area. The borderlands between Silesia and Czechoslovakia are also mountainous. The lowland courses of all the north German rivers are thus within the Prussian frontiers.

Prussia contains a large proportion of woodland, the most extensive forests being in East Prussia, Silesia and Brandenburg where conifers prevail. In the Rhenish and Hessian lands oaks and beeches are most prominent. The northwestern lowlands had few trees but in recent years large plantings of conifers have been made on the drier sandy lands.

Climate. — The climate of Prussia is transitional between the rainy and changeable type of western Europe and the more stable but more extreme type of eastern Europe. Rainfall decreases from west to east but temperature ranges increase, mainly because winters are colder.

Area and Population. — In 1939 Prussia had a total area of 113,410 sq.mi. and, according to the census of 1939, a population of 41,467,089. The six new *Lander,* with a total area of 55,814 sq.mi., had in 1939 a population of 28,269,000, increased to 30,766,000 by 1946. World War II and the postwar years saw considerable movements of population throughout the Prussian area. The North Rhine-Westphalian districts continued to have the densest populations (1,007 per sq.mi. in 1950) but the largest increases were in the eastern sections of west Germany. During the war there was a tendency to place new industrial establishments there rather than in the Rhine districts, where they were more accessible to Allied bombing. The *Auslands-deutsche* recalled between 1939 and 1944 were mainly settled in the eastern portions of Prussia. The still larger migration of about 9,000,000 people expelled from Poland and Czechoslovakia added to this westward movement. After the war the movement was continued by the refugees passing from east to west Germany. Large population increases, especially in rural districts, have been caused in this way, notably in Schleswig-Holstein and Lower Saxony.

Agriculture. — Except in Westphalia and the northern Rhinelands, and along a narrow belt from Münster to Silesia, where there was a slight predominance of industry, agriculture was everywhere the main occupation of the people of Prussia. The chief arable areas were along the Baltic coast and on the loess soils of the *Borde.* In Brandenburg and Lusatia arable land was mixed with woodland, on the geest with sandy waste. The reclaimed marshlands were either under the plow or meadow. Grasslands dominated the area from Schleswig-Holstein to the lower Rhine. Rye was the main grain crop everywhere (about 75% of the grain-growing area), especially prominent between the lower Ems and the Weser, and in Brandenburg and Posen. Wheat and winter barley were restricted to the better soil areas of the *Borde*, the drained marsh soils of the Eibe and Vistula, and the Lower Rhine. Oats became an important crop on the northwest lowlands, especially near the sea. The potato was widely grown, with heavy production east of Berlin and the middle Elbe. On the Rhenish plateau it took the place of grain as the main food crop. In later years sugar beet had become of very great importance as a crop on the *Borde* in Hanover and Saxony! and west of Cologne. In normal years there were surpluses of rye, oats and sugar.

The production of livestock did not meet the demand before World War II, nor was there a sufficiency of dairy produce. Cattle were most numerous in Schleswig-Holstein, and pigs were raised and fattened in great numbers, particularly on the lowland between Hamburg and the Ruhr. The numbers of sheep showed a long-continued decrease. Stall feeding of cattle was general except on the North sea *Märschen* where all-year outdoor grazing of dairy cattle was possible. Forage crops were widely grown and there was considerable import of animal foodstuffs,though the spread of sugar beet, with the use of the tops and the pulp from the scgar factories, had lessened the need for this. The value of animal products far exceeded that of crops.

Most of the land east of the Elbe and in Silesia was in large holdings of more than 250 ac., that in the western lowlands and the Rhine lands in holdings of 12 to 50 ac. The farms of the *Borde* were of intermediate size. During the nazi period steps were taken to divide some of the larger holdings and to consolidate the smallest. Under Soviet direction all holdings of more than 250 ac. were to be eliminated and subdivided into farms of 20 ac. About half the farms in the eastern zone were of this size by 1952.

Before World War II western Germany imported about 40% of its food and the east German area lacked some foods (*e.g.* meat, formerly secured from Schleswig-Holstein, and supplementary grain from Silesia). The lands taken over after the war by the U.S.S.R. and Poland formerly provided nearly a quarter of Germany's agricultural production. Since the population of the German Federal and Democratic republics is roughly equivalent to the prewar population of the whole Reich the loss of these Prussian areas created a serious problem.

The principal wine-growing districts of Prussia are the Rheingau and the Rhine province. The vineyards are terraced on the stony, southward-facing slopes of the Rhine and its tributaries, especially the Saar and the Moselle. The harvest is so uncertain that the industry can be maintained only by concentration on high-grade wines.

Mining and Power Production. — Prussia was far the largest producer of minerals in the Reich. Seventy per cent of German coal (127,000,000 tons in 1938) was mined in the Ruhr and a further 13% (26,000,000 tons) in Silesia. The high-grade coking coals of the Ruhr were of special importance in the metal industries. The Silesian field came entirely into Polish hands after World War II. The utilization of the Prussian lignite (brown coal) deposits was greatly extended after 1919, the output increasing to more than 250,000,000 tons in 1943. Two-thirds of this came from Brandenburg and the area between Magdeburg and Leipzig, the one-third from the Ville field west of Cologne. Oil is found near Hanover but the output of the wells is far exceeded by the synthetic production from coal and lignite. Most of the home-produced iron ore, only a small fraction of that consumed, was mined in the Hanover area and the Siegerland. Small quantities of ores of copper and of lead and zinc are still obtained from the Harz. Before it lost the Silesian mines in 1919 Germany ranked first in Europe as a zinc producer. The Stassfurt deposits are still an important source of salt, of potash for the chemical industry and of magnesium for the making of aluminum alloys. Before World War II Germany had a larger production of electricity than any other country in Europe, nearly all from thermal stations on or near the lignite (40%) and coal (36%) fields.

Industry. — Of the 14,500,000 people employed in German industry in 1939 about 9,000,000 were in Prussian factories and workshops. The main concentratioris were on the Ruhr coal field and along the Rhine front within easy reach of it, on the lignite field of the middle Elbe, and in Berlin and the North sea ports. The iron and steel industry was located on the Ruhr field because of its coke supplies. From its first development until 1919 it used principally the Lorraine ores but since that date has depended on imported (mainly Swedish) ores. Heavy engineering was closely situated around the steelworks but fabrication and light engineering were more widely dispersed; *e.g.*, shipbuilding at Bremen and Hamburg, railway material at Essen and Berlin, motor cars at Frankfurt. The largest manufacturers of electrical machinery had their works in Berlin. The heavy chemical industry, using coal, lignite and potash as basic materials, naturally developed on the Ruhr and the middle Elbe. Finer chemicals were manufactured around Frankfurt. The chief area for textiles was the Wuppertal, south of the Ruhr.

The dismantling of industrial plants and the breakup of the large cartels were prominent features of Allied policy immediately after World War II. The resulting widespread unemployment soon led to a reversal of the former and the latter was applied less drastically than was originally planned. In the German Federal Republic the production of electricity was in 1953 about double the prewar level, lignite exceeded the prewar level, and coal and textiles had reached it. Steel production was still limited to about two-thirds of the old level. In the German Democratic Republic where dismantling was carried much further and a large part of the remaining products were taken by the U.S.S.R. as reparations, output was still low though increasing as earlier restrictions were withdrawn.

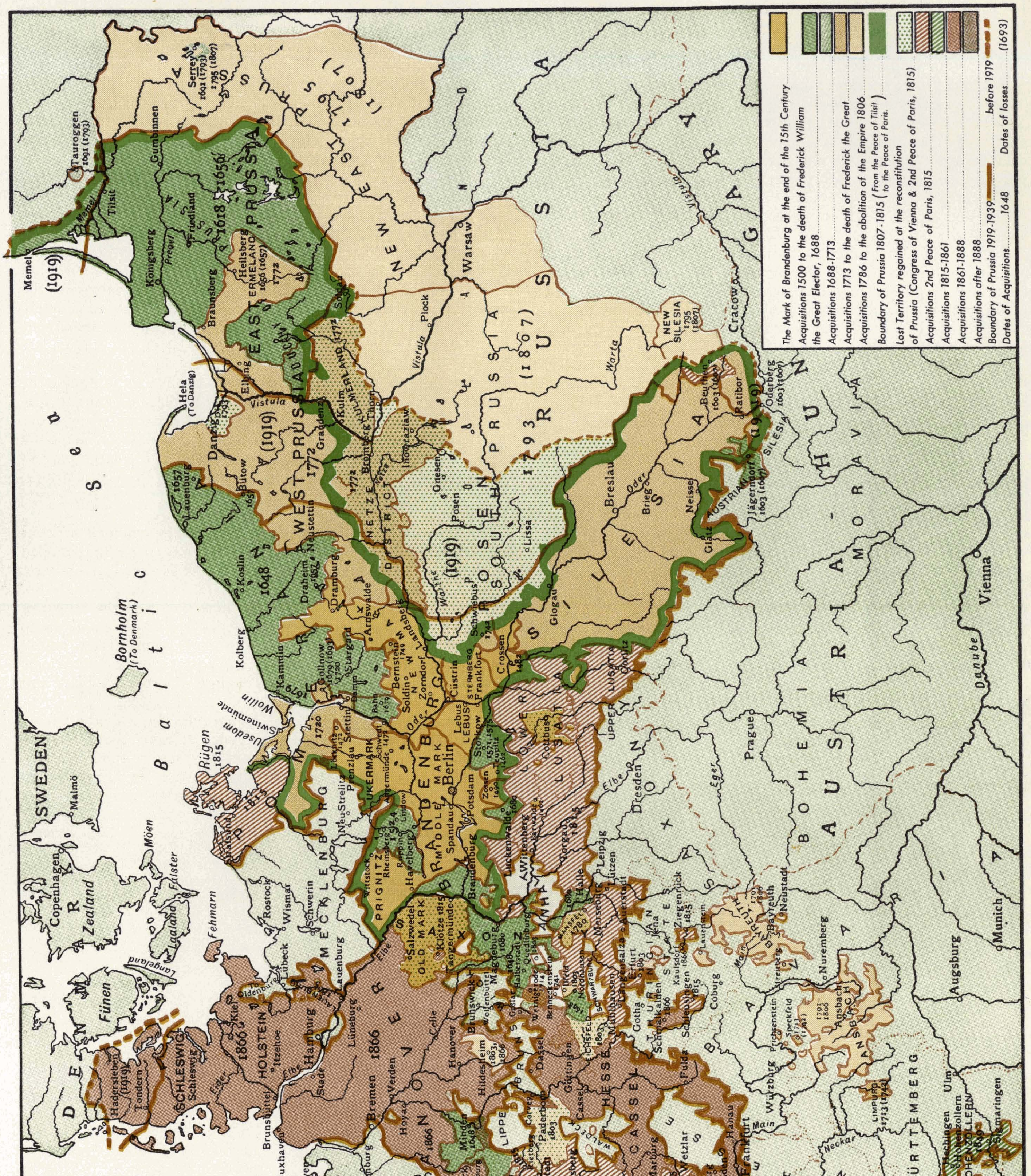
Communications. — Prussia was excellently provided with internal means of communication. Its railway network included about 17,000 mi. of track. The main trunk route was from west to east, through Aachen, Cologne, Diisseldorf, Hanover, Berlin, Danzig and Konigsberg. Important lines followed the Rhine in the west and radiated from Berlin to link the North sea and Baltic ports with southern Europe. In the years immediately before World War II they were supplemented by the through motor roads (*Autobahnen*). All the rivers are navigable across the plain and these were connected by an extensive canal system. The great Mittelland canal, opened in 1938, joined the Elbe with the Rhine, and the Dortmund-Ems system served the Ruhr area, while the Kiel ship canal gave a short route from Hamburg to the Baltic sea. The division of western and eastern Germany gravely disrupted the whole transport system, cutting off Hamburg from most of its hinterland and Berlin from its North sea ports.

BIBLIOGRAPHY.—N. Krebs (ed.), *Landeskunde von Deutschland: H.* Schrepfer, *Der Nordwesten,* vol. i, *B.* Brandt, *Der Nordosten*, vol. ii (Berlin, 1931–35); W. Müller-Wille, *Westfalen* (Munster, 1950); F. Klute (ed.), *Handbuch der geographischen Wissenschaft: Das deutsche Reich* (Potsdam, 1941); E. Mepnen, *Geographisches Taschenbuch* (Stuttgart, 1949); K. Mehnert and H. Schulte, *Deutschland-Jahrbuch* (Essen, 1949–); R. E. Dickinson, *The Regions of Germany* (London, 1945) and *Germany* (London, 1953). (T. HER.)

HISTORY

The state of Prussia, which has played so great a part in the history of Germany, came into being gradually, being formed out of wholly dissimilar components. The chief of these mere the mark of Brandenburg and the state of the Teutonic Order in Prussia (*i.e.*, the country originally inhabited by Prussians, Prusi or Borussi. a Baltic people speaking a language akin to Lithuanian and Latvian). The history of each of these, up to their union, must be treated separately.

The Teutonic Order. — In 1226 the Polish duke Conrad of Mazovia invited the Teutonic knights into his territory to combat the heathen Prussians. After a difficult struggle, the order conquered the territory, exterminated most of the native population, and invited German peasants and townspeople into the country as settlers. In the 14th century the state ruled by the knights was a power in northeastern Germany. In 1308 it conquered Polish Pommerellia and for a time the Neumark also, and through its connection nith the Order of the Sword. of Livonia, extended its influence as far as Estonia. A string of flourishing cities sprang up along its coast. In Marienburg, since 1309 the seat of the


PRUSSIA
1415-1939
English Miles
0 10 20 30 40 50 100
The Mark of Brandenburg at the end of the 15th Century
Acquisitions 1500 to the death of Frederick William the Great Elector, 1688
Acquisitions 1688-1713
Acquisitions 1713 to the death of Frederick the Great
Acquisitions 1786 to the abolition of the Empire 1806
Boundary of Prussia 1807-1815 (From the Peace of Tilsit to the Peace of Paris.)
Lost Territory regained at the reconstitution of Prussia (Congress of Vienna & 2nd Peace of Paris, 1815)
Acquisitions 2nd Peace of Paris, 1815
Acquisitions 1815-1861
Acquisitions 1861-1888
Acquisitions after 1888
Boundary of Prussia 1919-1939
before 1919
Dates of Acquisitions 1648
Dates of losses (1693)
North Sea
Baltic Sea
EAST PRUSSIA
WEST PRUSSIA
POMERANIA
BRANDENBURG
SILESIA
SOUTH PRUSSIA
NEW EAST PRUSSIA
POSEN
SAXONY
HANOVER
WESTPHALIA
RHINE PROVINCE
SCHLESWIG
HOLSTEIN
HESSE CASSEL
DENMARK
SWEDEN
HOLLAND
BELGIUM
FRANCE
BOHEMIA
AUSTRIA
HUNGARY
MORAVIA
BAVARIA
WÜRTTEMBERG
MECKLENBURG
OLDENBURG
RUSSIA

grand master of the order, the splendid castle was built which to this day testifies to the past glories of the order and formed the centre of its admirably organized administrative system. But even in the 14th century the order was beginning to decline owing mainly to the fact that once the struggle against the heathen was ended. it lost its original spiritual character. occupied itself only with purely mundane tasks, and thus lost touch with its original purpose. The rule of the knights. who admitted none of the local nobility into their ranks, came to be felt by the inhabitants as a foreign rule. When Poland and Lithuania united into a powerful state at the end of the 14th century, and the rulers of this state began to plan the recovery of the Baltic coast, the order could not rely fully either on the nobles or on the towns in its territory. After the defeat of their army at the battle of Tannenberg (1410) the knights were forced to cede part of their territory to Poland. In a second war the Poles took Marienburg, and at the peace of Thorn (1466) forced the order to cede them West Prussia and Ermeland, with Danzig and Thorn, and to acknowledge the suzerainty of the Polish king for the rest of their territory. At the beginning of the 16th century, the Reformation began to penetrate these regions also, and the grand master of the day, Albert of Brandenburg, a grandson of the elector Albert Achilles, proceeded, with the consent of the king of Poland. to take the decisive step which was tantamount to the end of the order's rule He went over to Protestantism, at the same time proclaiming himself hereditary duke of Prussia (152j). As his only son, Albert Frederick (1568–1618), was an imbecile, the power passed almost wholly to the estates. Albert Frederick's eldest daughter, Anna, married the elector John Sigismund, and through her Prussia passed in 1618 to the electors of Brandenburg. As Anna was also coheiress through her mother of the great territories which had been united under the rule of the dukes of Jiilich, Cleve and Berg on the lower Rhine, and as this ducal house had become extinct a few years previously (1609), the electors of Brandenburg could hope to acquire not only Prussia, but also considerable domains in west Germany. (See BRANDENBURG.)

Frederick William I.—Frederick William I (1713–40), the son and successor of Frederick I, has long been unjustly represented as a crude tyrant. He mas a sober-minded man, without any strong intellectual interests, but a first-class organizer and imbued with a stern sense of duty, based on religious sentiment. and he devoted his whole soul to the service of the state. He resumed the work begun by his grandfather, the Great Elector, and is the true father of the Prussian administrative system and Prussian officialdom He created a new central administrative service in the shape of the general directory, for which he drew up the instructions himself (1723). This organ acted as a general ministry, in which the agenda was distributed to the several members, partly by subject, partly on local lines. while all important measures were decided in general conference. The king reserved to himself the final decision. Each official received a commission stating his duties, emoluments and exact official regulations. All official bodies had to keep a record of, and send in a weekly report on, their activities. In most cases officials were nominated by the king at his discretion; only in the selection of the Landrate, who were in charge of the provincial districts (Krezse) the nobles still had a certain voice. Officials and magistrates were obliged to pass through a definite course of training, and could not be appointed unless they had passed the prescribed examination. The king organized a regular procedure of judicial appeal, making the *Kammergericht* in Berlin the supreme judiciary instance for the whole state. Judicial procedure was also simplified and improved in important respects. In the financial administration he introduced the strictest economy. He succeeded in increasing the revenue from the royal domains and prerogatives and from the indirect taxes to a considerable degree. and in achieving an annual surplus. This he put into a state exchequer, which contained 7,000,000 thaler at his death. He made special efforts to encourage trade and industry, following the principles of the mercantile system (*q.v.*), which at that time were everywhere accepted. As the country was thinly populated, he encouraged the immigration of efficient labour. Just as his grandfather had admitted a large number of the Huguenots expelled from France after the repeal of the Edict of Nantes by Louis XIV. so Frederick William allowed the Protestants expelled by the archbishop of Salzburg to enter his kingdom, settling most of them in East Prussia. Foremost a soldier, the king devoted particular attention to the training of the standing army, the numbers of which he raised from 40,000 to 80,000. It was still a mercenary army, recruited from volunteers at home and abroad. He took pains, however, to ensure that as high a proportion as possible should be composed of his own subjects and divided the whole Prussian territory into recruiting districts. the so-called "cantons"; each district was obliged to supply the men for one specified regiment. The recruiting was often done in a very arbitrary fashion, which gave rise to many complaints. Definite instructions were draan up and regular inspections carried through to ensure uniformity of training; the army thus created was superior to those of most other states. It was Frederick William who first gave Prussia the characteristic stamp of a military and bureaucratic state.

For all his military inclinations, Frederick William was a peaceable man by nature, and in his foreign policy always avoided military entanglements. When he came to the throne. Prussia was embroiled in the Northern War; at the conclusion of peace he succeeded in securing Western (Hither) Pomerania up to the Peene, which had formerly been in the hands of Sweden, with the important commercia! town of Stettin. He failed, hen-ever, to secure support for his claims, which were based on old succession treaties, to further portions of the Cleve-Julich heritage and to parts of Silesia. As a loyal German, he thought it his duty to maintain as good relations as possible with the emperor; but encountered profound mistrust in Vienna, where the growing strength of the Prussian state was watched with concern. and toward the end of his life was forced into an increasingly sharp opposition to the house of Habsburg.

Frederick the Great.—Frederick William died in 1740. He was succeeded by his son, Frederick the Great (1740–86), who was at that time 28 years of age. He had had violent conflicts with his father in his younger days, as his passionate and freedom-loving nature revolted against the severe discipline which his father thought necessary. Furthermore, the younger man's inclinations led him toward the new ideas of the Aufklarung, while the old king was a strict Calvinist. The crown prince's attempted flight (1730) brought this conflict to a head. The king had his son imprisoned. and even had an idea of excluding him from the succession; Frederick was only able to buy a reconciliation at the price of complete submission to his father's will. He was obliged to pass through a strict training in the administrative service and the army, a training which did much to prepare him for his later career.

For Frederick's conflicts with Maria Theresa in the first half of his reign, see AUSTRIA, EMPIRE OF; AUSTRIAN SUCCESSION. WAR OF; GERMANY; SILESIA. They ended in the acquisition of Silesia, with the exception of a few small districts south of the Riesengebirge. which remained in the hands of Austria. Frederick's successful resistance in the Seven Years' War against Austria, France and Russia raised his prestige enormously. From this time onward his state was recognized as a European great power. In addition to Silesia, he had also acquired East Frisia which came to him in 1744 on the extinction of the old princely house, through a succession treaty. At the first partition of Poland (1772) he also acquired West Prussia (except Danzig and Thorn), a particularly important district because it bridged the gap between East Prussia and the Brandenburg family dominions. Frederick carried on the internal development cf the Prussian state on the lines laid down by his father. He instituted a general civil code for his state in the shape of the Prussian Landrecht—a work not completed until after his death; accelerated judicial procedure, abolished torture, and introduced the principle that the crown should not interfere with the course of justice. In administrative matters, he sought to pay special consideration to the local peculiarities of the different provinces, and made frequent journeys of inspection to satisfy himself that his orders mere being carried out. The fiscal system was further developed; but an attempt to introduce the farming of taxes, on the French model (1766), proved unsuccessful and had to be abandoned. Under his rule the state revenue increased largely; on his death he left 55,000,000 thaler in the state exchequer. He had the low-lying country of the Oder and the Warthe drained, settled villages of colonists in the Pomeranian forests, arranged for the plantation of hops and potatoes, and founded factories. He left several detailed exposés of his administrative and political principles, notably in his political testaments of 1752 and 1767, which were designed to serve as a guide to his successor. Like his father, he considered himself the first servant of the state, and said that the prince should govern as though he had to render account to his subjects for all his measures. It did not, however, occur to him to do so. He rarely consulted with his ministers in person; he called for reports from them in writing, and dictated the answers, which he sent to them in writing. His liberal views in matters of religion led him to adopt the policy of toleration, on principle, toward the different churches: a policy which was also naturally dictated by practical considerations in a state which included a Protestant majority and a Catholic minority. His lively interest in all intellectual questions led him to take measures to improve the level of public education. In the upper schools the classics were made the principal subject of instruction. The king wished to establish compulsory primary education for all children from 5 to 13, but lack of means made it impossible to carry this out. Although Frederick was deeply influenced by the humanitarian ideas of the *Aufklärung,* and considered the furtherance of the people's welfare and of popular education to be among the monarch's essential duties, yet his guiding thought remained always to raise the forces of his comparatively small, weak state, by better organization, so as to maintain the position of power which he had won.

Collapse and **Reform.**—As Frederick left no issue from his marriage, contracted at his father's orders, with a princess of Brunswick, and as his younger brother, Augustus William, had predeceased him, the latter's son, Frederick William II, succeeded him on the throne (1786–97). He was indolent and dissipated, squandered the state exchequer and left the cares of government to his favourites. Under his reign no progress was made in the domestic organization of the state. In foreign affairs his participation in the war against revolutionary France brought him only losses, while the large accessions of territory that the second and third partitions of Poland (1793 and 1795) brought him were gains of but doubtful value. For the Prussian state! which after 1795 extended as far as Warsaw, thus received so large a percentage of Polish blood that had these frontiers proved permanent, its German character would have been endangered.

His son, Frederick William III (1797–1840), was a man of the best intentions, but pedantic, vacillating and narrow. The government fell more and more into the hands of the cabinet councillors who, under the system introduced by Frederick the Great, formed the sole channel of communication between the king and the ministers. But while under Frederick the councillors had been only executive organs of the king's will, under his weak successors they became the all-important personal advisers of the monarch. The Prussian state still kept the outward form given it by Frederick William I and Frederick the Great; but the living spirit was gone from it, and its swift and complete collapse after the first great military reverse (Jena, 1806), is easily comprehensible. Under the peace of Tilsit (1807) Frederick William was obliged to cede his entire territory west of the Elbe and the greater part of his acquisitions in Poland; he retained only Brandenburg, Pomerania, Prussia and Silesia. This fearful collapse, however, also released the forces of reconstruction which still lived on within the state, and during the so-called "period of reform" a complete reconstruction of the state was begun. The king himself always remained disassociated from, and at heart hostile to, these efforts, which appeared to him as a concession to Jacobinism; but as he knew no plan of his own for reconstructing the shattered state! he was forced to let the apostles of the new ideas have their way.

Heinrich, baron vom und zum Stein became the leading figure in the administration. He had long been urging reforms, but before 1806 without success. His fundamental idea was that in a modern state the people itself must be required to help in the conduct of public affairs because the state cannot exist unless it can count upon the willing co-operation and devotion of its citizens. The most important measures which he carried through mere the liberation of the peasants from serfdom, the reintroduction of municipal self-government under the Municipal act of 1808, and the abolition of cabinet government. He also planned to introduce self-government in the rural districts and participation of representatives of the people in the provincial administration and the central government. He was unable, however, to carry these measures into practice, being dismissed in the autumn of 1808 at Napoleon's order. The reforms were taken up again by Karl, prince von Hardenberg, in 1810, on his appointment as head of the ministry, although on lines rather different from those intended by Stein. Hardenberg really inclined more to enlightened despotism than to Stein's idea of self-government. His principal achievements were the reorganization of the finance and of the administrative system, the abolition of restrictions in industrial life, and the edict of 1811 which made the peasants free proprietors of their holdings, in return for the cession of a part of them to the former landlords. The peasants were thus required to buy their ownership at the price of giving up part of their holdings. Moreover, as the smaller holdings were excluded from the measure, the landlords could now take full possession of them, and their former cultivators sank to the position of agricultural labourers without property.

These years also saw a great reorganization of the army, carried through by Generals Gerhard von Scharnhorst and Hermann von Boyen. The underlying principle was the transformation of the mercenary army into a national army. Universal service was introduced, degrading punishments abolished, admission to the corps of officers revised and the internal organization of the army rearranged in more practical form. But for these reforms in all directions, the little state would have been incapable of the great achievements which it performed during the War of Liberation.

The Congress of Vienna. — After Napoleon's defeat in Russia, the Prussian General Hans Yorck von Wartenburg took his forces over to the Russian side and Frederick William III reluctantly followed his lead. The Prussian army played a principal part in the overthrow of Napoleon and Prussia re-emerged as a great power. At the Congress of Vienna, Prussia did not recover its Polish lands lost in 1807, which now went to Russia. In compensation it received Western Pomerania, the northern half of the kingdom of Saxony, Westphalia and the Rhineland. Its population was increased from under 6,000,000 to 10,000,000. Prussia ceased to be a northeastern German state and straddled across Germany. For the first time also it counted a large number of Roman Catholics amongst its people.

In the excitement of liberation the king had promised a constitution; after 1815 the promise was ignored. All that remained of it was the assurance that the state would not raise any new loan without the consent of an elected body. Meetings of the estates mere introduced for the individual provinces, but they were given only an advisory voice in local affairs. Prussia continued to be run by the old nobility and bureaucracy, who were increasingly out of touch with the liberal sentiment of the western provinces. The only striking advance in the reign of Frederick William III was the creation of the *Zollverein* (virtually complete by 1834) which brought all the German states except Austria under Prussian economic leadership.

The 1848 Revolution. — On the death of Frederick William III, his eldest son Frederick William IV (1840–61) ascended the throne. He had grown up in an age when the theories of romanticism had dominated Germany; these theories swayed him, and, like his father, he was averse at heart to the modern political demands. After long consideration, however, he determined in 1847 to convoke the members of all provincial diets to a united diet at Berlin. This body, however, immediately put forward a demand to be convoked at regular intervals, and to be recognized as a partner, with equal rights, in the legislation. The king refused to admit such claims, and the dellberations led to no practical result. Nevertheless, it was an event of no small importance that representatives of all parts of the Prussian state had, for the first time, met for common parliamentary debates.

Soon after this. revolution broke out all over Germany. Although the military remained the victors in the street fighting of March 18 in Berlin, the king nevertheless decided to give way and withdraw the troops from Berlin. He agreed to the convocation of a constituent national assembly. which was to meet in Berlin and collaborate with him in drawing up a constitution. But as democratic elements gained the upper hand in this assembly, the king dissolved it and enacted a constitution (Dec. 5, 1848), with the proviso that a freshly elected parliament should negotiate further on its final form. These negotiations proving very protracted, the parliament was again dissolved in the spring of 1849, and it was only when a chamber was elected on the three-class franchise that agreement was at last reached on a definitive constitution, to which the king took the oath on Feb. 4. 1850. Prussia now received a parliament. consisting of two chambers; the first chamber. called the *Herrenhaus* after 1854, was composed of representatives of the large landed proprietors and of the larger towns, and of members nominated by the king. either for life. or as hereditary members. The second chamber was elected by all taxpaying citizens, but as the electors were divided into three categories, according to taxes paid, electors with larger incomes were given much greater influence than the poorer classes. Yet, despite the limited franchise, this was a genuine constitution. The chambers had defined rights and were entitled to meet regularly. The budget was to be agreed annually between the chambers and the crown—a phrase which seemed to imply, though it did not, a large measure of parliamentary sovereignty. Inadequate as the constitution appears by democratic standards, without it there would have been later no constitutional conflict at all.

During the revolution of 1848 Frederick William IV hoped to lead the movement for unification. He said in a famous phrase: "Prussia is merged in Germany." His conservative principles soon reasserted themselves. On April 3. 1849. he refused the imperial crown, when it was offered to him by the Frankfurt national assembly; he would only accept it. he said, from the German princes. He and his friend Joseph Maria von Radowitz attempted to build a lesser German union, on conservative lines. known as the Erfurt union. In 1850 this was challenged by Austria; and as Frederick William shrank from war, Prussia was obliged to abandon its ambitions by the agreement of Olmiitz or Olomouc (Nov. 2, 1850).

William I and William II.—A period of reaction followed in Prussia. Frederick William IV appointed an extremely reactionary government. which remained in power until he became insane in 1857. His brother, William, prince of Prussia, acted as regent until his death (Jan. 2, 1861) and then ascended the throne as William I. The new ruler took at first a more liberal line than his brother. In 1858 he appointed a liberal ministry under Prince Hohenzollern, and for nearly four years Prussia experienced "the new era." William and his minister of war. Albrecht, count ron Roon, disagreed. however, with the chamber over the reorganization of the army. Roon wished to increase the army establishment, which had remained stationary since 1815, so that every Prussian should perform his military service. The lomer chamber were ready to agree with this, but insisted in return that the period of service be reduced to two years and that the *Landwehr*, or reserve, should play a more independent part. The struggle which followed was a conflict over the character of the Prussian army, not its size. By the constitution, the taxes were imposed permanently. The chamber could not cut off supplies. It could only refuse to authorize the expenditure of money already collected. In 1861 they authorized the additional expenditure for a single year. In 1862, as their demands were still refused. they refused authorization altogether. William first thought of abdicating. At the last minute Roon persuaded him to appoint Otto von Bismarck minister president (Sept. 23, 1862).

As the lower chamber refused to accept the budget which the king and the upper chamber had put forward, Bismarck argued that there was "a hole in the constitution"; and he governed without a budget for the next few years. The liberals were helpless. It would have been unconstitutional to refuse the taxes. They could only protest and wait for Bismarck to fail in his foreign policy. Instead he succeeded, and his defeat of Austria in 1866 led many liberals over to his side. He in turn was willing to confess the illegality of his actions. He asked for and received an Act of Indemnity (Sept. 1866).

Campaigns of 1864–71 which led to union of Germany under Prussia's leadership cannot be told here. (*See* SCHLESWIG-HOLSTEIN QUESTION; GERMANY; AUSTRIA, EMPIRE OF; FRANCO-GERMAN WAR.) The acquisition of Hanover, Kurhesse, Nassau and Frankfurt-am-Main after the war of 1866, gave Prussian territory a wholly new aspect. Its eastern and western halves, which up to this date had been separated by these districts, mere now linked up into a single great north German state, containing nearly two-thirds of the total population of Germany (in 1914, 40,000,000 out of a total population of 67,800,000).

With the unification of Germany in 1871 the king of Prussia became German emperor, in supreme command of all German armed fo ces. The Prussian army was, in fact, the main instrument by mhich Prussian power mas extended throughout Germany. Bismarck also combined Prussia and Germany in his own person. He mas both political head oi the empire as *Reichskanzlrr* and Prussian minister president. Roon was Prussian minister president for a short period in 1872–73; hut when he fell ill Bismarck resumed the office and kept it until 1890. His successor Georg Leo von Caprivi gave up the position of Prussian minister president; but this led to a conflict of policy between the two offices and ultimately to his resignation. The two posts were then reunited until the end of the empire in 1918.

The alliance concluded by Bismarck with the liberals at the time of the foundation of the empire had important effects. The Local Government act of 1872 increased the autonomy of the rural districts, thus linking up with the traditions of the age of Freiherr von Stein. The so-called *Kulturkanzpf—the* struggle against the Roman Catholic Church which was waged in the '70s—was also in accord with liberal ideas. It ended, however, finally, with the state restoring to the church its control over the preliminary training of the clergy, and retaining only a right of veto over appointments to ecclesiastical posts.

During the short reign of Frederick III (March–June 1888) and under William II, the situation remained in essence unchanged. The new Rural Districts act (*Landgemeindeordnung*) of 1892 carried existing institutions a step further. The fiscal reform carried through about the same time by J. von Miquel made self-assessment the basis of taxation, and provided relief for the poorer classes and heavier contributions from large incomes,

Reiorm of the franchise was often discussed, to give Prussia the same universal suffrage as the reich; but these proposals never came to anything, and the three-class franchise survived until the revolution of 1918.

Republic of **Prussia.**—The revolution ended the Prussian monarchy. It also severed the connection between the Prussian prime minister and the imperial chancellor. Prussia became a *Land* of the Weimar republic, with the same universal suffrage. Since Prussia was the most industrialized part oi Germany, its parliament had always a left-wing majority. Prussia was ruled between 1918 and 1932 by the Social Democrats, sometimes alone. sometimes in coalition with the Centre. The most outstanding personality was Otto Braun, the prime minister. Since the *Land* controlled the police, the Social Democratic government of Prussia was the essential defense of German democracy.

In 1932 the coalition of Centre and Social Democrats lost their majority. Franz von Papen, then chancellor, used this excuse to overthrow Prussian democracy. He was nominated imperial commissioner ior Prussia by Pres. Paul von Hindenburg and expelled the democratic government. This made easier Hitler's accession to power on Jan. 20, 1933. Soon afterward Hermann Goring took Papen's place as ruler of Prussia. The Prussian constitution was set aside by the National Socialists, its legislature was abolished but it still led a nominal existence as a component part of the reich. (*See* also BRANDENBURG; GERMANY.)

BIBLIOGRAPHY.—H. von Treitschke, *Origins of Prussianism (The Teutonic Knights)* trans. by E. and C. Paul (New York, 1942); F. Holtze, *Gcschichte der Mark Brandenburg* (Tiibingen, 1912); S. B. Fay, *The Rise of Brandenburg-Prussia to 1786* (Chicago, 1937); J. A. R. Marriott and C. G. Robertson, *The Evolution of Prussia* (Oxford. 1946); L. von Ranke, *Zwölf Bücher preussischer Geschichte,* vol. 25–27 (Leipzig, 1867–90); J. G. Droysen, *Geschichte der preussischen Politik bis 1756,* 2nd ed. 14 vol. (Leipzig, 1868); E. Bernrr, *Gcschichte der preussischen Staates,* 2nd ed. (Bonn, 1896); G. Schmoller, *Umrisse und Untersuchungen zur Verfassungs-Verwaltungs- und Wirtschaftsgeschichte, besonders des preussischen Staates, im 17 und 18 Jahrhundert* (Leipzig, 1898) and *Preussische Verfassungs-, Verwaltungs- und Finanzgeschichte* (Berlin. 1921); H. Prutz, *Preussische Geschichte,* 4 vol. (Stuttgart, 1900–02); A. Waddington, *Histoire de Prusse,* 2 vol. (Paris, 1911–22); R. Koser, *Geschichte der brandenburgisch- preussischen Politik,* vol. i (Stuttgart and Berlin, 1913); O. Hintze, *Die Hohenzollern und ihr Werk,* jth ed. (Berlin, 1915); H. von Treitschke, *Historische und politische Aufsätze,* 1st ed. (Leipzig. 1865–70); H. Tuttle, *History of Prussia, 1134–1757,* 4 vol. (New York, 1883–96); *Hohenzollern Jahrbuch* (Berlin: 1897 *et seq.*); *Forschungen zur brandenburgischen und preussischen Geschichte* (Berlin, 1888 *et seq.*).

(E. BRA.; A. J. P. T.)

PRUSSIA, in the original sense, a territory of Germany, stretching along the Baltic coast for about 220 mi. and occupying an area of 24,083 sq.mi. The eastern part formed the duchy of Prussia, conquered and colonized by the Teutonic Order and acquired by the elector of Brandenburg in 1618, furnishing his successor with his regal title in 1701. The western part, severed from the eastern half and assigned to Poland in 1466, was not annexed to Prussia until the partition of Poland in 1772, while Danzig and Thorn remained Polish down to 1793. The two districts were temporarily (1824–78) united to form a single province.

PRUSSIC ACID, also known as hydrocyanic acid or hydrogen cyanide, is a highly volatile, colourless liquid of extremely poisonous character. It was discovered in 1782 by K. W. Scheele, who obtained the compound from prussian blue. Prussic acid (HCN) and its compounds are used for many chemical processes, including the manufacture of pigments and dyes; the casehardening of iron and steel; electroplating; and fumigation. The acid is employed in the preparation of acrylonitrile, which is used in the production of acrylic fibres, synthetic rubber and plastics. In some states of the U.S. the legal method of inflicting capital punishment is by dropping pellets of cyanide into sulfuric acid, thus releasing the highly toxic prussic-acid gas, which causes death when inhaled. In variable but generally small proportions it is widely distributed among plants in the form of glycosides; *i.e.,* in combination with sugars. Amygdalin, which is present in bitter almonds, is an example of such glycosides; it yields prussic acid upon hydrolysis. Cyanides are the salts of prussic acid.

Preparation.— A convenient method of obtaining prussic acid in the laboratory is to add a cold mixture of 100 c.c. concentrated sulfuric acid and an equal volume of water slowly to 100 g. of coarsely granular potassium cyanide in a large flask connected to two U-tubes filled with anhydrous calcium chloride. The vapours emerging from these U-tubes are condensed by passing downward through a condenser and collected. Brine cooled to $-10°$ C. is circulated through the jacket of the condenser. A fully anhydrous product is made by adding phosphorus pentoxide to the liquid thus prepared, shaking for a short period and distilling once more.

Prussic acid is made commercially from sodium cyanide in a continuous manner by bringing together a 23% aqueous sodium cyanide solution and concentrated sulfuric acid in a lead-lined generator and condensing and collecting the vapours evolved. The sulfuric acid is kept slightly in excess over the cyanide in the course of the reaction. The residual prussic acid in the liquid, which forms 20% of the total, is recovered by boiling the solution, the vapours being condensed after a partial enrichment in a special "cooler." Prussic acid of 97.5%–98% strength is made from the combined crude condensate by fractional distillation. Large quantities of the acid are also prepared from commercial calcium cyanide by a similar process.

Important quantities of prussic acid are made in Germany from "Schlempe," a by-product of the sugar industry resulting from the treatment of beet molasses with strontia for the purpose of recovering the sugar present in this product. Schlempe contains 4% of nitrogen in the form of betaine, $(CH_3)_3N^+-CH_2-CO_2^-$, in addition to decomposition products of vegetable proteins. It is first distilled, the tarry matter carried over by the vapours being condensed and separated; the gases escaping the condenser are next preheated by passage through a tunnel in an externally heated chamber and are then conducted through the cyanizing chamber. This chamber is filled with firebrick checkerwork and is previously heated by direct gas fire to a temperature somewhat in excess of 1,000° C. The cyanized gas contains about 7% prussic acid, 7% ammonia and 24% carbon dioxide by volume. It is freed of ammonia by scrubbing with hot, dilute sulfuric acid. The prussic acid in the emergent gases is absorbed in water and the aqueous solution thus obtained, which contains 2%–3% prussic acid, is fractionally distilled to recover the prussic acid. The acid is condensed to liquid and further refined or it is directly converted to sodium cyanide.

Synthetic Methods.— Several possible methods for the synthesis of prussic acid have been investigated. Tmo such methods developed into successful commercial processes and became employed for the preparation of the compound on a very large scale. A brief description of these processes follows.

Synthesis by Controlled Oxidation *of* a Hydrocarbon Ammonia Mixture.— Prussic acid is formed when a mixture of methane and ammonia, containing an insufficient amount of oxygen for complete combustion, is passed through a glowing platinum gauze. The reaction giving rise to the compound may be expressed as $2NH_3 + 2CH_4 + 3O_2 \rightarrow 2HCN + 6H_2O$. Leonid Andrussow, who discovered this method, developed it into a successful technical process. Methane and ammonia are mixed in the approximate ratio 11:10 and sufficient air is added to the mixture to give an oxygen content of about 15.5%. The mixture is passed through two or more layers of incandescent platinum iridium gauze with 3% to 5% iridium. The gauze is constructed of 0.16-mm. wire. The several layers of the gauze, resting on a special support, are held between ceramic rings inside a short tube, the whole constituting the converter. The cold gases enter the converter usually at a linear velocity of 103 cm. per second, emerging at a temperature of 1,000°–1,030° C. at a little over 500 cm. per second. The heat generated by the reaction is sufficient to maintain the gauze at the desired temperature. The gases emerging from the converter may be passed through sodium hydroxide solution after being cooled sufficiently. The prussic acid is quantitatively absorbed and may be recovered as sodium cyanide. Alternatively, the ammonia is removed by scrubbing with dilute acid and the prussic acid is absorbed in cold water in special towers and recovered by distillation. Of the total ammonia fed into the converter approximately 63% is utilized in the formation of prussic acid and 10% to 20% is lost by complete combustion. Platinum losses resulting from catalyst deterioration amount to about 1 g. per metric ton of hydrocyanic acid produced.

Aliphatic hydrocarbons other than methane are capable of undergoing the reaction. Methane receives preference, however, since higher hydrocarbons tend to deposit carbon and cause what is known as spotting of the catalyst. This results in loss of efficiency and a greater rate of deterioration of the gauze.

Synthesis by Dehydration of *Formamide.*—In this process formamide is dehydrated in the vaporized condition by passing it, in admixture with a large proportion of ammonia, over an aluminum phosphate catalyst heated to 360° C. The reaction expressing the change is $HCONH_2 \rightarrow HCN + H_2O$. The original formamide ammonia mixture contains 3%–5% of formamide. Dehydration is carried out at atmospheric pressure and proceeds very rapidly. The prussic acid formed is absorbed in sodium hydroxide solution and may be recovered as sodium cyanide.

Formamide is prepared through the reaction of anhydrous ammonia with methyl formate at 30°–60° C. under a pressure of 15 atm.: $HCOOC_2H_5 + NH_3 \rightarrow HCONH_2 + CH_3OH$. It is purified to analyze 99.7% by fractional distillation. Methyl formate is made by the reaction of carbon monoxide with methyl alcohol in the presence of 1% sodium as sodium methoxide: $CO + HOCH_3 \rightarrow HCOOCH_3$. The reaction is carried out at 110° C. under 100 atm. and proceeds quite readily with evolution of heat. The product is freed from the dissolved sodium methoxide by distillation and the mixture of methyl formate and methyl alcohol thus obtained is used directly for the preparation of formamide. The methyl alcohol recovered in the distillation step contains a small amount of unreacted methyl formate and is used for the preparation of additional quantities of methyl formate. The process is, therefore, essentially a complete synthesis of prussic acid, utilizing ammonia and carbon monoxide as the starting materials.

The yield of prussic acid based on ammonia exceeds 92%; it is somewhat more than 85% when calculated on the basis of carbon monoxide used. Approximately 5.5 lb. of methyl alcohol are lost in the process for every 100 lb. of prussic acid produced. The catalyst, if it should become deactivated by a coating of carbon, is reactivated by blowing air through the heated mass. It can be used for several years before it becomes necessary to replace it.

Physical and Chemical Properties.— Prussic acid boils at 25.7° C. and freezes to a snowlike, white mass melting at $-14.9°$ C. It is highly volatile even in the frozen condition. The dielectric constant of prussic acid is the second highest known, indicating the strongly polar character of its molecule. In this respect the compound bears a great resemblance to water, and like water it is a strongly ionizing solvent. The abnormally high heat of evaporation of the liquid is also ascribable to the highly polar character of the molecule. Prussic acid is miscible in all proportions with water and most organic solvents. The vapours of prussic acid are combustible and mixtures with air containing 7%–40% prussic acid by volume are explosive. The products of combustion are carbon dioxide and nitrogen.

The elements in the molecule of prussic acid may be combined in one of two possible ways, $H-C\equiv N$ or $H-N=C$, designated respectively as the normal (nitrile) and the iso (carbylamine) forms. The fact that both methyl cyanide, CH_3-CN, and methyl isocyanide, CH_3-NC, result from the reaction of prussic acid with diazomethane, CH_2N_2, would seem to indicate that both forms coexist in liquid prussic acid, possibly in a state of dynamic equilibrium (see ISOMERISM: *Tautomerism*). Evidence indicates that the molecules of normal structure largely predominate in the liquid. The dissociation constant of prussic acid in aqueous solution at 18° C. is 1.3×10^{-9} or $\frac{1}{230}$ that of carbonic acid, which is itself a weak acid. The degree of acidity developed in aqueous solution is, for this reason, too small to affect the colour of most indicators. The vapours of prussic acid react with remarkable rapidity, nevertheless, with solutions of alkalies, which can therefore serve effectively for the elimination of the compound from a stream of air containing prussic acid.

Polymerization of Prussic Acid.—Prussic acid in the pure form is stable and can be kept unchanged almost indefinitely in sealed glass containers. The acid gradually polymerizes in the presence of minute amounts of substances of basic character such as ammonia, sodium cyanide, etc. The polymer is a black solid of approximately the same empirical composition as prussic acid. Polymerization is accompanied with the evolution of considerable heat and is greatly accelerated as the temperature rises. For this reason the polymerization of comparatively large quantities, which may cause a great rise in temperature with the consequent rise in pressure, may result in an explosion. The addition of small quantities of a strong acid, or of compounds giving rise to acids by gradual reaction with water, effectively stabilizes the commercial acid.

Chemical **Behaviour.**—Prussic acid cannot be esterified directly. Its esters, $R-CN$ (*i.e.*, the nitriles), are usually obtained through the interaction of an alkali metal cyanide with an organic halide or sulfate. Methyl cyanide can, for example, be prepared by heating methyl iodide with an alcoholic solution of potassium cyanide according to the equation: $KCN + ICH_3 = CH_3CN + KI$. The fact that nitriles, $R-CN$, may be prepared through the dehydration of the amides of the corresponding acids, $R-CONH_2$, definitely demonstrates that these compounds are normal cyanides, $R-C\equiv N$. The reaction of organic halides with silver cyanide or mercuric cyanide leads to the formation of isonitriles, $R-N=C$, which differ in their properties from normal nitriles. Prussic acid combines with aldehydes and ketones in the presence of small quantities of substances of basic character, such as potassium cyanide or amines, generally at room temperature, forming cyanohydrins. Acetaldehyde cyanohydrin results, for example, from the reaction of acetaldehyde with prussic acid: $CH_3CHO + HCN = CH_3CH(OH)CN$.

Prussic acid is capable of reacting with ethylene oxide under pressure in the presence of a basic catalyst at a moderately high temperature to form ethylene cyanohydrin:

$$CH_2-CH_2O + HCN \rightarrow HOCH_2CH_2CN$$

This compound is readily dehydrated on distilling in the presence of certain catalysts to acrylonitrile, $CH_2=CHCN$. This is the basis of one of the technical preparations of the latter compound, which has assumed great importance. Acrylonitrile, together with butadiene, is used in the preparation of the acrylic type of synthetic rubber. In the polymeric form it is used for the manufacture of an important synthetic fibre; another synthetic fibre is made from the copolymer of acrylonitrile and vinyl chloride.

Chlorine, reacting with prussic acid in dilute aqueous solutions, gives cyanogen chloride, $ClCN$: $2HCN + Cl_2 = ClCN + HCl$. Bromine reacts similarly, forming cyanogen bromide.

The cyano group, $C\equiv N$, present in prussic acid, is capable of various transformations because of the reactive or "unsaturated" character of the nitrogen-to-carbon bonds. The addition of water, or hydrolysis, can take place in steps, the formation of formamide, $HCONH_2$, being the first stage and that of ammonium formate, $HCOONH_4$, the second stage of the reaction. Hydrolysis takes place readily in the presence of concentrated hydrochloric acid or moderately concentrated sulfuric acid. Concentrated sulfuric acid destroys the ammonium formate, the final products of the reaction being ammonium sulfate and carbon monoxide. Four atoms of hydrogen may be added to the molecule of prussic acid to obtain methylamine, $CH_3.NH_2$. Addition may be brought about by passing a mixture of prussic acid with a large excess of hydrogen over platinized asbestos heated above 150° C.

Metallic Cyanides.—The cyano group or radical behaves in many respects like an element and, combining with metals, gives the metallic cyanides which resemble the metallic halides. This resemblance is particularly marked in the case of alkali metal salts. The radical shows a marked power, on the other hand, of forming complex salts such as potassium ferrocyanide, $K_4Fe(CN)_6$. In these compounds, usually one metal atom forms part of the complex cyanide anion. For example, potassium ferrocyanide dissociates into the potassium cations, K^+, and ferrocyanide anions, $Fe(CN)_6^{4-}$. Ferrous ions, F^{++}, and cyano ions, CN^-, are present in the solution in such minute quantities, in this instance, that ordinary analytical tests fail to reveal their presence; and the stability of the complex is such that the addition of a mineral acid yields the corresponding free ferrocyanic acid, $H_4Fe(CN)_6$. This behaviour is common to many, but not by any means all, of these complex salts. Some, like potassium zinc cyanide, $K_2Zn(CN)_4$, are easily decomposed by acids with the liberation of prussic acid.

The tendency to form complex cyanides is most marked in the metals of Group VIII and contiguous metals (transition elements, see PERIODIC LAW, THE). Most complex cyanides are of the following types: $K[R(CN)_2]$, where R is Cu, Ag, Au; $K_2[R(CN)_4]$, where R is Zn, Cd, Hg, Ni, Pd, Pt; $K_4[R(CN)_6]$, where R is Cr, Mn, Fe, Co, Ru, Os, Ir; $K_3[R(CN)_6]$, where R is Cr, Mn, Fe, Co, Rh, Ir; $K_4[R(CN)_8]$, where R is Mo or W.

Sodium Cyanide is one of the two commercially most important salts of prussic acid. It is prepared in a pure form, analyzing 96%–98% NaCN, by the Castner process, which utilizes the reaction of metallic sodium with ammonia and charcoal. A less pure form of the compound is made from prussic acid. In Germany a large portion of the prussic acid obtained from Schlempe is converted to sodium cyanide.

The Castner Process.—Metallic sodium is melted with charcoal in a steel vessel and dry ammonia is blown into the liquid, while the temperature is gradually raised to 600° C.; the mass is finally heated to about 850° C. in order to complete the conversion of the last remaining portion of sodium cyanamide into cyanide. The molten mass is filtered through iron turnings, after being cooled to some extent, and is cast in molds in the form of spheroids of convenient size. The reaction proceeds in three steps: sodium amide is the first product, $Na + NH_3 = NaNH_2 + H$; the amide reacts rapidly with charcoal forming sodium cyanamide, $2NaNH_2 + C = Na_2CN_2 + 2H_2$; and this finally combines with an additional atom of carbon to form sodium cyanide, $Na_2CN_2 + C = 2NaCn$.

Preparation From Prussic Acid.—Prussic acid is absorbed in aqueous sodium hydroxide solution of such strength that a saturated solution of sodium cyanide (45% by weight) is produced. The use of an excess of prussic acid is avoided, since otherwise a dark product is obtained because of the polymerization of the free acid. The solution is evaporated in *vacuo* to a paste, which is centrifuged to give a product containing 10% water. The remaining water is removed by drying this product on heated trays in vacuo. The dried powder, which analyzes 90%–92% NaCN, is compressed into rectangular cakes of convenient size.

Properties of Sodium *Cyanide*.—Sodium cyanide is a colourless solid crystallizing in the cubic system. It forms a dihydrate, $NaCN.2H_2O$, which crystallizes in large colourless plates decomposing above 34.7° C. Sodium cyanide is soluble in water, alcohol and anhydrous ammonia: it melts at 563.7' C.

In aqueous solution sodium cyanide is partially hydrolyzed to prussic acid and sodium hydroxide: $NaCN + H_2O = NaOH + HCN$. When aqueous solutions of sodium cyanide are heated hydrolysis of the cyano group takes place at an appreciable rate and ammonia and sodium formate result: $NaCN + 2H_2O = HCOONa + NH_3$. This reaction also takes place at ordinary temperatures, although at an extremely slow rate.

Calcium Cyanide has acquired considerable commercial importance since the introduction of its preparation from cyanamide: a mixture of 10 parts commercial calcium cyanamide, 8 parts common salt and 0.5–1 part calcium carbide is fed into an electric furnace of the arc-resistance type with conducting hearth and a single suspended graphite electrode. Alternating current passing through the charge heats this to 1,200°–1,400° C., and the fused mass overflows to a pan in which an internally water-cooled rotating drum picks up a thin layer of the melt. The cyanide is thus chilled rapidly in the form of a thin sheet which breaks into flakes as it is scraped off and collected. The product analyzes more than 45% $Ca(CN)_2$ and contains impurities derived from the coal and coke used in the manufacture of cyanamide and from the salt. Calcium cyanide is formed through the combination of calcium cyanamide with carbon. The carbon is present in the commercial product in the required amount because of its mode of formation from carbide: $CaC_2 + N_2 = CaCN_2 + C$. Rapid cooling of the fused cyanide is essential for the prevention of reversion to cyanamide, which takes place rapidly between 400° and 700° C.

Calcium cyanide in the pure form is a white powder which melts at 640° C. ± 30° C., when heated rapidly, to a clear liquid. The melt soon becomes turbid and finally solidifies as it reverts to calcium cyanamide. An important property of calcium cyanide is its reaction with atmospheric moisture which takes place according to the equations:

$$Ca(CN)_2 + H_2O \rightarrow Ca(OH)CN + HCN$$
$$Ca(OH)CN + H_2O \rightarrow Ca(OH)_2 + HCN$$

The reaction takes place rapidly if the cyanide is finely ground and the relative humidity is in excess of 35%. It forms the basis of the use of calcium cyanide as a fumigant.

Heavy Metal Cyanides.—The simple cyanides of heavy metals are insoluble in water, with the notable exception of mercuric cyanide. Cuprous, silver and zinc cyanides have acquired some commercial importance.

Cuprous Cyanide, CuCN, the only stable cyanide of copper, is made by adding a solution of sodium cyanide to one of cuprous chloride in saturated aqueous sodium chloride. It is soluble in solutions of alkali metal cyanides. The complex salts obtained through the combination of cuprous cyanide with alkali cyanides are used in the electrodeposition of copper on iron. Cuprous cyanide is also important as a reagent for the introduction of the CN radical into aromatic compounds by reaction with aromatic diazo compounds.

Silver Cyanide, AgCN, separates as a white flocculent precipitate when hydrocyanic acid is added to an aqueous solution of a soluble silver salt. It dissolves in sodium cyanide solution, forming the complex salt $NaAg(CN)_2$, which is used in the process of electrodeposition of silver.

Zinc Cyanide, $Zn(CN)_2$, may be prepared by adding hydrocyanic acid to a solution of zinc acetate in water. It separates as white crystals which dissolve in solutions of alkali cyanides, with the formation of a complex cyanide.

Potassium Ferrocyanide, $K_4Fe(CN)_6$, together with the corresponding sodium salt, finds wide use in the preparation of Prussian blue, in the dye industry for the fixation of aniline black dyes and in the casehardening of iron by the "cementation" process. It may be prepared through the reaction of ferrous sulfate and potassium cyanide in aqueous solution. It is obtained more economically from commercial calcium cyanide. Commercial calcium cyanide is dissolved in water and treated with the calculated quantity of ferrous sulfate. To the filtered solution potassium chloride is added, thus precipitating the nearly insoluble potassium calcium ferrocyanide, $K_2CaFe(CN)_6$; this is filtered, washed and then boiled with the required quantity of aqueous potassium carbonate solution. The solution is filtered and concentrated by boiling in cast-iron vessels, and the salt is allowed to crystallize during 14 days on wires or strings suspended in the liquid. The sodium salt may be prepared similarly by the use of sodium chloride and sodium carbonate in the process in place of the potassium salts.

Potassium Ferricyanide, $K_3Fe(CN)_6$, is prepared by oxidizing potassium ferrocyanide in aqueous solution electrolytically or with chlorine. Electrolysis is carried out in diaphragm cells with nickel electrsdes. Potassium ferricyanide crystallizes out from the anode liquor on cooling, and the mother liquor is replenished with fresh ferrocyanide and returned to the cell. The reaction may be represented ionically as follows: $Fe(CN)_6^{4-} = Fe(CN)_6^{3-} + e$; $H_2O + e = OH- + 1/2H_2$.

Oxidation with chlorine is carried out by conducting gaseous chlorine into a cold 10% solution of ferrocyanide. The reaction is represented by the equation: $2K_4Fe(CN)_6 + Cl_2 = 2K_3Fe(CN)_6 + 2KCl$. The passage of chlorine is discontinued when the conversion of the ferrocyanide is just completed. The solution is evaporated to the crystallizing point, a little caustic potash is added to eliminate the small amount of prussian green formed, which is precipitated as ferric hydroxide and removed by filtration. The ferricyanide is recovered by crystallization in an 85%–90% yield. Potassium ferricyanide, used in combination with hypo, is a common photographic chemical (Farmer's reducer).

Iron Cyanide Blues form an important group of pigments. They may be prepared directly through the interaction of ferric salts with alkali ferrocyanides or of ferrous salts with alkali ferricyanides in neutral or acid solution. They are amorphous substances containing variable quantities of combined water. Depending upon the procedure followed in their preparation, soluble or insoluble varieties may be produced. The soluble types, which may be represented by the formula $K\ Fe[Fe(CN)_6]aq.$ and contain a maximum of four molecules of water, may be prepared by mixing cold neutral solutions of ferric chloride and potassium ferrocyanide, the latter being used in excess. Insoluble blues conform to the formula $Fe_4[Fe(CN)_6]_3aq.$ and contain a maximum of 10–11 molecules of water. They are formed when an excess of a ferric salt solution is added to a neutral or slightly acid solution of potassium ferrocyanide.

Blues prepared by the direct method lack the desirable brilliancy of colour; they are generally known as Prussian blue. Fine qualities can be prepared only by an indirect process depending upon the oxidation of potassium ferrous ferrocyanide or of mixtures of this substance with ferrous ferrocyanide:

$$6K_2Fe[Fe(CN)_6] + 3H_2O + 3O = Fe[Fe(CN)_6]_3 + 3K_4[Fe(CN)_6] + 2Fe(OH)_3$$
$$3Fe[Fe(CN)_6] + 3H_2O + 3O = Fe_4[Fe(CN)_6]_3 + 2Fe(OH)_3$$

Paris blue, also called chinese blue. is the finest of iron blues. It is made as follows: a solution of 66 kg. ferrous sulfate (120 kg. of commercial product) in 600 1. water and one of 7j kg. potassium ferrocyanide (83 kg. of commercial product) in 1.000 1. of water are added simultaneously to 600 1. of water with vigorous agitation. The precipitate is washed by decantation, the wet paste is brought to the boiling temperature and a solution of 44 kg. ferric chloride (80 kg. of commercial product) in zoo 1. of water heated to 70° C. is added in the course of one to one and one-half hours. The liquid is boiled with stirring for one-half hour and diluted with boiling water to 4.000 1.; the precipitate is then washed six to eight times with hot water by decantation and finally filtered and dried first at 40°–45° C. then finally at 70° C. It is important that the ferrous sulfate solution be free of ferric sulfate; sufficient purity is assured by allowing the solution to remain in contact with iron filings for one to two days.

Five main varieties of iron blues are recognized in commerce:

prussian blue, paris blue, bronze blue, milori blue and steel blue. In chemical composition they are nearly identical. Milori blue is a special quality, showing a bright colour and a reddish tint. It is distinguished by exceptional softness and is largely used for printing inks.

Detection and Estimation. — The presence of prussic acid in an aqueous solution may be demonstrated by a variety of methods; one that is most commonly employed depends upon the conversion of the acid into prussian blue: one or tuo drops of moderately concentrated sodium hydroxide solution and of freshly made ferrous sulfate solution are added to the liquid, and the whole is boiled. The liquid is cooled and acidified and a drop of ferric chloride solution is added; a precipitate of prussian blue then forms if prussic acid was present in the original solution. One of the most satisfactory methods for the quantitative determination of prussic acid is titration of the acid in the form of its alkali metal salt with standard silver nitrate solution. with a few drops of 10% potassium iodide solution as an indicator. The end point is reached when a permanent opalescence is observed in the solution; at this point the reaction $2NaCN + AgNO_3 = NaAg(CN)_2 + NaNO_3$ is just complete. It can be seen that every formula weight (see MOLECULE, CHEMICAL) of silver nitrate used is equivalent to two formula weights of prussic acid.

Toxic **Action.**—Hydrocyanic acid is highly toxic through inhibition of cellular oxidative processes. Acute poisoning from hydrocyanic acid or its salts, the cyanides, is manifested by dizziness, nausea, staggering and loss of consciousness if the amount absorbed is sufficient. Death ensues rapidly if lethal quantities are absorbed through ingestion of the cyanides or through the inhalation of HCN gas in sufficient amounts. In sublethal poisoning recovery is usually complete within a few hours and there are no permanent aftereffects. In sublethal doses the CN radical is rapidly detoxified by the body through combination with sulfur, which forms nontoxic sulfocyanides. Man can withstand 50–60 parts of HCN per 1,000,000 parts of air for one hour without serious consequences. while exposure to concentrations of 200–500 parts per 1.000.000 parts of air for 30 minutes is usually fatal.

First-Aid Treatment for Cyanide Poisoning. — Carry patient to fresh air and have him lie down and keep warm. Call a physician. If the patient is breathing, break an amyl nitrite pearl in a cloth and hold lightly over the nose for not more than 15 to 20 seconds or have him inhale aromatic spirits of ammonia. Repeat every five minutes for 2j minutes if recovery is not forthcoming. This poison is rapid in action and few patients survive.

If the patient has stopped breathing give artificial respiration until breathing starts; then administer amyl nitrite as above.

If cyanides have been swallowed and the patient is conscious give one pint of 1% sodium thiosulfate solution (or soapy water or mustard water) by mouth every 1j minutes until vomiting occurs Never give anything by mouth to an unconscious person. During World War II p-am~nopropiophenone, administered orally, was found by the medical division, chemical narfare service, U.S. army, to have value in the prophylaxis of cyanide poisoning.

Pest Control. — The use of prussic acid for the control of insect and other pests has become quite general since D W. Coquillet first employed the compound in 1886 for the control of scale insects of citrus trees in California. Prussic acid is extensively used as a fumigant for the control of insects in stored goods, of household pests and of insect and rodent pests occurring in ships and railuays cars and for a variety of other purposes as well as for the control of agricultural pests. The liquid is available in stout steel cylinders for shipment over long distances. A product consisting of prussic acid absorbed in wood-pulp disks or in granular diatomaceous earth in sealed tins is also available.

Periodic general fumigation of flour mills has become common practice in the U S. Liquid in cylinders is used for this purpose. It is sprayed at each floor from special spray nozzles attached to a permanent piping system or to rubber hose reaching all parts of the floor. The liquid is ejected with compressed air. This method of application is also utilized in the fumigation of other large buildings and ships The most effective and economical method of flour-mill fumigation consists in injecting the liquid into the various machines, thus producing the highest concentration of the fumigant at the sources of infestation. An elaborate, permanent machinery piping system forms an essential part of this method.

The pressure of demand for effective measures directed at the prevention of insect damage to stored goods led to the development of vacuum fumigation technique. Specially constructed large cylindrical or rectangular airtight chambers are used for this purpose. The commodities to be fumigated are introduced into the chamber on special trucks, the chambers are sealed tight and evacuated and the prussic acid is then injected in the form of vapours. The doses required may vary, according to the commodities fumigated and the magnitude of the load, between $1\frac{1}{2}$ and 3 lb. or more per 1,000 cu.ft. of space.

A convenient method of fumigation of dwelling houses and commercial establishments of moderate size utilizes disks of wood pulp impregnated with liquid prussic acid. The disks are contained in sealed metal cans which are opened just before use by means of a special cutter. The disks are evenly scattered throughout the various floors of the building on heavy paper placed on the floor.

The introduction of calcium cyanide made possible the satisfactory solution of a number of difficult pest-control problems. The mode of action of this product depends upon its reaction with the moisture in the atmosphere, generating vapours of prussic acid. In the finely ground form it is the most effective agent known for the destruction of burrowing animals such as rats, rabbits, ground hogs, etc. It is also one of the best fumigants for the control of ants and termites in their nests. A granular form is best suited for this purpose; it is applied on the walks in a thin layer in quantities corresponding to $\frac{1}{8}$ to $\frac{1}{4}$ oz. per 1,000 cu.ft. of space. Application is begun an hour after sunset and the house is allowed to remain closed overnight. The temperature within the house should be rising and preferably between 60° and 70° F. and the air should be calm. Several applications at weekly intervals are recommended. An important use of calcium cyanide is in the fumigation of grain in storage, for which a granular form of the product is used. It is applied to the grain at a controlled rate by a special device at the time the grain is run into the bin. A dosage of 10 to 20 lb. per 1,000 bu. of wheat gives satisfactory control of insects without damage to the grain.

Casehardening.—Casehardening of iron or steel articles by immersion in a fused cyanide bath came into general use, especially in the United States and Canada. after its introduction in 1910. The bath material usually consists of 60% sodium cyanide mixed with other salts such as sodium carbonate or sodium chloride. It is fused-in mild steel or chromium-steel pots and the temperature is raised to a point above 760° C. The cyanide gradually decomposes and the resulting carbon combines with, and penetrates into, the metal. The rate of penetration of carbon into mild steel is about 0.01 in. per hour and about 50% greater when nickel steel is used. Casehardening usually implies a case depth of 0.015–0.060 in.; cases of smaller depth, in some instances only 0.005 in. thick, are produced for surface hardening. Sodium cyanide is added to heat-treating baths to prevent decarburation of the treated pieces. A concentration of 10% is usually regarded sufficient for this purpose, but lower or higher concentrations may be used in connection with low and high carbon steels.

Electroplating. — A solution containing the double cyanide of sodium and silver, $NaAg(CN)_2$, or the corresponding potassium salt, and a molecular excess of the alkali cyanide serves for electroplating metal articles with silver. The article to be plated, its surface thoroughly cleaned, and a sheet of silver are suspended in the solution a few inches apart; and a direct current is passed through at a rate of three amperes per square foot of surface. The article to be plated is made the cathode, the silver the anode. As electrolysis proceeds, the silver anode gradually dissolves, and an equal quantity of the metal is deposited out of the solution upon the surface of the article. The concentrations of the double salt commonly used correspond to two ounces to four ounces silver per imperial gallon. The solution improves with use. Plating with gold. gold-silver or gold-copper alloys is done in a similar way. Cyanide solutions are also used in deposition of copper, zinc, brass and cadmium. more especially on iron.

Flotation.— In the flotation process of ore concentration, separation of metal sulfides is effected by a rising current of air bubbles through the vigorously agitated water suspension of the ore containing a little oil or other flotation agents. The metal sulfides rise with the froth and are obtained in a concentrated form by collecting the froth. G. E. Sheridan and G. G. Griswold discovered in 1922 that the addition of a small amount of sodium cyanide to the suspension of ore previously made faintly alkaline with soda ash prevents the flotation of zinc and iron sulfides without affecting that of lead and copper sulfides. By making use of this effect the sulfides of zinc and iron may be separated from those of lead and copper. The iron and zinc sulfides may be separated by a second treatment in more strongly alkaline solution, the zinc alone floating.

Sodium and calcium cyanides are used extensively in the process of gold and silver extraction. *See* CYANIDE PROCESS.

BIBLIOGRAPHY.—Sir E. Thorpe, "Cyanides," *Dictionary of Applied Chemistry* (1939); *H. E.* Williams, *The Chemistry of Cyanogen Compounds and Their Manufacture and Estimation* (1915); *K. K.* Chen, C. L. Rose and G. H. *A.* Clowes in *Journal of the American Pharmaceutical Association,* vol. *24,* p. 625 ff. (1935); *H. N.* Beilby and W. Nelson, *Chemistry and Industry,* vol. 51, p. *445* ff. (1932); R. T. Cotton, *Insect Pests of Stored Grain and Grain Products (1941)*; *W.* Blum and G. B. Hogaboom, *Principles of Electroplating and Electroforming (Electrotyping)* (1924). (V. M.)

PRUTZ, HANS (1843–1929), German historian, son of Robert Eduard Prutz (1816–1872), the essayist and historian. was born at Jena on Nay 20, 1843, and studied at Jena and Berlin. His *Preussische Geschichte* (4 vols., Stuttgart, 1899–1902) is an attempt to apply scientific rather than patriotic canons to a subject which has been mainly in the hands of historians with a Prussian bias. In 1902 Prutz resigned the chair of history in the university of Konigsberg, which he had held since 1877.

His other works include: *Aus Phonicien,* a collection of historical and geographical sketches (1876); *Quellen-beitrage zur Geschichte der Kreuzzüge (1876)*; *Kulturgeschichte der Kreuzziige (1883)*; *Staatengeschichte des Abendlandes im Mittelalter* (1885–87); *Geheimlehre und Geheimstatuten des Tempelherrenordens* (Danzig, *1879)*; *Entwickelung und Untergang des Tempelherrenordens (1888)*; *D. geistl. Orden,* (1907).

PRYNNE, WILLIAM (1600–1669), English Parliamentarian and scholar, son of Thomas Prynne, was born at Swainswick near Bath, and educated at Bath grammar school and at Oriel college, Oxford. He was called to the bar at Lincoln's Inn in 1628. In 1629 Prynne came forward as the assailant of Arminianism in doctrine and of ceremonialism in practice, and thus drew down upon himself the anger of William Laud. *Histrio-mastix,* published in 1632, was a violent attack upon stage plays in general, in which the author pointed out that kings and emperors who had favoured the drama had been carried off by violent deaths, and applied a disgraceful epithet to actresses, which, as Henrietta Maria was taking part in the rehearsal of a ballet, was supposed to apply to the queen, After a year's imprisonment in the Tower Prynne was sentenced by the Star Chamber on Feb. 17, 1634, to be imprisoned for life, and also to be fined £5,000, expelled from Lincoln's Inn, rendered incapable of returning to his profession, degraded from his degree in the University of Oxford, and set in the pillory, where he was to lose both his ears. The latter portion of the sentence was carried out on May 7, and the rest of his punishment inflicted except the fine and part of the imprisonment.

In 1637 he was once more in the Star Chamber, together with John Bastwick and Henry Burton. In *A Divine Tragedy Lately Acted* he had attacked the Declaration of Sports, and in *News from Ipswich* he had assailed Matthew Wren and the bishops generally. On June 30 a fresh sentence, delivered on the 14th, was executed. The stumps of Prynne's ears were shorn off in the pillory, and he was branded on the cheeks with the letters S.L., meaning "seditious libeller," which Prynne, however. interpreted as "*stigmata laudis*." He was removed to Carnarvon castle, and thence to Mont Orgueil castle in Jersey, where he occupied himself in writing against popery.

Immediately upon the meeting of the Long parliament in 1640 Prynne was liberated and on April 20, 1641, reparation was voted by the house of commons, at the expense of his persecutors. Prynne now attacked the bishops and the Roman Catholics and defended the taking up of arms by parliament. He showed a vindictive energy in the prosecution of Archbishop Laud. He prepared the evidence against him, and, having been entrusted with the search of Laud's papers. he published a garbled edition of the archbishop's private "Diary!" entitled *A Breviate of the Life of Archbishop Laud.* He also published *Hidden Works of Darkness brought to Light* in order to prejudice the archbishop's case. Prynne supported a national church controlled by the state, and issued a series of tracts against independency. He denounced John Milton's pamphlet in favour of divorce, was answered in the *Colasterion,* and contemptuously referred to in the sonnet "On the New Forcers of Conscience." He also opposed violently the Presbyterian system, and denied the right of any church to excommunicate except by leave of the state (*e.g., Four Serious Questions* [1644]; *A Vindication of Four Serious Questions* [1645]). He was throughout an enemy of individual freedom in religion.

Prynne took the side of parliament against the army in 1647, supported the cause of the 11 impeached members, and visited the University of Oxford as one of the parliamentary commissioners. In 1648 Prynne was returned as member for Newport in Cornwall. He at once took part against those who called for the execution of Charles I; the result was his inclusion in "Pride's Purge" on Dec. 6, when, having resisted military violence, he was imprisoned. After recovering his liberty Prynne retired to Swainswick. On June 7, 1649, he was assessed to the monthly contribution laid on the country by parliament. He not only refused to pay, but published *A Legal Vindication of the Liberties of England,* arguing that no tax could be raised without the consent of the two houses. He was imprisoned in various places from 16jo to 1653, and on his release renewed his pamphleteering activities.

On the restoration of the Rump parliament by the army, on May 7, 1659, 14 of the secluded members, with Prynne among them, claimed admittance. He was prevented from taking his seat, and another attempt in December also failed. He was returned for Bath to the Convention parliament and to the parliament of 1661. During 1663 he served constantly on committees, and was chairman of the committee of supply in July, and again in April 1664. The last time he addressed the house appears to have been in Nov. 1667.

Prynne was more notable as a scholar than as a politician. His voluminous writings, though devoid of style and orderly arrangement, derived a lasting value from the historical materials, and especially from the original records, printed in them. His knowledge of the national archives, unrivalled in that age, was fittingly acknowledged by his appointment in 1661 as keeper of the records in the Tower. In that office he not only continued his publications but also did much to rescue the records from the neglect into which they had fallen and to secure their proper and orderly preservation. Prynne died unmarried on Oct. 24, 1669.

See E. W. Kirby, *William Prynne* (Cambridge, Mass., London, 1931), which contains a bibliography of his writings.

PRYOR, ROGER ATKINSON (1828–1919), U.S. soldier and jurist! was born near Petersburg, Va., on July 19. 1828. He graduated at the law school of the University of Virginia in 1848, and in 1849 was admitted to the bar. He served'as a Democrat in the national house of representatives. 1859–61, and was re-elected for the succeeding term, but owing to the secession of Virginia did not take his seat. He served in the provisional Confederate congress (1861) and also in the first regular congress (1862) of the Confederate constitution. He entered the Confederate army as a colonel: became a brigadier-general (April 16, 1862), and took part in the battles of Williamsburg, Seven Pines, second Bull Run and Antietam. Owing to a disagreement with President Davis he resigned his commission in 1863, and entered Gen. Fitzhugh Lee's cavalry as a private. He was taken prisoner Nov. 1864. but was released on parole by order of the president. In 186j he removed to New York city, where he practised law. He was judge of the New York court of common pleas, 1890–94, and of the New York supreme court: 1894–99, when he retired from the bench. He died in New

York city on March 14, 1919.

PRYTANEUM AND PRYTANIS. 1. In ancient Greece, each State, city or village possessed its own central hearth and sacred fire; the fire (*cf.* at Rome the fire in the temple of Vesta) was kept alight continuously, tended by the king or members of his family. The building in which this fire was kept was the Prytaneum (Πρυτανεῖον), and the chieftain (the king or prytanis) probably made it his residence. The word prytanis is applied to those who, after the abolition of monarchy, held the chief office in the State. Rulers of this name are found at Rhodes as late as the 1st century B.C. The Prytaneum was regarded as the religious and political centre of the community. When colonists went out they took with them a brand from the Prytaneum altar to kindle the new fire in the colony; the fatherless daughters of Aristeides, regarded as children of the State at Athens, were married from the Prytaneum as from their home; foreign ambassadors and citizens who had deserved especially well of the State were entertained in the I'rytaneum as public guests. In Achaea, this central hall was called the *Leïton* (town-hall), and a similar building is known to have existed at Elis. The site of the Prytaneum at Athens cannot be definitely fixed. The Prytaneum mentioned by Pausanias, probably the original centre of the' ancient city, was situated somewhere east of the northern cliff of the Acropolis. Curtius places the original Prytaneum south of the Acropolis in the old Agora, and regards that of Pausanias as a building of Roman times (*Stadtgesclzichte,* p. 302). Many authorities hold that the original Prytaneum of the Cecropian city must have been on the Acropolis. From Aristotle's *Constitution of Athens* (ch. 3) we know that the Prytaneum was the official residence of the archons, but, when the new Agora was constructed they took their meals in the *Thesmotheteion* for the sake of convenience. There was also a court of justice called the court of the Prytaneum; it tried murderers who could not be found, and inanimate objects which had been the means of causing death.

2. For the PRYTANEIS of the Boule see BOULE.

PRZEMYSL, a town of Poland, in the province of Rzeszów, 60 mi. W. of Lvov, Soviet Union, by railway. Pop. (1960) 46,000. It is situated on the river San, and is the seat of a Roman Catholic and a Greek Catholic bishop. the cathedral dating from the 15th century. The industries comprise the manufacture of machinery, the refining of naphtha, corn-milling and the sawing of timber. On the hill above the town are the ruins of an old castle, said to have been founded by Casimir the Great.

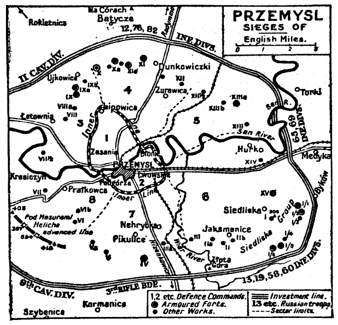
Przemysl was founded at an early date on the borderland between Poland and Russia. Russian princes founded a state there in the 11th century which became absorbed in the principality of Galich or Halicz and was annexed by Casimir the Great after 1330. It was occupied by Austria from 1773 to 1915. Polish after 1918. it was occupied by the U.S.S.R. in 1939 and Germany during World War II.

BRZEMYSL, SIEGES OF. In 1914 Przemysl was protected by a ring of forts 36 m. in circumference. Some of the forts were of recent construction. but the fortress as a whole was not strictly up-to-date. To clear the foreground in front of the fortified line no fewer than 18 villages and some five miles of forest were levelled to the ground on mobilization. The armament of the fortress included four large modern howitzers of about 12in. calibre and some 9in. and 6in. howitzers of older pattern. There were in all about 1.000 guns in the fortress, hut more than half of these were old. short-range weapons of little value except for close defence. There were 114 machine-guns, of which two-thirds were mobile.

The eventual garrison left in the fortress when the Austrian armies retreated from the San on Sept. 18, 1913. consisted of: $61\frac{1}{2}$ battalions (of which $40\frac{1}{2}$ were Landsturm)! seven squadrons. four field batteries, 33 fortress artillery companies. 48 Landsturm artillery brigades. eight sapper companies, and various technical and administrative units. The total strength was approximately 130.000 men and 21,000 horses.

The First Siege.—The Austrian armies withdrew from the San on Sept. 18; by Sept. 24 the investment of the fortress was 'complete. On the south-west front the garrison held a line a mile or two in advance of the ring of forts; elsewhere the line of the forts was held. The siege of the fortress was undertaken by Radko-Dimitriev's III. Army.

While arrival of the siege artillery material was still delayed by the state of the communications, the Austrians renewed the offensive early in October. In the hope of capturing Przemysl by a *coup de main* before the progress of the enemy offensive compelled the raising of the siege, Radko-Dimitriev carried out several violent assaults between Oct. 5–8 against the Siedliska group of works to the south-east of the town. These assaults broke down with heavy loss, and the approach of the Austrian III. Army necessitated the withdrawal of the investing forces.



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The fortress was entered by Austrian infantry of the field armies on Oct. 11, on which date Radko-Dimitriev's III. Army retreated to the east bank of the San.

Period Between the First and Second Sieges.—During the Austrian attempts to force the San line, which lasted throughout October, the fortress lay in the centre of the battle line and its garrison took an active part in the operations. Its reserves of supplies and material were also largely drawn on by the field armies to make good the deficiencies caused by the poor working of the lines of communication. During their retreat the Russians had systematically destroyed the railways and bridges, and the continued wet weather had rendered the roads almost impassable. Thus it was natural that the reserves of Przemysl should be used for the benefit of the field armies, from whose operations, great results were expected at the time. But when the offensive proved fruitless and Russian pressure necessitated a retirement which would leave the fortress again isolated, special efforts mere made hastily to reprovision it. They were so far successful that the fortress was enabled to hold out for $4\frac{1}{2}$ months in the second siege.

Second Siege, **Nov.** 6,1914–March **22, 1915.—**The strength of the garrison was approximately the same as in the first siege, but a detachment of aeroplanes had been added. Kusmanek had now laid out new entrenched positions from one to two miles in advance of the line of forts, to give ,more depth to the defence and to keep the Russian siege artillery at a greater distance. On Nov. 9 the investment of the fortress for the second time was complete. The siege was now undertaken by a specially formed XI. Army under General Selivanov, consisting of four divisions of second-line troops. It had been decided to reduce the fortress by blockade rather than by assault. During November and December such fighting as occurred was initiated rather by the sorties of the garrison than by the attacks of the besiegers.

During February and the first half of March the Austrian field armies made repeated efforts to advance to the relief of the fortress, but unsuccessfully.

Meanwhile the Russians had gradually closed in and had commenced a systematic bombardment of the fortress. On March 13 they carried the advanced positions on its north front. Kusmanek's situation was now desperate; his supplies and munitions were almost exhausted, and the final effort of the field armies to come to his rescue had definitely been abandoned. He determined on an attempt to save a portion of the garrison by a breakthrough to the east. The effort was made on the morning of the 19th, but was soon brought to a stand. The fate of the fortress was now sealed. On the morning of March 22 Kusmanek surrendered, after destroying the works and military stores as far as possible. The numbers of the garrison then amounted to about 110,000.

Recapture of the Fortress.—The Russians did not hold the fortress for long. At the beginning of May, Field Marshal Mackensen's offensive on the Dunajec broke through the Russian line and drove their armies back to the San. On May 30 the

Austrians attacked on the south-west and the Germans on the north of the fortress. The former made little progress, but the German heavy artillery, which included 42 cm. howitzers, made short work of the northern group of forts. On the night of June 2 the Russians abandoned the fortress.

Conclusions.—Przemysl was the only land fortress of World War I which stood a prolonged siege after complete investment, but the length of its resistance was seemingly due to the Russians' lack of efficient siege artillery, as is confirmed by the speed with which Mackensen's heavy guns reduced the forts at the time of its recapture. Nor can it be admitted that the fortress served any strategical aim commensurate with the efforts expended on its defense and attempted relief. It is true that its resistance during the first siege was of value to the Austrians when their armies again advanced to the San, in assuring to them a bridge-head over the river. But during the second seige Przemysl was an embarrassment rather than a source of strength and led to several ill-considered efforts at relief which cost the Austrian field armies dearly. The fortress did not control any line of supply vital to the Russian armies operating west of it toward Cracow, since there was a railway available through Jarostow. The Russians could therefore afford in the second siege to resort to a simple blockade by second-line troops, so that the fortress did not even weaken their field armies to any appreciable extent.

BIBLIOGRAPHY.—H. Hillger, *Krieg und Sieg, Befreiung vor Przemysl* (1915); E. Ludendorff, *My War Memories* (trans. 1919); E. von Falkenhayn, *General Headquarters, 1914–1916, and its Critical Decisions* (trans. 1919); J. Daniloff, *Russland im Weltkriege, 1914–1915* (1925); A. W. F. Knox, *With the Russian Army, 1914–17* (1921). *See* also WORLD WAR I (Bibl.). (A. P. W.)

PSALMANAZAR, GEORGE (*c.* 1679–1763), French adventurer. After various escapades, including a pilgrimage to Rome in the guise of a Japanese convert, he came to London, where he imposed on many people, notably on the bishop of London, who employed him to translate the Catechism into what was supposed to be Japanese. In 1704 and 1707 he published fictitious works on Formosa. Eventually he confessed to his imposture.

He died in London on May 3, 1763.

His *Memoirs of . . . known by the name of George Psalmanazar* (1764) do not disclose his real name or the place of his birth. His fictitious publications include: *Historical and Geographical Description of Formosa* (1704); *Dialogue between a Japanese and a Formosan* (1707); *An Enquiry into the Objections . . . with George Psalmanazar's Answer* (undated).

See P. W. Sergeant, *Liars and Fakers* (London, 1926).

PSALMS, the first in order and importance (*cf.* Luke xxiv. 44) of the third division of the Hebrew Old Testament, known as the "Writings." The Hebrew name of the Psalms is *tehillim,* or "praise-songs," which expresses a predominant, though by no means the entire, character of the collection. This anthology of Hebrew poetry also includes petitions (iv.), laments (xliv.), imprecations (lviii.), meditations (cxix.), historical reviews (cvi.), and even a marriage ode (xlv.). But there can be no doubt that the purpose of the collection was to gather the sacred poetry of Israel for use in the *post-exilic* worship of the temple. This is shown by the technical and professional titles of the psalms, as well as by their general character and their occasional references (note the definite allusions to the destruction of Jerusalem, the exile or the dispersion in li. 18, lxxxix. 38, 44, cvi. 47, cxxvi. 1, cxxxvii. 1, cxlvii. 2).

As the book lies before us, it is a collection of collections, being divided into five books, which themselves contain certain smaller distinguishable groups of psalms. The first four books are each closed by a doxology, at least as old as the Septuagint version (second half of 2nd century B.C.). In Bk. I. (i.–xli.) practically all the psalms are ascribed to David (the exceptions can be explained). In Bk. II. (xlii.–lxxii.) there is more variety, xlii.–xlix. being ascribed to "the sons of Korah," l. to Asaph, li.–lxv. to David, lxvi., lxvii. simply to "the chief musician" or choir-conductor, lxviii.–lxx. to David, lxxii. to Solomon (lxxi. is anonymous). The editorial note at the end of this book, "Finished are the prayers of David the son of Jesse," shows there was once a collection of "Davidic" psalms, and that there has been a rearrangement of material bringing psalms of other groups above the rubric. In Bk. III. (lxxiii.–lxxxix.) there is an "Asaph" group (lxxiii.–lxxxiii.) followed by a miscellaneous appendix (Korah, David, Ethan). We have clear evidence of other editorial work in the overwhelming predominance of the name "Elohim" for God in Psalm xlii.–lxxxiii. as compared with the personal name, "Yahweh" (the occurrences are 200:43; in Psalms, i.–xli. 15:272); this is confirmed by the fact that Ps. xiv. of the first Book reappears as Ps. liii., with its fourfold "Yahweh" changed into "Elohim" (so also in Pss. xl. 13–17 and lxx.). In Bks. II. and III. alone do we get psalms ascribed to guilds of temple-singers. Bks. IV. and V. are divided by the doxology of cvi. 48 (*cf.* 1 Chron. xvi. 35, 36, where a liturgical formula has been transformed into a historical statement). But the division seems artificial (perhaps made to get five books of psalms corresponding with the five books of the law), since Psalms cv.–cvii. are closely related in subject-matter. If, therefore, we take Bks IV. and V. together, we find in them a distinct group of "Pilgrim" psalms (cxx–cxxxiv.), and a scattered one of "Hallelujah" psalms (civ.–cvi., cxi.–cxiii., cxv.–cxvii., cxxxv, cxlvi.–cl) largely liturgical. Ps. cviii. seems to have been made by combining lvii. 7–11 and lx. j–12, which again proves the existence of separate collections, since the same material would not originally appear twice in the same collection.

The Hebrew psalms are in rhythmical, but unrhymed verse, the most frequent type being that of the three-beat line. The other characteristic of Hebrew poetry is its parallelism ("synonymous," li. 2; "antithetic," i. 6; "synthetic," cxxi. 4). The musical accompaniment was melodic unison, not the harmonies of modern music, so that its chief use, beyond support to the singers, was to synchronize the beats, as by cymbals (1 Chron. xv. 19, xvi. 5). Six distinct instruments are named in Ps. cl. (*see* Wellhausen, *Psalms,* Appendix, "Music of the Ancient Hebrews"). The singing was by professional choirs with a response ("Amen," "Hallelujah") from the worshippers (1 Chron. xvi. 36, 2 Chron. xxix. 27, 28). For a glowing description of the ritual see Ecclus. l. 11–21.

At first sight, the contents of the Psalter may seem to occasion relatively little difficulty to the exegete, as compared with the prophecies. The psalms are for the most part simple and often conventional in language, and without those references to obscure historical events which make the writings of the prophets so difficult. But the apparent gain is really a great loss to historical exegesis. Whilst the absence of reference to contemporary events makes the psalms much more capable of use then than now in worship and devotion — it was in some measure due, we may suppose, to elimination and adaptation — yet it also makes the investigation of the original meaning more difficult. Thus it is usually impossible to give a precise historical background to a particular psalm. The titles professing to do this, and to ascribe authorship, are of little use for critical purposes, and represent a late and usually worthless conjecture. Scholars have now generally abandoned the earlier attempts to ascribe particular psalms to precise events from the Davidic down to the Maccabean age; there is considerable variety of opinion as to the nature, date, authorship and origin of the psalms considered individually.

Four main questions arise: (1) to what extent are the psalms primarily and originally "cultic," more or less officially composed for use in public worship, and to what extent are they private religious lyrics, gathered from many sources, and subsequently adapted to use in the temple-services? (2) In close relation with this question comes another as to the significance of the speaker in many of the psalms; does the "I" mean the whole community, or is it an individual person who is speaking? (3) To what period of the religious history of Israel do the psalms chiefly belong, and to what extent are they pre-exilic in origin, though admittedly post-exilic in present adaptation and arrangement? (4) Are they a native product or are they dependent on Babylonian or Egyptian models, as the creation stories of Genesis are dependent on Babylonian mythology? It will be seen that these are not merely academic questions, for each of them may affect the exegesis of a particular psalm. A quarter of a century ago, the answers to these four questions generally given by critical scholarship were as follows: (1) the psalms are chiefly poems of the individual, though some were intended from the outset for use in the temple; (2) the "I" of the psalms usually represents the community; (3) the psalms are almost wholly post-exilic in origin; (4) they are native products. All these answers are now being met with vigorous criticism. At the present moment the protagonists in this criticism are the German scholar, Gunkel, and the Norwegian scholar, Mowinckel. Some account of their views must be given, as they cannot be neglected by the modern student of the psalms.

Gunkel's leading principle is that the psalms should be studied in their "classes" (Gattungen) or types, of which he finds four of chief importance, viz., "hymns" (*e.g.*, cxlv., cxlvii., cxlviii., cl.), "national laments" (*e.g.*, xliv., lxxix., lxxx., lxxxiii), "individual laments" (iii., xiii., liv., lxxxviii.) and "individual thanksgivings" (xxx., lxvi., 13 seq.). These classes are differentiated by the use of regular formulae, such as "Deliver us, Yahweh," or "I will thank Yahweh," and by more or less regular forms of composition. so that we are not left to subjective impressions only when deciding as to what class a particular psalm belongs. On the basis of this differentiation Gunkel constructs a general history of the "classes," partly from internal evidence, such as the greater length, individualization, or composite character of the later representatives of the class, and partly from the parallels with psalm-like compositions found elsewhere in the Old Testament, which it is possible to date with confidence, such as the Song of Miriam (Exod. xv. 21), the song of the seraphim heard by Isaiah in the temple (vi. 3), the lyrics of Jeremiah and the "Psalms of Solomon" (1st century B.C.). Gunkel's general conclusion is that hymns of praise and national laments were found at an early date, whilst individual laments arose later, but prior to Jeremiah. He admits that prophecy influenced the language, eschatological outlook and spirituality of the Psalms, but claims that this influence was exerted before as well as after the exile. He argues that the existence of similar compositions in Babylonia and Egypt at a much earlier date confirms the intrinsic evidence that "Psalm-composition belongs to the earliest periods of Israel's history."

Mowinckel, whilst recognizing and using the classification of psalms by their type, throws his emphasis on their cultic character, and indeed barely admits the existence of any psalms not cultic in origin (his exceptions are i., cxii., cxxvii.). The psalms were composed by the temple-singers, whom he regards as existing from the early days of the temple. The class of psalms to which he gives primary attention is that containing references to the enthronement of Yahweh as king (xlvii., xciii, xcv.–c., with which many others are to be linked). These he connects with an alleged festival of the New Year (originally beginning in the autumn), a festival after the analogy of that celebrated at Babylon in honour of Marduk. The cultic acts of this festival (*e.g.*, the procession bringing the ark into the temple) were realistically conceived, *i.e.*, they were supposed to help in bringing about that which they "dramatized." Thus they anticipated the future (eschatology) while recalling the past (mythology). There is a similar "realism" in Mowinckel's interpretation of the numerous petitionary psalms, which are held to attribute misfortune and sickness to magicians and sorcerers, who are the original "workers of iniquity" so frequently mentioned. Such psalms were employed, with suitable accompanying rites, as part of the temple-cult; they counteracted adverse magic by exorcisms and imprecations of these "enemies." There were prophets as well as priests, or priest-prophets, attached to the temple, who gave oracles; thus the petition of Ps. lxxxv. 1–7 is answered by the oracle of vv. 8–13. It should be said that a "cultic" interpretation of the psalms as a whole has been independently urged by other scholars, *e.g.*, by J. P. Peters, who further conjectures that the "Elohistic" psalms belonged to northern temples (cf. the northern "Elohistic" saga-writers), the Korahite to Dan, the Asaphite to Bethel, and were afterwards incorporated in the liturgy of Jerusalem.

It will be seen, therefore, that there is considerable division of opinion at the present time in regard to our first quesrion, the cultic element in the Psalter, Mowinckel regarding practically the whole Psalter as cultic in origin, whilst Gunkel regards the majority of the psalms as of private and occasional origin, though subsequently introduced into the cult. On this point Gunkel's view seems more convincing, from the intrinsic evidence and from the general probabilities. Like a modern hymn-book, the Psalter seems to contain many poems not originally intended for use in worship, but subsequently adapted to it—indeed, the religious wealth of the Psalter seems largely due to this variety of origin. On the other hand, Mowinckel does make a strong case for the special interpretation of the psalms of the enthronement of Yahweh, even though he brings far too many under this head. His explanation of the "eschatological" features is also attractive; less so seems his too sweeping connection of sickness and misfortune with magic, though there is probably an element of real truth in his contentions (the tendency of those who discover some neglected truth is to generalize to excess on the basis of it). In a collection so extensive and varied as the Psalter we need not regard any one explanation or theory as necessarily applicable to more than a part of the material. Variety of origin almost follows from variety of date, and their issue is most naturally variety of meaning, even where the same conventional phrases may be used.

In regard to the closely linked question as to the collective or individual interpretation of the speaker in the psalms, Gunkel follows Balla in reaction from the view that was general a quarter of a century ago (*e.g.*, Smend, Cheyne), *i.e.*, that the "I" of the Psalms is collective, personifying the nation. Mowinckel agrees with Gunkel so far as the "individual laments" are concerned, but recognizes a primitive "corporate personality" finding utterance through the leader or king as its representative. We may ask whether this principle does not admit of a wider application than even Mowinckel allows. It seems to go a long way towards explaining the puzzling combination of "collective" and "individual" elements in such a psalm as the xxii., and the rapid transitions so often found (cf. xliv. 5–7 and 14, 15). The same phenomena occur in relation to the Servant of Yahweh in Deutero–Isaiah, and admit of the same explanation—thzi the primitive mind draws no such hard and fast limits between the individual and the community as we do (see The Cross of the Servant, by H. Wheeler Robinson, pp. 32–36; The Psalmists, ed. D. C. Simpson, pp. 82 seq.). We may often find it impossible to decide whether a psalm is collective or individual—because the ancient category was neither one nor the other, but a third category including both.

In regard to dating the composition of individual psalms, there seems to be some danger of a similar excessive reaction from the view associated with the name of Wellhausen, open as that is to criticism. The arguments of Gunkel and Mowinckel, amongst others, do show in their different ways that psalms were composed in the pre-exilic period, a fact which has been too grudgingly admitted. The intrinsic evidence of some of the psalms, such as the reference to a human king, or the processional features of the second part of xxiv. ("Lift up your heads, O ye gates"), or the primitive cosmology of the first part of xix., confirms the probability that some of these pre-exilic productions would survive in a post-exilic Psalter, So long as we are thinking of the origin and original meaning of a particular psalm, we must always be prepared to admit that it may go back to a relatively early date, however much modified in its present adaptation to the needs of the second temple. On the other hand, we use any psalm in its present form as an early document only at considerable risk; we may conjecture, but we cannot prove. The main reasons for regarding the contents of the Psalter as largely post-exilic remain unaffected by recent criticism, *i.e.*, those that spring from the general relation of the religion of the psalms to the prophetic religion. If with Gunkel we regard the majority of the psalms as the expression of individual piety, we have to ask whether such wide-spread piety is conceivable before the work of the great prophets. The psalms represent a partial fulfilment of the prophecy of the New Covenant made by Jeremiah; is it likely that they preceded it? We cannot reasonably doubt that the prophets of the 8th and 7th centuries were pioneers, and that they taught truths that were new to their cbntemporaries, even though they may have used forms of expression and even of thought which were more or less conventional. Nor can there be any doubt that the religion of the Psalter as a whole is closely related to the prophetic teaching. We seem to have parallel phenomena in the formulation of Israel's laws (Deuteronomy, the Law of Holiness, the Priestly Code) and in the Wisdom Literature; in all three cases ancient elements are given a new setting, but the new setting gives them a new meaning. Laws, proverbs and psalms are alike reinterpreted and restated in the light of the prophetic teaching, which had certainly taken time to permeate the nation's religion. Nothing has come to us through the editorial sieve that could not be given a plausibly orthodox meaning according to post-exilic standards. Thus the psalms as a whole must still be treated as a post-exilic book. This might be confirmed by the subtler test of psychological usage, hardly to be simulated; the word "spirit," for example, is used of man in the psalms with psychical predicates in a way not found elsewhere in the pre-exilic literature of the Old Testament.

As for the relation of the psalms to the similar compositions of Babylonia, we find many interesting and instructive parallels of form, language and thought, but not less striking differences which must not be ignored, due to the far higher religious standpoint of Israel, and the suppression of magic in the interests of religion (though some of the older forms and expressions doubtless continued to be used). The resemblances may be partly explained by the independent development of closely related peoples (G. R. Driver, in *The Psalmists*, pp. 109 seq.), and partly by the entrance of the Hebrews into a land dominated by Mesopotamian influence (as the Tell el-Amarna tablets prove); but it is quite possible that there was some direct influence also, even prior to the exile. This possibility also applies, but in a much smaller degree, to the influence of Egypt; there is the well-known parallelism of the "Hymn to the Sun" of Ikhnaton with Ps. civ., which matches the close relation of the "Teaching of Amenophis" to our canonical Book of Proverbs. But whatever contributions came directly or indirectly from without, there is good ground for holding that in all that really matters the Psalter is a native product, and that to Israel still belongs the undiminished glory of carrying the religious lyric to its highest point of development.

Any attempt to characterize the teaching of this anthology must be made with the full consciousness of its variety of authorship, purpose and date. It is the most varied of the books of the Old Testament, and offers many unreconciled antitheses. Devotion to the sacrificial system and ritual of the temple is found side by side with prophetic protests against the popular reliance on them. Faith in the exact retributive justice of God within the limits of earthly life does not exclude the perplexities of those who could not be blind to the sufferings of the innocent and the prosperity of the wicked. The nationalistic demand for supremacy over, and even for vengeance on, enemies is neighbour to the universalistic sense of Israel's missionary stewardship for all the world. The recoil from the shadow of death, which leaves no light of Yahweh's presence beyond the grave, does not wholly prevent the conviction of a fellowship with God that virtually conquers death. But certain comprehensive truths may be usefully remembered in the study of the Psalms.

The central religious principle is, of course, the idea of God. The monotheism is sometimes implicit rather than explicit, for there are a number of references to other "gods" (lxxxvi. 8, lxxxix. 6, xcv. 3, etc.); yet these are perhaps no more than the survival of ancient phraseology. The general standpoint of the psalms is that of an exalted and imageless monotheism (cxv.), unlimited in power, universal in range. The most prominent attributes of Yahweh are "lovingkindness" (chesedh) and "righteousness" (*ṣedhek, ṣedhakah*), combined in cxlv. 17, expanded in xxxvi. 6–11; they are complementary, not antithetical. To these must be added the mystery and majesty of God—the quality which we have come to call "the numinous," best expressed in Ps. xc.; the wrath of God cannot be measured by human norms of right and wrong. This great God is omnipresent (cxxxix. 7–12), and eternal (xc. 1, 2; cii. 26–28). Around this great and exalted personal centre in heaven, but on the lower level of earth, we may trace a series of concentric circles in nature, history, human society, the temple, narrowing at last to the personal religion in which man can look right up to God. Nature is directly controlled in all its detail by God, and no "laws of nature" come between Him and His creation. The cosmology of the "nature" psalms (viii., xix. 1–6, xxix., lxv., civ., cxlviii.) is crude; man walks on a flat earth, with the "shades" of Sheol beneath his feet, and Yahweh with His angels above his head, on the solid firmament; round about the earth is the primaeval ocean and its monsters, overcome long since by Yahweh's creative power. The great facts which emerge from this primitive setting of man's life are the dignity and glory of his high place (viii.) amid the glories of Yahweh's creation (xix. 1–6) and His universal providence (civ.). The power of the enthroned Yahweh is manifest in the majesty of the thunderstorm which sweeps the earth, whilst in the heavenly palace His angels glorify Him (xxix.).

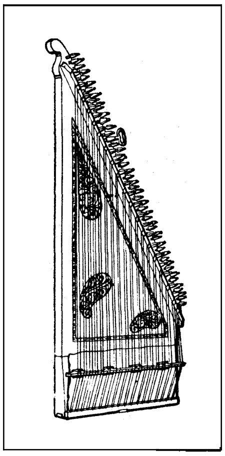
The peculiar providence of God is, however, best seen in the redemptive history of Israel (lxxxi. 10). At great crises, Yahweh has intervened to save His chosen people (cxiv.). The God of the past (cv., cvi.) will be the God of the future, when His rule shall be proved supreme over all (xlvii., and the other "enthronement" psalms). A prince of the house of David shall be his vicegerent (lxxxix. 3 j seq.; cf. ii., lxxii.) and the final judgment of men shall vindicate His righteousness (i. 5). This is the essential faith of the righteous, the company of those who fear Yahweh and are remembered by Him (cf. Mal. iii. 16), the group to whom we seem to owe the most "spiritual" of the psalms. They live in a society of mingled elements, and have many enemies, without and within, for there are imprecations against unworthy Israelites (lxix., cix.) as well as against the ungodly heathen (cxxxvii., lxxxiii., lix., lviii.), and they may be under unjust rulers (lii.). Their great problem is that which troubled the best minds and hearts of Israel, and found no solution within the Old Testament, *i.e.*, the strange and perplexing prosperity of the wicked and the adversity of the righteous in a world governed by an omnipotent and righteous God (xlix., xxxix., xxxvii., lxxiii.).

The sacramental centre of this faith is the Temple in Jerusalem, to which the exile turns with passionate longing (xlii., xliii.—originally a single psalm). (The devotion to the "Law" came later, except for i., xix. 7–14, cxix.) To the temple come the pilgrims from afar (cxx.–cxxxiv.), full of pride in the holy city (xlviii.), the spiritual home of many proselytes as well as of Jewish exiles (lxxxvii.). The temple is Yahweh's earthly dwelling-place (cxxxii. 13, 14) to which His "guests" may come (xv., xxiv.); its sacrifices (lxvi. 13–1j, cxvi. 13) and processions (lxviii. 24–27, cxviii., xxvi. 6j mark supreme moments of religious experience. This is the normal attitude of the Psalmists towards the temple; but the emphasis of the Book is prophetic rather than priestly, and this finds utterance sometimes in the contrast of "spiritual" religion with external rites (xl., l., li., except for the added verses, li. 18, 19). The personal religion of the psalmists is marked by trust in Yahweh based on history and experience (xvi., xxiii., xci., ciii.), by the consciousness of "righteousness" (xviii. 20–24), not divorced from fundamental ethical qualities (xv., xxiv., ci., l.), by the awakening to a sense of sin and of the need of forgiveness, usually, it would seem, through misfortune, sickness, the fear of death (xxxii., li., cxxx.), and in the highest examples, by a victorious conviction of fellowship with God (lxxiii. 23–26) which even death will not be able to break. This last is the more noteworthy, because there does not seem to be either here or elsewhere in the psalms any explicit teaching of immortality or resurrection (some have found the hope in xvi., xvii., xlix.).

Such is the relatively simple faith of the most influential book of the Old Testament, which has claimed so supreme a place in the public worship and private devotion of Jew and Christian. Its magical secret lies in its simple and concrete expression of universal religious experience. Its value is altogether independent of our enquiries into its sources; indeed, it has won its place by its lowly submissiveness to reinterpretation in order to meet the ever-changing needs of the unchanging human heart.

BIBLIOGRAPHY.—E. A. Leslie, *Psalms* (1949); S. L. Terrien, *Psalms and Their Meaning for Today* (1952); J. Wellhausen, *The Book of Psalms*, tr. by Howard Furness (1898); B. Duhm, *Die Psalmen* (1899); F. Baethgen, *Die Psalmen* (1904); J. E. McFadyen, *Messages of the Psalmists* (1904); S. R. Driver, *The Parallel Psalter* (trans., 1904); C. A. Briggs and E. G. Briggs, *Critical and Exegetical Commentary on the Book of Psalms*, 2 vol. (1906); R. E. P. Ernle, *The Psalms in Human Life* (1909); C. F. Kent (ed.), *Songs, Hymns and Prayers of the Old Testament* (1914); W. G. Jordan, *Religion in Song* (1917); C. G. Montefiore, "The Psalter: Its Contents and Date," *Quarterly Review*, pp. 1–20 (July 1918); W. E. Addis, in A. S. Peake (ed.), *Commentary on the Bible* (1920); S. Mowinckel, *Psalmenstudien*, vol. i–vi (1921–24); J. M. P. Smith, *The Religion of the Psalms* (1922); R. Kittel, *Die Psalmen* (1922); J. P. Peters, *The Psalms as Liturgies* (1922); A. Lods, "Les Idées de M. Mowinckel," in *Revue de L'histoire des religions*, pp. 15–34 (1925); H. Gunkel, *Die Psalmen, übersetzt und erklärt*, 4th ed. (1925–26); A. C. Welch, *The Psalter in Life, Worship and History* (1926); D. C. Simpson (ed.), *The Psalmists* (1926); H. Gunkel, in R. H. Kennett, *Old Testament Essays* (a convenient summary in English of his views) (1928); N. Nicolsky, *Spuren Magischen Formeln in den Psalmen* (1927); Moses Buttenwieser, *The Psalms* (1938); H. Gunkel and J. Begrich, *Einleitung in die Psalmen*, 2 vol. (1928 and 1933); W. O. E. Oesterley, *The Psalms*, 2 vol. (1940).
(H. W. R.; X.)

PSALTERY, PSALTERION or SAWTRIE, an ancient stringed instrument twanged by fingers or plectrum, and mentioned many times in the English Bible, though precisely what form of instrument is implied by these various references is doubtful. In its mediaeval form it consisted of a shallow box sound chest over which strings varying in number were stretched, being fastened at one side to pegs and at the other to wrest pins. In the early rectangular form the strings, numbering 10 to 12, were of uniform length, the pitch being varied by their thickness and tension. When the triangular form succeeded the rectangular, the stringing was that of the harp, pitch being dependent on the length. The psaltery was held in an upright position against the chest of the performer, until, owing to the increasing number of strings, it grew too cumbersome, when it was placed flat on a table or on the knee. From the psaltery descended the spinet and the harpsichord.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THE PSALTERY, A MEDIAEVAL INSTRUMENT PLAYED BY FINGERS OR PLECTRUM

PSAMMETICHUS (Egypt. PSAMMETK), the name of three kings of the Saite, 26th dynasty, called by Herodotus respectively Psammetichus, Psammis and Psammenitus. The first of these is generally considered to be the founder of the dynasty; Manetho, however, carries it back through three or four predecessors who ruled at Sais as petty kings under the 25th, Ethiopian, dynasty. It is known from cuneiform texts that 20 local princelings were appointed by Esar Haddon and confirmed by Assur-bani-pal to govern Egypt. Kiku (Necho), father of Psammetichus, was the chief of these kinglets, but they seem to have been quite unable to hold the Egyptians to the hated Assyrians against the more sympathetic Ethiopians. The labyrinth built by a king of the 12th dynasty is ascribed by Herodotus to the Dodecarchy, or rule of 12, which must represent this combination of rulers. If the dynasties were numbered thus before Manetho, the numeral may be the cause of Herodotus' confusion.

After his father's death Psammetichus I (664–610 B.C.) was able to defy the Assyrians and the Ethiopians, and during a long reign marked by intimate relations with the Greeks restored the prosperity of Egypt. The short reign of the second Psammetichus (594–588 B.C.) is noteworthy for the graffiti of his Greek, Phoenician and Carian mercenaries at Abu Simbel. The third of the name was the unfortunate prince whose reign terminated after six months in the Persian conquest of Egypt (525 B.C.). It has been conjectured that the family of the Psammetichi was of Libyan origin; on the other hand, some would recognize Negro features in a portrait of Psammetichus I, which might connect him with the Ethiopian rulers. (F. LL. G.)

PSELLUS, MICHAEL CONSTANTINE (1018–after 1078), Byzantine author, scholar and statesman, whose writings are of fundamental importance for the understanding of his period, was born in Constantinople. After an excellent education, he became a civil servant; he then entered the imperial secretariat and under Constantine IX (1042–55) he was prominent at court. He was also distinguished for his scholarship and in 1045 became head of the faculty of philosophy in the reorganized University of Constantinople. After an unsuccessful retreat in 1055 to a monastery on Mt. Olympus in Bithynia, he returned to public life and was exceedingly influential during the years 1056–78, particularly under the regime of his friends the Ducas, the last of whom, Michael VII, had been his pupil.

His *Chronographia*, a lively and highly individual history based on his own experiences, is an invaluable source. The *Chronographia* was edited with French translation in the Budé series by E. Renauld, 2 vol. (1926–28); English translation by E. R. A. Sewter (1953). Other works were edited in J. P. Migne, *Patrologia Graeca*, vol. 122 (1864); K. N. Sathas, *Bibliotheca medii aevi*, vol. 4–5 (1874–76); E. Kurtz and F. Drexl, 2 vol. (1936–41). The extensive corpus of his works (some unedited) ranges from philosophy and theology to letters, orations, poems and incursions into demonology and Chaldean lore. He has been condemned as a timeserving and unstatesmanlike politician but, apart from the encyclopaedic nature of his knowledge which gained him fame in his own day, he also stands out as a distinguished historian and keen philosopher.

BIBLIOGRAPHY.—G. Moravcsik, *Byzantinoturcica*, 2nd ed., vol. 1, pp. 437–441 (1958); G. Ostrogorsky, *History of the Byzantine State*, pp. 280–281 (1956); É. Renauld, *Étude de la langue et du style de Michel Psellos* (1920); P. Joannou, *Die Illuminationslehre des Michael Psellos und Joannes Italos* (1956); J. M. Hussey, *Church and Learning in the Byzantine Empire, 867–1185* (1937).
(J. M. HY.)

PSEUDO-CODINUS: *see* CODINUS, GEORGIUS.

PSEUDONYM, a false or invented name, particularly the fictitious name under which an author produces his work in order to conceal his identity. The same end is gained by publication without any name, or anonymously. The body of works thus produced either without the author's name or under a fictitious name became known as anonymous and pseudonymous literature. Many books affording a key to the identity of the various writers have been published. Though Fredericus Geisler published a short treatise on the subject entitled *Larva detracta*, etc., in 1669, the chief early work was that of Vincent Placcius (1642–99), whose *Theatrum anonymorum et pseudonymorum* was published in 1708 edited by L. F. Vischer; supplements were published in 1711 and 1740.

Other works included *Dictionnaire des ouvrages anonymes et pseudonymes* (1806–09), by Antoine A. Barbier; *Deutsches Anonymen-Lexikon, 1501–1850* (1902–07) and *Deutsches Pseudonymen-Lexikon* (1906), by M. Holzmann and H. Bohatta.

In English, R. Thomas' *Handbook of Fictitious Names* appeared in 1868. *Dictionary of the Anonymous and Pseudonymous Literature of Great Britain*, by S. Halkett and J. Laing, was revised and published posthumously in four volumes in 1882–84. Other English works were W. Cushing, *Initials and Pseudonyms*, 2nd series (1886, 1888), and *Anonyms* (1890); and F. Marchmont, *A Concise Handbook of Literature issued under Pseudonyms or Initials* (1896).

PSICHARI, ERNEST (1883–1914), French author, grandson of Ernest Renan, and son of Jean Psichari, director of studies at the École des Hautes Etudes in Paris, was killed on the western front on Aug. 22, 1914. He was one of the leaders of the young generation before World War I who sought to "rationalize" war and the defense of their country; he sought to provide the psychological basis for heroic action.

His work is that of an intellectual who must justify the "great sacrifice." In the year before World War I *L'Appel des armes* had a powerful moral effect among young intellectuals. It is the story of a captain in the Algerian army who converts to the military ideal the antimilitarist son of an internationalist, who finds mental peace in military obedience.

This was followed by *Les Voix qui crient dans le désert. Le*

Voyage du centurion appeared as the finished form of this work. In 1917 Jean Psichari presented to the Luxembourg library 25.000 volumes on mental subjects, in memory of Ernest.

See Henri Massis, *La Vie d'Ernest Psichari (1916)*; *L.* Aguettant, *Ernest Psichari* (1920); *A.* M. Goichon, *Ernest Psichari* (1925).

PSILOMELANE, an ore of manganese, is one of a group of hydrated manganese oxide minerals, with very similar appearances and properties, which are difficult to distinguish. They frequently occur in hard black botryoidal or stalactitic masses with a smooth surface, hence the name from the Greek *psilos,* "smooth," and *melanos,* "black." However, they may also be soft and earthy, in which case they are known as wad (*q.v.*). They are distinctly crystalline, and not amorphous as once supposed. The name psilomelane was originally applied to material from Schneeberg, Saxony, which has the formula $BaMnMn_8O_{16}(OH)_4$, and should be restricted to this composition. The other manganese minerals of similar appearance are referred to as being of the psilomelane type. See also PYROLUSITE. (L. S. RL.)

PSITTACOSIS, an infectious disease of world-wide distribution, is caused by a virus and is transmitted to man from various birds. The infection has been shown in about 70 different species of birds, but parrots and parakeets (Psittacidae, from which the disease is named)! pigeons, turkeys and a few other species have been the principal sources of human infection.

The disease is also called ornithosis, especially when seen in nonpsittacine birds.

History. — The association between the human disease and sick parrots was first recognized in Europe about 1880, but it was not until 1929–30 that a thorough study of the disease was made. In those years outbreaks of severe cases, attributed to contact with imported parrots, occurred in 12 different countries of Europe and America. During the investigations conducted at that time in Germany, England and the United States, experimental transmission was accomplished and the causative agent was revealed. Strict regulations followed concerning importation of psittacine birds, which doubtlessly reduced the incidence of the disease but did not prevent the intermittent appearance of cases. The infection was later found in domestic stocks of parakeets and pigeons and subsequently in other species. An increase in number of cases in Great Britain and the U.S. appeared in 1952, following relaxation of regulations concerning commerce in psittacine birds and increase in the popularity of parakeets as pets. Infected turkeys have also accounted for many cases. In 1954, a peak year in the U.S., 563 cases were reported, 200 of them related to poultry-dressing plants.

The Disease in Man. — Psittacosis is an acute febrile illness in which some degree of inflammation of the lungs (pneumonitis) occurs, sometimes detectable only by X-ray examination. It tends to be severe in older persons. The duration is two to three weeks, and convalescence often is protracted. Before modern chemotherapeutic drugs were available the case fatality rate was approximately 20%, but penicillin and the tetracycline drugs reduced this figure almost to zero. Diagnosis can be rendered more accurate by examination of specimens of the patient's blood serum taken early in the illness and during the second or third week. A rise in antibody content in the later specimens, detected by the complement fixation test in which inactivated (noninfectious) psittacosis virus is used, confirms the diagnosis.

Virus. — The infectious particle, or elementary body, of psittacosis virus is spherical in shape and is one of the largest of the viruses. being 200–300 $m\mu$ (.0002–.0003 mm. or .000008–.000012 in.) in diameter. Like all viruses, these particles invade tissue cells of the animal they attack, multiply within the cell, eventually destroying it, and are thus released to invade other cells of the same or another host. Unlike most viruses, those causing psittacosis and related infections are susceptible to chemotherapeutic drugs, as indicated above. Viruses of this type, in addition to occurring in birds, have been found in mice, hamsters, cats, opossums, sheep and cattle, but as far as is known these do not infect man. A similar virus that is transmitted from man to man directly is that of lymphogranuloma venereum. The generic name *Miyagawanella* has been suggested for this entire group, commemorating the work of the Japanese scientist Y. Miyagawa on lymphogranuloma venereum. An English bacteriologist, S. P. Bedson, during the 1930s contributed basic information on the psittacosis virus, and, in the U.S., K. F. Meyer made extensive studies over several decades on the epidemiologic aspects of the disease

Transmission and Control. — Psittacine birds apparently acquire the infection in the nestling stage and may become carriers of the virus even though they remain in good health. When such birds are crowded or chilled, as during shipping, or placed under other adverse conditions, the latent infection may be aggravated and become acute. The bird then shows obvious signs of illness and the virus is discharged in excess nasal secretions or in a watery diarrhea. After such infectious material is dried it readily infects other birds or men, in the form of an inhaled dust. When psittacosis occurs in poultry plants it is seen especially in the personnel exposed to dust or feathers. In a few outbreaks transmission from man to man has occurred, especially from a severely ill patient to nursing or medical attendants, but this is exceptional.

Although it has been impossible to control psittacosis completely on a national scale, some parakeet aviaries have been maintained free of infection by scrupulous care in keeping the birds isolated from disease sources and by practising good husbandry. Chemotherapeutic measures also offer promise. To protect himself and his household, the individual bird owner should avoid contact with sick birds, purchase birds if possible only from known healthy stock and strive to keep his pet in sound condition. (F. B. G.)

PSKOV (German. PLESKAU). a town of U.S.S.R. in the Pskov district of the Leningrad oblast, in 57° 48' N.. 28° 22' E., situated on both banks of the Velikaya river, 9 mi. S.E. from Lake Pskov. Pop. (1956 est.) 69,000. The chief part of the town, with its kremlin on a hill, occupies the right bank of the river, to which the ruins of its old walls (built in 1266) descend. The old cathedral in the kremlin has been four times rebuilt since the 12th century; the present edifice (1691–99) contains some very old shrines, and also the graves of the bishops of Pskov and of several Pskov princes. The church of Dmitriy Solunskiy dates originally from the 12th century; others are of the 14th and 15th centuries.

History.—Pskov, formerly the sister republic of Novgorod and one of the oldest cities of Russia, maintained its independence and its free institutions until the 16th century, being thus the last to be brought under the rule of Moscow. It already existed in the time of Rurik (9th century); and Nestor states that in the year 903 Olga, wife of Igor. prince of Novgorod, was brought from Pleskov (*i.e.,* Pskov). The Velikaya valley and river were from a remote antiquity a channel for the trade of the south of Europe with the Baltic coast. Pskov being an important strategic point, its possession was obstinately disputed between the Russians and the Germans and Lithuanians throughout the 11th and 12th centuries. It became in the 12th century a *prigorod* of the Novgorod republic; *i.e.,* a city having its own free institutions, but included in certain respects within the jurisdiction of the metropolis, and compelled in time of war to march against the common enemy. Pskov had, however, its own prince (defensor municipii); and in the second half of the 13th century Prince (Timotheus) Dovmont fortified it so strongly that the town asserted its independence of Novgorod, with which, in 1348, it concluded a treaty wherein the two republics were recognized as equals. Its rule extended over the districts of Pskov, Ostrov, Opochka and Gdov (farther north on the east side of Lake Peipus). The vyeche or council of Pskov was sovereign, the councils of the subordinate towns being supreme in their own municipal affairs. The council was supreme in all affairs of general interest, as well as a supreme court of justice, and the princes were elected by it; these last had to defend the city and levied the taxes. which were assessed by 12 citizens. But while Novgorod constantly showed a tendency to become an oligarchy of the wealthier merchants, Pskov figured as a republic in which the influence of the poorer classes prevailed. Its trading associations, supported by those of the working classes, checked the influence of the wealthier merchants.

Its strong walls and its 40 large and wealthy churches bear testimony to the wealth of the inhabitants, who then numbered about 60.000. As early as the 13th century Pskov was an important station for the trade between Novgorod and Riga. A century later it became a member of the Hanseatic league. Its merchants and trading associations had factories at Narva. Reval and Riga, and exported flax. corn, tallow, skins. tar, pitch, honey and timber for shipbuilding. Silks, woolen stuffs and all kinds of manufactured wares were brought back in exchange. In 1399 the prince of Moscow claimed the privilege of confirming the elected prince of Pskov in his rights; and though, 50 years later, Pskov and Novgorod concluded defensive treaties against Moscow, the poorer classes continued to seek at Moscow protection against the rich.

After the fall of Novgorod (1475) Pskov was taken (1510) by Basil Ivanovich. prince of Moscow, and a *voyvode* or deputy was nominated to govern the city. Moscow, at the end of the 17th century, abolished the last vestiges of self-government at Pskov, which thenceforward fell into rapid decay. Near this city the Teutonic knights inflicted a severe defeat upon the Russians in 1502. Pskov became a stronghold of Russia against Poland, and was besieged (1581) for seven months by Stephen Báthory during the Livonian War. and in 1615 by Gustavus Adolphus of Sweden. Under Peter the Great it became a fortified camp. Under the tsarist regime the province of Pskov extended from Lake Peipus to the sources of the western Dwina, and after the 1917 revolution the province of Pskov, though much diminished, remained an administrative unit. In 1927 it was incorporated in the newly created Leningrad area (*q.v.*).

PSOCOPTERA (CORRODENTIA), an order of insects, the best known of which are book-lice, pale flightless insects about 1 or 2 mm. long, found among old papers, on dusty shelves or in cereals. Outdoor species, called bark lice, are mostly winged and occur on the bark and foliage of trees. sometimes under stones or in ground litter. The outdoor species are not economically important. but book-lice often are a considerable nuisance. Psocid is a general term for any member of the order.

Psocoptera usually are not more than $\frac{1}{4}$ in. long, and the wing venation of flying species is distinctive. Tarsi are two- or three-segmented and cerci are absent; mouth parts are for chewing, with the lacinia of the maxilla usually elongate and chisellike. Metamorphosis is gradual, and occasionally the gregarious nymphs of outdoor species form conspicuous clusters on tree trunks. Psocids eat molds, cereals and organic debris.

About 150 species of psocids have been found in the United States, but neither this figure nor the estimate of 1,250 described world species approaches the total number that exist, because the group. now arranged in over 20 families, has been rather neglected by entomologists.

See also INSECT.

See D. J. Borror and D. M. DeLong, *An Introduction to the Study of Insects,* ch. xiv, pp. 169–179 (1954). (A. B. GU.)

PSORIASIS. — Psoriasis is a moderately common disease of the skin, of great chronicity. It may begin at any age, and a familial history of psoriasis is common. Individuals affected by the disease are ordinarily otherwise healthy; the only exception to this is arthritis in some patients. The lesions of psoriasis are usually characteristic. consisting of sharply outlined dull red patches of varying size, with thickening of the skin, and a heavy rough scale which is silvery or asbestoslike in colour.

Psoriasis has a characteristic distribution over the body in a majority of cases, involving principally the scalp, the elbows, the front of the knees and the trunk. It does not cause loss of hair. Involvement of the nails is quite common. and this may be mistaken for a ringworm infection. The disease varies a great deal in severity and in many patients it will show periodic flareups. In general, nervous tension will make psoriasis worse. There is no regular relation of the disease to any type of diet. Sunlight is usually very helpful, and a considerable variety of local treatments are effective temporarily. Most of the proprietary medicines sold for the treatment of psoriasis contain organic compounds of mercury or various types of tars. Arsenic internally was formerly used in the treatment of psoriasis. but is now rarely employed. X-ray therapy is used with decreasing frequency; it carries definite risks if used in excess. No infectious agent has ever been isolated regularly from lesions of psoriasis. and there is no evidence that the disease is in the least contagious. Compounds such as cortisone or ACTH have been employed successfully in some patients, but are variable in their effects and are justified only in the most severe cases, particularly those with associated arthritis. (D. M. P.)

PSOROSPERMIASIS, a term formerly applied to infection with any one of several groups of Protozoa. including the Cnidosporidia, Myxosporidia, Gregarinida, Coccidia or Sarcosporidia, all of which have in common a resistant spore or cystic stage, which develops in the intestines, liver, kidneys, ureters, musculature or other tissues of the host. (E, C. F.)

PSYCHE, in Greek mythology. the personification of the human soul. The importance, in Platonic philosophy, of love (in the highest sense) as an agent of the soul's progress leads, in art from the 4th century B.C., to representations, allegorical or playful, of Psyche (generally represented as a winged girl, a relic of the old conception of the soul as a bird or insect) in company with Eros (*q.v.*), usually in amatory scenes. The tale of Cupid and Psyche, in the *Metamorphoses* of Apuleius, is interesting as the only ancient fairy tale which is told as such. In it Psyche, the youngest daughter of a king, arouses the jealousy of Venus, who orders Cupid to inspire her with love for the most despicable of men.

Cupid, however, falls in love with her and carries her off to a secluded spot, where he visits her by night, unseen and unrecognized by her. Persuaded by her sisters that her companion is a hideous monster, and forgetful of his warning, she lights a lamp to look upon him while he is asleep; in her ecstasy at his beauty she lets fall a drop of burning oil upon the face of Cupid, who awakes and disappears. Wandering over the earth in search of him, Psyche falls into the hands of Venus, who forces her to undertake the most difficult tasks. The last and most dangerous of these is to fetch from the world below the box containing the ointment of beauty. She secures the box, but on her way back opens it and is stupefied by the vapour. She is only restored to her senses by Cupid, at whose entreaty Jupiter makes her immortal and bestows her in marriage upon her lover.

See O. Waser in W. Roscher, *Lexikon,* iii, 2327 *et seq.* (3924) ; *L.* C. Purser, ***The*** *Story of Cupid and Psyche* (1910).

PSYCHIATRY is the branch of medicine which specializes in the study and treatment of illnesses causing various kinds of behavioural disturbances. These disorders include: disturbances of mood, as seen in depressive states and anxiety; excessive or inadequate affective responses or inadequate social control of emotions; conditions characterized by disorganized thinking and perception, such as phobias, obsessions, delusions, hallucinations; transient as well as irreversible impairments in intellectual activities; and certain physical disturbances which simulate diseases associated with malfunctioning of body organs.

Psychoanalysis, to be distinguished from psychiatry, is both a particular theory of personality development and functioning and a particular method of psychotherapy used in psychiatry. Strictly defined, psychology is the scientific study of the mind; it is not a medical specialty. *(See* PSYCHOANALYSIS ; PSYCHOLOGY; PSYCHOTHERAPY.)

Questions of symptomatology and diagnosis, and those concerning etiology, treatment and prevention, are the problems of psychiatry. Sometimes the sufferer's condition is manifested in behaviour that is so grossly inappropriate that the existence of an illness is easily recognized. At other times, the difficulty may be known only to the sufferer. Irrational violence or the striking immobility of severely depressed persons are obvious pathological conditions. On the other hand. states of apprehension, obsessive thoughts and unreasonable fears may exist for prolonged periods without recognition. In the latter instance, the conditions become known only through the subjective reports of the ill. or when the symptoms intrude upon ordinary routine activities and force a general awareness of a mental illness.

In explaining the genesis of behavioural disorders, modern psychiatry emphasizes the patient's genetic predisposition; the influence of anatomical, physiological and biochemical processes; and the determining effect upon the nervous system of the recording of the person's ongoing series of life experiences, beginning with the prenatal period and extending through childhood experiences in the family to the environmental and cultural pressures. To the psychiatrist, the sum of these factors determines personality. A human being's personality is recognized as his characteristically recurring patterns of behaviour in response to life experiences, to and with other persons. (See PERSONALITY.)

This article is organized as follows:

I. HISTORY

A. EARLY HISTORY

Many modern scientific concepts regarding psychiatric disorders are derived from the historical past. References to mental disorders in early Egyptian. Indian, Greek and Roman writings show great insight, but for the most part the philosophers, physicians and theologians who contemplated and wrote about the problems of human behaviour regarded psychiatric illnesses as a reflection of the displeasure of the gods or as evidence of demoniac possession. Only a rare few realized that behavioural problems were not separable from physical illnesses and that the sufferers should be treated humanely rather than exorcised, banished or punished. Although progress was slow in banishing the belief in supernatural causes, as early as 860 B.c., some Greek priests supplemented their incantations and exorcisms for the mentally disturbed with recommendations for kindness and physical and recreational activities such as walking, riding and listening to soothing music.

A significant advance toward scientific understanding of mental disorders occurred in the 6th century B.C. when the Greek healers turned to observation and interest in experimentation. At this time: Alcmaeon made the first dissection of the human body and observed the connection of sense organs, such as the eye and the ear, to the brain. Searching for the seat of reason and of the soul, Alcmaeon decided that they were located in the brain.

Shortly after Alcmaeon reported on his experimentation, the problem of mental disorders gained the attention of Greek philosophers. Empedocles spoke about the significance of emotions and the possibility that love and hate were the fundamental sources of change in behaviour. Plato incorporated concepts of Empedocles in his consideration of the role of Eros in the personal and social life of man. This medical and philosophical thought was not recaptured until Sigmund Freud (*q.v.*) presented his theories and clinical studies in the late 19th century.

Hippocrates (*q.v.*), a sensitive! perceptive observer of clinical phenomena, described many mental disorders found in modern times, including psychosis after pregnancy, delirious states associated with infections such as tuberculosis and malaria and the acute confusion which follows severe hemorrhage. He flatly rejected the idea that mental disturbances were caused by the intervention of the gods or by possession. He also took an unequivocal position concerning the legal rights and responsibilities of the mentally disturbed. Athenian lam recognized the rights of the mentally disturbed in civil affairs, but gave no special consideration to the mentally disturbed when they became involved in capital crimes. Through the vast respect accorded him, Hippocrates was able to provide this consideration. In the Athenian courts, if it could be proved that the person on trial suffered from a condition which Hippocrates designated as paranoia, the court would appoint a guardian for the accused.

Hippocrates classified mental disorders into three categories: mania, melancholia and phrenetis. His descriptions reveal many of the classical symptoms which are recognized in epilepsy, mania, melancholia and paranoia. To Hippocrates, hysteria mas a mental disease, but it was limited to women. As he saw it, hysteria was caused by the wandering of the uterus through the body and symbolized the body's pining for the production of a child; he thought that marriage was the best remedy for hysteria.

Hippocrates and his followers were the first group of physicians who approached mental illness scientifically. Their understanding of mental disorders emphasized natural causes, clinical observations and brain pathology. They were the first to describe and examine empirically the clinical materials of psychiatry. In establishing a movement toward the biological study of mental illness, Hippocrates challenged and won people away from the theological interpretations. Many physicians after Hippocrates contributed substantially to psychiatry. notably Asclepiades, Celsus, Aretaeus and Soranus (*qq.v.*). Soranus, in his instructions for the treatment of disturbed patients, prescribed the use of tact and discretion; he stated that the patient's attention must be tactfully directed to his difficulties; he advised the physician to observe the mental patient's tolerance to sedation and warned of the need to supervise the patient through his period of convalescence.

The high point in medical thought of this period was reached in the work of the Roman physician Galen (2nd century A.D.), who, through a scientific approach to the study of the anatomy of the nervous system. drew attention to the role of the brain in mental functioning. He discovered that the existence of a symptom did not necessarily mean that the organ or the part of the body which expressed the symptom was the affected portion. As a consequence of his experimental work and his studies of mental disorders, Galen developed a theory of the rational soul as divided into an external and an internal part. The external part consisted of the five senses. The soul's internal functions were imagination, judgment, perception and movement. On the basis of his experimentation, Galen concluded, as Plato had thought and Aristotle had denied, that the brain, not the heart, was the seat of the soul. His observations had shown him that compression of the heart affected only the function of the arteries. Galen rejected the idea that hysteria resulted from the wandering of the uterus about the body, but he considered it to be caused by a local engorgement of the uterus.

In the period following the death of Galen, primitive thinking about mental illness re-emerged. Witchcraft and demonology dominated medical thought of medieval times and continued to exert an influence into the 19th century. However, beginning with the 16th century, signs of scientific questioning began to appear again. Among the physicians who challenged demoniacal explanations of mental disturbances were Paracelsus, Agrippa and Johann Weyer. Beginning with Francis Bacon in the 17th century, a number of philosophers, recognizing that the functions of the mind were a part of their concern with the natural order of the universe, began to exert an effect on medical thought. Notable among those who contributed to the modern science of psychopathology were Descartes, Hobbes, Locke, Condillac and Hume.

B. 19th Century

1. Humanitarian Movement. — Paralleling the reappearance of scientific questioning and the development of medical science was an improvement in the public attitude toward the mentally ill. These combined factors resulted in the establishment of mental hospitals and in more humane treatment methods. The humanitarian movement received its initial impetus through the efforts of the great French physician Philippe Pinel (*q.v.*), who after the French Revolution was placed in charge of the Bicêtre, the hospital for the mentally ill in Paris. Under Pinel's supervision, a completely new approach to the handling of mental patients, as well as a new concept of mental hospital operation, was introduced. Chains and shackles were removed from the patients. In place of dungeons, the patients were provided with sunny rooms and permitted to exercise on the hospital grounds. The reforms which Pinel sponsored and their gratifying results placed France in the forefront of psychiatry.

In England, several generations of the Tuke (*q.v.*) family supported the humanitarian movement. Through the efforts of William Tuke and his son Henry, aided by the Society of Friends, York Retreat was opened (1796) for the humane care of the mentally ill. In the United States, an energetic and courageous Kew England woman, Dorothea Dix (*q.v.*), between 1841 and 1881 carried on a campaign to arouse the people and the legislators to an anareness of the inhumanities which prevailed in all of the country's mental hospitals. Not only was Miss Dix the leading spirit in improving the care of mentally ill in the United States, but she also helped in promoting the reform movement in Canada and in Scotland. The modern mental hospital in North America and in western Europe aims at providing a friendly, encouraging, therapeutic atmosphere. The hospital staff attempts to provide a variety of activities designed to help the patients regain mental health. While there is still a large gap between practice and theory in many hospitals, the modern mental hospital is moving in the direction of the "open-door" policies initiated in England. The term open-door symbolizes the trend away from the locked ward toward freedom of the patient to move about the hospital and recognition of the therapeutic effects of a sheltered, supportive environment where all the staff help the patients and patients help each other to health. (See also Hospital.)

2. Biological Movement. — Along with humanitarian reform in hospital practice and treatment methods during the late 18th and the 19th centuries, there was a resurgence of medical and scientific interest in psychiatric theory and practice. Great strides were made during this period in establishing a scientific basis for the study of mental disorders. A long series of observations by brilliant clinicians in France. Germany and England culminated in Emil Rraepelin's (*q.v.*) classification of mental disorder. Kraepelin's integration of a mass of descriptive clinical data into meaningful symptom categories was a major contribution to psychiatry, and his classification system served as the basis of all subsequent nosologies.

Rapid advances in studies of anatomy, psychology, pathology, chemistry and bacteriology led to the expectation of discovering specific brain lesions for the various forms of mental disease. While this search did not attain the results desired, the scientific emphasis was productive in that it did elucidate the gross and microscopic pathology of many brain disorders which produce psychiatric disability. In addition. the research effort illuminated the role of infectious and metabolic disturbances in the production of mental diseases. One of the notable achievements of this period was the discovery of Treponema *pallidum* (Spirochaeta *pallida*), the organism causing syphilis, as the basis of the brain pathology producing general paresis (*q.v.*). Other discoveries were the causation of pellagra psychosis in a vitamin deficiency and the recognition of delirious reactions caused by malnutrition and pernicious anemia. Significant observations also were made on the cellular changes in the brain which accompany the presenile and senile psychoses, and a number of pathological conditions associated with mental retardation were identified. The advances made in the 20th century toward establishing the biochemical correlates of mental disturbances and in developing the tranquilizing agents represent the moving fringe of the earlier search for etiological specificity in disordered body organs and systems.

3. Psychological Movement. — Certain of the major psychotic states, notably schizophrenia and manic-depressive reactions, frustrated the effort to find in cellular pathology the principal causative agent of mental disease. Other explanations were needed for the many puzzling aspects of these conditions, and these explanations emerged in a wave of psychological viewpoints, beginning with the study of hypnosis in relation to hysteria. The arrival of Franz Anton Mesmer (*q.v.*) in Paris dated the beginning of broad scientific interest in psychological factors as influencing or altering human behaviour. Advancing the belief that the distribution of a universal magnetic fluid in the body was the basis of health and disease, Mesmer opened a clinic in Paris where he treated all kinds of diseases, including hysterical paralysis, in a ceremonial setting in which he "magnetized" the patients by applying to their bodies iron rods treated with various chemicals. Mesmer's therapy was a group method of treatment; he moved among his patients touching each of them with his hand and waving a wand over them.

Mesmer's own personal success was short-lived, and he was branded a charlatan. His work was studied by a committee of the Academy of Sciences whose members included Jean Sylvan Bailly, Benjamin Franklin, Lavoisier and LeRoi. The committee was unable to find any evidence of animal magnetic fluids, but it was impressed with the results produced by Mesmer's touching of the patients. It advised against the use of mesmerism and warned of potential dangers from harmful imitations. Outside France the recommendations of the academy went unheeded, and mesmerism spread throughout the world. A French magnetizer, Charles Poyen, introduced séances of magnetism in the United States from which the watchmaker P. P. Quimby (*q.v.*) obtained his first conceptions of faith healing and successfully treated Mary Baker Eddy for hysterical paralysis. Use of mesmerism as an anesthetic during surgery was advocated by several physicians, but this practice passed quickly with the introduction of nitrous oxide and chloroform.

The first physician to be attracted by scientific curiosity to the serious study of mesmerism was the English surgeon James Braid, who provided a descriptive formulation of the condition and introduced the term hypnotism. After Braid, the scientific study of hypnotism lagged until a French country doctor, A. A. Liébault, resumed interest in the subject and learned to use hypnosis for the induction of sleep. Liébault subsequently made wide use of hypnotism in his medical practice, and he also taught the technique to the French physician Hippolyte Bernheim, the English neurologist J. M. Bramwell and the renowned French neurologist Jean Martin Charcot (*q.v.*).

Questioning the view that psychological factors could cause hysteria, Charcot conducted, at the Sâlpetrière hospital in Paris, an extensive and detailed study designed to determine the organic factors associated with the condition. On Feb. 13, 1882, Charcot presented a report of his findings to the Academy of Sciences. He convinced the academy members that the phenomena of hypnotism were manifestations of abnormality and that the characteristics of the hypnotic state could be observed only in patients with hysteria. The same academy that earlier had condemned research on animal magnetism was thus won to a new point of view. Charcot's success prepared the way for the harvest of psychological insights that followed. Among his many students was Freud.

Charcot's views were not accepted by all French physicians, however. Bernheim, who was professor of medicine at Nancy, vigorously challenged Charcot's conclusion, maintaining that the phenomena observed at the Sâlpetrière took place only when conditions of suggestion were set up by the hypnotist. He stressed the study of the process of suggestion and the characteristics of suggestibility, and rightly claimed that the latter were not restricted to hysterical persons. Bernheim's work, apart from pro-

viding a new perspective on hypnosis, had other implications; some psychiatrists have regarded it as the first attempt to evolve a general understanding of human behaviour. Developing out of his studies, for example, were new questions concerning, the legal responsibility of criminals and the causes of criminal behaviour; Bernheim, by advancing the belief that mechanisms of suggestion underlay the endless variety of normal and abnormal behaviour, chailenged the concept that the will was the agent of crime and evil. Along with Charcot, Bernheim put to final rest the persisting concern with demoniac possession.

Pierre Janet (q.v.) also studied hysteria and furthered rhe acceptance of psychological causation. Recognizing the neurotic components of hysteria (fixed ideas and inner conflict with reality), Janet insisted upon psychological treatment for the condition. His psychotherapy was founded primarily on the use of persuasion and of techniques for altering the patient's environment. The work with hypnotism and hysteria opened the door for further recognition of the psychoneuroses. (See also HYPNOSIS; *HESTERIA.)*

C. MODERN SCHOOLS

Freud took the first steps toward providing the theoretical structure upon which much of modern psychiatry rests. Adoli Meyer (q.v.) also played a prominent role in the development of modern psychiatry through his pluralistic and interactional concepts of human behaviour; he drew attention to the multiple biological, psychological and social factors that influence personality. Both Freud and Meyer were greatly aided in the construction of their theories by knowledge of the work of the great English theoretical neurologist John Hughlings Jackson (q.v.).

Drawing from the genius of Charles Darwin and Herbert Spencer, Jackson set forth an evolutionary theory to explain the function and development of the nervous system. In the development of his theory, Jackson drew from his extensive and careful clinical observations of epilepsy and other diseases of the brain. He concluded that the functions of the nervous system were integrated at progressively more complex levels, with mentation, the highest level of iunction, located within the cerebral cortex. Jackson viewed the symptoms accompanying impaired brain function as representing both the disappearance oi the most recently acquired functions of the brain, and the reappearance oi earlier and more primitive functions that had become submerged during the evolutionary process. According to Jackson, when injury to the brain produced a permanent defect in the functioning of the nervous system, in addition to symptoms caused by loss of function and symptoms representing re-emergence of more primitive functions, the organism also produces another type of symptom to compensate or substitute for the loss. Jackson's theoretical position inherently postulates that the understanding of any behavioural disturbance is dependent upon knowledge of the progressive development of a particular type of behaviour in a given organism as well as knowledge of the presentation of such behaviour in other living species. Such assumptions are basic ior both the psychoanalyst and psychobiologist.

1. *Psychobiological School.— The psychobiological school of psychiatry, established by Meyer represents in broad outline the theoretical structure of the general field of modern psychiatry. Meyer, who moved to the United States in 1892 from Switzerland, received his training in Switzerland and in other countries of Europe; his training in many ways paralleled that of Freud. Throughout his career, Meyer emphasized that the understanding of human processes and the problems of human behaviour lie in the utilization of knowledge from biology, psychology and sociology. The explanation of the total personality requires study of the physical attributes of the individual as well as the many social, cultural and emotional influences to which he has been exposed. Meyer stressed the importance of early parental influences in the development of the personality of the child and conceived of mental disturbances as progressive habit formations. The techniques he developed for psychiatric examination are the basis of all those used in English-speaking countries. Meyer insisted that understanding of maladaptive behaviour required a comprehensive study of the life history of the individual, tracing the development of the personality through each progressive and unfolding stage to the present life situation. To Meyer, the individual was both a product and a victim of his life experiences. Meyer emphasized that each individual personality had its assets and its liabilities. The existence of faulty habit patterns implied possibilities of teaching healthy ones. To the psychiatrist he appealed for careful study of the development of symptoms, and cautioned that symptoms should not be attributed to a, specific cause. Meyer's orientation departed markedly from that of theorists and practitioners who explained mental phenomena solely on a physical basis.*

The weakness of Meyer's psychiatry lies in its failure to work through the study of intrapsychic processes and their origin in family life; recognition of the importance of these forces represents some of the most significant thought of the psychoanalytic school. The psychobiologists emphasize that psychiatric disabilities are reactions rather than disease processes with established courses.

2. *Psychoanalytic School.— The psychoanalytic movement originated in the perceptions and meticulous clinical observations of Freud. After studying with Charcot, Freud returned to Vienna, where he was associated with Josef Breuer in studies of neurotic patients under hypnosis. Freud and Breuer observed that their patients tended to relive earlier life experiences, which could be associated with the symptomatic expression of the illness. When the sources of the patients' ideas and impulses were brought into consciousness during the hypnotic state, the patients showed improvement. Although the collaboration was proceeding well, Breuer became disturbed by the responses which the patients made to him (a phenomenon later defined by Freud as the transference relationship) and discontinued the study; Freud pursued it alone.*

Observing that most of his patients talked freely without being under hypnosis. Freud evolved the technique of free association (see ASSOCIATION, MENTAL). *In treatment! he advised the patient to speak freely and to say anything that came into his mind, without regard to its assumed relevancy or propriety. Noting that patients sometimes had difficulty in making free associations, Freud concluded that certain painiul, anxiety-ridden (traumatic) experiences were repressed from conscious awareness. Freud noted that in the majority of the patients seen during his early practice the events most frequently repressed were concerned with disturbing sexual experiences. Thus he hypothesized that anxiety was a consequence of the repressed energy (libido) attached to sexuality; the repressed energy took expression in various symptoms that served as psychological deiensive mechanisms.*

Freud later modified his concept of anxiety. His new concept regarded anxiety as the emotion generated by the threat of some fearfuloccurrence or of impending danger. In later years, Karen Horney (q.v.) and other psychiatrists extended Freud's concept of a threatening event leading to the arousal of the anxiety. The more recent theories of anxiety included not merely feelings of fear, guilt and shame consequent to sexual fantasies that the person regards as reprehensible; anxiety is conceived also as resulting from the arousal of fantasies of aggression and hostility and from fears of loneliness caused by separation from a person on whom the sufferer is dependent.

Freud's free-association technique provided him with a tool for studying the meanings of dreams, slips of the tongue, forgetfulness and other mistakes and errors in everyday life. From these investigations he was led to a new conception of the structure of personality: the id, ego and superego. (1) The id is the reservoir of drives and impulses derived from the genetic background and concerned with the preservation and propagation of life. Freud regarded the drives resting in the id as the prime sources of the sexuality and aggressive impulses that are needed to perpetuate the race and to satisfy the biological needs ior food, water, oxygen and warmth. The impulses of the id are seen as operativ beyond conscious awareness. (2) The ego (q.v.), in contrast to the id, operates in the conscious and preconscious levels of awareness. It is the portion of the personality concerned with perception, cognition and executive actions. (3) The third portion of the personality structure, Freud called the superego. In this rests the individual's accumulated ideals and values and the mores of his family and society; the superego serves as a censor on the ego functions.

In the Freudian framework, conflicts among the three structures of the personality are repressed and lead to the arousal of anxiety. The person is protected from experiencing his anxiety directly by the development of various psychological defensive mechanisms. The defensive mechanisms (described in the article DEFENSE MECHANISMS) are adaptive mechanisms learned through the family and the cultural influences to which the growing child is exposed. They become pathological when they interfere with the capacity of the adult to pursue the satisfactions of living in a society. The existence of these patterns of adaptation or mechanisms of defense are quantitatively but not qualitatively different in the psychotic and neurotic states.

One of Freud's fruitful contributions was his concept of transference. In the course of his work with his patients, Freud became aware of the deep attachments they formed for him. Learning that the patients of other analysts reacted similarly. he concluded that these emotional attachments represented a repetition of the relationship the patient previously had with his parents or their substitutes. The love or hatred which the patient felt for his parents and which he unconsciously projected to the analyst influenced the patient's capacity to make free associations. By objective treatment of these responses and the resistances they evoked, as well as by bringing the patient to analyze the origin of his feelings, Freud concluded that the analysis of the transference and the patient's resistance to its analysis were the keystones of psychoanalytic therapy. Psychoanalytic therapy contrasts with all other forms of psychotherapy in its emphasis on transference. Recognition of the transference relationship has been of major importance to the entire field of psychiatry, however, and to medicine generally.

Freud described the development of personality as a psychosexual evolution that begins at birth and continues through childhood. In the framework of Freud's libido theory, the personality develops through a series of stages: oral, anal, urethral, oedipal and genital. The implication of these stages to personality development is that various body zones have the capacity for pleasurable sensation. As the child grows, the centres of body gratification pass progressively from one area to another. See also PSYCHOANALYSIS.

3. Interpersonal Schools.—The U.S. psychoanalyst Harry Stack Sullivan emphasized the careful study of the interaction between the developing child and his parents and his later relations with others as providing a more significant operational method of understanding human behaviour than that of the libido theory. Sullivan's conceptions, which represent a blend of psychoanalysis and psychobiology are represented in the interpersonal school of psychiatry.

4. Psychosomatic Medicine.—The term psychosomatic medicine does not properly refer to a school in psychiatry; rather it describes the directed interest of a growing group of psychiatrists who, in close collaboration with other colleagues in medicine, are concerned with the study of reactions to anxiety as expressed through physiologic disturbances. In these instances responses of bodily organs rather than inappropriate symbolic behaviour are the defenses against threat. Psychosomatic disorders comprise not only the "organ neuroses" noted in early psychiatric classifications but also many other physiologic disturbances known to be precipitated by emotional stress. Bodily reactions to stress take expression in cardiovascular disorders: respiratory ailments such as certain forms of asthma and attacks of hyperventilation; gastrointestinal disturbances leading to belching, flatulence, anorexia, obesity, constipation and diarrhea; migraine and tension headaches; pelvic pain; dysmenorrhea; dyspareunia (in women, difficult or painful coitus); and impotence and frigidity. Psychosomaticists also study and treat the stress-induced responses contributing to modifications of the diabetic metabolism, the neurodermatoses, gastric and duodenal ulcers and ulcerative colitis.

Psychosomatic medicine is concerned not only with describing the nature of conflict- or stress-induced physiologic disturbances but also with defining the conditions under which disturbances of internal organs take place. Much emphasis is placed on the fact that emotional problems aggravate all illness and that denial of the existence of an emotional disturbance provokes greater disability.

In determining proper treatment, the psychosomaticist is interested in learning the kinds of situations and thoughts that produce personality disturbances. This knowledge is essential to understanding and preventing many conditions, such as the hallucinations and delusions that some patients have when they are deprived of sight during cataract operations. The gynecologist and obstetrician seek information about the patient's feelings concerning contraceptive practices. artificial insemination, therapeutic abortion and other emotionally laden areas of medicine. The surgeon can be assisted by knowledge of the patient's fears of mutilation or disfigurement; a patient's negative response during convalescence or unwillingness to undertake rehabilitative measures may be a consequence of his emotional attitudes to physical illness. All these conditions, as well as many others, require the attention of either a psychiatrist working in the medical service of a hospital or with a group of physicians who have understanding of psychosomatic interaction.

II. DIAGNOSIS AND CLASSIFICATION OF MENTAL DISORDERS

A. DIAGNOSIS

The psychiatric diagnosis is based on examination of the patient and history of his illness. Information is obtained concerning possible hereditary influences, the patient's physical maturation and his emotional and social development. taking into account experiences in both the family and community environment. Physical as well as neurological examinations are made and, when indicated, supplemented by psychological tests and other special examinations such as electroencephalographic or biochemical and serological tests. Together these procedures provide data upon which the psychiatrist makes his diagnosis and formulates the determinative factors that explain the reaction patterns of his patient.

1. Symptomatology.—The actions of the mind cannot be isolated and separated into independent functions, such as the senses, memory, imagination, reason, desire or perception. Nor do the symptoms of mental disorders represent disease of a particular area of the brain. Psychiatric symptoms are expressions of loss or impairment of some function or of failure in development of that function. Loss of function may arise from psychological conflict, or it may occur secondary to a structural disturbance of the brain. For example. a defect in memory could be the consequence of an inherited defect; it could result from a blow to the head or from a growing brain tumour; or it could be the expression of a psychological conflict.

For most psychiatrists, anxiety and its control represent the central problem in psychopathology. Although many stressful experiences and conditions give rise to both fear and anxiety, these emotional reactions are usually differentiated. In general, fear is temporary and is directly related to some external event. Anxiety, in contrast is aroused by any threat to the person's wholeness or his self-concept. It is a pervasive sense of apprehension or tension, the source of which is not consciously recognized. Anxiety has its antecedent in the tensions of early infantile life, and it is aroused in the growing child and in the adult in relation to actual or fantasied interpersonal conflicts.

When fear or anxiety is aroused, the person attempts to adapt and bring about a state of equilibrium or condition without tension. Rightly or wrongly, in actuality or in fantasy, the anxious person expects to receive an unfavourable reaction or estimate of his personal worth or conduct from someone whom he respects or whom he considers to be in authority. Through learning, the expressions of anxiety tend to be disguised or converted into various socially adaptive mechanisms; thus, most people are unaware of anxiety or of the circumstances that provoke it. When the person becomes anxious, however. the anxiety interferes with his capacity to recognize, evaluate and manage properly the situations associated with it. The ability to learn or profit from experience is impaired and capacity to adapt to new situations is limited because only a restricted range of stereotyped and repetitive responses is available.

Hostile and aggressive attitudes, expressed both overtly and covertly, are among the commonest psychiatric symptoms. Such impulses are often repressed in the psychological sense; by reaction formation they may re-emerge as pathologically excessive solicitousness and gentleness. Sometimes the hostile impulses are projected onto other persons; this is a common occurrence with paranoid types, who ascribe their destructive impulses to others. It should be noted that aggressive trends are utilized constructively in certain sports and work.

Pathological disturbances of motility are recognized in the behaviour of hyperactive, nonproductive persons. In these conditions, there may be a tremendous drive to action or to speech, often leading to what is designated as a stream or flight of ideas. Constant repetition of speech or of body movements is an expression of a motility disturbance underlying a compulsive drive. Various mannerisms may occur in which the person grimaces, repeats gestures, shows peculiar types of gait or repeats meaningless words or phrases.

Healthy affect, or the feeling tone of a person's life, is e ident in ability to make controlled and variable responses to daily life experiences. Affectivity penetrates and colours the psychological life and influences the thought and action of every person. Disturbances of affect may lead to disturbances of consciousness, motility and intellect. Affective state can modify a person's judgment and ideas to the extent of distorting his capacity to evaluate reality, and thus it may lead to delusional and hallucinatory thinking.

Pathological elation, a condition seen in the manic behaviour of some psychotics, is an affective state of abnormal confidence and enjoyment. It is also recognized with certain brain syndromes such as general paresis, brain tumours and multiple sclerosis. A less frequently observed pleasurable state is that of ecstasy. The opposite of elation and ecstasy is depression, varying from mild downheartedness and indifference to feelings of despair and hopelessness.

Disturbances in perception and thought are seen in hallucinations and illusions, phobias, obsessional thinking and delusions; in apparently disconnected or loose associations; and in unusual retardation or flights of ideas.

2. Predisposing and Precipitating Factors.—Diagnosis of a psychiatric illness requires consideration of the predisposing and precipitating factors. These include a wide range of situations and conditions: hereditary background; effects of previous illnesses; presence of physical defects; use of drugs such as alcohol and narcotics; existence of nutritional and vitamin deficiencies; vocational, sexual or economic stress; and exposure to particular kinds of privation. Numerous studies have been and are being conducted to determine the precise correlates of mental disorders.

Heredity.—The exact role of heredity in the development of mental and emotional disorders is still a matter of conjecture. Evidence indicates that certain inborn errors of metabolism transmitted through recessive genes underlie some forms of mental retardation. Based on studies of the incidence of schizophrenia among persons with various relationships to a schizophrenic patient, F. J. Kallmann postulated that schizophrenia is transmitted by recessive genes in the form of a predisposition; the schizophrenic reaction develops when a biologically vulnerable person is placed under particular stress. Kallmann reported a concordance rate for schizophrenia of 86% of identical twins and of only 14.5% among fraternal twins and siblings. Criticisms of attributing mental disorders solely to genetic factors rest largely upon the potentiality that parents have for transmitting their emotional difficulties to the next generation through the prolonged social learning that takes place in the course of family living.

Age.—Mental and emotional illnesses tend to make their appearance at certain ages. Adolescence, the middle years and senescence are associated with periods of major physiological changes and psychological stresses involving problems in family, vocational and social roles. During adolescence, the incidence of psychotic reactions rises rapidly. The young person must deal with the stresses arising from sexual maturation, the decisions to be made in the selection of a vocation and the conflicts that ensue in becoming emancipated from parents and assuming independent status. For women, the middle years are particularly critical, as they terminate the opportunity and hope for child bearing. This period also often brings emotional stress with the departure of children from the home and the need for the mother to find satisfactions in new roles and activities. Men at this age often have emotional problems associated with waning sexual energies and failure to attain to aspired goals. In old age, psychiatric disability tends to be precipitated with the mounting limitations of physical incapacities, the loss of satisfactions from work life and the emptiness of the retirement years, the loneliness that comes through the death of old friends and associates and other stresses.

Sexual Factors.—While sexual behaviour in itself does not appear to be a source of mental disturbance; attitudes toward sexual acts and emotions aroused in relation to sexual strivings contribute to psychiatric illness or influence the content of the illness. No sexual act is in itself a cause of mental illness, but the unremitting anxiety and guilt that some persons experience over such acts may be a cause.

Married persons appear to be considerably less susceptible to mental disorders than the widowed,-single and divorced, but marriage in itself will neither cure nor prevent mental illness. In a marriage from which no sense of security is derived, the emotional disturbance of a partner may be aggravated.

No specific psychiatric disability is aroused by pregnancy or the postpartum period. The mental disturbances which occur sometimes with pregnancy and childbirth arise from the emotional significance these events have to the mother. For a woman who is psychologically unprepared and emotionally immature. the bearing of a child may arouse unconscious and repressed conflicts toward her own parents and siblings. Approximately one-half the psychiatric reactions to pregnancy are schizophrenic; rhe other half are manic-depressive or psychoneurotic.

Alcohol.—Alcohol plays an important role in producing mental disease; there is a direct correlation between the amount of alcohol consumed in a community and the incidence of observed alcoholic psychoses. Underlying the habituation to alcohol usually is a primary personality disturbance. The same personality defect occurs with narcotic addiction.

Disease *and Injury*.—In western countries wnere the diet generally is adequate. cerebral impairment resulting from vitamin and other nutritional deficiencies is seen most often as a secondary complication in the elderly or seriously psychotic. Of infectious processes, syphilis was once the source of the most serious disturbances, but general paresis (*q.v.*) caused by syphilis became infrequent after the development of penicillin treatment.

Congenital or acquired physical defects often play an important role in creating personality disturbance. Acceptance of one's body and its acceptance by others represent a nuclear issue in the development of a secure personality. Children born with defects or children whose physical characteristics are unattractive to their parents often develop self-disparaging and self-defeating attitudes. The consequence is frequently a defect in the ability to make social adaptations that may be severe enough to cause psychiatric disability. Adults who suffer a disruption of their body image through injury, surgery or illness also are liable to personality disturbance. Among the commonest precipitants of psychiatric disability are head injuries, which may lead either to organic brain syndromes or to neuroses.

At one time overwork was considered a cause for mental illness. In the modern view the person who works long hours and excessively does so in order to fulfill a personal need—to reduce anxiety or as an outlet for energy or creativity. Work is also a means of maintaining human contacts in an otherwise withdrawn person. When a breakdown does take place in relation to vocation, usually a disruption of some important human relationship is threatened or has taken place. No evidence exists that mental efforts, in the absence of anxiety, produce psychotic or neurotic illness.

B. Classification

Kraepelin's classification system for mental disorders, established in 1883, was in general use until 1917, when the American Psychiatric association introduced the system that became the basis of that recommended in 1948 by the association in the fourth edition of Standard *Nomenclature* of Diseases and Operations. This classification system is more comprehensive and more flexible than the earlier schemes, and it also can be applied to the practice of psychiatry in general hospitals, in out-patient clinics and in private office practice, as well as in mental hospitals. According to this system, mental disturbances may be classified into three general categories representative of physical and psychological pathology: (1) acute and chronic brain disorders caused by or associated with impairments of brain tissue function; (2) mental deficiency; and (3) psychogenic disorders having no clearly defined physical or structural change in the brain. The psychogenic disorders, the major group, comprise the psychoneuroses, the majority of psychotic reactions, psychosomatic disorders and personality disorders.

1. Brain Disorders.—Acute.—Acute brain disorders are organic brain syndromes, usually temporary, from which a patient recovers. Although they generally involve reversible impairments in brain function, some of these disturbances may result in permanent changes in brain tissue, which can be detected by modern micropathological techniques. For the most part, they are the result of a serious disruption of the metabolism of the brain, particularly its capacity to metabolize glucose, its basic energy source. The symptoms of these disorders have been known under the general term of delirium.

Delirious reactions are characterized by varying degrees of disturbances in consciousness and impaired awareness of surroundings. Some persons have the capacity to develop these reactions more readily than others, and the form and content of the delirium tend to be related to the underlying personality and the life experiences. The delirious person may show variable states of cloudiness, bewilderment, periodic somnolence, stupour or, in the deepest stages, coma. Usually, in states of confusion or bewilderment, the sufferer is anxious or apprehensive. Upon being questioned, he shows impairment in his ability to grasp meaning and to comprehend correctly the environment as to place, time or person. He is disoriented. Along with delusions, some persons experience frightening hallucinations (*q.v.*).

Deliria are commonly associated mith febrile illness, toxic states, metabolic disturbances (such as uremia, pellagra or pernicious anemia), states of cardiac decompensation and trauma following head injury. The best known of the acute brain syndromes is the delirium tremens of the alcoholic. See also Delirium.

Chronic.—Chronic brain disorders result from a permanent impairment of cerebral tissue and are characterized particularly by disturbances in memory, judgment and affect (any experience of emotion or feeling). General paresis was once the most prevalent of these conditions, accounting for 8% to 10% of the patients committed to public mental hospitals. The use of penicillin for the treatment of syphilis greatly reduced the incidence of this disease.

At mid-20th century, the most frequently encountered chronic brain disorders are those suffered by large numbers of elderly presenile persons or those that occur as a consequence of cerebral arteriosclerosis in later life. Both these conditions are most prevalent in the U.S. and in western European countries which have expanding aged populations. In the U.S. chronic brain syndromes due to senile and arteriosclerotic psychoses account for approximately 40% of the hospitalized mentally ill.

2. Mental Deficiency.—This, the second large category of mental disorders, is defined as an impoverishment in intellectual competency which results either from an innate fault in the individual's developmental potentiality or from arrested development. Thus, the mentally defective person is not equipped with intellectual capacities, judgment, social skills and foresight that are possessed by the average person. This condition is discussed in the article Mental Deficiency.

3. Psychogenic Disorders.—Psychogenic disorders are defined as conditions whose causes or origins are not clearly traceable to a physical cause or to structural damage of the brain and the nervous system. These disorders include the major psychoses, such as the schizophrenic, paranoid, manic-depressive and involutional reactions; psychophysiological (psychosomatic) reactions; psychoneurotic reactions; and personality disorders. They are characterized by varying degrees of personality disturbances, ranging from catastrophic to minor interference in interpersonal relations. Distinctions are easily made between the psychoses and psychoneuroses when the symptoms are well-defined, but these illnesses can be very difficult to differentiate at their early stages or in the borderline states. Symptomatology most commonly is the basis of distinction, but the disorders are also distinguished on legal and social grounds.

Psychosis.—The diagnosis of psychosis usually implies a greater severity of personality disturbance than that occurring in psychoneurosis. In the psychotic person the inner emotions and experience are so disturbing that he is frequently unable to carry on ordinary social functions. The psychotic has a limited capacity for differentiating his own subjective experiences, *i.e.*, describing what he is, has actually observed, tried or known; his capacity to interpret and respond to his environment therefore is gravely impaired. In other terms, he is unable to deal with reality; he creates his own special environment in which his perceptions are distorted or falsified in the form of delusions or hallucinations. The thought processes of the psychotic are often so disorganized that his thinking appears disrupted and irrational. (*See* also Psychoses.)

Psychoneurosis.—Unlike the psychotic, the psychoneurotic presents personality traits which are regarded as a socially acceptable adaptation against anxiety. In psychoneurosis, the inner experiences do not bring about a gross disturbance of external behaviour. The neurotic has the ability to maintain contact and good testing of the external environment. Although his thinking may be restricted or distorted by his overvalued and limited ideas, he does not suffer delusions and hallucinations. Moreover, he is not excessively withdrawn socially, and he usually retains his interest in the people and the world about him.

The question as to whether a neurosis may become a psychosis has been argued for years, but there is no certain or definitive knowledge. Psychiatrists who consider the psychotic reaction as a disease process usually reject the idea that progression can occur. On the other hand, most psychiatrists recognize a large number of borderline states, particularly with schizoid personalities, where the social adaptation of the patient is very precarious. The multiplicity of neurotic symptoms that certain patients suffer, the ambivalence they demonstrate, their disturbed psychosexual iife and their poorly developed self-concept have given rise to the classification by some psychiatrists of "pseudoneurotic schizophrenics." (*See* also Neuroses.)

Personality Disorders.—Personality disorders are a group of conditions in ahich there are persisting patterns of inadequate or antisocial behaviour rather than of predominantly psychological or emotional disturbances that cause suffering and a sense of distress. Persons who always react mith undue excitability and ineffectiveness in the presence of minor stress or who regularly display judgment that is not dependable are among those classified as having personality disorders. Such persons have little control over their hostile feelings, are fickle in their relations with others and are unable to form enduring or satisfactory relationships. Vocationally and socially these persons do poorly, even though they may be of normal or superior intelligence and physically well-endowed. Also included in the group with personality disorders are persons who exhibit extreme emotional instability characterized by explosive outbursts of rage upon minor provocation. At times, these personalities may be blustering and threatening; at other times they can be despairing and inaccessible. Two other common forms of personality disorder are seen in persons exhibiting either passive dependence reactions or passive aggressive reactions. The former are generally helpless, indecisive and clinging. When faced with minor problems, they show anxious and panic-stricken behaviour. In contrast, the passive aggressive person expresses his hostility in stubbornness. procrastination and inefficiency.

One of the most complex groups of the personality disorders is the category of sociopdths. Persons with sociopathic tendencies act out their hostility on the rest of the world. As a group, they make up the mass of the criminals and delinquent elements of society. Their symptomatology may also include various kinds of pathology expressed in sexual deviations. The commonest expression of this is homosexuality, but there are other forms, such as exhibitionism, voyeurism, masochism and sadism. (See also HOMOSEXUALITY; SEXUAL DEVIATIONS.)

Psychophysiologic Disorders. — In the psychophysiologic disorders, also designated psychosomatic conditions, anxiety produces a dysfunction in bodily organs through inappropriate activation of the involuntary nervous system and the glands of internal secretion. Thus the psychosomatic symptom emerges as a physiological concomitant of an emotional state. For example, in a state of rage, the angry man's blood pressure is likely to be elevated and his pulse and respiratory rate to be increased. When the anger passes, the heightened physiologic processes usually subside. However, if the man had a persistent inhibited aggression (chronic rage) which he was unable to express overtly, the emotional state remains unchanged, though unexpressed in the overt behaviour, and the physiological symptoms associated with the angry state persists. With time, such a person becomes aware of the physiological dysfunction. Very often he develops concern over what appears as an inappropriate activation of body organs, but he will deny or be unaware of the emotions which evoke the reactions. See above, History: *Modern Schools:* Psychosomatic Medicine.

III. TREATMENT OF MENTAL DISORDERS

1. Psychopharmacology.—One of the most striking advances in the symptomatic treatment of mental illnesses in the first half of the 20th century was the development of the series of pharmacological agents commonly known as tranquilizers. These drugs contrast sharply with the hypnotic and sedative drugs that formerly were in use and that clouded the patient's consciousness and impaired his motor and perceptual abilities. The tranquilizers can allay the symptoms of anxiety and reduce agitation with much less disturbance of consciousness. However, valuable as the tranquilizing substances have been, there is need for further study of their effects alone and in combination with other drugs; also drugs with extended and improved properties should be developed. Occasionally the tranquilizing drugs have toxic side effects, giving rise to such conditions as jaundice or a parkinsonianlike reaction; both these symptoms are reversible upon withdrawal of the drug. The drugs produce other minor symptoms because of their action on the autonomic nervous system.

Tranquilizers are used in treating many different kinds of disturbances but are particularly effective in relieving the symptoms of tension, overactivity, agitation, impulsiveness, explosive outbursts and destructive behaviour. Since they are prescribed for symptoms, they are not specific to the treatment of any diagnostic category. They have been more useful in treating the various psychotic states than in psychoneurotic reactions and personality disorders. The drugs also have been used in the treatment of toxic delirious states resulting from overuse of alcohol and in mental conditions resulting from brain damage.

Because of their ability to modify the behaviour of even the most disturbed patients, these agents have affected greatly the management of the hospitalized mentally ill. They have been responsible for dramatic changes in the behaviour of many psychotic patients. The noisy, untidy, crowded and unpleasant atmosphere that formerly pervaded the wards of many mental hospitals has largely disappeared; in the absence of the destructiveness. apathy and untidiness formerly exhibited by many patients, hospitals can be maintained more attractively. Because of the quieting effects of the tranquilizers, hospital staffs are able to devote more of their attention to other therapeutic efforts, and patients have been given greater freedom to move about and much more rehabilitative assistance. (See also NEUROPHARMACOLOGY AND PSYCHOPHARMACOLOGY; TRANQUILIZING DRUGS.)

2. Shock Therapy. — In 1933. Manfred Sakel of Vienna presented the first report of his work with insulin shock. Until the discovery of the superiority of the tranquilizing agents, variations of insulin shock therapy (also called insulin coma therapy) were commonly used in the treatment of schizophrenia and other psychotic conditions. With insulin shock treatment, the patient is given increasingly large doses of insulin which reduce the sugar content of the blood and bring on a state of coma. Usually the comatose condition is allowed to persist for about an hour, at which time it is terminated by administering warm salt solution via stomach tube or by intravenous injection of glucose. Insulin shock had its greatest effectiveness with schizophrenic patients whose illness had lasted less than two years (the rate of spontaneous recovery from schizophrenia also is highest in the first two years of the illness). Insulin shock therapy also had more value in the treatment of paranoid and catatonic schizophrenia than in the hebephrenic types.

Electroconvulsive therapy, introduced in Rome in 1938 by U. Cerletti and L. Bini, has been widely used in treating disturbance5 in which severe depression is the predominant symptom. It has been particularly recommended for manic-depressive psychoses and other types of depression. The technique is essentially the passage of alternating currents through the head between two electrodes placed over the temples The passage of the current causes an immediate cessation of consciousness and the induction of a convulsive seizure. In general, electroconvulsive treatments are given three times a week for a period ranging from two to six weeks; some acutely disturbed patients, however. have been given as many as two or three treatments in a single day. Following a course of treatment there is usually an impairment of memory, varying from a slight tendency to forget names to a severe confusional state. The memory defect diminishes gradually over several months. Electroconvulsive therapy, like insulin shock, declined in use after the tranquilizing drugs were introduced.

3. Psychosurgery.—The first treatment of mental disturbances by means of brain surgery was developed by the Portuguese neurologist Antonio de Egas Moniz (*q.v.*), the first operation being performed by Egas Moniz' colleague Almeida Lima, in 1935. The operation, called prefrontal lobotomy or leucotomy mas based on experimental studies demonstrating that certain neurotic symptoms induced in chimpanzees could be modified by cutting brain fibres. Egas Moniz' original operation consisted of cutting two openings in the skull, one on each side above the temple. and then severing the nerve fibres connecting the thalamus with the frontal lobes of the brain.

Prefrontal lobotomy has come to be generally regarded as a radical procedure to be followed only after all other forms of treatment have proved ineffective, and since the introduction of the tranquilizing agents the condition of only a very few patients warrants such a drastic measure. Patients selected for this operation usually show chronic agitation and severe distress, persistent depression, emotional aggressiveness and excited and impulsive behaviour. Phobias, obsessions, hallucinations and delusions not of long-standing duration have been relieved by this procedure. On the other hand, psychosurgery has had relatively little effect in modifying behaviour that characteristically expresses cruelty, avoidance of responsibility, excessive use of alcohol or pathological sexuality; it also has proved generally ineffective in the treatment of the chronic and withdrawn psychotic. The procedure tends to accentuate difficult personality traits by lowering inhibitory controls and by leading to development of facetious and tactless social behaviour. Many patients after the operation tend to shoa Increase in self-esteem coupled with lack of self-criticism.

The effect of lobotomy on intellectual functions has been a subject of much controversy. Ordinary psychological tests and observations reveal little change in the patient's psychological functioning in the months immediately following the operation.

It is believed, however, that lobotomy results in significant deterioration in intellect over the course of years. Patients who prior to their illness possessed the ability to perform tests requiring a high degree of abstraction showed great impairment in these capacities after lobotomy. Also, close observation of performance of persons with high intellectual capacity indicates a reduction in such capacity after surgery.

4. Psychotherapy. — Psychotherapy is the treatment of personality disturbances by psychological means. The essential factor in the many different techniques of psychotherapy is the establishment of an understanding and accepting relationship between therapist and patient. In this relationship, the therapist does not deprecate, censure or judge the patient, and the patient is encouraged to discover and speak of his emotional life. This is necessary if the aim of treatment is greater insight into the sources of the patient's difficulties and his achievement of greater personal satisfactions. There are many types of psychotherapy, and the indications for their use depend upon a number of variables, including the nature of the illness, age and intellectual capacity of the patient, estimate of his motivation and his capacity to face anxiety. These are discussed in the separate entries PSYCHOTHERAPY; PSYCHOANALYSIS; and PSYCHOLOGY, APPLIED: *Clinical* Psychology.

IV. CHILD PSYCHIATRY

The increasing recognition of the crucial influence of parent-child relationships on the child's personality development has provided a strong impetus to the study of psychiatric disorders of childhood. The approach to the diagnosis and treatment of children's mental and emotional disturbances is necessarily different from that with adult patients. The child is living through the most active and critical phases of his development. His personality is constantly being molded and changed as he moves from one developmental stage to another. In assessing the healthy or unhealthy patterns of a child's personality development, the psychiatrist must have extensive knowledge of the ever-changing patterns of personality, particularly at the various age levels through adolescence.

Although many of the general principles relating to therapy of adult psychiatric disorders apply to child psychiatry, a number of special problems arise with children which require special techniques. Usually the parents of the child bring him for treatment, or he is referred to the psychiatrist by a community agency — the school or the juvenile or family court. Because much of the essential information on the child's behaviour and other medical, psychological and social factors must be obtained from the parents, the pediatrician, psychologist, teacher or social workers, child psychiatrists work closely with the parents and other specialists who have been in frequent or close contact with the child. Thus, in the field of child psychiatry, the working relationship between the psychiatrist and the related social and medical disciplines is closer and more essential than it is in adult psychiatry, where the patient usually can provide much of the pertinent and necessary information on his life and his condition.

For the most part, child psychiatry is concerned with the study and treatment of the different neurotic reactions or problems of emotional maladjustment that affect children. The emotional maladjustments of children frequently are manifested in behaviour difficulties, unpleasant character traits or psychosomatic disturbances. Neurotic reactions include habit spasms. stammering, overactivity and phobias. Ticlike movements of the face and other parts of the body are common. Among infants, deprivation of mothering or problems in the infant's relationship with the mother may lead to withdrawn behaviour, continuous crying, inability to eat, insomnia and physical or mental retardation or both. Older children are often seen for such habit disturbances as persistent nail biting, thumbsucking, bedwetting and temper tantrums. Children also are referred for treatment because of conduct problems or propensities for disobedience, lying, stealing, destructiveness, fighting, fire setting, cruelty and running away from home.

As in the treatment of adult patients, psychiatric treatment of children requires determination of any genetic, constitutional or physical factors that have contributed to the disturbance. Also, it is essential that the relationship between the child and the parent be assessed for its contribution to the disturbed behaviour. Where there are disturbing influences that can be associated with parental dissension, alcoholism, hostility, cruelty, neglect, overprotection of the child, excessive ambitions for and expectations of the child, it is common to find behavioural disorders. The existence of neurotic, psychotic or psychopathic illness in the parents also contributes to a faulty parent-child relationship. The parents' unconscious feelings about the child and the kinds of conflicts which disturb the parent-child relationship also must be determined. (It must be recognized that the emotional behaviour of the parents is sometimes the result rather than the cause of the child's misdemeanours.) Another important source of personality problems is the child's relationship with brothers and sisters. In addition, the death or loss of a parent often has a profound and lasting effect, as it reduces the child's opportunity for healthy growth through continuing identification with or differentiation from the absent parent.

School experiences also can create personality problems. Many children exhibit conduct and learning disturbances because they have been unable to cope with modern methods of instruction. Children with perceptual difficulties, for example, may fail to learn to read or may not develop the reading skills appropriate to their age level, because of the scanning method of teaching reading without phonetic sounds or spelling out the letters in a word. As a consequence, they often become anxious over their failure to meet the standards of their family and their class. When these emotions are aroused, conduct disturbances may ensue.

V. PSYCHIATRIC TRAINING AND ORGANIZATION

A. TRAINING

1. United States. — In the United States, to qualify as a specialist in psychiatry, a physician must complete a period of training in an accredited or qualified hospital or other institution. Usually the physician enters a psychiatric residency training program after one year of medical internship, which followed his obtaining the degree of doctor of medicine from an accredited medical school. Residency training in psychiatry provides supervised experience in the diagnosis and treatment of mental and emotional illnesses. It includes opportunities for using all the varieties of treatment in specialized psychiatric hospitals and institutions, out-patient departments, various kinds of children's services and general hospitals. The resident physician in psychiatry also is required to take formal course work in such fields as psychobiology, psychopathology and psychodynamics, neuroanatomy, neurophysiology and neuropathology. Upon completion of this training, the physician may apply for examination by the American Board of Psychiatry and Neurology. The certificate of the board indicates that the physician has completed his general training; it does not measure his level of competence in the performance of special therapies.

The clinical psychologist, in contradistinction to the specialist in psychiatry, is not trained in medicine. He has the degree of doctor of philosophy in psychology and has been trained in the theory and practice of psychological testing of mental patients. In some institutions he may, under supervision, receive training to do certain forms of psychotherapy. The training of the clinical psychologist, unlike that of the psychiatrist, does not equip him to diagnose, to prescribe drugs and medicine, or to administer shock therapy and other psychiatric diagnostic and treatment procedures.

For the most part, the psychoanalyst in the United States has obtained the degree of doctor in medicine and has completed a residency in psychiatry. In addition, he has completed the requirement of a personal psychoanalysis and has conducted the analysis of several patients under the supervision of a qualified training analyst. Also he has undertaken and completed certain other didactic and clinical training. The majority of qualified psychoanalysts in the United States are members of or candidates for membership in the American Psychoanalytic association.

A small group of clinical psychologists, social workers and others also have been trained to do psychotherapy and psychoanalysis. These persons were trained largely in the past by psychoanaiysts in England and other western countries of Europe. The U.S. medical profession generally believes that clinical psychologists, social workers and lay analysts who practise psychotherapy or psychoanalysis should do so in collaboration with a psychiatrist or a physician. This position is based on the belief that proper psychiatric diagnosis requires a physical and neurological examination; only those trained in medicine are able to decide whether the somatic symptoms of an illness are due to an underlying physical process or are representative of an emotional disturbance. On the other hand, psychologists and other nonmedical persons trained in psychoanalysis have made many fundamental and valuable contributions toward the elucidation of the basis of behaviour and the understanding of personality development.

2. Great Britain.--In Great Britain the physician may begin his training for the specialty of psychiatry after he has completed his preregistration appointments and his national service. He then serves on the staff of a mental hospital for a minimum of two years, at which time he may be examined for the diploma in psychological medicine (D.P.M.) by the Conjoint board. The D.P.M. does not qualify the recipient as a consultant in the national health service; such senior appointments are approved by a committee of outstanding specialists, who judge the candidate in competition with others applying for the post.

The teaching program of the Institute of Psychiatry of the British Postgraduate Medical federation conducted at the Maudsley and Bethlem Royal hospitals in London is similar to that of the best residency programs in the United States. In terms of formal scholarship. the British institute is more exacting than any of the American institutes. The British institute awards its own D P.M., which has higher standards and requires more extensive training than the certificate of the Conjoint board. While the British institute is the only fully developed British university postgraduate centre in psychiatry, Great Britain has other institutes, hospitals and clinics in which special kinds of psychiatric training can be obtained. The Institute of Psychoanalysis in London provides specialized training much like that of the psychoanalytic institutes and training centres in the United States.

3. Other **Countries.**—In Canada, although each province makes its own arrangements for awarding diplomas in psychiatry, the training of the physician specializing in psychiatry is much like that of the psychiatrist trained in the United States. The training of psychiatrists in Australia and New Zealand is similar to English psychiatric training. South Africa has modeled its training program in psychiatry closely after that of the Netherlands. There, to become registered as a specialist psychiatrist or specialist in mental disorders, the applicant must be qualified as a medical practitioner for at least six years, and must satisfy certain clinical requirements in medicine and surgery as well as in psychiatry. Upon fulfilling these requirements satisfactorily, he obtains a higher degree in his specialty. Several universities in India award a diploma in psychological medicine,

B. Organizations

1. United States.—The American Psychiatric association, oldest national medical association in North America, was founded in 1384, and in the early 1960s had a membership of more than 10,000 psychiatrists, The organization has an information service, and publishes several journals as well as a biographical directory of its members. Its aims are the improvement of treatment of the mentally ill and the furtherance of psychiatric education and research.

The National Institute of Mental Health of the United States public health service is the major federal government agency concerned with the prevention and treatment of psychiatric disorders. Through the provisions of the National Mental Health act of 1946, the institute makes grants-in-aid to support training, research and community services in the United States. The institute also conducts an extensive research program at the National Institutes of Heaith in Bethesda, Md.

2. Great Britain.—In Great Britain the important official bodies concerned with mental illness are the Board of Control (psychiatric division of the ministry of health) and the General Board of Control for Scotland. Under provisions of the New Mental Health act, before parliament in the early 1960s. these boards would be abolished and regional mental health review tribunals established. A standing Mental Health Advisory committee (a statutory body) aids and advises the minister of health on mental health matters. The Medical Research council plays an important role in distributing funds for psychiatric research.

In England, the major professional psychiatric organization is the Royal Medico-Psychological association. Similar professional bodies have been established throughout the British commonwealth. The Canadian Psychiatric association, chartered in 1951 and associated with the Canadian Medical association, has more than 600 members. Since most matters related to the practice of medicine fall within the jurisdiction of the provincial governments in Canada, the Canadian Psychiatric association has been active in developing its relations with these governments.

3. Other Countries.--Psychiatrists of Australia and New Zealand are organized as the Australian Association of Psychiatrists. In India, the psychiatric organization is known as the Indian Psychiatric society. In South Africa the National Group of Neurology, Psychiatry and Neurosurgery represents the aims of the specialty. Each organization supplies information on its aims, its members and the psychiatric facilities of the country. Similar organizations exist in other European and South American countries.

4. International.—International bodies concerned with mental health are discussed in the article MENTAL HEALTH.

See PSYCHOLOGY, ABNORMAL; NECROSES; PSYCHOSES; PARANOID REACTIONS; SCHIZOPHRENIA; DEMENTIA; etc.; see also Index references under "Psychiatry" in the Index volume.

BIBLIOGRAPHY.—Sigmund Freud, *Vorlesungen zur Einfuhrung in die Psychoanalyse* (1916–18), auth. Eng. trans. rev, ed., *General Introduction to Psychoanalysis*, by Joan Riviere, pref. by E. Jones and G. Stanley Hall (1920 *et seq.)*; E. Jones, *Lije and Work of Sigmund Freud*, 3 vol. (1953–57); F. J. Kallmann, *Heredity in Health and Mental Disorder* (1953); Adolf Meyer, *Commonsense Psychiatry*, ed. by A. Lief (1948); "Life Stress and Bodily Disease," *Res.* Pub., *Assn. Res. in Nerv. & Ment. Dis.*, vol. xxix (1950); A. P. Noyes and L. C. Kolb, *Modern Clinical Psychiatry*, 5th ed. (1958); H. S. Sullivan, *Interpersonal Theory* of *Psychiatry*, ed. by H. S. Perry and M. L. Gawel (1953); J. Taylor (ed.), *Selected Writings of John Hughlings Jackson*, vol. ii (1958); G. Zilboorg and G. W. Henry, *A History of Medical Psychology* (1941); B. Hart, *Psychology of Insanity*, 4th ed. (1931); T. A. Ross, *Common Neuroses*, 2nd *ed.* (1937); J. C. Whitehorn, *Psychotherapy, Modern Medical Therapy in General Practice* (1940); L. B. Kalinowsky and P. H. Hoch, *Shock Treatments, Psychosurgery and Other Sonzatic Treatments in Psychiatry*, 2nd ed. (1952).

(L. C. K.)

PSYCHICAL RESEARCH. Psychical research is the scientific study of various odd happenings which are often reported and believed in but about the reality of which there is considerable doubt. Examples of such alleged occurrences are thought transference, foretelling the future, hauntings involving both appearances of ghosts and movements of objects, messages received through mediums from the spirits of those who have died, etc. All such alleged events may be included in the class of the paranormal, and are such that the general principles of scientific expectations would make them seem impossible. Early subjects of study by psychical research included hypnotism, which is no longer regarded as paranormal and which fits in to the scientific picture of the human organism (see HYPNOSIS). It is the aim of psychical research to achieve a similar scientific understanding of any paranormal phenomena that do not prove to be illusory.

In 1882 the Society for Psychical Research was founded in England. Its first task was to study objectively the evidence for the various paranormal phenomena, in order to discover whether they were real or merely results of fraud or errors of observation. Its second task was the scientific investigation of any paranormal phenomena that were proved to be real, in order that their nature might be more fully understood and that they might take their place with the accepted data of science. In some cases (of which the best-known example is thought transference or telepathy) the first task has been achieved: it is known that they really take place and the present concern is to find out more about their nature. In other cases (such as hauntings) modern investigators possess little more reliable knowledge than the pioneers of the early days of psychical research did; inquiries are still being made regarding how much of what is alleged is description of real events of a paranormal character and how much is the misinterpretation of purely natural events.

The founding of the Society for Psychical Research in London was followed six years later by the founding of a similar society in the United States. Similar societies were founded later in most European countries, and active work is carried on. particularly in the Netherlands, France and Italy. Universities have been slower to recognize psychical research as a serious subject for study. The founding of the parapsychological laboratory at Duke university, Durham, N.C., under J. B. Rhine in 1927 was an important step in this direction. Later a department of psychical research was opened at the University of Utrecht under W. H. C. Tenhaeff.

One of the causes of interest in psychical research in the last half of the 19th century was the rise of the spiritualist movement about the middle of that century; many intelligent persons were uncertain of the reality of the alleged facts on which spiritualism was based, and were uneasy about their uncertainty. Spiritualism grew out of the acceptance of the reality of spirit communication and the use of this as the basis of a new religion. Psychical research grew out of curiosity as to these facts and the determination to submit them to scientific investigation. These were not necessarily divergent interests: some of the early psychical researchers were also spiritualists, as, for example, F. W. H. Myers and Sir Oliver Lodge. Other psychical researchers (such as the physiologist C. Richet) accepted the facts of spiritualism but rejected the spiritualist explanation, while others were not committed to either view.

Existence After Death.—This interest in the problems of spiritualism led to the consideration by psychical research from its earliest days of empirical evidence for human survival of death, evidence derived from mediumistic seances or from any other field of observation. It is with empirical evidence only that psychical research is concerned, not with the validity of any form of reasoning offered in proof or disproof of the continuance of human existence after death. While some progress has been made in this problem, the advance has been by no means spectacular. In some nays, advances in psychical research have made the solution of the problem of providing proof of survival more difficult. The experimental demonstration of the existence of psi cognition (obtaining knowledge by telepathy or clairvoyance) as a paranormal capacity among some persons makes it possible to explain evidence by information apparently coming from spirits, as possibly resulting from the psi cognitive capacities of the medium. For example, some of the early researchers (*e.g.,* Myers and Lodge) left sealed packages with the intention of communicating the contents after their death. In fact, neither experiment was successful, but if they had succeeded their success might have been explained as due to the clairvoyant powers of the medium. A modification of such an experiment is an attempt by a medium to communicate the message during the lifetime of the person depositing it; failure during his lifetime followed by success after his death would provide strong though not coercive evidence that he was communicating after death. No experiment of this type, however, had been completed by the beginning of the 1960s.

Cross-correspondence was a type of evidence which started to develop soon after Myers' death in 1901. Ostensibly this was an experimental demonstration of survival arranged from the other side of the grave, presumably by Myers himself. Essentially it was communication, through different mediums. of fragments of a message which made a coherent whole only when fitted together. Success in such a task cannot easily be explained by reference to the paranormal cognitive powers of the medium. Its results are not easy to evaluate, but many competent judges are of the opinion that the cross-correspondences provide strong evidence of the survival of the deceased persons who were their ostensible originators.

Evidence along different lines was sought by Whately Carrington, who applied psychological tests to communicators in the attempt to discover whether a single communicator coming through different mediums showed constant measurable characteristics that would indicate that he was one and the same person. Critical examination of Carrington's results shows that he obtained no evidence of the identity of his communicators. The research method was ingenious, however, and the problem remained to be taken up by some other research worker.

Telepathy.—Much more striking success has attended the experimental investigation of what is called thought transference or telepathy. The typical form of this experiment is that in which the task is card guessing: an agent turns up and looks at successive cards in a pack of playing cards and a percipient tries to tell him which they are. Promising results were obtained early but critics urged the necessity for further precautions against error before it could be accepted that a thought could pass from one mind to another without use of the ordinary sensory channels of communication. Further experiments with a different type of card mere carried out at Duke university (see PARAPSYCHOLOGY). They were also carried out with full precautions against error and a high rate of success by S. G. Soal and K. M. Goldney in Great Britain.

In the meantime, however, Rhine had thrown doubt on the appropriateness of regarding these as tests of telepathy, since he found that equal success could be obtained when no one looked at the cards. The performance mould then commonly be called clairvoyance. Extrasensory perception (ESP) is a term commonly used now to cover both telepathy and clairvoyance. The more noncommittal term psi has also been suggested to cover all types of paranormal cognition, and is widely used and understood.

There is, from time to time, an arousal of public interest in telepathy through the appearance on the stage of an entertainer who is supposed to demonstrate telepathy. Less frequently the demonstration is of "eyeless sight." The resources of stage telepathy have been enlarged by the development of small wireless receiving sets which can be concealed on the person, although impressive demonstrations were given earlier by the use of codes and other methods. Such trick telepathy has no bearing on the question of whether real extrasensory perception takes place. The experimenter has the task of arranging his conditions so that the experimental subject has no opportunity to trick him. Without such precautions, the experiment is of no value for demonstrating the reality of the phenomenon under investigation.

Supernatural Foresight.—A form of paranormal cognition for which there is a long tradition of anecdotal evidence is the foreseeing of the future by dreams and by various devices such as looking at the flight of birds or at the entrails of sacrificial animals, or listening to the wind blowing through leaves (see DIVINATION). No important contribution to psychical research has been made by studying any of these devices. On the other hand, experiments have been done in which the percipient's task is to guess the future order of a pack of cards after a process of shuffling and cutting. There seems to be a strong indication that some subjects can succeed in such a task of precognition, although the evidence is less overwhelmingly strong than that for experimental extrasensory perception.

Physical **Phenomena.**—Psychical research has also been concerned with paranormal physical phenomena such as levitation, materialization and the moving of heavy objects. Sir William Crookes studied both the phenomena of the medium D. D. Home (*q.v.*) and a materialized figure (Katie King) which developed in the presence of the medium Florence Cook, and satisfied himself as to their genuineness. **A** remarkable physical medium was an uneducated Italian woman, Eusapia Palladino, who exasperated psychical researchers by her crude attempts to cheat if controls were relaxed. **A** critical experimental study of her, however, by three experienced psychical researchers produced striking physical phenomena under conditions which the experimenters considered were such that fraud was impossible.

The most remarkable studies of materializations were made in France by G. Geley and Richet. Wax gloves have been produced which are reported to have been made by spirit hands dipped into molten wax and dematerialized after the wax solidified. There are numerous photographs of the quasi-material substance ectoplasm, which is supposed to be exuded from the medium's body to form the substantial basis for materializations. Many of these photographs show part of the ectoplasmic substance in the shape of human faces or other parts of the human form. These photographs are plainly not in themselves evidence of the reality of ectoplasm, as the wax gloves are not evidence of the reality of materialized hands. In both cases, their weight as evidence depends on the reliability of the persons obtaining them.

Physical phenomena are often lightly dismissed because they can easily be simulated by fraudulent means and are so simulated by dishonest mediums. Their investigation is made difficult by the fact that they are generally produced in darkness or reduced light. At the same time, it should be noticed that those investigators who became convinced of their genuineness were fully alive to the possibilities of fraud and were satisfied that their precautions to exclude fraud were adequate. Such experienced scientific investigators as Crookes, Lodge, Sir W. Barrett and Richet could not have been easily deceived.

Spontaneous Phenomena. — In addition to these various experimental lines of investigation, a large field of spontaneous phenomena has engaged the attention of psychical researchers. This field includes apparitions of the living and of the dead and also hauntings. An early inquiry into apparitions revealed that these had little of the appearance of the ghost of fiction. They were not vague sheeted figures, but of the form and appearance of living persons for which they were often mistaken. It has been argued that there is little reason for regarding them as spirits but rather as hallucinatory perceptual experiences which may originate from a genuinely paranormal process. It was argued that apparitions of persons near the point of death occurred too often for the coincidence between death and the apparition to be entirely a chance coincidence.

Spontaneous reports of hauntings suggest that these are of two main types: that in which an apparition is repeatedly seen in the same place and that in which the main phenomena are noises and displacement of household objects. A good example of the former type is the apparition described by a woman who wrote in the *Proceedings of the Society for Psychical Research* (vol. viii, *1892)* under the pseudonym of Miss Morton. This apparition was constant in form, stereotyped in action, seen only occasionally and never when watched for. It was sometimes seen by more than one person at the same time, but also it might be seen by one person and not by another who was also present; it could apparently be seen by animals. The seeing of it differed, therefore, from the perception of a material object and also from an autogenic hallucination. Various theories have been put forward, but the data on hauntings are neither full enough nor sufficiently systematically collected to make it possible to subject alternative theories to critical tests.

The haunting characterized by noise and displacement of objects is commonly called a poltergeist haunting, and cases have been reported for a long time. Epworth rectory, Lincolnshire, the home of Charles Wesley, was the scene of such phenomena, and W. Barrett had the opportunity of observing and recording similar events at Derrygonnelly farm.

Poltergeist phenomena at different times and different places show a curious parallelism. One feature that nearly all have in common is the presence of a young person, boy or girl, somewhere between the ages of *12* and *20.* This fact led many of the early observers to suppose that all poltergeist phenomena were products of normal mischief. Many cases, however, cannot be explained in this may without much straining of the evidence. There seems to be better ground for supposing that the phenomena (whether normal or paranormal) are products of mental strain in the young person concerned. Various theories have been put forward to account for poltergeist phenomena, many of which have little evidential support. A fuller understanding must await a closer study of such cases with the use of modern recording devices. Sensational newspaper stories of poltergeist phenomena are not to be regarded as a safe basis for any kind of theory. *See* also PARAPSYCHOLOGY; SPIRITUALISM.

BIBLIOGRAPHY.—C. Richet, *Thirty Years of Psychical Research* (1923); E. Osty, *Supernormal Faculties in Man* (1923); G. Geley, *Clairvoyance and Materialisation* (1927); H. F. Saltmarsh, *Evidence of Personal Survival From Cross-Correspondence* (1938); S. G. Soal and F. Bateman, *Modern Experiments in Telepathy* (1954); R. C. Johnson, *Psychical Research* (1955); J. B. Rhine and J. G. Pratt, *Parapsychology* (1958); G. R. Schmeidler and R. A. McConnell, *ESP and Personality Patterns* (1958).
(R. H. T.)

PSYCHOANALYSIS. In the years *1880–82* a Viennese physician, Josef Breuer (1842–1925), discovered a new procedure by means of which he relieved a girl, who was suffering from severe hysteria, of her various symptoms. The idea occurred to him that the symptoms were connected with impressions which she had received during a period of excitement while she was nursing her sick father. He therefore induced her, while she was in a state of hypnotic somnambulism, to search for these connections in her memory and to live through the "pathogenic" scenes once again without inhibiting the affects that arose in the process. He found that when she had done this the symptoms in question disappeared for good.

This was at a date before the investigations of J. M. Charcot and Pierre Janet into the origin of hysterical symptoms, and Breuer's discovery was thus entirely uninfluenced by them. But he did not pursue the matter any further at the time, and it was not until some ten years later that he took it up again in collaboration with Sigmund Freud. In *1895* they published a book, *Studien über Hysterie,* in which Breuer's discoveries were described and an attempt was made to explain them by the theory of *catharsis.* According to that hypothesis, hysterical symptoms originate through the energy of a mental process being withheld from conscious influence and being diverted into bodily innervation *(conversion).* A hysterical symptom would thus be a substitute for an omitted mental act and a reminiscence of the occasion which should have given rise to that act. And, on this view, recovery would be a result of the liberation of the affect that had gone astray and of its discharge along a normal path *(abreaction).* Cathartic treatment gave excellent therapeutic results, but it was found that they were not permanent and that they were dependent on the personal relation between the patient and the physician. Freud, who later proceeded with these investigations by himself, made an alteration in their technique, by replacing hypnosis by the method of free association. He invented the term *psychoanalysis,* which in the course of time came to have two meanings: (1) a particular method of treating nervous disorders and *(2)* the science of unconscious mental processes, which has also been appropriately described as "depth psychology."

Subject Matter of Psychoanalysis. — Psychoanalysis finds a constantly increasing amount of support as a therapeutic procedure, because of the fact that it can do more for certain classes of patients than any other method of treatment. The principal field of its application is in the milder neuroses — hysteria, phobias and obsessional states — but in malformations of character and in sexual inhibitions or abnormalities it can also bring about marked improvements or even recoveries. Its influence upon dementia praecox and paranoia is doubtful; on the other hand, in favourable circumstances it can cope with depressive states, even if they are of a severe type. In every instance the treatment makes heavy claims upon both the physician and the patient: the former requires a special training, and must devote a long period of time to exploring the mind of each patient, while the latter must make considerable sacrifices, both material and mental. Nevertheless, all the trouble involved is as a rule rewarded by the results. Psychoanalysis does not act as a convenient panacea (*cito, tute, jucunde,* "I proclaim, be secure, be happy") upon all psychological disorders. On the contrary, its application has been instrumental in making clear for the first time the difficulties and limitations in the treatment of such affections.

The therapeutic results of psychoanalysis depend upon the replacement of unconscious mental acts by conscious ones and are operative in so far as that process has significance in relation to the disorder under treatment. The replacement is effected by overcoming internal resistances in the patient's mind. The future will probably attribute far greater importance to psychoanalysis as the science of the unconscious than as a therapeutic procedure.

Depth Psychology. — Psychoanalysis, in its character of depth psychology, considers mental life from three points of view: the dynamic, the economic and the topographical.

From the first of these standpoints, the dynamic one, psychoanalysis derives all mental processes (apart from the reception of external stimuli) from the interplay of forces, which assist or inhibit one another, combine with one another, enter into compromises with one another, etc. All of these forces are originally in the nature of instincts; that is to say. they have an organic origin. They are characterized by possessing an immense (somatic) persistence and reserve of power (repetition-compulsion), and they are represented mentally as images or ideas with an affective charge (cathexis). In psychoanalysis, no less than in other sciences, the theory of instincts is an obscure subject. An empirical analysis leads to the formation of two groups of instincts: the so-called "ego instincts," which are directed toward self-preservation, and the "object instincts," which are concerned with relations to an external object. The social instincts are not regarded as elementary or irreducible. Theoretical speculation ieads to the suspicion that there are two fundamental instincts which lie concealed behind the manifest ego instincts and object instincts; namely, (a) Eros, the instinct which strives for ever closer union, and (b) the instinct for destruction. which leads toward the dissolution of what is living. In psychoanalysis the manifestation of the force of Eros is given the name *libido.*

Pleasure-Pain Principle. — From the economic standpoint, psychoanalysis supposes that the mental representations of the instincts have a cathexis of definite quantities of energy, and that it is the purpose of the mental apparatus to hinder any damming up of these energies and to keep as low as possible the total amount of the excitations to which it is subject. The course of mental processes is automatically regulated by the pleasure-pain principle, and pain is thus in some way related to an increase of excitation and pleasure to a decrease. In the course of development the original pleasure principle undergoes a modification with reference to the external world, giving place to the *reality principle,* whereby the mental apparatus learns to postpone the pleasure of satisfaction and to tolerate temporarily feelings of pain.

Mental Topography. — Topographically, psychoanalysis regards the mental apparatus as a composite instrument, and endeavours to determine at what points in it the various mental processes take place. According to the most recent psychoanalytic views, the mental apparatus is composed of an id, which is the reservoir of the instinctive impulses; of an ego, which is the most superficial portion of the id and one which is modified by the influence of the external world; and of a superego, which develops out of the id, dominates the ego and represents the inhibitions of instinct characteristic of man. Further, the property of consciousness has a topographical reference; for processes in the id are entirely unconscious, while consciousness is the function of the ego's outermost layer, which is concerned with the perception of the external world.

At this point two observations may be in place. It must not be supposed that these very general ideas are presuppositions upon which the work of psychoanalysis depends. On the contrary, they are its latest conclusions arid are in every respect open to revision. Psychoanalysis is founded securely upon the observation of the facts of mental life, and for that very reason its theoretical superstructure is still incomplete and subject to constant alteration. Second, there is no reason for astonishment that psychoanalysis, which was originally no more than an attempt at explaining pathological mental phenomena, should have developed into a psychology of normal mental life. The justification for this arose with the discovery that the dreams and mistakes (*parapraxes,* such as slips of the tongue, etc.) of normal men have the same mechanism as neurotic symptoms.

Theoretical Basis. — The first task of psychoanalysis was the elucidation of nervous disorders, The analytical theory of the neuroses is based upon three ground pillars: the recognition of (1) repression, (2) the importance of the sexual instincts and (3) transference.

Censorship. — There is a force in the mind which exercises the functions of a censorship, and which excludes from consciousness and from any conscious influence upon action all tendencies which displease it. Such tendencies are described as "repressed." They remain unconscious, and if the physician attempts to bring them into the patient's consciousness he provokes a resistance. These repressed instinctual impulses, however, are not always made powerless by this process. In many cases they succeed in making their influence felt by circuitous paths, and the indirect or substitutive gratification of repressed impulses is what constitutes neurotic symptoms.

Sexual Instincts.- or cultural reasons the most intensive repression falls upon the sexual instincts; but it is precisely in connection with them that repression most easily miscarries, so that neurotic symptoms are found to be substitutive gratifications of repressed sexuality. The belief that in man sexual life begins only at puberty is incorrect. On the contrary, signs of it can be detected from the beginning of extrauterine existence; it reaches a first culminating point at or before the fifth year (early period), after which it is inhibited or interrupted (latency period) until the age of puberty, which is the second climax of its development. This double onset of sexual development seems to be distinctive of the genus Homo. All experiences during the first period of childhood are of the greatest importance to the individual, and, in combination with his inherited sexual constitution, form the dispositions for the subsequent development of character or disease. It is a mistaken belief that sexuality coincides with "genitality." The sexual instincts pass through a complicated course of development. and it is only at the end of it that the "primacy of the genital zone" is attained. Before this there are a number of "pregenital organizations" of the libido— points at which it may become "fixated" and to which, in the event of subsequent repression. it will return (regression). The infantile fixations of the libido are what determine the form of neurosis which sets in later. Thus the neuroses are to be regarded as inhibitions in the development of the libido.

The Oedipus Complex. — There are no specific causes of nervous disorders: the question whether a confiict finds a healthy solution or leads to a neurotic inhibition of function depends upon quantitative considerations; that is, upon the relative strength of the forces concerned. The most important conflict with which a small child is faced is his relation to his parents, the *Oedipus* complex; it is in attempting to grapple with this problem that persons destined to suffer from a neurosis habitually fail. The reactions against the instinctual demands of the Oedipus complex are the source of the most precious and sociaily important achievements of the human mind; and this probably holds true not only in the life of individuals but also in the history of the human species as a whole. The superego, the moral factor which dominates the ego, also has its origin in the process of overcoming the Oedipus complex.

Transference. — By transference is meant a striking peculiarity of neurotics. They develop toward their physician emotional relations. both of an affectionate and hostile character, which are not based upon the actual situation but are derived from their relations toward their parents (the Oedipus complex). Transference is a proof of the fact that adults have not overcome their former childish dependence; it coincides with the force which has been named *suggestion,* and it is only by learning to make use of it that the physician is enabled to induce the patient to overcome his internal resistances and do away with his repressions. Thus psychoanalytic treatment acts as a second education of the adult. as a correction to his education as a child.

Within this narrow compass it has not been possible to mention many matters of the greatest interest, such as the *sublima-*

tion of instincts, the part played by symbolism, the problem of *ambivalence,* etc. Nor has there been space to allude to the applications of psychoanalysis, which originated, as we have seen, in the sphere of medicine, to other departments of knowledge (such as anthropology, the study of religion. literary history and education) where its influence is constantly increasing. It is enough to say that psychoanalysis, in its character of the psychology of the deepest unconscious mental acts, promises to become the link between psychiatry and all of these other fields of study.

The Psychoanalytic Movement. — The beginnings of psychoanalysis may be marked by two dates: 1895, which saw the publication of Breuer and Freud's *Studien uber Hysterie,* and 1900, which saw that of Freud's *Traumdeutung.* At first the new discoveries aroused no interest either in the medical profession or among the general public. In 1907 the Swiss psychiatrists, under the leadership of E. Bleuler and C. G. Jung, began to concern themselves in the subject, and in 1908 there took place at Salzburg a first meeting of adherents from a number of different countries. In 1909 Freud and Jung were invited to the United States by G. Stanley Hall to deliver a series of lectures on psychoanalysis at Clark university, Worcester, Mass. From that time forward interest in Europe grew rapidly; it showed itself, however, in a forcible rejection of the new teachings, characterized by an emotional colouring which sometimes bordered upon the unscientific.

The reasons for this hostility are to be found, from the medical point of view, in the fact that psychoanalysis lays stress upon psychical factors, and, from the philosophical point of view, in its assuming as an underlying postulate the concept of unconscious mental activity; but the strongest reason was undoubtedly the general disinclination of mankind to concede to the factor of sexuality such importance as is assigned to it by psychoanalysis. In spite of this widespread opposition, however, the movement in favour of psychoanalysis was not to be checked. Its adherents formed themselves into an international association which survived World War I, and by 1926 there were psychoanalytic societies in Vienna. Berlin. Budapest, London, Switzerland, the Netherlands, Moscow and Calcutta and two in the United States. There were psychoanalytic polyclinics in Vienna. Berlin and London, and several training institutes were in process of organization. At that time, too, three journals were the official organs of the societies on the continent and in England: the *International Zeitschrift fur Psychoanalyse, Imago* (concerned primarily with applications of psychoanalysis to nonmedical fields) and the *International Journal of Psychoanalysis.* (S. Fr.)

Bibliography.—J Breuer and S. Freud, *Studien uber Hysterie* (1895); Freud, *Traumdeutung* (1900), *Zur Psychopathologie des Alltagslebens* (1904), *Drei Abhandlungen zur Sexualtheorie* (1905), *Vorlesungen zur Einführung in die Psychoanalyse* (1916). Freud's complete works have been published in Spanish (*Obras completas*) (1924) and German *(Gesammelte Schriften)* (1925); the greater part of them has been translated into English and other languages. Short accounts of the subject matter and history of psychoanalysis will be found in: Freud, *Über Psychoanalyse* (the lectures delivered at Worcester, Mass.) (1909), *Zur Geschichte der psychoanalytischen Bewegung* (1914), *Selbstdarstellung* (in Grote's collection *Die Medizin der Gegenwart*) (1925). Particularly accessible to English readers are: A. A. Brill, *Psycho-Analysis* (1922); E. Jones, *Papers on Psycho-Analysis* (1923); S. Ferenczi, *Theory and Technique of Psychoanalysis* (1927).

Controversial Literature,: Karen Horney, *New Ways in Psychoanalysis* (1939) and *Self-Analysis* (1942); Clara Thompson, "Penis Envy in Women," *Psychiatry,* 6:2, p. 123 (1943); Erich Fromm, "Sex and Character," *ibid.,* 6:1, p. 21 (1943), "Selfishness and Self Love," *ibid.,* 2:4, p. 507 (1939) and "Faith as a Character Trait," *ibid.,* 5:3, p. 307 (1942); Franz Alexander and Thomas French, *Psychoanalytic Therapy* (1946); Franz Alexander, "Psychoanalysis Revised," *Psychoanalytic Quarterly,* vol. 9, p. 1 (1940), *Our Age of Unreason* (1942) and "Indications for Psychoanalytic Therapy," *Bulletin of the N.Y. Acad. of Med.,* 20:6, p. 319 (June, 1944).

Discussion of Controversial Viewpoints: Robert Waelder, "The Problem of Genesis of Psychical Conflict in Earliest Infancy," *Internat. Jour. of Psychoanalysis,* vol. 28, p. 406 (1937) and "Present Trends in Psychoanalytic Theory," *Bulletin of the Menninger Clinic,* vol. 8, p. 1 (1943); Fritz Wittels, "Neo-Adlerians," *Am. Jour. of Sociology,* vol. 15, p. 433 (1939); Ludwig Jekels, "Psychoanalysis and Dialectics," *Psychoanalytic Review,* vol. 28, p. 228 (1940); Ernest Jones, "Review of Alexander's 'Our Age of Unreason,'" *Internat. Jour. of Psychoanalysis,* vol. 24, p. 90 (1943); H. Hartmann and E. Kris, "The Genetic Approach in Psychoanalysis," *Psychoanalytic Study of the Child,* vol. 1 (1946). (S. Fr.; X.)

Later Developments. — The above article appeared in 1926. It was written by Freud and translated by Ernest Jones. Except for the omission of certain general topics to which Freud alludes, it represents clearly the status of psychoanalytic theory at that time.

After 1926 there was an uninterrupted expansion of psychoanalytic activities in England and the United States. Before the nazis came into power there had been psychoanalytic societies in the U.S.S.R., Japan, Italy. France, the Netherlands, Switzerland, some of the Scandinavian countries, Czechoslovakia and Hungary, as well as in Germany and Austria. The eruption of World War II and other political upheavals suppressed or disrupted many of these societies. Many members were sent to concentration camps, and all who could escape migrated to other countries. An effort is now under way to rebuild these societies, their training institutes and their clinics.

In the United States there was a steady growth of the societies after World War II and of the institutes which provide psychoanalytic training, either independently or, in a few cases, in connection with universities. As of April 1956, the American Psychoanalytic association had a membership of 619. There were 14 training institutes, and 3 more in the process of formation, with a student body of approximately 1,000. At the same time there were societies and institutes in Argentina, Brazil, Canada, Chile, Belgium, Great Britain, the Netherlands, France, Germany, Italy, Sweden, Switzerland, Austria (Vienna). India, Israel and Japan, and small groups in many other localities, such as Australia, Ireland, Cuba and Ceylon. All of these groups are federated into the International Psychoanalytic association, which after the end of the war resumed its biennial meetings.

During the period of war and upheaval, most of the continental journals were suppressed, but in Great Britain the *International Journal of Psycho-Analysis* and in the U.S. the old *Psychoanalytic Review* and the *Psychoanalytic Quarterly* continued to appear regularly. After the war several additional psychoanalytic journals came into existence. Among these were the American *Imago,* the *Revue française de psychanalyse,* the *Revista de Psicoanálysis* (Argentina) and one in Italy, and such closely related journals as *Psychosomatic Medicine* and *Psychiatry.* Still newer journals and yearbooks are the *Psychoanalytic Study of the Child* (1945–), *Psychoanalysis and the Social Sciences* (1947–) and the *Journal of the American Psychoanalytic Association* (1953–); the *Yearbook of Psychoanalysis* (reprinted articles) from 1944 through 1955. The *Annual Survey of Psychoanalysis* (an extensive digest and review) began in 1953 with a summary of the publications of 1950.

Implicit in Freud's 1926 article are the lines along which both theoretical and technical developments were to occur in the subsequent years. These can be outlined in general terms as follows:

1. The topographical schema of psychological organization, which Freud then emphasized, gradually dropped into a position of relatively less importance. This was largely a result of the influence of Freud's own later writings, in which his attention shifted to more dynamic problems. *(See* Freud, *Hemmung, Symptom, und Angst* [1926; translated into English in 1936, under the title *Problem of Anxiety]*; also Anna Freud, *The Ego and the Mechanisms of Defence* [German, 1936; English, 1937].)

2. The role of anxiety and of the conscious and unconscious defensive measures which the ego utilizes in dealing with instincts and anxiety came to occupy a central position in analytic thinking.

3. These developments were related to a growing interest in the psychoanalytic study and treatment of the child. Starting with the early reports of Freud, Hug-Hellmuth and Jung, child analysis was systematically developed by Anna Freud, Melanie Klein and others, especially in Vienna and London. *(See* Anna Freud, *Einführung zur Kinderanalyse* [1927]; Melanie Klein, *Psycho-Analysis of Children* [1932].)

4. Special problems concerning female sexuality became objects of intensive investigation by Freud, Ernest Jones, Helene Deutsch, Jeanne Lampl-de Groot, Ruth Mack Brunswick, Sandor Rado,

Karen Horney and others.

5. Psychoanalytic theory and technique were applied increasingly to the study of organic physiology and pathology. These studies of the interrelationship between organic and psychic processes are exercising a profound influence on medical education and on the everyday practice of surgery and internal medicine. *(See* Edward Weiss and O. S. English, *Psychosomatic Medicine* [1943]; Flanders Dunbar, *Emotions and Bodily Changes* [1935] and *Psychosomatic Diagnosis* [1943]; F. Deutsch [ed.], *The Psychosomatic Concept in Psychoanalysis* [1953]; E. Wittkower and R. A. Cleghorn [eds.], *Recent Developments in Psychosomatic Medicine* [1954]; "Psychosomatic Medicine Monographs"; and the files of the journals *Psychosomatic Medicine* and the *Psychoanalytic Quarterly.)*

6. Psychoanalytic technique and theory have come into wide use in field work in anthropology and sociology: Geza Roheim, Margaret Mead, B. Malinowski, Abram Kardiner, J. Dollard and others.

A survey of certain of these and of other developments will be found in Freud's *New Introductory Lectures on Psycho-Analysis* (1933) and the *Index of Psychoanalytic Writings,* 5 vol., ed. by Grinstein (New York, 1956).

Areas of Controversy. — It is instructive to look back on the controversies which have revolved around psychoanalytic theory and technique. Early schisms occurred over such issues as the basic role which Freud ascribed to biological instinctual processes in human psychology. Jung moved away from this in a direction which was in essence mystical. Otto Rank reverted to an 18th-century facultative will psychology. Alfred Adler placed an unbalanced emphasis on an artificially isolated power drive. Of necessity these viewpoints entailed a rejection of psychoanalytic technique as well as theory, and the supporters of these psychologies did not designate their theories as psychoanalytic, but used various other names (individual psychology, analytical psychology, etc.) to distinguish them from Freud's psychoanalytic psychology. None of these three early separations resulted in the development of a systematic school of theory. technique, experimentation or instruction. The result was that their adherents were gradually disappearing.

More recent controversies are over details of theory or technique and do not lead to a complete departure from the parent stem. The leaders continue to subscribe to the main body of psychoanalytic thought and to look upon themselves as psychoanalysts.

The more valid among the controversies current at mid-20th century focus on such questions as the definition of instincts, details of libido development and the relative importance of infancy, puberty and adolescence in the genesis of neurosis; and on such technical issues as the duration and continuity of treatment and the handling of transference phenomena. Certain specious issues are often interwoven confusingly with these legitimate issues, however. Some of these are reminiscent of the ancient battles over heredity versus environment, and take the form of polemics over what is called a "genetic" versus a "cultural" origin of neuroses, as though it were possible to isolate the influence of the one from that of the other. Such 'pseudo-controversies are scientific catchpennies, and because they are devoid of meaning quickly disappear.

A more significant area of inquiry is developing around the validity of all quantitative metaphors, as these are used not merely to characterize the interplay of psychological processes but as a basis for explaining variations in human behaviour. This development is related to the rapidly evolving changes in current concepts of the way the human brain works. Through the coming years these developments will lead slowly to important clarifications and simplifications in the conceptual structure of psychoanalysis.

Disagreement is essential to the growth of any science. In the state of psychoanalysis at mid-century one might deplore only a tendency on the part of some critics to broadcast theoretical concepts widely to a lay public before they have been sufficiently tested. This creates a furor of verbal disagreements and makes it difficult to maintain an atmosphere of quiet objective research. It seemed doubtful, however, that any of the issues which were in dispute at that time would lead to the development of new schools or to such schisms as occurred in earlier years.

Bibliography. — O. Fenichel, *The Psychoanalytic Theory of Neurosis* (1945); S. Freud, *A General Introduction to Psycho-Analysis,* authorized Eng. trans. of rev. ed. by Joan Riviere (1935), *New Introductory Lectures on Psycho-Analysis* (1933), *The Future of an Illusion* (1928), *Civilization and Its Discontents* (1930), *Moses and Monotheism* (1939), for a complete list of all English translations of Freud's works (by James Strachey) see *International Journal of Psychoanalysis,* xxvi (1945) or the *Psychoanalytic Quarterly,* xv (1946); E. Glover and M. F. E. Brierley (eds.), *An Investigation of the Technique of Psychoanalysis* (1940); Ives Hendrick, *Facts and Theories of Psychoanalysis,* 2nd ed. (1939); L. S. Kubie, *Practical and Theoretical Aspects of Psychoanalysis* (1950); J. Rickman, *Index Psychoanalyticus — 1893–1926* (1928). (L. S. K.; B. D. L.)

Influence on Literature and Art. — The two principal figures in the history of psychoanalysis and modern art were Sigmund Freud and Carl G. Jung. Of Freud's work, the most important for literature and the other arts were *The Interpretation of Dreams* (1900), *Three Contributions to the Theory of Sex* (1905), *Beyond the Pleasure Principle* (1920) and a number of the essays and papers in *The Collected Papers of Sigmund Freud* (the English translation published 1924). Conspicuous for their influence on the arts among these last were such essays as "The Dynamics of the Transference" (vol. ii). "Turnings in the Ways of Psychoanalytic Therapy" (vol. ii). "The Moses of Michelangelo" (vol. iv), "The Relation of the Poet to Day-Dreaming" (vol. iv) and "The Unconscious" (vol. iv). The work of Jung best known to modern writers and artists included *Psychology of the Unconscious* (1916), *Psychological Types, or the Psychology of Individuation* (1920), *Modern Man in Search of a Soul* (1931) and several essays which attempted to explain the psychology of art; of these. his "Psychology and Poetry" (which appeared in *Transition,* translated by Eugene Jolas, in 1930) is perhaps best known. A number of other pioneers in the establishment of psychoanalysis in the 20th century contributed to the very large body of work on psychology and the arts. Most of these followed through suggestions made originally by Freud and Jung, but they also investigated more exhaustively subjects that were for the most part only peripheral to the major interests of the two leading spokesmen for the field. Among these psychoanalysts who were interested in the application of their disciplines to the arts and to criticism were Wilhelm Stekel, Otto Rank, Ernest Jones and Charles Baudouin. The most important works of these men were Rank's *The Incest-Motive in Poetry and Legend* (1912), Jones's *Hamlet and Oedipus* (1910 and 1949) and Baudouin's *Psychoanalysis and Aesthetics* (1924). In addition, there were numerous critics whose analysis of the arts was strongly marked by their preoccupation with psychoanalysis and psychiatry: among them the most influential were Herbert Read, Kenneth Burke, Frederick C. Prescott and Maud Bodkin. Psychoanalytic investigations of the lives of writers and artists were responsible for a large body of additional work. Freud himself contributed to this kind of writing in his *Leonardo da Vinci: a Psychosexual Study of an Infantile Reminiscence* (1910) and in his essay "Dostoyevsky and Parricide" (English translation published in *Partzsan Review,* fall, 1945). In both cases, Freud attempted to find in the work of the artists evidence that would help toward an understanding of their "psychic life." Biography, following upon the suggestions contained in these contributions and others, as well as the great body of clinical investigation, developed a special approach toward the arts, in which the work of art was related to and explained in terms of the artist's psychological history. Conspicuous examples of this form of psychobiography were René Laforgue's *The Defeat of Baudelaire: a Psycho-Analytical Study of the Neurosis of Charles Baudelaire* (1931), Saul Rosenzweig's "The Ghost of Henry James" (in *Character and Personality,* Dec. 1943), Edmund Wilson's biographical studies of literature (many of them contained in *The Wound and the Bow,* 1941), Joseph Wood Krutch's *Edgar Allan Poe: a Study in Genius* (1926) and Van Wyck Brooks's biographies of Mark Twain *(The Ordeal of Mark Twain,* 1920) and Henry James *(The Pilgrimage of Henry James,* 1925).

The question of the influence—of the degree of it and of all the peculiarities of its nature—is as complex as the influence itself is varied and widespread. There were writers and artists who professed to have and sometimes had a great knowledge of psychoanalysis and who worked in terms of a direct recognition of its value for their art. These included most of the surrealists, some of whom (like André Breton) had had actual experience as analysts, and other writers who (like Ludwig Lewisohn, Georg Groddeck, H. R. Lenormand) spoke of psychoanalysis with varying degrees of accuracy and conviction. Of Lenormand's plays, beginning with *Le Mangeur de rêves* (1922), those which presented tragedy based chiefly on psychoanalytic knowledge of character included *L'Homme et ses fantômes* (1924), *Asie* (1931) and *Pacifique* (1937); all these works reflect wide and accurate acquaintance with the discipline and the conclusions of psychoanalysis, though Lenormand objected to their being labeled Freudian. Also included in this first group of writers was Thomas Mann, who not only knew and greatly respected the work of Freud, but was also extremely judicious in his application of this knowledge to his fiction. In an essay on "Freud's Position in the History of Modern Thought" (1928; included in *Past Masters, and Other Papers*, 1933), Mann applauded Freud for his intelligent concern with the psychic life as well as his wish to find new sources of cure and therapy. One of Mann's first uses of his wide acquaintance with psychoanalysis was in the novel *The Magic Mountain* (1924), but here the reference to psychoanalysis is mixed with a generous and eclectic use of many other kinds of knowledge and speculation—notably the philosophies of Arthur Schopenhauer and Friedrich Nietzsche. That he remained objective concerning the advantages of analysis for modern society was abundantly indicated in such remarks from the novel as this made by the character Settembrini: "Analysis as an instrument of enlightenment and civilization is good. in so far as it shatters absurd convictions, acts as a solvent upon natural prejudices, and undermines authority. . . . But it is bad, . . . in so far as it stands in the way of action, cannot shape the vital forces, maims life at its roots. . . ." (*The Magic Mountain*, Thomas Mann, p. 283, Mod. Library Ed.; A. A. Knopf, Inc., N.Y., 1927.) In his fictional reconstruction of the biblical story of Joseph, Mann quite deliberately made use of the speculations of both Freud and Jung concerning the value of myth and its symbolic recurrence, through a racial (or "collective") unconscious. Mann's fiction showed the skill of an intellectually disciplined mind whose application of psychoanalysis, as well as of other knowledges, never allowed it to dominate but made it serve the original aesthetic form and subject.

The knowledge of psychoarialysis also led modern novelists to establish the analyst himself as an important fictional personage, sometimes available to satirical observation (as in Waldo Frank's novel *The Bridegroom Cometlz*, 1938), sometimes placed in a crucial role as adviser and "physician of the soul" (as in Lewisohn's *The Island Within*, 1928) and sometimes credited with providing the means of a novel's resolution (as in Arthur Koestler's *Arrival and Departure*, 1943). The substance and content of psychoanalytic disclosures (or their equivalents in the artist's imagination) often dominated the content of works of literature. Reliance upon the revelations of the subconscious mind was conspicuous in such works as the fiction of Anaïs Nin; surrealist poetry, prose and painting; Groddeck's *Der Seelensucher* (1922); F. Scott Fitzgerald's *Tender Is the Night* (1934); Conrad Aiken's *Great Circle* (1933), *King Coffin* (1935) and much of his poetry (particularly *The Coming Forth by Day of Osiris Jones*, 1931); and both the poetry and fiction of Dylan Thomas. Notable for its literary approximation of clinical analysis was the novel by Italo Svevo (Ettore Schmitz) *La Coscienza di Zeno* (1924; translated as *The Confessions of Zeno*, 1930), in which the narrative is presented as a continuous self-analysis by the hero. In musical comedy and the theatre the role of the psychoanalyst was presented in Moss Hart's *Lady in the Dark* (1941) and T. S. Eliot's *The Cocktail Party* (1950).

A second group of writers and artists included those who undeniably showed the influence of psychoanalysis but who resisted the labels Freudian and psychoanalytic. These persons gained prominence in literature and art in one of two ways. either they formulated their own theories of the unconscious and other psychoanalytic concerns in an effort to disprove Freud or to discount his values; or their work followed the lines and treated of the material with which psychoanalysis was largely concerned without having derived from a study of it. An important opponent of psychoanalysis was D. H. Lawrence; his novel *Sons and Lovers* (1913) interested psychoanalysts and critics who found a direct influence in its presentation of familial problems. Lawrence's reply was to repudiate psychoanalysis as too narrowly and harmfully scientific; but in the energy of his protest lay an earnest of the contribution made by psychoanalysis to his thinking. In a great number of letters and essays, Lawrence attacked both Freud and Jung, though he gave a qualified approval of another analyst, Trigant Burrow. His principal long attacks on psychoanalysis were *Psychoanalysis and the Unconscious* (1921) and *Fantasia of the Unconscious* (1922). In these works, Lawrence accused psychoanalysis of putting a false and debilitating emphasis upon scientific probing and examination which not only misunderstood the vital sources of human action but helped to defeat human vitality and tended to reduce the "life forces" to objects of intellectual curiosity. These reflections were associated in a large portion of Lawrence's writings of every kind with a general attack upon modern rational and intellectual life, as well as with his repudiation of the mechanistic, life-defeating impact of modern industry upon human vitality. Other writers offered in their work tempting opportunities for critics who wished directly to attach the label Freudian to them. but in large part rejected it or confessed to an ignorance of the disciplines that had allegedly influenced them. Among these writers were Sherwood Anderson and Eugene O'Neill; particularly in some of the latter's plays (especially *Mourning Becomes Electra*, 1931) there is abundant evidence of his realization of psychoanalytic techniques and discoveries, though O'Neill himself denied any direct line of influence. Franz Kafka was a special case: many of his writings show a line of relationship to his own familial circumstances, revealed especially in "Letter to My Father"; but, while critics did quite successfully exploit that relationship, Kafka's work derived from a complex of other influences which made a too-simple psychoanalytic explanation misleading. (See *The Kafka Problem*, edited by Angel Flores, 1946).

The final kind of influence concerned the role which psychoanalysis played in a number of the major preoccupations of modern writing and art. Psychoanalysis could rightfully claim a share in the motivating influence upon the release (of literature chiefly, but of the other arts as well) from the restraining and inhibiting cultural and traditional limits of taste and decorum which had fairly well held until the end of World War I. In these circumstances, psychoanalysis may be considered a social instrument, providing a rationalization of social change; but this was not to be its enduring purpose, nor had it been its original or exclusive aim. In many ways, the conjunction of psychoanalysis with social revolt was accidental, and the notoriety hindered the serious progress of the science as much as it helped to popularize it. The clinical studies begun by Freud and revealed in *Three Contributions to the Theory of Sex* and other places had a rather important voice, though by no means an exclusive one; the work of other psychologists, of sociologists and anthropologists was equally important, and the general impact of the war served as a primary cause of the release of inhibitions among artists regarding the treatment of these matters. What psychoanalysis did was immensely to extend and partly to provide phraseology for the discussion of sex matters or for their dramatization in works of literature. The attitude toward psychoanalysis on this level of influence was often largely undiscriminating, amateurish and ignorant. The principal terms and the popular notions of psychoanalysis were used over and over again in the popular and semi-popular literature of the 1920s, as the Marxist and pseudo-Marxist ideas found their way into the work of the 1930s. The catalogue of works which reflected this type of influence is very great; the use of psychoanalysis was sometimes very shrewd, sometimes quite mistaken and misleading and often merely the result of a desire to be fashionable. In one way or another the work of the following writers showed the widespread impression made by psychoanalysis upon the modern world: Floyd Dell, Max Eastman, Maxwell Bodenheim, Conrad Aiken, Susan Glaspell, Evelyn Scott, Waldo Frank. F. Scott Fitzgerald, Carl Van Vechten, May Sinclair, J. D. Beresford and Aldous Huxley. In the work of most of these. psychoanalysis was little more than incidentally acknowledged, or was used merely as a form of intellectual small change. By 1940 the relationship of psychoanalysis to social analysis had become much more complex; it was combined with economic determinations of history, with anthropology and with theology.

The actual study of psychoanalytic influence on modern literature and art contains many varied problems. In the first half of the 20th century at least. the influence was often haphazard and incidental, and art borrowed from it a means of confusing its terms and its disciplines. Until the time of World War I, the career of psychoanalysis had been largely handicapped by a considerable rejection of it as a valid psychology. The writer or artist, aware of a significant new contribution to human knowledge, even in the early years, was both distrustful and confused concerning its actual value for him. New terms, discoveries, emphases (or extensions of original terms) served to confuse him further. In addition, the sources of information from which the artist was able to draw were often quite remote in both nature and quality of precision from the original; as psychoanalysis became popular, numerous books, essays, editorials, conversations and amateurish "games" served often to give portions of "information" or vagrant notions of what psychoanalysis was actually doing. This variety of circumstance accounted for the vast majority of errant and erroneous uses of what was, when separated from its accurate source, mostly a fashionable mode of discourse, or a jargon.

For those who considered psychoanalysis seriously and with some accuracy, it made substantial contributions in at least three separate areas of creative work. The first of these was the study of the unconscious itself—often quite aside from the psychoanalytic purpose for making that study. The pioneering influence in this connection was Freud's *The Interpretation of Dreanzs.* His investigation of the "dream work" had a profound and widespread effect upon the arts. especially as it gradually made available to artists certain information concerning the "behaviour" of the unconscious. The dream not only provided an extension of the uses to which the various languages of the arts might be put; it also suggested a range and a new reordering of symbolism which could be applied in varied ways to literature and art. In literature, the techniques practised in stream-of-consciousness writing were greatly extended through adaptations or applications of Freud's original suggestions. A considerable range of literary styles was made possible as a consequence, as well as new departures in the structure of novels, plays and poems. The popularity of this method was largely the result of the great success of James Joyce's *Ulysses* (1922), imitated in a great number of novels which followed its publication. *Ulysses* was followed by *Finnegans Wake* (first published in part as "Work in Progress" in the magazine *Transition,* 1927 to 1929; as a book, 1939), a much more elaborate and exhaustive exploitation of the literary resources of psychoanalysis, in combination with many other disciplines, knowledges and techniques available to the erudition of its author. The techniques initiated or perfected by Joyce were subsequently taken over in other fictions, stylized and combined with more traditional forms of analysis. The most important contribution made by them lay in the revisions seen of the individual dream consciousness and a world view that was at once anthropological, mythical and cultural. Other applications of the information about the unconscious made available to the arts included the so-called "automatic writing" of the surrealists, especially of André Breton, Louis Aragon, Philippe Soupault, René Crevel and Paul Éluard. These artists, and others, did not confine themselves, however, to a mere simulation of mental disorders in their work; it did remain close to what the founders of surrealism thought were their psychoanalytic origins Breton's definition of surrealism, given in the *Manifestes du surrealisme* (1924), established both the nature and the limitation of their work: "Pure psychic automatism by which it is intended to express, verbally, in writing, or by other means, the real process of thought. Thought's dictation, in the absence of all control exercised by the reason and outside all aesthetic and moral preoccupations." (André Breton, *Manifestes du surréalisme,* p. 46; Éditions du Sagittaire, Paris, 1924). In its later development, the sponsors of surrealism acknowledged that such work could easily be confined to a too narrow and repetitious form of creation and proposed (in Breton's essays and in those of Nicholas Calas) to free themselves from the limits of psychoanalytic descriptions of the unconscious. This independence of the limits of clinical psychoanalysis was much less true of surrealist painting (Max Ernst, Yves Tanguy, Salvador Dali and others), which for the most part continued to realize pictorially and without much variation the desires resident in the unconscious.

The second most conspicuous contribution made by psychoanalysis to modern literature and art had chiefly to do with the re-examination and exposition of human behaviour and the motives underlying it. This revision of view, involving as it did much attention to a person's sex life and his relationship to his parents from infancy on, did much to encourage both illuminating and wildly erroneous changes in the explanation of motive. The range of information concerning such mental disorders as were available, to novelists and dramatists especially, increased as the techniques of psychoanalysis expanded and theorists multiplied. Earlier fiction of the 1920s often remained content to speak superficially of "repressions," "neuroses" and "free association" and to narrate visits to psychoanalysts as part of a social fashion. As familiarity with psychoanalysis increased, the use of it became more "professional" in its efforts to achieve clinical exactness. The novels, dramas and motion pictures of the late 1930s and of the 1940s demonstrated much detailed knowledge of psychiatry and a willingness to exploit its opportunities for characterization and melodrama. An early example of such exploitation is Fitzgerald's *Tender Is the Night,* whose major theme depends upon the risk taken by a promising young American psychoanalyst when he marries his patient, and is thus forced to call increasingly upon his reserves of nervous and moral energy until both are completely exhausted. The novel revealed a considerable acquaintance with the terminology, practices and techniques of the clinic and the sanitarium, and some skill in appropriating them to the problems of a novel's form and structure.

The third contribution is largely the work of Jung. The difference between his influence and Freud's can best be explained by reference to their differing explanations of the term "libido." Freud had used this term to designate sexual energy; Jung preferred to expand its definition. Linked with this fundamental difference of interpretation was the much greater emphasis Jung put upon what he called the "collective unconscious," which has been described as "the precipitate of humanity's typical forms of reaction since the earliest beginnings." (J. F. Jacobi, *The Psychology of Jung,* p. 8; Yale University Press, New Haven, Conn., 1943.) The role of the artist became extremely important for Jung; he was considered a form of priest of the "collective unconscious" because he relates the conscious life of his fellows to its archetypes in the unconscious. This view of the unconscious and of its availability to art and literature had no small influence upon 20th-century writers and artists. It was one of several germinal theories which stimulated a great critical interest in myth and mythology. Among the critics whose interpretations of literature showed its influence were Maud Bodkin *(Archetypal Patterns in Poetry,* 1934), Elizabeth Drew *(T. S. Eliot. The Design of His Poefry,* 1949) and P. W. Martin *(Experiment in Depth,* 1955). Jung's influence served in a way to counteract Freud's rather narrow view of the artist and the tendency of his followers to analyze art in terms of the artist's psychic nature. Jung was in a much larger sense concerned with the act of creation and with its significance as a restatement and reshaping of recurrent mythical themes.

At the halfway mark of the 20th century, the usefulness of psychoanalysis for criticism and its influence upon the artist had grown much more complex and varied than at the beginning. New explorations of Freud and Jung continued to appear, as well as a considerable number of studies by psychoanalysts of the arts, by critics of psychoanalysis and psychiatry. In literature especially, the groundwork of psychoanalytic knowledge was accepted as familiar to the majority of both artists and critics. *See* also Index references under "Psychoanalysis" in the Index volume.

BIBLIOGRAPHY—Kenneth Burke, *The Philosophy of Literary Form, see* title essay and "Freud—and the Analysis of Poetry" (1941); Frederick J. Hoffman, *Freudianism and the Literary Mind* (1945); H(ermann) B(oeschenstein), "Psychoanalysis in Modern Literature" in *Columbia Dictionary of Modern European Literature,* ed. by Horatio Smith, pp. 651–657 (1947); Stanley E. Hyman, *The Armed Vision,* ch. 6 (1948); Patrick Mullahy, *Oedipus: Myth and Complex* (1948); Roy P. Basler, *Sex, Symbolism, and Psychology in Literature* (1948); Lionel Trilling, "Freud and Literature" in *The Liberal Imagination,* pp. 34–57 (1950), *Freud and the Crisis of Our Culture* (1955); W. David Sievers, *Freud on Broad-way* (1955). (F. J. HN.)

PSYCHOGALVANIC REFLEX. The term psychogalvanic reflex (P.G.R.) refers to a change in the electrical properties of the body (probably of the skin) following noxious stimulation, stimulation that produces emotional reaction and, to some extent, stimulation that attracts the subject's attention and leads to an aroused alertness. Galvanic skin response (G.S.R.) and electrodermal response (E.D.R.) are preferable synonyms. Though most of the work on this phenomenon has involved human subjects, it can be demonstrated in other mammals. The P.G.R. can be demonstrated in several ways, but usually with what are essentially modifications and improvements of the method of C. S. Féré (1888). In these, the response appears as an increase in the electrical conductance of the skin (a decrease in resistance) across the palms of the hands or feet. In the experimental arrangements, the subject forms one arm of a balanced Wheatstone bridge electrical circuit *(see* INSTRUMENTS, ELECTRICAL MEASURING: *Indicating Instruments).* When his resistance to the passage of a weak, impressed electrical current decreases, the bridge is thrown out of balance as indicated by the deflection of a galvanometer. The amount of change in his resistance can be calculated from the magnitude of this deflection or from the amount of external resistance that must be introduced elsewhere in the bridge to rebalance it. The response appears with a latency of about two seconds after stimulation with a pin prick, threat of injury, etc.; it rises to a maximum after two to ten seconds and subsides at about the same rate.

The P.G.R. is mediated by the sympathetic division of the autonomic nervous system. It is a part of the general arousal or activation pattern of physiological responses that mobilizes and fits the person for effective reaction in an emergency, as described by Cannon (1932). In addition, parts of the premotor cerebral cortex appear to have a roie in producing the P.G.R., and Darrow (1936) suggested that it is an accessory to the activity of the postural mechanisms, for which it could play a preparatory function. The consensus is that the P.G.R. is associated with activation of the sweat glands by the postganglionic sympathetic fibres, but that the perspiration actually secreted does not produce the characteristic decrease in skin resistance by acting as an electrolytic conductor.

A more sensitive indicator of minimal emotional arousal than other physiological responses, the P.G.R. has figured extensively in studies of emotion and emotional learning. It can help to uncover complexes of emotional sensitivities when used with word association tests or interviews; by observing when the response occurs, the skilled worker can deduce which stimuli evoke emotional disturbance. The P.G.R. is involuntary in the sense that subjects cannot suppress it readily, if at all, though it can be produced by voluntary acts such as deep breathing or moving., As a detector of emotion, the response often has served as one of the indicators in the "lie detector," along with blood pressure, pulse and respiration. If a neutral stimulus such as a light or tone is paired with mild pain, the neutral stimulus acquires the power to evoke the P.G.R. With such conditioning, the response can become a useful indicator for studying human learning as well as for detecting feigned deafness, blindness or anesthesia. *See* also EMOTION.

BIBLIOGRAPHY.—R. A. McCleary, "The Nature of the Galvanic Skin Response," *Psychological Bulletin* (1950); D. B. Lindsley, "Emotion" in S. S. Stevens (ed.), *Handbook of Experimental Psychology* (1951); R. S. Woodworth and H. Schlosberg, *Experimental Psychology,* rev. ed. (1954). (H. F. HT.)

PSYCHOKINESIS, the influencing of physical events by an organism's psychological state (*i.e.,* by "thinking" or "willing") without the mediation of effector activities or forces known to physics. See PARAPSYCHOLOGY.

PSYCHOLOGICAL TESTS AND MEASUREMENTS. A psychological test may be defined as a scientifically standardized procedure for assessing some clearly defined mental characteristic. It is the scientific standardization—particularly the preliminary checking and calibration by *ad hoc* research—that distinguishes a psychological test from an ordinary interview or an academic examination.

This article is organized as follows:

I. HISTORICAL DEVELOPMENT

1. Earliest Types **of** Test.—The need for precise techniques to assess mental differences between individuals was first explicitly recognized by Sir Francis Galton (*q.v.*) and formed an essential part of his attempt to transform individual psychology into a genuine science. During the latter half of the 19th century. when psychology mas becoming an experimental science, it was found that laboratory measurements displayed marked variations from one person to another. Interest at that time centred chiefly on the general study of the mind as such. and these individual variations were consequently treated as errors of measurement, to be eliminated by some method of averaging. Galton noted that many of the differences seemed to be related to the individual's ability and temperamental characteristics as displayed in everyday life, and resolved to study and standardize the procedures from this new point of view.

Of his earlier "mental tests" (as he called them), many were suggested by the experimental techniques already used in laboratory work. In Great Britain the dominant school of psychology at that date held that all mental processes developed out of the sensory experiences of the individual or the associations formed between them. It seemed to follow that a subject's general efficiency might best be measured by testing his ability to discriminate elementary sensations. Galton therefore began by devising methods for measuring tactile, visual, auditory and muscular discrimination. The discrimination of weights had long been employed by E. H. Weber. G. Fechner (*qq.v.*) and their followers to demonstrate the general Weber-Fechner law (see PSYCHOPHYSICAL METHODS) and one of Galton's earliest and best-known tests consisted of a calibrated series of weights for measuring the accuracy with which each person could discriminate such differences. These sensory tests were later supplemented by tests for speed and strength of movement, quickness of reaction and extent of associative memory. Later Galton came to realize that still more complex processes would yield better estimates of general efficiency and accordingly constructed a number of tests for "higher mental processes." No less valuable were the statistical techniques that he devised for validating and standardizing the new procedures — the percentile and the average deviation as metrical units, the scaling procedures based on the normal frequency distribution and above all the coefficient of correlation.

In the later stages of his work he received active assistance from J. M. Cattell (*q.v.*), a U.S. student who had worked in Wilhelm Wundt's laboratory at Leipzig and acted for a short time as Galton's assistant. In 1890 Galton and Cattell published the program of mental tests which, with various other devices, Galton had regularly used in his anthropometric laboratory for studying the characteristics of individuals. On returning to the United States, Cattell and his co-workers started at Columbia university the systematic application of a similar scheme of tests to college students and thus initiated the long series of researches carried out with the aid of these new techniques. The most important was embodied in a long and influential monograph (1901) by C. Wissler (one of Cattell's research students), which reviewed the results obtained and applied for the first time the Galton-Pearson correlation coefficient to measure the relations of the test results with each other and with independent criteria.

In 1892 James Sully had opened a department of education at University college, London, where a school for boys happened to be available on the premises. There he and Galton (who had transferred his laboratory to the college) joined in applying tests of physical and mental characteristics to school children. Sully held that the measurement of attention would provide the best estimates of a child's intelligence; accordingly he devised tests for the "span of prehension" (the maximum number of letters apprehended in a single glance or of digits recalled after a single hearing) and reported that the differences thus detected varied closely with the child's "general mental capacity."

In 1905 Galton obtained a grant from the British Association for the Advancement of Science for repeating his anthropometric survey of the British Isles, with the inclusion of tests for mental capacities, and a committee was formed to make preliminary inquiries with W. McDougall (head of Sully's laboratory in London) as secretary. It worked in co-operation with a second committee appointed to study mental and physical factors in education. The outcome was a series of investigations, carried out mainly under McDougall's guidance, by W. Brown, C. Burt, C. Spearman and others, with a view to constructing intelligence tests for school children.

2. General and Special Abilities. — Galton, in the course of his investigations, had been led to distinguish between "special aptitudes" (corresponding roughly to the old-fashioned "faculties") and "general ability" — a kind of superfaculty determining mental efficiency in all forms of cognitive activity. In France Alfred Binet (*q.v.*), an admirer of contemporary British psychology and particularly of the views elaborated by Galton, adopted this distinction, but since in French the word "ability" possessed a different meaning he substituted Herbert Spencer's term "intelligence." In 1904 the French ministry of public instruction appointed a commission to study the diagnosis and training of mentally deficient children and, as a member of the commission, Binet set about compiling standardized scales for measuring not only "pedagogical attainments" but also what he termed "general intelligence" and "partial aptitudes." He determined to discard "the instrumental methods popular in German laboratories" and to compile a series of problems, graded in difficulty and requiring for their solution "little else but pencil, paper, pictures, and a few common objects." The success of his novel procedure as a means of diagnosing subnormal pupils attracted widespread attention, and his age scale of intelligence tests was almost immediately translated and adapted by psychologists in Belgium, Britain, Germany and the U.S.

3. Group Tests. — Previously, all such tests had to be applied individually. For the purpose of large-scale examinations of school children, however, it was desirable if possible to develop a type of test which could be applied collectively. Accordingly, in London and elsewhere a number of researches were carried out to investigate the possible use of what were subsequently known as group tests. The result was the type of problem commonly used in the English 11+ examination: "analogies," "opposites," "syllogistic reasoning," "code tests," "completion tests" (a device suggested by H. Ebbinghaus) and the like, usually combined into a booklet of half a dozen subtests. Similar principles were adopted for constructing and standardizing tests for the chief subjects of the school curriculum, and in 1913 the London County council appointed an official psychologist to study and apply mental and scholastic tests, particularly in connection with the examination of cases of subnormal and supernormal ability.

4. Performance Tests. — In the United States, in order to test foreign immigrants, special attention was given to performance tests; *i.e.*, tests not entailing a knowledge of some particular language. H. A. Knox developed "construction" and "imitation" tests, S. D. Porteus a series of graded maze tests, H. H. Goddard and W. F. Dearborn form boards, W. Healy a picture-completion test. Finally. R. Pintner and D. G. Paterson combined a carefully chosen selection to form a "performance scale" which was widely used for those handicapped by deafness, lack of schooling or other disabilities. In the field of education E. L. Thorndike (*q.v.*), who had joined Cattell at Columbia, quickly became the leader of the test movement in the United States and. though at first doubtful about the hypothesis of a general ability, was active in producing scientifically standardized tests of scholastic abilities. By the end of the first decade of the 20th century more than 50 well-tried tests for various capacities — sensory discrimination, perception, memory, attention, learning, imagination and the like — were available in standard form and were described in G. M. Whipple's Manual of Mental and Physical Tests (1910), with tabulated norms of performances and full instructions for use and marking.

5. Vocational Testing. — Just before the outbreak of World War I, Hugo Miinsterberg (*q.v.*) and others in the United States initiated a series of pioneer investigations on adolescents and adults to study the value of psychological tests for purposes of vocational guidance and selection (see PSYCHOLOGY, APPLIED). During the war group tests of intelligence were administered to about 1,750,000 recruits for the U.S. army, and a more limited use was made of aptitude tests for assigning men and women to the most suitable trades in the various fighting services. Similar efforts on a more restricted scale were made in Great Britain. The success of such methods for military purposes resulted after the war in a rapid development of psychological testing for education and industrial purposes. The experience gained during the 20 years of peace in these two fields proved invaluable in World War II, when both countries made full use of mental testing in the various branches of their navies, armies and air forces.

6. Testing Temperamental Characteristics. — The application of test procedures to what were called the affective and conative (as distinct from the cognitive) aspects of the mind developed far more slowly. The emphasis laid by McDougall (*q.v.*) on emotional tendencies as the chief determinants of personality and character led several of his research students to apply test procedures to the assessment of temperamental qualities. At first the procedures used were based chiefly on the ordinary laboratory techniques for investigating the physical effects of emotion — changes in blood pressure, speed of pulse, skin temperature and, most striking of all, the so-called psychogalvanic reflex (a transitory increase in the electrical conductivity of the skin induced by emotional stimulation). As with intellectual testing. it soon appeared that tests based on these more elementary processes and requiring highly elaborate apparatus mere neither the most convenient nor the most effective. Galton had already attempted "psychometric experiments" for the study of associated ideas and had noted how such devices brought to light unconscious interests and motives. particularly early sentiments strongly tinged with emotion, differing widely with different individuals. For stimuli he relied mainly on lists of suitable words. Later investigators tried pictures, ink blots (first used by Binet) or ambiguous drawings (a method described by William James) and so developed what British psychologists called apperception tests and U.S. writers projective tests. The success obtained with these procedures and the growing interest in the affective aspects of behaviour (due largely to the influence of the psychoanalytic school) led to numerous researches with a variety of tests and other devices for assessing these deeper constituents of personality.

7. Recent Research. — From about 1930 onward there were no new developments affecting the basic principles or ideas, most of the work being concerned either with improving research techniques already introduced or with constructing and applying tests for an ever-widening range of abilities, attainments and other characteristics of individual behaviour. On the theoretical side special attention was paid to the refinement of the statistical procedures used in constructing and validating new test batteries, and particularly to such technical questions as scaling, reliability, item analysis, factor analysis, better sampling of test items and test populations and. above all, to improved criteria for validation. On the practical side, the increasing use of tests for educational. commercial and military purposes, especially by public bodies, led to an attempt to assess not merely theoretical value but also the practical value of large-scale testing: test B may have a much lower theoretical validity than test A and yet, because it adds more to information already available and is at the same time far less expensive. it may have a much higher practical value for the purpose intended. Since financial considerations are involved, it is desirable to measure the utility of a test by applying the mathematical procedures used in what the economist terms decision theory.

A classified list of the tests available for various purposes, with a detailed description and critical evaluation of each, is to be found in the *Mental Measurements Yearbook,* published about every five years by Oscar Buros. The *Fifth Mental Measurements Yeavbook* (1959). covering 1952–58, includes nearly 1 000 different tests; the majority are achievement tests, dealing with the chief subjects of the school. college and university curriculums. In particular the adoption of psychological methods in the armed forces during World War II led to a vast multiplication of tests employed for measuring the abilities and attainments of adults.

Most psychological tests are comparatively short lived and are quickly replaced by more adequate versions. A few, however, have proved to be of relatively lasting value. Of these the best known is the original Binet scale; in Britain one of the London revisions and in the U.S. one of the Terman revisions (the Stanford-Binet) are in regular use, particulariy for individual examination of educationally subnormal children. A late version of the latter exists in two parallel forms and contains 62 items grouped into 20 levels of difficulty, 6 (or in one case 8) for each half year (2 to 4 years) or each year (5 to 14 years nith four adult levels) ; *e.g* , for year 5 typical items are defining by classification or description, using two words from a standard list of 45, copying a square, repeating a sentence of five monosyllables from memory; for year 10, reading and summarizing a short paragraph, indicating what is absurd in a picture, repeating six digits. For testing adults the Wechsler-Bellevue intelligence scale gained widespread popularity during the 1950s. particularly with clinicians. This consists of six verbal and five performance tests and, with the aid of a presented table, the measurements are expressed in terms of a conventional intelligence quotient; a simplified version also was devised for use with children. Other tests are available for infants, for the blind, the deaf and those otherwise handicapped.

Group tests of intelligence are even more widely used. Under this title the *Yearbook* describes over *100* U.S. versions, available to the general public. most of them composite batteries based on about half a dozen of the stock types of problem described above. In Britain fresh group tests are prepared every year, but are not published until they are no longer required for official purposes. The name intelligence test is perhaps misleading; most of them are not so much tests of innate general ability as tests for general classification.

Less progress has been made with individual tests for special mental capacities — observation, memory, imagery, quickness and the like—but improved apparatus was devised for testing sensory capacities — form vision, colour vision, hearing, pitch discrimination, etc. So-called multiaptitude batteries became increasingly popular; these commonly cover such aptitudes as verbal, numerical and mechanical abilities and, less frequently, speed, accuracy, memory, judgment, reasoning, etc. One of the earliest and best known is L L. Thurstone's test of primary mental abilities, which largely provided a model for later batteries of this type. There are in addition numerous tests for more complex abilities; *e.g.,* artistic and musical capacity and professional aptitudes for medicine, law, engineering, teaching and the clerical professions.

II. CHARACTERISTICS MEASURED, CONSTRUCTION AND USES

A. Characteristics Measured

As a result of a vast amount of detailed research on the lines of these earlier inquiries, three main types of mental characteristics can be measured by means of psychological tests or similar devices with tolerable accuracy. The majority of the tests in regular use can be accordingly classified under three main heads: (1) tests of attainments (*i.e.,* of acquired knowledge or skill in various fields) ; (2) tests of abilities, either intellectual or practical; and (3) tests of other characteristics of personality; *e.g.,* emotional: temperamental and moral qualities (including interests, attitudes, ideals and motivational tendencies generally).

1. Educational and Vocational Attainments. — The attainments commonly tested may be subdivided into two broad groups, educational and vocational. Of the educational or scholastic tests the most. thoroughly standardized are those designed to measure achievement in the ordinary subjects of the elementary school curriculum — reading, spelling, arithmetic, composition, drawing, handwriting and handwork. With these the norms usually consist of standard (*i.e.,* average) performances for each sex separately at each age of school life, together with some indication of the range of individual variation (generally in the form of standard deviations) and of border lines fur certain types of child or school; *e.g.,* for mentally deficient children or special schools for the educationally subnormal.

Tests also are available for more advanced subjects in the curriculum, to be used with older children at the secondary school stage; *e.g.,* for foreign languages, both ancient and modern, and for the various branches of mathematics and science. However, because of the difficulty of securing fair samples of pupils at these higher stages, the standardization of tests is less reliable. Attempts have also been made, particularly in the United States, to develop tests for academic subjects taken at the university stage — teaching, medicine, dentistry, engineering. accounting and law.

For occupational guidance and selection in commerce and industry. vocational psychologists endeavoured to construct tests for assessing the extent to which a given applicant possesses the kinds of knowledge and skill required for this or that specific type of employment. Norms of performance are commonly given for the occupations to which they relate and border lines below which efficient performance cannot be safely expected. Many large firms maintain their own trade-test departments for compiling, standardizing and administering tests of the proficiency of their own employees (see PSYCHOLOGY, APPLIED: Vocational *Guidance*).

2. General and Special Abilities.—Tests of ability differ from tests of attainment or proficiency in that, while the latter are intended to measure the actual results derived by formal education or occupational training, the former seek to estimate differences in mental capacity, regardless of the effects of instruction, training or experience. Whether such capacities exist and, if so, what is their precise nature, have been the topics of somewhat heated discussion.

Galton's contention that there were two main types of cognitive capacity for which tests could be developed—general ability and special aptitudes—met with a double opposition. Spearman and his followers contended that the assumption of a single general factor only would suffice to account for all innate intellectual differences; the hypothesis of special abilities or aptitudes they repudiated as an obsolete relic of the old-fashioned theory of faculties. On the other hand, most U.S. investigators—Thorndike, Thurstone and their collaborators—early accepted the existence of special or primary abilities but were highly skeptical of anything described as general ability or "intelligence." The numerous researches carried out by educational and industrial psychologists leave little doubt about the existence of special abilities, and in his later years even Spearman acknowledged their influence, at least on a limited scale. Most British psychologists accept the hypothesis of general intelligence as well, and the majority of the former critics—Thorndike, Brown, G. Thomson and Thurstone—retracted or at any rate moderated their earlier objections in varying degrees.

The attempt to identify the precise nature of the various special abilities or aptitudes has formed an important object of later factorial research. Unlike the "faculties" of the older psychologists, the abilities that can most readily be distinguished turn out to be decidedly complex and may themselves be analyzed or subdivided into more elementary types of capacity, almost without limit. In fact, the whole structure of the mind appears to consist in a hierarchy of abilities, the more general being usually the earliest to mature; during the course of the child's development, they become progressively differentiated into the more specialized, while the more elementary tend to combine into the more complex.

The special abilities so far established may be conveniently classified according as they arise from differences in the processes involved or in the mental content. The latter are the easiest to isolate and measure. The more elementary relate to differences in the sensory content: effective tests are available for the visual perception of form and colour, for the discrimination of audible pitch and loudness and for the discrimination of touch, weight and muscular movement. Equally well established are the differences between the chief types of mental imagery, and there are tests and questionnaires intended to discriminate between visualizers, audiles, motiles and (most common) the various mixtures. From the standpoint of educational and vocational guidance, four content factors are of prime importance, namely, the abilities (or groups of abilities) which underlie (1) the understanding and the use of words (so-called verbal ability), (2) the understanding and use of number and numerical relations (so-called arithmetical ability), (3) the visual and kinaesthetic perception of space and (4) the control of co-ordinated movements such as are involved in mental skill and mechanical dexterity. Less clearly distinguishable are the factors entering into the understanding and use of relations, especially logical relations, and into aesthetic appreciation in its various forms.

Of factors defined in terms of the processes involved, the most important are those for speed, mechanical memory, productive association (*i.e.*, imagination in the popular sense of the word) and certain formal processes underlying rational thinking—abstraction, generalization and inductive and deductive inference. Since efficiency in tests for all these different activities depends in some degree on general ability or "intelligence," it is essential, when assessing the primary or specific ability in and for itself, to include some test of intelligence as well in order to eliminate its effects by means of partial regression or some equivalent device. On the whole, however, it must be admitted that tests for special abilities can claim neither the high reliability nor the high validity of tests for general intelligence.

With young children it is desirable, so far as possible, to assess innate potentialities—a problem which cannot be solved by tests alone. With adults it is usually sufficient to assess their actual abilities or aptitudes at the time of testing. Accordingly, the earliest vocational tests were commonly based not so much on abstract psychological theory as on a direct study of the work required, often investigated at first hand by a psychologist who himself undertook employment on the job in question. However, the attempt to compile efficient tests for the complex aptitudes required in all the various branches of commerce or industry is a lengthy and circuitous way of tackling the problem. Hence experts in vocational guidance tended more and more to determine the fundamental abilities required for different occupations on the assumption that the same elementary ability may enter (though in varying degrees) into several different occupations. For this purpose the results of theoretical studies, particularly by factorial techniques, proved of increasing value.

Before turning to the method of assessing temperamental characteristics and what is commonly termed personality, it will be well to consider first of all the various technical devices that were progressively worked out for compiling and calibrating tests of abilities and attainment and then to review the chief uses, both theoretical and practical, to which such tests may be put.

B. CONSTRUCTION AND STANDARDIZATION

1. Sampling **of** Tests and Persons.—Since mental measurements are far more liable to be affected by error than physical measurements, special care has been devoted to ascertaining the most effective methods for constructing and calibrating the procedures used. The first requisite is to define, in precise scientific language and in the light of current psychological theory, the particular characteristic to be measured. Such a definition is needed not merely to select suitable tasks or test material but also to secure an adequate criterion. The abstract definition must be capable of translation into concrete operational terms, so as to indicate what wili be the outward and visible signs of the inner postulated trait. The kind of behaviour chosen for observation may consist of answers to oral or printed questions, manipulations of the parts of some piece of apparatus, or relatively complex reaction to some standard situation.

The main part of the psychologist's task, however, is to test the test, *i.e.*, to determine (1) its reliability and (2) its validity. This involves a twofold process of sampling: it is essential (a) that the items selected for the test include typical specimens of the activities in question and (*b*) that the persons selected for testing form a typical sample of the population for whom the test is designed. Both items and persons therefore must be chosen in accordance with the principles recognized as necessary in order to ensure that the samples are genuinely random or at any rate truly representative. As a rule in the trial experiment the number of persons tested will be far smaller than the number to whom the test eventually is to be applied. On the other hand, the number of items should be much larger than the number to be incorporated in the final version. The items selected must be as numerous and as varied as the conditions of the examination permit. Consequently, unlike the question paper set at an ordinary examination which usually requires one full-length essay or about four to eight questions involving fairly long replies, most psychological tests comprise a large number of short problems—often as many as 50 or more to be answered in half an hour. Each is so framed as to reduce to a minimum all irrelevant forms of skill and knowledge (*e.g.*, reading, writing and cultural information) and to elicit answers that require a minimum of subjective judgment in deciding whether each reply is right or wrong. For example, "Jim is taller than Harry, but shorter than Tom; and Dick is shorter than Harry: which is the tallest of the four—Jim, Tom, Dick or

Harry? (put a line under the right name)." In such a question all the words used can be read by an average child of seven, but the problem in reasoning cannot be solved until a mental age of nearly ten, and at that age every child (with rare exceptions—*e.g.*, invalids absent for long periods) can understand the sentence. For such children, therefore, the ability to find a correct answer depends solely on capacity to reason and their replies can be marked mechanically by a clerk or even a machine.

2. Reliability. — In administering the preliminary version the first thing is to ascertain whether the results are self-consistent or, as it is usually termed, reliable. When any object or quality is measured more than once: the measurements almost invariably differ in some degree, and with psychological traits these variations may be Iarge. Hence earlier investigators made a practice of applying each test at least twice and calculating the correlation between the two sets of results. Later investigators were more often content with a single application and divided the entire series of items into two equivalent subsections. In this case the usual procedure is to carry out an analysis of variance, tantamount to calculating the average correlation for all possible methods of division. The correlation computed by one or the other of these methods is known as the reliability coefficient.

3. Validity. — By the validity of a test is meant the degree to which it succeeds in measuring the trait that it was intended to measure. For this a criterion is needed. The simplest check is to obtain subjective estimates for the trait drawn up by one or more experienced observers who have known the persons tested for a long period. When the test is to be used as a predictor, it is better to follow up the persons tested during subsequent years and secure new and independent measurements based on their after history. Occasionally some well-established test of known reliability and validity is deemed a sufficient criterion. In all these cases the accuracy of the new test is assessed by correlating the test results with those of the criterion, and the index thus obtained is known as the validity coefficient. But, where practicable, by far the safest procedure is to base the criterion not on a single set of assessments derived from direct observation or a single test but on a wide range of tests and assessments, all assumed to measure the same quality; the criterion will then be the general factor underlying the whole series of assessments, each being duly weighted. This method involves calibration by means of factor analysis (see below). With a composite test, it is also desirable to validate not merely the test as a whole but each component item—a procedure known as item analysis—-and those items with low correlations with the criterion are then rejected.

4. Types of Measurement. — When a sufficiently reliable and valid version has at length been constructed, the final step is to reduce the assessments to terms of a quantitative scale and then compile norms for precisely defined groups of the general population; *e.g.*, in the case of children, average performances for either sex at each successive age. To obtain scaled assessments for different kinds of trait, various types of measurement are available; *e.g.*, (1) classificatory, requiring only the determination of the presence or absence of the class attribute, expressed on a binary scale by 0 or 1; (2) ranking, requiring the determination of more or less, expressed by ordinal numbers; (3) differential, requiring the determination of equal differences or intervals; (4) ratio scales, requiring the determination of equality of ratio; (5) multidimensional scales, expressed by the assignment of a matrix of numbers.

In some instances, as in testing for colour blindness, the assessment is essentially qualitative or classificatory. Modern psychology, however, is skeptical of classification into types: border-line cases and mixed types are nearly always found and are often the most numerous. In most cases, therefore, the assessment is quantitative. and the ultimate aim is to obtain a graded measurement. With many tests (*e.g.*, for drawing or handwriting) the quality assessed exhibits varying degrees of excellence! but these have to be judged by subjective impression. In suck a case the nearest approach to a comparable measurement is obtained by simply arranging the individuals' performances in an order of merit. Each examinee is then given a rank, stating his position in the whole group, but, since groups differ in size, the ranks are then converted to percentile form. However. the intervals between successive ranks and percentiles are far from equal, since persons near the general average are usually far more numerous than those toward either extreme. Hence neither ranks nor percentiles are additive. With the majority of tests it is reasonable to assume that, in a representative sample of the population, the underlying measurements will be distributed approximately in accordance with the normal curve. Accordingly, by using tables for the normal distribution. any percentile can be converted into a multiple of the standard deviation (s.d.). Such measurements are said to be in "standard measure" or "standard score" (see below).

Often, however, the trait itself by its very nature implies an appropriate quantitative measure. With tests for elementary processes, such as sensory discrimination or speed of reaction, for instance, there are as a rule obvious objective units; *e.g.*, grams for the discrimination of weight, seconds for the measurement of speed. As ordinarily administered, many of the tests for higher mental processes also turn, directly or indirectly, on the measurement of speed. With group tests a limited time is usually imposed, and the raw measurement consists of the number of correct solutions achieved in the time allowed. With individual tests a limited number of problems may be set, each of the same difficulty as the others and all well within the capacity of the examinees. The measurement then consists of the time taken by the person to complete them all. Speed, however, is not always a satisfactory index of ability, and in general it is better to use a series of items, varying in difficulty and arranged in order of increasing complexity, from one so easy that all can answer it up to one so hard that all will fail; with this modification the actual number correctly solved really depends more on qualitative efficiency than on sheer speed. Tests of the former type are termed uniform tests and tests of the latter type graded tests.

5. Comparable Scales. — Standard *Measure*.—With such varying procedures and different methods of construction the raw measurements, taken as they stand, will seldom be comparable from one test to another. Hence it is usually desirable to convert the measurements as originally obtained to terms of a scale where the zero point and the unit shall always indicate the same amounts. This means a further process of calibration. One device, which is almost always available in a well-planned research. is to treat the average of the entire sample of persons as marking the zero point for the general population; different individuals can then be measured in terms of their deviation about this average, and each deviation can be expressed as a multiple of the average deviation of all the persons in the sample—*i.e.*, the standard deviation of the group. Once again, then, the measurements will be in "standard measure." Yet, even here, it is often wiser to deduce each standardized measurement indirectly from the examinee's rank (as described above) instead of directly from the ra measurements themselves Measurements in terms of the s.d. involve the use of plus and minus signs and of fractions—a type of scaling which has obvious inconveniences in actual practice. Consequently, it is often preferable to substitute an artificial scale in which all the measurements are positive integers (*e.g.*, one with a mean of 50 and an s.d. of 10, or a mean of 100 and an s.d. of 15) ; the latter has the additional merit of yielding scores that are analogous to the familiar intelligence quotients.

Mental Quotients. — As originally computed the intelligence quotient or mental ratio developed out of a method of standardization popularized by Binet. For the fundamental unit he proposed to take the increment of growth from year to year, with the ability of a newborn infant as the zero point. On this basis characteristics which, like intelligence, mature with increasing age or, like school attainments, accumulate from year to year can be assessed in terms of a mental age. Binet therefore standardized the various problems in his scale according to the age at which the average child could correctly answer them, the whole series thus forming an age scale measuring intelligence in terms of mental years.

However, unless the children to be compared are all of the same chronological age. this does not yield a satisfactory indication of their inborn ability. With many graded tests, including Binet's, the standard deviation for successive age groups increases roughly in proportion to the increase in age. This suggests using the ratio of the child's mental age to his chronological age (usually expressed in percentage form) as an index which may be expected to preserve a fair degree of constancy from year to year up to the time of puberty—a device first proposed by Wilhelm Stern in 1911. With a percentage scale the mean is necessarily 100 and, with the versions of the Binet intelligence scale commonly used in the U.S. and Britain, the standard deviation for complete age groups is approximately 15. However, the underlying assumptions on which the method is based are only broadly true, and "mental ages" and "mental ratios" or "quotients" computed in this way are suited only for rough practical purposes, not for scientific research. In the vast majority of cases the most satisfactory scale is one based on standard measures derived from percentile ranks.

Other methods of scaling, based on more complicated statistical techniques. were put forward from time to time. some of them intended to provide an "absolute scale." Since mental characteristics often consist of patterns of traits rather than of simple graded qualities, one or two statistical writers suggested that the ideal measurement in psychology should take the form not of a single figure but of a "matrix" of elementary assessments, such as will describe a complex structure rather than an isolated tendency and can itself be treated as a unitary system. The easiest way to handle such a matrix is to convert it by a canonical transformation into a "factor"—a method developed by British psychologists who adopted Karl Pearson's techniques.

C. Uses of Psychological Tests

1. Theoretical Value.—Psychological tests are widely used both as a research technique for investigating the basic characteristics of the human mind and as a practical tool in studying individuals for purposes of educational or vocational guidance. Their adoption for such purpqses, however, has not escaped criticism. particularly from psychologists of the Cambridge school such as C. S. Myers and O. L. Zangwill. That their warnings need to be borne in mind is shown by the exaggerated claims often made in popular expositions of the subject and by the way in which teachers, school doctors and sometimes education authorities rely on raw measurements obtained from unchecked or inadequately standardized tests, as if they could always be accepted at their face value. Nevertheless, an impartial study of the results achieved fully demonstrates the value of such methods in the hands of those who have been trained in their use and are aware of their inevitable limitations.

Contrary to the common notion, mental tests were first devised for the solution of theoretical rather than practical problems. Galton and most of his immediate followers were interested primarily in problems of mental inheritance. To some extent their early inferences were vitiated by the nai've assumption that innate characteristics are directly observable—a notion accepted by most biologists at that date. So far as human beings are concerned, it is universally acknowledged that any actual measurement is bound to be the composite product of both heredity and environment interacting one uith the other and, without special mathematical techniques, it is difficult to disentangle their relative influence. However. in spite of persistent skepticism as to the possibility of distinguishing the tao components, there has been a fruitful revival of research in psychogenetics, and the substitution of R. A. Fisher's statistical procedures for the cruder methods of Galton and Pearson yielded trustworthy conclusions in regard to the inheritance of inteliigence and other mental characteristics.

The interest of McDougall and those who worked with him centred rather on what they called the structure of the mind. McDougall himself conceived the hypothetical abilities and emotional propensities that enter into various forms of mental activity as analogous to the hypothetical "forces" of physics. This analogy suggested the adoption of a mode of analysis which would resolve the more complex manifestations of behaviour (the "resultants" of such forces) into elementary "components" in accordance with the so-called parallelogram law of dynamics. For this purpose Pearson's mathematical formulas for reducing a matrix of correlation coefficients to a set of orthogonal components seemed to provide the most appropriate working procedure, and, in various simplified forms, it was widely used for determining the "factors of the mind" both on the cognitive (or intellectual) and on the affective and conative (*i.e.,* motivational) aspects. Tests are then constructed for estimating the various "general" and "special" factors (*e.g.,* general intelligence and special or primary abilities on the cognitive). Here again criticism was active, being directed partly against the type of mental structure set up by different investigators and partly against the somewhat crude computing methods used by earlier workers. The introduction of electronic means of calculation have made it practicable to adopt more precise and elaborate techniques, which led to improvements in the test procedures themselves and in the assumptions on which they are based.

2. Practical Value.—From 1910 onward the rapid development of mental testing was due mainly to the recognition of its practical uses. In Britain, particularly in large industrial areas such as London and Liverpool, with their overcrowded slums, the poverty, squalor and truancy, together with the hostility of many parents to the aims of the schools, prevented many pupils from achieving the full educational progress of which they were in fact capable. Surveys carried out during the earlier decades of the 20th century showed that many children were being certified as mentally deficient who were merely dull or backward, while many who had high ability failed to pass the scholarship examination which entitled them to a free place in a secondary school. The introduction of mental tests together with other psychological techniques did much to alleviate these forms of educational injustice.

Where tests are used for selection on an extensive scale, their predictive value is commonly assessed in terms of a correlation coefficient. Thus, to check the efficiency of the so-called 11+ examination carried out annually by most English education authorities (when about 700.000 pupils are examined for admission to a grammar school), representative samples are followed up and reports obtained from the headmasters toward the end of the secondary course. On an average about 20% are selected from the entire age group and out of this 20% roughly one in four are subsequently reported as unsuitable, while about the same number of those rejected appear to have been rejected wrongly. These proportions are equivalent to a correlation of approximately 0.90. It should be noted, however, that the pupils who were wrongly selected or wrongly rejected are nearly always border-line cases, so that the inaccuracy of the assessment is not so serious as is often alleged. Moreover, these apparent errors are due not merely to defects in the examination itself but also to the inevitable fluctuations in each child's subsequent development and to various accidental conditions, such as ill-health or inadequate motivation at the time of testing.

With adults formal testing is, as a rule, less satisfactory. Nevertheless, it is not without its value in occupational guidance and selection. Here the method of estimating the efficiency of the various procedures has to be modified. The commonest method is to adopt the device of matched groups. One batch of candidates is selected in the ordinary manner and the other on the basis of the test results. The after histories of both are then systematically compared. In the main the data obtained fully justify the value of scientific testing as an adjunct to other procedures. When tests are used for diagnosing individuals or for predicting their subsequent progress, it is essential that the marks or measurements not be accepted in isolation from all other information. A single test scale, particularly if obtained during a group examination, may prove a precarious indication of the characteristic the investigator wishes to assess. But when interpreted in the light of other data (past history, family records, environmental conditions, observations of general behaviour, etc.) their value is unquestionable. (Cy. B.)

III. TESTS OF PERSONALITY AND TEMPERAMENT

In personality testing the first major task—shared with all other kinds of psychological testing—is the construction of tests that are sound and reliable and that are addressed to significant traits of individual behaviour. The second major task is the development of interpreters with sufficient diagnostic and interpretive skill to appraise the individual case. Attainment of the first goal requires research procedure and statistical analysis (see Construction and Standardization, above). The possibility of evolving a "psychodynamic portrait" from test scores, however, is more a matter of the intuition and skill of the test interpreter than of the particular tools employed. It is for this reason that so much stress is put upon the professional training of the practitioner in the field of personality testing.

An obvious problem in personality testing is the selection of the proper factors for measurement from among the seemingly endless number of traits, attitudes, values, behavioural tendencies, points of view, qualities of mind and other characteristics a person manifests; the next problem is that of organizing them so as to give rise to an integrated and functional view of this person as a distinct individual. The level of understanding desired rests on proper evaluation of three components: (1) the attributes of personality; (2) the structure or dynamic interplay of these attributes; and (3) the behavioural implications of this system of attributes.

G. W. Allport listed about 50 definitions of the term personality, drawn from philosophical, legal, sociological and theological as well as psychological writings, Many of the definitions stressed the way in which the person is perceived by others. This emphasis, however, seems too restricted, for it neglects the inner. subjective components of mental life and their implications for overt behaviour, An adequate view of personality must be broader. incorporating latent traits as well as those more manifest. It should also emphasize the organized pattern of traits and attributes underlying and determining the behaviour of the individual.

From this standpoint, temperament is seen as a factor or component of personality. Specifically, it refers to typical modes of reaction, states of energy and moods. The descriptive adjective "capable" would refer to personality but not to temperament, the adjective "impulsive" would refer to both. Another broad term often used in speaking of personality is "character." Following the above, character also is to be seen as an aspect of rather than as a synonym for personality. The emphasis in character is on morally sanctioned and approved attitudes and behaviour. (See also PERSONALITY; CHARACTER; TEMPERAMENT.)

The commonest unit of description and measurement of personality is the trait. A trait is an enduring quality showing itself in the typical way a person behaves in many different situations. All trait descriptions imply a basis of comparison with other persons. a dimension of variation. Thus most traits are present to some degree in most persons; the trait becomes salient only if it characterizes a person to a greater or lesser degree than the average. In personality analysis the psychologist looks for these significant departures from the norm; in personality testing one of the tasks is to specify units of variation for a trait and then to locate persons as high, average or low.

A vexing problem in the psychology of traits is their number. Allport and H. S. Odbert assembled a list of 17,953 English adjectives used to describe specific modes of behaviour and thought. Each of these words represents a potential trait for the personality psychologist. Such a list obviously needs to be reduced in length if economy and efficiency of descriptive language are to be attained. One such attempt mas made by Cattell, using the technique of factor analysis, a method developed first by Thurstone on the basis of work by Spearman. Cattell succeeded in defining what he believed to be the 12 "primary" trait dimensions of personality. These dimensions ranged from cyclothymic (voluble, emotionally expressive) *v.* schizothymic (withdrawn, reserved) through surgency (cheerful, buoyant) *v.* desurgency (listless, phlegmatic) to sophistication (cool, detached, aloof) v. simplicity (attentive to people, sentimental).

Another significant attempt to specify the major dimensions of variation in personality was that of H. A. Murray, who defined a set of needs which either singly or in combination could be used to explain the behaviour of any person. Examples from Murray's list are these: need:achievement, to succeed in something difficult, to rival and excel others; need:infavoidance, to avoid humiliation, to refrain from action through fear of failure; need:sentience, to seek and enjoy sensuous impressions.

Several other bases for the choice of terms to describe and analyze warrant citation. The language of diagnostic psychiatry has been a continuously important source of concepts. Personality tests for factors such as hypochondriasis (excessive preoccupation with bodily functions), paranoia (exaggerated and irrational distrust and sensitivity) and hypomania (overexcitability. improvident and unmodulated discharge of energy and impulse) are examples of this tradition. Systematic testing methods also have been based on the theory of value types developed by E. Spranger, on recurrent and self-revelatory modes of perception (H. Rorschach) and on occupational choices and vocational preferences (E. K. Strong).

In the years since Binet's first test of intelligence was issued there has been a great increase in the numbers and kinds of testing instruments. A bibliography for mental testing and rating scales published in 1939 contained 4,279 citations; a supplement published in 1946 contained 3,294. It is obviously impossible to discuss any save the most important or most representative examples in this review. For a more thorough description and appraisal of personality and temperament tests the reader is referred to the series of Mental *Measurements* Yearbooks and to textbooks on psychological testing such as those by Anne Anastasi, L. J. Cronbach and D. E. Super (see Bibliography).

A. EARLY TESTS OF PERSONALITY

1. Free Association. — One of the first methods systematically used as a test of personality was the free association technique introduced by Galton in his studies at the London anthropometric laboratory which he founded in 1884. The free association method was later used by the German psychiatrist Emil Kraepelin, who presented a list of words to psychiatric patients, requiring them to give in response the very first word that came to mind for each stimulus. The Swiss psychiatrist C. G. Jung (1910) developed a special stimulus list of 100 words for use in diagnosis of the "complexes" of unconscious conflict envisaged by his theory; various diagnostic indicators in inner conflict were enumerated, such as delay or acceleration of response, inability to respond, facial grimaces, changes of skin colour, etc. A similar list was prepared by the U.S. investigators Grace Kent and A. J. Rosanoff (1910). Many other lists were later developed, but the two of Jung and Kent-Rosanoff continued to be the most widely used. (See also ASSOCIATION. MENTAL.)

2. Questionnaire. — Galton also can be said to have originated the questionnaire method, although a prominent early practitioner of the technique was G. S. Hall, particularly in his studies of developmental psychology and adolescence (1891, 1904). However. the prototype of the modern personality questionnaire was the Personal Data Sheet developed by R. S. Woodworth (1918) for use as a screening device to detect men psychologically unfit for military service. The Personal Data Sheet included 116 items selected from a much larger number of items on the basis of the correlation between each one and the total score for all the items. This method of inventory construction is called the internal consistency method and was widely followed in the development of other tests. The questions in the data sheet covered ten categories of distress, such as physical symptoms, fears, antisocial moods and compulsions, and included items such as these: "Are you frightened in the middle of the night?" "Do you have continual itching in the face?" and "Does liquor make you quarrelsome?" The score on the test was simply the number of such items answered in the unfavourable or "disturbed" direction. Although at first very widely used, the Personal Data Sheet gradually was displaced by inventories covering a greater number of trait categories and including items less obvious and susceptible of direct dissimulation.

One of the personality inventories widely used in testing of secondary school and university students is the Bell Adjustment Inventory. first published in 1934 by H. M. Bell; the inventory also has a less frequently used adult form. The test contains 140 questions of the "yes," "no," "in" response variety, attempting to assess personal adjustment under four categories (home. health, social and emotional); it also yields a total score. The adult form includes the above plus 20 additional questions covering occupational adjustment. The inventory is useful as a quick diagnostic indicator of the extent and locus of a subject's problems, but is too transparent and easily falsified for use in settings nhere "faking" is likely to occur or where significant deficiencies of self-insight are to be expected.

Another questionnaire that has enjoyed wide usage is the Bernreuter Personality Inventory, first published by R. G. Bernreuter in 1931. In its original version this test contained four scales, each in itself the descendant of an earlier and independent test: neuroticism, self-sufficiency, introversion and dominance. The 125 items in the test were taken from these earlier instruments, and resemble those cited above for the Woodworth Personal Data Sheet. Many of the items contributed to the score on more than one of the factors, giving rise to a doubt concerning their statistical independence. A factor analysis of the test by J. C. Flanagan in 1935 suggested the presence of only two discriminable dimensions: self-confidence and sociability. Nonetheless, most users continued to score the test for the original four scales, occasionally using the two factors of Flanagan as additional scores.

Research analyses of the Bernreuter test showed it to have serious weaknesses in regard to its openness to "faking" and to its failures in the detection of psychiatrically disturbed or maladjusted persons who are unaware of their problems or whose modes of self-defense cause them to minimize or deny their doubts and anxieties when asked to report on their well-being.

3. Ink Blot.—Experimentation with ink blots and interpretive responses given to more or less unstructured materials represents another theme in the development of methods for testing personality. Binet, the originator of the intelligence test, also conducted studies in this domain. A number of U.S. investigators around the turn of the century espoused the method, but tended to be more interested in it as a way of studying imagination and the "higher mental processes" than as a technique for personality analysis. Whipple's testing manual (1910) contained a description of ink-blot methods and instructions for their experimental use. The major impetus to the development of this method, however, came from the Swiss psychiatrist Rorschach, who, on the basis of prolonged experimental tryout of various blots and various methods of administering them to subjects, evolved in 1921 a series of ten blots and a technique of administration and analysis that have remained the unquestioned standards in the field. Rorschach's genius lay in his recognition of the importance of formal and structural elements in response to the blots as well as the content of such responses. Following Rorschach's death shortly after the introduction of his method, the work was carried forward on the continent by his student E. Oberholzer and in the United States largely through the efforts of S. J. Beck and B. Klopfer.

4. Situational-Observational.— In the method of situational testing the subject is asked to carry out some task or to do a certain thing, his behaviour then being observed and rated or calibrated in some specified way. The performance requested may be one from everyday life (*e.g.*, to participate in an impromptu discussion), or it may be quite alien to the subject's usual experience (*e.g.*, interrogation concerning a make-believe crime by a hostile and disparaging investigator). The first extensive application of situational techniques was found in the work of H. Hartshorne, M. A. May and their collaborators (1928–30). Their researches, done primarily with school children, attempted to derive quantitative indices of behaviour such as cheating, lying, stealing, cooperativeness and persistence. Their results were so much opposed to the prevalent belief that conduct is merely the manifest expression of generalized traits (such as honesty, generosity, selfishness, etc.) that for several years other efforts to develop testing methods for these factors were inhibited.

Nonetheless, the situational-observational method began to take root, and a clear statement of its aims and purposes was made in a book published by the United States Office of Strategic Services psychological staff, Assessment of Men: Selection of *Personnel* for the *Office* of Strategic Services (1948). The method, involving the intensive observation and study of the person over a two- or three-day period of time and utilizing a wide variety of techniques and testing aids, gradually came to be called that of personality assessment, and by the mid-1950s this approach had become one of the most significant developments in psychology of the postwar period.

B. Empirically Constructed Tests

The weaknesses of the Woodworth test and other questionnaires of this type are exceedingly difficult to avoid in tests constructed by internal consistency methods. In this approach, the test developer first writes or chooses the items for his test, and also decides how they should be scored so as to indicate "nervousness," "leadership," "occupational dissatisfaction," "poor morale" or whatever the factor is that he intends to appraise. The items are then put into a preliminary test, which is given to a sample of persons and scored. The individual items are next correlated with the total scores, the purpose being to discover any that do not have a significant correlation with the total; such items are eliminated from the test, the justification being that they do not co-vary with the general tendency being measured by the full set of items. The remaining items—those that do correlate well with each other—are retained for the final version of the test.

This psychometric purification results in a scale or test that represents well the view of the psychological trait that the test developer had in mind when he began his work. The method makes no secure provision, however, for correcting the developer's erroneous preconceptions as to which way items should be answered to indicate abnormality (if this is what he is seeking to measure) and for revealing which items are diagnostically useful. "Nervous" people do not always answer an item in the way one would expect from their symptomatology. For example, more often than not they may answer "false" to the item "Thoughts run through my head so that I cannot get to sleep at night," even though they have insomnia, while well-adjusted people may feel rather free to admit that they have this problem on occasion. Following the method of internal consistency, this item might be keyed "true" because it had a high correlation with total score, whereas a comparison of the answers with a nontest criterion of "nervousness" would reveal that denial of this common experience was the diagnostically more important response.

A contrasting mode of test development is the "known-group" or "empirical" method, in which the responses of externally classified groups (*e.g.*, persons in a certain occupation, students nominated as outstanding leaders, diagnosed patients in a psychiatric hospital) are studied to determine empirically (by observation) what if any questionnaire responses differentiate the group from control or base-line groups. Such a method will automatically reduce the effect of preconceptions held by the test maker; furthermore. if his list of test items was large, it will indicate new diagnostic insights for the trait. The former constitutes a distinct gain for test validity, where validity is taken to be the test's correspondence with the external nontest world; the latter constitutes an equally distinct gain in the control of faking, for such newly discovered relationships will be beyond the knowledge of most persons to whom the test is given and they will not know how to distort their answers to produce the desired effect.

1. SVIB.—Perhaps the leading example of the tests that have used known groups in scale construction is the Strong Vocational Interest Blank (SVIB), first published in 1927. The inventory was continuously expanded and revised until by 1958 scores for over 50 different occupations could be obtained. A parallel vocational interest blank for women was brought out by Strong in 1935, this form being scorable for about 25 occupations. The male form of the SVIB contains 400 items, grouped into eight sections. The first five cover the categories of occupations, school subjects, amusements. miscellaneous activities and peculiarities of people. Preferences are indicated for each item by circling the letter "L," "I" or "D" (for "like," "indifferent" or "dislike"). The last three sections of the test call for ranking of certain activities in order of preference, choosing options in pairs of items and the rating of own abilities and other characteristics.

Scoring keys were developed by studying the responses of persons successfully engaged in a specified occupation and then contrasting their item statistics with those obtained from a sample of men in general. Items that revealed clear and significant differences were selected and marked for scoring so as to stress the responses actually given by men in the particular occupation.

The test scores of a person who takes the SVIB are entered on a profile sheet that provides letter-grade equivalents ("A," "B" and "C") for each of his scores. An "A" rating signifies a high score, in the range usually observed among persons actually employed in the field; a "B" rating is in a more indeterminate range; and a "C" rating indicates a score significantly lower than those typically found for persons working in the field. These letter ratings, it should be emphasized, are indications of the correspondence between a person's interests and those of persons in the occupational fields; they do not necessarily indicate anything about his aptitudes for work in those fields. The co-variation of scores for the different occupational keys permitted the grouping of scales on the profile sheet into "job families." For example, scores on the keys for lawyer, advertising man and author-journalist usually vary concurrently and are therefore grouped together into what test interpreters call the verbal-linguistic cluster. These scale clusters on the profile sheet have enabled skilled users of the Strong test to develop complex forms of profile interpretation and even a form of personality analysis that goes far beyond the simple listing of areas of vocational choice and vocational rejection.

The profile sheet also provides for the listing of several scores besides those directly pertaining to a specific occupation. (1) The occupational-level scale reflects differences between interests of unskilled and semiskilled workers on the one hand and those of business and professional men on the other. (2) The interest-maturity scale was based on a contrast between males of age 15 and those of age 25 (the age at nhich Strong iound a fairly stable crystallization of interest patterns). (3) A specialization-level scale reflects interests characteristic of medical specialists and of research workers in other scientific fields. (4) Finally, a masculinity-femininity scale shows the degree of similarity between the person's interests and those characteristic of men or of women, respectively.

2. Kuder Preference Record.—This test. first begun in 1934 by G. F. Kuder. and issued in various forms since then (1939,1942, 1948), also yields scores indicative of occupational interests The vocational form of the test (Form C) includes 168 item triads describing three different activities or interests. The respondent selects in each triad the one he likes most and the one he likes least. On the basis first of logical groupings of the items and later of extensive statistical analysis ten interest scales were developed: outdoor (agricultural, naturalistic), mechanical, computational, scientific, persuasive, artistic, literary, musical, social service and clerical. A verification scale to detect carelessness and failure to observe instructions is also included. A profile sheet for the record provides for an automatic conversion of raw scores to percentiles, and the profile pattern gives a visual picture of the high, average and low rankings over the ten categories.

Both the Strong and the Kuder tests are very popular. The Kuder has the advantage of a smaller and simpler set of categories and lends itself to situations where self-interpretation of scores is a necessity. The Strong test, however, contains a greater fund of information and is also supported by a significantly greater amount of validating research literature.

3. Minnesota Multiphasic.— The Minnesota Multiphasic Personality Inventory of S. R. Hathaway and J. C. McKinley, first published in 1943, contains 550 true-false questions, many borrowed from earlier tests such as the Woodworth Personal Data Sheet and the Bernreuter Personality Inventory. It also includes, however, original items more directly pertinent to the areas typically examined by a thorough diagnostic interview in a psychiatric setting; the questions cover 26 such categories.

Fourteen scores are reported on the standard profile for this test. These scales and the diagnostic aim of each are summarized as follows: (1) Cannot say—to identify records rendered invalid by the exclusion of too many items. (2) Lie—items involving improbable claims to moral virtue and rectitude, the answering of which in the scored direction implies an attempt to falsify or the presence of strong repressive-constrictive trends. (3) "K"—reflects the subject's habitual style of verbal behaviour and self-description, ranging irom restrictive prudence and inhibition at one end to crudity and lack of restraint at the other; scores on certain of the other scales are adjusted up or down according to the person's score on the "K" scale. (4) "F"—includes highly unusual and atypical response choices, serving to identify records with an undue number of answers of an unusual or infrequent kind whether due to carelessness, deliberate falsification or distorted thought processes. (5) Hypochondriasis—reflects somatic complaints and preoccupation with bodily functions. (6) Depression—indicates general morale, feelings of depression and worry. (7) Hysteria—reveals tendencies toward repressive, immature emotional life and psychological expressions of inner conflict. (8) Psychopathic deviate—identifies persons of disruptive, rebellious temperament who find it hard to accept rules, restraints and orderly habits of life. (9) Masculinity-femininity—attempts to detect deviations of interests and outlook toward those characteristic of the opposite sex. (10) Paranoia—indicates attitudes of undue or irrational suspiciousness coupled with exaggerated sensitivity. (11) Psychasthenia—a heterogeneous set of doubts, worries, anxieties and complaints synthesized as a general index of agitation and perplexity. (12) Schizophrenia—reveals trends toward alienation from self and others, loss of self-direction and frankly delusional thought content. (13) Hypomania—a gauge of emotional expansiveness, excitability and accelerated tempo of thought and behaviour. (14) Social introversion—seeks to identify persons of diffident, anxious and retiring disposition.

These 14 scores are plotted on a profile sheet that provides an automatic conversion of the raw score totals to standard scores. A standard score is one that has been statistically adjusted so that its average value is always 50 and its standard deviation 10, to permit direct comparisons among scales. The profile of scale scores for the Minnesota Multiphasic, like that for the SVIB, lends itself very well to complex configural interpretations; psychologists skilled in the use of the inventory are frequently called upon to prepare personality analyses of patients tested in clinics and hospitals. The inventory is principally oriented toward matters of psychopathology and morbidity and has shown its greatest validity when applied to clinical and psychiatric problems; it has shonn less utility when applied to problems of normal behaviour and everyday life.

Personality inventories more directly concerned with the functioning of normal persons have not proved in general to be so popular as tests like the Minnesota Multiphasic, the Bernreuter and the Bell. Among inventories designed for nonpsychiatric testing may be mentioned the Edwards Personal Preference Schedule, published in 1954; the California Psychological Inventory, in 1956; the Maudsley Personality Inventory. 1959; the Study of Values; and the factorial tests described below.

C. Study of Values

The Study of Values was first introduced by Allport and P. E. Vernon in 1931, and then revised in 1951 by Allport, Vernon and G. Lindzey. The test is derived from a theory of Spranger, postulating that in the life of each person a great single unifying theme or value may be discovered. The Study of Values seeks to measure the relative strength of six such values: (1) theoretical—having a dominant interest in the discovery of truth, valuing critical, rational and logical thinking; (2) economic—primarily interested in utility, in the practicality and efficiency of things; (3) aesthetic—places highest value on form and harmony, seeks out and prefers artistic experience; (4) social—directed toward altruism and philanthropy, values the welfare of others and of mankind; (5) political—is power oriented, seeks esteem and renown, control over others; (5) religious—concerned with unity, the mystic nature of existence and of the cosmos.

The test contains 45 questions presenting either two or four propositions that the subject must rate in order of preference. An example is the following: "In your opinion, can a man who works in business all the week best spend Sunday in: (a) trying to educate himself by reading serious books; (b) trying to win at golf, or racing; (c) going to an orchestral concert; (d) hearing a really good sermon." The classification of these options under the value types of theoretical, political, aesthetic and religious obviously is not difficult, and this very ease reflects one of the limitations of the test — its openness to deliberate dissimulation. Another limitation resides more in the theory than in the test itself; that is, in the restricted applicability of the six value types. Even insofar as the unity thema concept in personality is correct, these particular six values contain an aristocratic bias in that they apply more to persons of intellectual, ratiocinative temperament than to the average man or woman.

D. Factor Analysis

The inventories discussed up to this point have dealt with either (1) dimensions of measurement taken directly from the settings in which the test is to be used (*e.g.,* the SVIB) or (2) with dimensions taken from theoretical systems whose goals were to explain and account for human behaviour (*e.g.,* the Study of Values). In inventories developed by the technique of factor analysis a markedly different basis of choice is to be seen. In factor analytic tests the factors to be measured are not necessarily those that seem on the surface most relevant to a particular setting or those that a previous theorist has talked about; on the contrary, the dimensions of choice are those that most economically summarize the variations of response to be found among the components of the testing battery.

The underlying logic of factor analysis is mathematical, and its principie of faith is that mathematically basic test dimensions will also be psychologically basic. Suppose that a number of experimental tests of "personal adjustment" were tried out and then scores on the experimental tests were intercorrelated. Undoubtedly some of the tests would overlap each other, and the full set mould contain an unnecessary amount of duplication. The aim of factor analysis in this example mould be to specify the extent of such redundancy and then to indicate the minimum number of underlying factors that could be used mathematically to account for all the scores found in the experimental battery. Direct measurement of these underlying factors could be said to be a more efficient and more valid way of assessing the domain of personal adjustment.

The technical methods of factor analysis are mathematically complex and difficult, but their purpose is simple: to identify the dimensions that will represent most economically the set of interrelationships given by a battery of test scores or test items. At first discovery, the factors may seem strange or different from the usual ways in which the test elements have been discussed. although this is partly a function of the names the analyst chooses to assign to his factors. A second, more significant, difficulty is that the new mathematical factors may have less accuracy as predictors of nontest behaviour than the mathematically impure tests the factors are designed to replace. In such instances the factor analyst seeks an optimum combination of factor-pure tests from which a valid prediction in a specific practical situation can be made.

Perhaps the leading U.S. exponent of factor analytic methods in personality test development has been J. P. Guilford, whose various inventories are used widely and are among the most important examples of factorially based devices. The Inventory of Factors STDCR (1940) included scales for social introversion, thinking introversion, depression, cycloid disposition and rhathymia (happy-go-lucky, carefree). The Guilford-Martin Inventory of Factors GAMIN (1943) covered the factors of general activity, ascendancy, masculinity. inferiority and nervousness. A third test, the Guilford-Martin Personnel Inventory (1943), included scales for the factors of objectivity, co-operativeness and agreeableness. A later test, the Guilford-Zimmerman Temperament Survey (1949), included 300 questions scaled for ten factors: general activity, restraint, ascendance, sociability, emotional stability, objectivity, friendliness. thoughtfulness, personal relations and masculinity.

Another leading exponent of factorial technique is R. B. Cattell, whose most widely used inventory was the Sixteen Personality Factor Questionnaire (1950). The inventory had two parallel forms, each with 187 items; a third form having 105 items was later added. Several examples from Cattell's designations of the 16 scales can be given: cyclothymia v. schizothymia; general intelligence v. mental defect; emotional stability *v.* general neuroricism; surgency v. desurgency; bohemianism *v.* practical concernedness; sophistication *v.* rough simplicity; and anxious insecurity v. placid self-confidence.

E. Projective Methods

Although projective methods for studying personality were used by Galton, Jung, Kent and Rosanoff and others, as mentioned above, it was not until the appearance of Rorschach's ink-blot technique in 1921 that the approach began its rise to prominence. Even in Rorschach's own work, however, the theoretical implications of the method were little developed. for he saw himself as an empirical scientist engaged in the development of a diagnostic tool having practical objectives. The first significant formulation of the theory and point of view of projective testing was given by L. K. Frank (1939). The fundamental theorem is that when confronted with unstructured stimuli the subject will impose structure on them in such a way as to reflect his own needs and impulses; properly interpreted, the subject's responses therefore can be used as guides to his private world of fantasy, his attitudes, fears, aspirations and the like.

1. Theory of **Projective** Methods. — The word projection in reference to this process and to this category of tests is somewhat equivocal. There has been a tendency to identify the theorem of projective testing with the psychoanalytic (Freudian) concept of projection; *i.e.,* with the mode of ego defense in which unacceptable impulses are externalized and attributed to others or to outside agents (see Defense Mechanisms). However, the projective test protocol is by no means delimited to denied and expulsed ("projected") psychological material of this sort, or even primarily focused upon it.

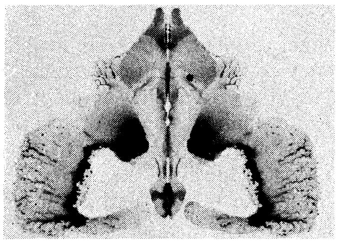
Another meaning of projection is simply that which stands out from its surroundings, that which extends beyond something else. This meaning of the term is somewhat applicable to projective tests insofar as the ambiguity of the stimuli and the freedom of the test situation often do permit the appearance of highly salient mental content, those concerns that are most active and impelling in the mental life of the subject at the time of testing.

However, a third meaning of projective. the geometric or cartographical one, is probably closest to the implications of Frank's thesis. In this meaning the external representation is not considered as merely a general derivative of its originating source. but as a specific point-for-point rendition of it. Thus, a geometric drawing gives an exact representation of the three-dimensional object from which it is made, and a map is intended as a precise guide to a given section of terrain. If to an amorphous ink blot a person replies, "Eyes of bloody fire," and then adds, "but it could be a dear little dancing mouse," the discontinuity is only apparent; each response represents a psychic event. and the path from the first to the second (*i.e.,* the relation between them) is as determined and meaningful in the psychic topography as the interval between points A and B in the geographic counterpart. The theoretical aim of the projective test is therefore no less ambitious than this: to chart in a faithful and interpretable way the full range and depth of the psychic life of a person.

In practice, the classification of tests as projective or nonprojective has followed lines of custom and convenience not always in accord with consistent interpretation of the theory. Freedom for the subject to respond as he wishes would seem to be an essential element of the projective method if crucial features of the subject's mental life are to have full opportunity to manifest themselves. The instructions in the Rorschach test, where the subject is asked merely to report on what he sees, satisfy this requirement very well; on the other hand, an activity check list where the subject simply marks "like" and "dislike" does not. The Rorschach test is therefore properly classified as a projective test, and the activity check list as nonprojective. However, one of the tests classified by custom as projective, the Szondi test, requires the subject to make this same "like" *v.* "dislike" response to a series of photographs of European mental hospital patients; the Szondi test therefore has no more and no less freedom of response than the nonprojective activity check list.

This logical confusion is seen again in the factor of ambiguity of stimulus materials, held to be an essential condition for projective responses. The ink blots of the Rorschach test are for the most part amorphous and lacking in readily perceived meaning. Yet the geometrical figures that the subject copies in the (projective) Bender-Gestalt test are clear and precise, certainly less ambiguous in point of fact than the more difficult items in a (nonprojective) test of spatial visualization. On this particular dimension of stimulus ambiguity, therefore, the nonprojective test of spatial visualization would have to be rated as closer to the projective test ideal than the projective Bender-Gestalt.

2. Rorschach Test.—The Rorschach ink-blot test contains ten stimulus cards, five achromatic ones having only shades of gray and black, and five chromatic blots incorporating various colours. The cards are presented to the subject in a standard sequence with brief instructions on the order of: "I am going to show you a series of ink blots, one at a time. The blots do not necessarily represent specific things; different people see different things in them. Would you please look at this blot and tell me what you see, what it makes you think of?" The examiner keeps a record from this point on of comments, responses, time consumed, how the cards are held and turned, etc. Questions are answered in noncommittal fashion; *e.g.*, "Whatever comes to your mind," "It's entirely up to you."



INK BLOT, SIMILAR TO THOSE USED IN RORSCHACH'S TEST

Analysis of the test covers four principal categories:

1. The first of these is location, the part or parts of the blot utilized in the response. The main elements in this category are the "whole" response, which involves the complete blot, the large detail and the small detail. The usual protocol (record of responses) strikes a balance among these three components; emphasis on one or another affords evidence for significant modes of personality functioning. For example, concentration on large, common details is held to be characteristic of the mundane, practical, fact-centred personality.

2. The second main scoring category concerns the determinants of the response; *i.e.*, whether form, colour, apparent texture of the surface, shadings, etc., in the blot influenced the response. Here again a balance among the elements ordinarily prevails, and deviations from the base line provide hints of salient trends in the personality. An excitable, uninhibited. effervescent person might have many responses in which colour is a vital feature; an aggressive, explosive person might show form elements subordinated to colour in nearly every instance. Where there is doubt about what qualities in the blot have given rise to a certain response, the examiner makes discreet inquiries. For example, to a certain red-coloured portion of blot the subject says, "And there I see a bow tie." The examiner, returning to this response after finishing the ten blots, might ask, "Can you tell me why that part is a bow tie?" If the respondent answers, "Why, because it's shaped like one, that's why," the examiner might go on to ask, "Would it still look like a bow tie if it was entirely black?" The form-dominated perceiver would probably now respond "Of course," the colour-dominated, ('Certainly not."

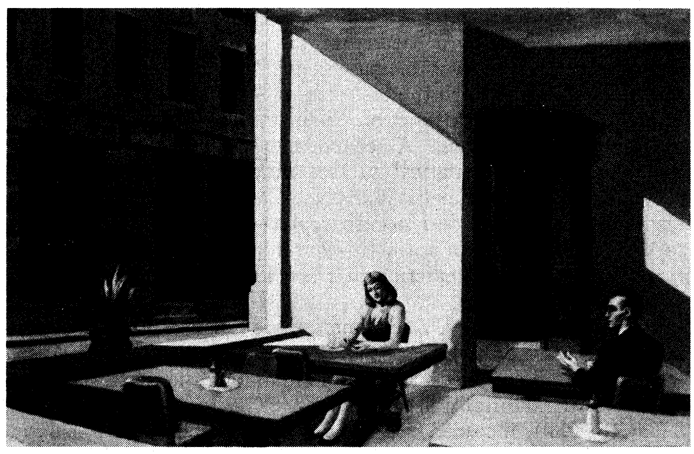
3. The third category is that of the content of the response. Here again common clusters appear. Most records contain some references to human beings, to animals and to natural phenomena of one sort or another. The absence of any of these or overconcentration on a particular one constitute bases for interpretation.

4. A fourth category, more or less included in the interpretations of the first three but still listed as a separate feature in the scoring, has to do with the popularity or originality of each response. For certain blots certain responses are so typically given that they are labeled "populars." Persons whose perceptual habits and reactions are generally similar to others will give an appreciable number of such "popular" replies during the course of the testing. Psychotic or deranged subjects might give very few or none at all. At the other end of the scale are responses that are seldom encountered or that the examiner hears for the first time. Such responses are called "original." A further classification into good quality (O+), average quality (O) or poor quality (O−) is necessary in order to distinguish between creatively original perceptions and those involving distorted or warped conceptions.

On the basis of these and other ancillary scoring procedures the Rorschach analyst attempts to synthesize a model of the functional psychology of the person, one that depicts the formal properties of his personality (*e.g.*, intellectual ability, introversion-extroversion, inhibitions. constraints, level of affective energy, etc.) as well as his particular concerns and problems. The validity of this final formulation rests in large part on the skill and wisdom of the examining psychologist. Critics of psychological testing methods have too seldom recognized this elementary principle, blaming the tests, when prophecy has failed, rather than the prophets.

3. Thematic Apperception Test.—The second most widely used test of the projective group is the Thematic Apperception Test (TAT). first issued in 1935 by Murray and Christiana D. Morgan. In the TAT, pictures are presented on cards to the subject, who is asked to make up a story having an antecedent. a plot and a resolution. Stress is laid on the concept of "imagination" in instructions, with the offhand comment being made that "imagination is one form of intelligence." There are 31 pictures in all, these being grouped into special subsets of 20 each for younger and older subjects, male or female. The manual calls for two one-hour testing sessions, ten cards being administered at each. The more unusual and dramatic pictures are reserved for the second sitting, along with one entirely blank card. The subject ordinarily tells his stories aloud, the examiner copying them verbatim. However, all these procedural matters vary widely in practice, depending upon the examiner; the variability in this respect is much greater than for other tests of wide usage.

In the analysis of test results there is also much less standardization in the TAT than in other tests. Some examiners have utilized Murray's "need-press" system of concepts or variations of it; some apply psychoanalytic notions of defense, repression, projection, etc.; others merely attempt a subjective-intuitive résumé of the personality of the storyteller. For special purposes the stories can be scrutinized for particular themes or qualities; one such scoring, for example, is based upon the number of manifestations of the need for achievement; another is based on appraisal of the stories for their level of originality. The test method



BY COURTESY OF STEPHEN C CLARK

"SUNLIGHT IN A CAFETERIA" BY EDWARD HOPPER. A PAINTING SIMILAR TO THOSE USED IN THEMATIC APPERCEPTION TESTS (*see* TEXT) also has been applied in anthropological field studies to help shed light, for example, on child-rearing attitudes, on moral codes and sanctions and on philosophical values.

F. Other Methods

There are literally hundreds of additional projective methods for the assessment of personality that could be discussed in a complete review of the topic. A few examples are given below, classified by type of task or method of testing.

1. Constitutive Methods.—In these the subject imposes a form or structure upon an amorphous or plastic substance or upon partially structured or semiorganized fields. Examples are the Rorschach test; Hans Zulliger's three-blot ink-blot test modeled after the Rorschach; the sentence-completion method proposed by A. F. Payne in 1928; and finger painting as introduced by Ruth F. Shaw in 1930.

2. Constructive Methods.—In these the subject is asked to build or construct something, the implication being that some of the organizing principles in his own personality will be manifest in his test constructions. M. Lowenfeld's Mosaic Test, introduced in 1929, is an example. The subject is given a set of 465 small wooden blocks of six colours and five shapes and asked to "make anything you like out of the pieces." The mosaics can then be evaluated on some 23 factors, including such characteristics as concreteness *v.* abstraction. over-all harmony of design, simplicity *v.* complexity and emphasis on form or colour.

3. Interpretive Methods.—In these the subject is asked to tell what a specific stimulus. such as a picture, suggests or means to him. The Thematic Apperception Test provides one example of the type. The Four-Picture Test of the Dutch psychologist D. J. van Lennep, in which the subject is requested to tell a story incorporating the people and backgrounds shown in four pictures, is another.

4. Cathartic Methods.—In these methods the aim is to release pent-up emotions and feelings in such a way as to permit interpretation and personality diagnosis. An example is the "therapeutic doll" of D. M. Levy, which the subject may dismember, cuddle, maltreat. etc.. at will.

5. Refractive Methods.—This category includes the use of any conventionalized mode of communication or expression, verbal or written, as a basis for personality assessment. Handwriting analysis (graphology) is a prominent example.

Bibliography.—G. W. Allport, *Personality: a Psychological Interpretation* (1937); Anne Anastasi, *Psychological Testing* (1954); O. K. Buros (ed.), *Mental Measurements Yearbook* (1935 *et seq.*); R. B. Cattell, *The Description and Measurement of Personality* (1946); L. J. Cronbach, *Essentials of Psychological Testing*, 2nd ed. (1960); H. J. Eysenck, *The Scientific Study of Personality* (1952); L. K. Frank, *Projective Methods* (1948); F. Galton, *Inquiries Into Human Faculty and Its Development* (1883); H. Hartshorne *et al., Studies in the Nature of Character*, 3 vol. (1928–30); H. A. Murray, *Explorations in Personality* (1338); P. Pichot, *Les Tests Mentaux* (1949); H. Rorschach, *Psychodiagnostics*, Eng. trans., 4th ed. (1949); C. Spearman, *The Abilities of Man* (1927); D. E. Super, *Appraising Vocational Fitness, by Means of Psychological Tests* (1949); E. K. Strong, Jr., *Vocational Interests of Men and Women* (1943); L. M. Terman *et al., Sex and Personaiity: Studies in Masczilinity and Femininity* (1936); L. L. Thurstone, *The Vectors of Mind: Multiple-Factor Analysis for the Isolation of Primary Traits* (1935); P. E. Vernon, *Personality Tests and Assessments* (1953); G. M. Whipple, *Manual of Mental and Physical Tests* (1910). (H. G. G.)

IV. ATTITUDE MEASUREMENT

An attitude may be defined as the degree of positive or negative feeling associated with some psychologicai object or event (see Attitude). The psychological object may be a job, a racial or ethnic group, a governmental policy or a book title; it may be a person, a thing, an institution or an idea.

A. Approaches

One possible approach to attitude measurement entails asking respondents direct questions demanding "yes" or "no" ansners. This approach often has been used, with varying degrees of success, in the assessment of public opinion to predict, say, voting behaviour. Often it results in a large proportion of "don't know" or "undecided" responses, difficult to evaluate, Not infrequently, particularly on emotionally tinged public issues, respondents either consciously or unconsciously distort their replies, yielding results biased in the direction of the popular or socially approved response. These difficulties have prompted the development of less direct procedures fcr measuring attitudes.

An attitude schedule is a set of carefully constructed statements about a psychological object, together with some device, such as a rating scale, by which the subjects express their feeling toward each statement. Methods of attitude measurement differ, one from another, primarily in the means for constructing and selecting statements to be included on the schedule. The three main approaches to attitude measurement may be distinguished by noting nhether the focus is upon the statements, the subjects or the responses.

1. Methods Focusing on Statements.—These methods utilize judgments from a group of respondents to scale the attitude statements. Subsequently the scale values of the statements may be used to locate any individual on the attitude continuum on the basis of his responses to the schedule.

Procedures for measuring attitudes were pioneered by Thurstone, through a series of articles and monographs beginning in 1927. Thurstone extended the psychophysical methods (*q.v.*) by proposing a model for scaling psychological magnitudes of stimuli independent of any corresponding physical stimulus magnitudes. The class of methods including those proposed by Thurstone, all of which are independent of physical measurement, are known as the psychological scaling methods.

Puired *Comparisons*.—Of the psychological scaling methods, the earliest is the method of paired comparisons. In applying this method to the selection of statements for attitude measurement, statements are presented in pairs, with judges instructed to select that statement of each pair which they view as indicating a more favourable attitude toward the psychological object in question. For example, in selecting items for a schedule designed to measure attitude toward public censorship, the following two items might be paired: (1) "to protect the public it sometimes is necessary that censorship be exercised"; (2) "books and plays should be subject to moral censorship." Each respondent would be asked to select statement (1) or (2) as representing a more favourable attitude toward public censorship.

As presented to a sample of judges, each statement is paired with every other statement. Proportions of responses are generated of the form P,,, the proportion of judgments that statement i is more favourable than statement j; these serve as the basic data for application of the method. Data are treated by Thurstone's law of comparative judgment, a theoretical model transforming the proportions and operating on them so as to provide numerical scale values associated with each attitude statement. (In the simplest application of the model, it is assumed that affective values toward each statement have a normal distribution in the population of respondents and that the population variances and covariances of those distributions all are equal.)

Successive Intervals.—A related method for selecting attitude statements is the method of successive intervals, also suggested by Thurstone. Each separate statement is rated by every member of a group of judges to indicate favourability of attitude implied by the statement, the rating being in the form of a check mark in one of several response categories. Categories are defined to extend from "extremely unfavourable" to "extremely favourable," with intermediate categories suggesting more moderate attitudes. A law of categorical judgment here provides the model by which proportions of category ratings are transformed and yield scale values indicating degrees of attitude associated with the statements. Once again it is assumed that in the population attitudes are normally distributed. The method of successive categories has the advantage of providing quantitative estimates of the degree of ambiguity of attitude for each statement (indicated by the variances of distributions of judgments, measured on the attitude continuum). Such estimates are valuable for selecting statements to be included on an attitude schedule. Because of its theoretical advantages. the method of successive intervals has largely replaced the similzr method of equal appearing intervals for construction of attitude schedules.

Having determined scale values for each attitude statement and selected those to be included on a schedule, the problem remains to estimate the attitude of individual respondents. A simple procedure is to present the schedule to each individual with instructions to check those statements with which he agrees. An average of the scale values for those items checked serves to locate the individual on the attitude continuum.

2. Method Focusing on Subjects. — A method proposed by Rensis Likert treats attitude statements much on the order of objective test items. An attitude schedule is constructed from a group of statements (with unknown scale values) selected to represent either favourable or unfavourable attitudes toward a psychological object or event. For each statement, subjects are instructed to respond by checking one of several possible response categories; *e.g.*, "strongly agree," "agree," "uncertain," "disagree" or "strongly disagree." Likert suggested the arbitrary assignment of weights to these categories: 4, 3, 2, 1, 0, respectively, when statements convey a favourable attitude; 0, 1, 2, 3, 4, respectively, for unfavourable statements. For a given schedule, an attitude score is found for every subject simply by summing the weights associated with the responses of that subject. The approach is aimed at the direct assignment of attitude scores to individual subjects, avoiding the intervening step of assigning scale values to statements.

The Likert method often has been implemented by utilizing techniques of item analysis, borrowed from objective psychological test theory, to select appropriate statements for a refined final form of attitude schedule.

Both the Likert and Thurstone methods have often been successfully employed for measuring attitudes. The several studies comparing results of the two approaches fail to show marked superiority of either approach over the other. Theory underlying the judgment methods of Thurstone is somewhat more completely defined, and in accordance with the theoretical measurement model, application of the Thurstone methods yields scores with wider general interpretations as numbers (as opposed to numerals representing order relations but not distance along an attitude continuum).

3. Methods Focusing on Responses. — In these methods an attempt is made to assign scale values to both subjects and statements from a single administration of the statements to the subjects. The methods demand a set of attitude statements which vary along a single psychological dimension and assume subjects' responses to depend only upon their positions on this same dimension.

Scalogram Analysis. — One prominent response method is scalogram analysis, proposed by Louis Guttman. In applying scalogram analysis, it is assumed that any subject asked to accept or reject a set of attitude statements will accept all those with scale values at or below that point on the attitude continuum at which the subject is located, rejecting those statements with scale values higher than his own location. Consider the following four statements, listed in the order of increasingly favourable attitude toward cold climate.

A. I am able to tolerate occasional cold weather.
B. At times I enjoy cold weather.
C. I would enjoy living where the climate is one of cold winters.
D. I revel in cold weather, and would choose to live only in an area with cold climate.

For this set of sentences, anyone accepting the most extremely favourable statement D also would be expected to accept the statements reflecting a more moderate positive attitude toward cold climate; A, B and C; a person accepting statement C also would be expected to accept A and B; and for someone accepting statement B, acceptance of A also would be anticipated. Conversely, if one rejects statement B, it may be safely predicted that he will reject statements C and D. Under these conditions, the statements are said to be scalable. While there are 16 possible response patterns, patterns of acceptance (+) or rejection (0) among four statements, only 5 of these (in general, $n + 1$, where n is the number of statements) are expected to occur for four scalable statements:

	Statement			
Pattern	A	B	C	D
1	0	0	0	0
2	+	0	0	0
3	+	+	0	0
4	+	+	+	0
5	+	+	+	+

Subjects thus are divided, by responses to the four statements, into five groups classified according to favourability of attitude. Statements also become ordered in terms of the attitude variable by the observed response pattern.

Unfolding Technique. — A second response method for attitude measurement, known as the unfolding technique, was proposed by Clyde H. Coombs. Subjects are asked to rank a set of attitude statements according to the extent of their agreement with each. Analysis of such rankings yields information regarding the attitude of the subject relative to the set of statements.

Let the letters A, B, C and D represent four attitude statements, listed in order from unfavourable to favourable attitude. A given subject, S, might rank the statements in the order C, D, B, A in terms of his agreement with them. By "unfolding" the rank order, the investigator could achieve a conception of the relative locations of statements and subject on the attitude continuum. The following portrayal is consistent with S's ordering of agreement with the four statements. The line segment represents the attitude continuum, progressing from unfavourable, on the left, to favourable, on the right.

S
A B C D

The rank order assigned the statements by a given subject is interpreted as the order of distances between statement and subject on the attitude continuum and thus serves to locate (within a narrow range of values) the affective position of the subject relative to the locations of the statements. Analysis of responses from a group of subjects allows more definite estimates of the locations of statements.

4. Internal Consistency, Reliability and Validity. — Each of the prominent methods for attitude measurement mentioned above includes means for checking the internal consistency of the method. In addition, reliability of measurement may be determined; numerous applications have verified that consistent and reliable measures of attitude may be obtained. A thorny problem, however, is that of determining the validity of attitude measurement. Immediately the investigator is faced with the task of specifying a behavioural criterion against which validity may be assessed. Except for instances in which attitudes are expressed through political action (*e.g.*, voting behaviour), instances of successful specification of such criteria are rare. A few studies indicate that these methods of attitude measurement exhibit at least greater validity than that attending the direct questioning of respondents.

B. Consumer Preference Measurement

Closely related to attitude measurement is the measurement of consumer preference, or acceptance of consumer products. However, the ultimate aim is somewhat distinct from that of attitude measurement: attention is directed toward the degree of acceptance of a product, judged by numerous consumers, rather than toward the placement of a person along a psychological continuum.

Psychological scaling methods that focus upon stimuli (analogous to statements in attitude measurement) are ideally suited to the aim of consumer preference measurement. These methods yield scale values associated with each stimulus rated or judged by a consumer sample. Stimuli might be food items, items of apparel or other consumer products. By the method of paired comparison or the method of successive intervals it becomes possible quantitatively to evaluate the relative preferences displayed for a group of such items. and to estimate degree of acceptance of the items by a population of consumers (when the judging group is a random sample from that population).

An interesting application of models for consumer preference measurement allows prediction of consumer choice of competing products on an open market, or even prediction of relative purchase of each of several competing products when these are offered at different (known) costs to the consumer. For the latter problem. there enters the question of (negative) utility of money, which presumably combines with preference for the commodities to dictate proportions of purchase of each. Exploratory research on these problems suggests that the measurement methods are highly reliable and provide a valid quantitative model for estimation of consumer choice behaviour.

1. Multidimensional **Scaling.**—An extension of the psychological scaling methods not only provides conclusions concerning the distribution of sensory preferences among product samples, but also serves to indicate the (linearly independent) psychological components of the general sensory distinctions. This extension is known as multidimensional scaling, since it yields a solution for the several psychological dimensions responsible for the general differences in preference among stimuli. As an example, consider five distinct samples of coffee, to be evaluated for general flavour characteristics. Preference values could be obtained using the method of paired comparisons, presenting samples in pairs to a group of judges. There are ten pairs of the five samples (in general, $n(n-1)/2$ pairs of n stimuli); for each pair the proportion of judges indicating preferred flavour for each of the two brews of coffee would be determined. Application of the law of comparative judgment would yield solution of general preference scale values for each of the five samples.

Now the coffee samples could be presented again, this time utilizing the method of triads. Samples are presented in groups of three. with judges instructed to determine relative degree of similarity between pairs of samples within the triad. ("Stimulus i is more similar to stimulus j than to stimulus k.") With five stimuli, there are ten triads (in general, $n(n-1)(n-2)/6$ triads for n stimuli), and for each triad, three judgments are required, since each stimulus is compared with the stimuli of every other pair. The result of such an experimental procedure is the generation of n matrices of proportions, one for every stimulus sample, each of order $n \times n$. The elements of the ith matrix take the form ${}_iP_{jk}$, the proportion of times stimulus i is judged more similar to stimulus j than to stimulus k.

The proportion ${}_iP_{jk}$ is postulated to depend upon the difference between distances d_{ij} and d_{ik}, where d_{ij} represents (affective) distance of stimulus i from stimulus j and d_{ik} represents distance between stimuli i and k. Assuming the distribution of differences in distance. $(d_{ij} - d_{ik})$ to be normal in the population, with equal variances and covariances, a solution is provided for every distance of the form d_{ij}. Having solved for all such distances, imposition of a spatial model (*e.g.,* assuming analogy to Euclidean space) will serve to determine the minimum number of dimensions required to account simultaneousiy for all empirically derived distances. Analysis of the configuration of interstimulus distances within the space may provide clues concerning the psychological characteristics of the dimensions.

2. Detection of Sensorv Differences in Consumer Products,—In numerous consumer industries, sensory characteristics of the product assume great importance. For manufacturers of processed foods and beverages, perfumes, colour reproductions, to name only a few, the quality of the product depends largely upon its sensory characteristics. Industrial testing for control of sensory characteristics of products has made considerable use of the psychophysical methods, particularly of the constant method.

A typical problem is that of assuring uniformity of the product. Not always does strict uniformity necessarily result from careful control of ingredients; minor variations in climatic conditions, time of preparation, storage conditions and many other factors as well as quality and quantity of ingredients may affect the product. To assure no major variability in the product as marketed, sensory tests often are conducted. New batches of the product typically are compared aith a standard batch, knonn to be of acceptable quality. In the case of foods and beverages, this constitutes taste testing for flavour characteristics. Samples of the product are judged in pairs, often by expertly trained judges. One member of each pair is the standard, the other is called the variable. The task of the tasters is to judge, for each pair, which is the sweeter, saltier, more pleasant, more bitter or the like. On the basis of numerous ratings, proportions of such judgments are obtained for each variable as compared with the standard. Statistical procedures are available for guiding the decision concerning acceptability of quality. For example, it might be decided that a batch would be unacceptable if as many as 5% of consumers were to detect a deficiency in the product as compared with the usual standards. Application of the constant method and related statistical tests would serve to yield a decision concerning quality of each batch in terms of such a criterion. A rnethod of analysis nearly identical to that of the constant method of psychophysics is the probit method of biometrics, developed in England by Fisher and D. J. Finney, in the United States by C. I. Bliss.

The psychophysical methods have proved useful not only for quality control of a product; they also are frequently applied to the development of improved consumer items. In this application, detection of a difference in a given direction, that the new product has more desirable characteristics than the old, serves as evidence upon which the new product may be marketed, either replacing the old or competing with it with some assurance that the new product will maintain a favourable competitive position.

See INTELLIGENCE; EXAMINATIONS; MOTIVATION; DIFFERENTIAL PSYCHOLOGY; PSYCHOPHYSICAL METHODS; see also Index references under "Psychological Tests and Measurements" in the Index volume.

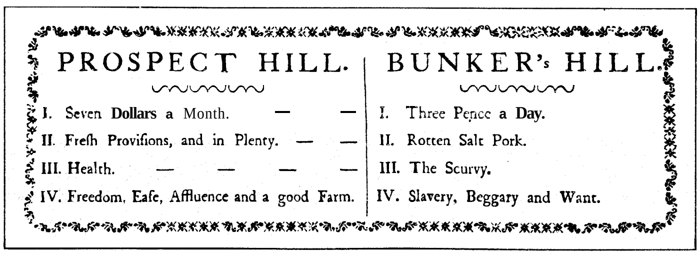
BIBLIOGRAPHY.—For a general survey of methods of attitude measurement *see* Allen L. Edwards, *Techniques of Attitude Scale Construction* (1957). For a more extensive treatment of psychological scaling and a useful bibliography of the field *see* Warren S. Torgerson, *Theory and Methods of Scaling* (1958); *see* also J. P. Guilford, *Psychometric Methods,* 2nd ed. (1954).

(L. V. Jo.)

PSYCHOLOGICAL WARFARE consists of the use of propaganda against an enemy, together with such military, economic or political measures as the propaganda may require. Though often looked upon as a modern invention, it is as old as history. The conquests of Genghis Khan were aided by expertly planted rumours about the large numbers of ferocious Mongol horsemen in the khan's army. False though they were, these rumours frightened the enemy. Centuries later, in the American Revolution, Thomas Paine's *Common* Sense was but one of many examples of pamphlets and leaflets used to strengthen the colonists' will to fight.

In its modern form, consisting of the application of mass communications techniques to strategy and warfare, psychological warfare differs from the military propaganda of the past in two ways: it is proportionately a larger ingredient of the whole process of war; and modern scientific advances in communications, such as high-speed printing and radio, together with important developments in the fields of public-opinion analysis and the prediction of mass behaviour, make psychological warfare more nearly manageable and predictable than techniques used in the past.

Military doctrine of the United States and its allies in the North Atlantic Treaty organization recognizes a specific field of military responsibility for planning and conduct of psychological warfare in time of actual war. In the late 1950s U.S. military experts sought to define the psychological warfare responsibilities of armies in situations short of actual warfare. The suggestion was made that "psychological operations" be used as the descriptive term



PROSPECT HILL.	BUNKER's HILL.
I. Seven Dollars a Month. — —	I. Three Pence a Day.
II. Fresh Provisions, and in Plenty. — —	II. Rotten Salt Pork.
III. Health. — — — —	III. The Scurvy.
IV. Freedom, Ease, Affluence and a good Farm.	IV. Slavery, Beggary and Want.

DISGUISED TACTICAL PROPAGANDA

Leaflet issued by the colonial command during the battles for Boston, it is an invitation to the British troops to desert for short-of-war measures to be undertaken by armed forces in the international mass-communications field. Psychological warfare and psychological operations are therefore the same function; in both cases they are attached to the military and are separated, except for wartime, from the normal informational, promotional or propaganda activities of the civilian agencies of government.

Within armies, psychological warfare or psychological operations include training and equipping of specialized units in peacetime armed forces, both regular and reserve, and the application of these skills to military situations when action comes. It is most effective when the entire army knows of its availability and effects. The short form of the term, psywar, spread through the U.S. armed forces after the Korean war. The kind of psywar understood by the armed forces is a far narrower and more specialized operation than that to which scholars, journalists and politicians refer when they say "psychological warfare."

In this more general sense of the term; different meanings can be found, no one of which is necessarily related to the others, even though they may frequently become confused.

First, there is psychological warfare as armies practise it. This involves the use of printing presses, radio stations and air-dropped leaflets in pursuing goals of modern warfare.

The term psychological warfare also is used to describe the pseudo-psychiatric twisting of personality by techniques such as "brainwashing" ("thought reconstruction" is the official Chinese Communist term) or the psychopharmaceutical techniques reportedly used in the European Communist countries. In this sense, the United States has not engaged in "psychological warfare." The only U.S. effort in the field has been developing preventives and countermeasures as far as possible.

Finally, psychological warfare is loosely and often improperly used to describe all the forms of power struggle between nations: the "cold war," the "chronic war," "protracted struggle" (in Mao Tse-tung's phrase), "extended strategy" and the like. This is too broad a use for the term to remain meaningful. Marshall plan expenditures, Mutual Security weapons deliveries, technical-aid programs—each of these has a psychological effect on the many audiences which make up the international scene, but unless any technique involves the manipulation of opinion through communications, it embraces more than psychological warfare does under the stricter definition.

During World Wars I and II there appeared a group of new terms for forms of struggle which exceeded the 19th-century concepts of war. The operations in all cases had antecedents; the new element was not in any case the act itself but the labeling of the act and the formal creation of government agencies to carry it out. Four major forms of international struggle were usually described: psychological warfare, political warfare, economic warfare and warfare in the sense of armed combat, sometimes rather redundantly called "military warfare." Political warfare in British usage includes propaganda, diplomacy, intrigue, conspiracy and sabotage. In U.S. usage, political warfare consists of international struggle through the manipulation of persons, organizations or institutions. British usage seems to be yielding to the U.S. in this respect. Economic warfare (*q.v.*) consists of the manipulation of property, prices or other economic factors to the disadvantage of the international antagonist. In view of these definitions, psychological warfare can be restricted to those forms of struggle which depend on mass communication.

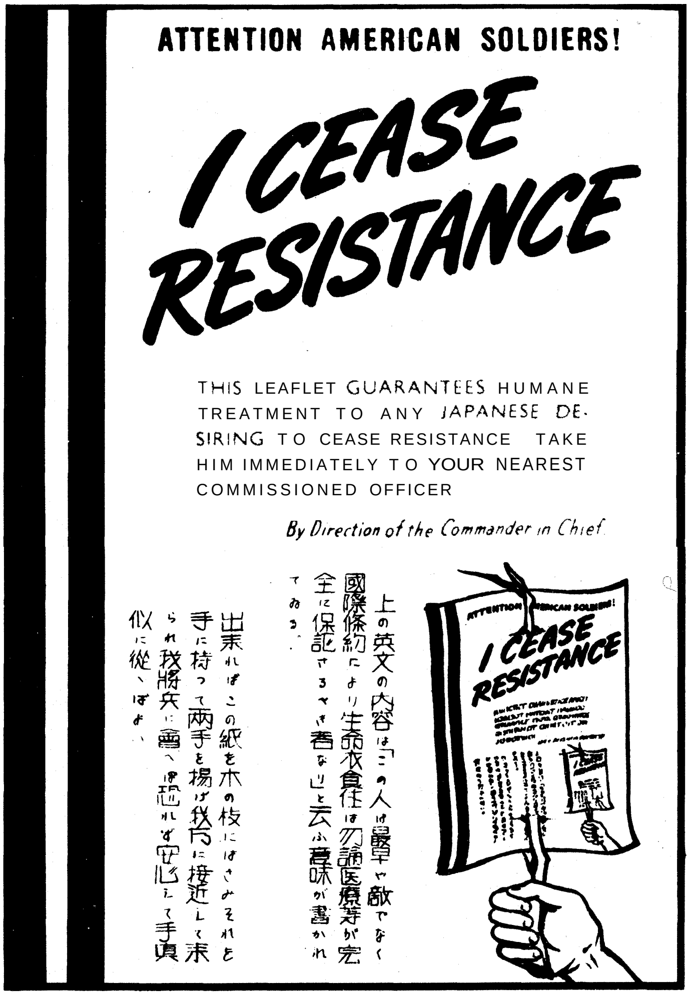
The search for terms has involved both the avoidance of explicitness (when clarity would either assist the enemy or arouse annoyance in the country of the government concerned) and a quest for understandability. These two goals not being reconcilable, a marked degree of governmental indecision has been noted. "Information," "psychological strategy," "co-ordinated operations," "strategic services" and similar euphemisms are often employed.

Modern psychological warfare is neither better nor worse than other forms of struggle. Insofar as it does the least damage to the human body, compared with other weapons, while achieving what may be maximum results in terms of cost. psywar may be regarded as a "better" weapon. A dead enemy is of no use to one's own side or to mankind, and his death may be very costly to achieve, while a live, surrendered enemy is usually useful.

Most psychological warfare material is truthful. Truth is easier to document than falsehood, and it is infinitely superior to lies where consistency is concerned. Lies were used wholesale in World War I; it is a safe guess that they were used less in World War II. Lies continue to be used in military conflict, but they are useful only in exceptional cases. The truth presented in psywar is rarely the whole truth, and the degree of veracity varies with the different countries engaged. During World War II the United States practice of covert psychological warfare, which presumably would be reactivated in the event of future conflict. was the responsibility of the Office of Strategic Services (OSS), while overt psychological warfare was reserved to the army and navy and the Office of War Information (OWI).

Overt or white propaganda is that emanating from a known source, while covert or black propaganda is issued from a falsified source. The British "German" transmitter, Gustav Siegfried Eins, which pretended to be inside the Hitlerian Reich, is a good example of black propaganda. Many Germans thought for a while that it really was German. In contrast, transmissions of the Domei (Japanese) news service in clear newspaper English to the U.S. during 1941–45 were a good example of white propaganda. Though admittedly Japanese, the dispatches filled a lot of U.S. newspaper space and embarrassed the U.S. war effort.

Apart from communications media, psychological warfare is sometimes divided into levels which reflect the frame of space and time in which the military propaganda is expected to operate. Strategic psychological warfare is the term denoting mass com-



TACTICAL PSYWAR

Surrender leaflet distributed to Japanese troops in the Philippines and other Pacific islands during World War II. The first version of the leaflet carried the words "I surrender," which so shocked the Japanese that they would not use it munications directed to a very large audience or over a considerable degree of territory. An appeal to the enemy civilian population to hoard food in order to protect their families against privation would be strategic in character. Tactical psychological warfare usually implies a direct connection with combat operations; the most common form is the surrender demand, although on other occasions tactical psywar may merely ask the enemy to retreat, tell individual soldiers to seek cover, warn city populations of bombing raids or instruct civilians on how to behave if an airborne force suddenly lands among them. Consolidation psywar consists of messages distributed to the rear oi one's own advancing forces for the sake of protecting the line of communicztions, establishing military government and carrying out the governmental tasks of the commanding general.

The same levels of distinction are sometimes made by use of the criterion of "action response." If an armed force or government uses psywar to prepare an audience for an action to be taken at an indefinite later time, the propaganda is called strategic; if a specific action is called for, it is termed tactical. Continuation of the cold war and the threat of "multipolar politics" arising from the admission of a great number of new states to the UN and the community of nations have accented the importance of multinational psychological operations in support. of strategic security.

Two separate but equally important intelligence functions always accompany professionally managed psychological warfare. The first and mosr obvious intelligence function consists of the analysis of one's own and the competing propagandas, together with the general flow of mass communications through the audience which is addressed. Sometimes particularly important decision-making parts of the audience, termed target groups, mill be evaluated in detail. Who is reaching them and through what broadcasts or printed media? What do the audience members prefer? What do they repeat? The amount of communications in an enemy's propaganda to outsiders will often reveal his intentions; an enemy government's home broadcasts almost inevitably show what the enemy leaders think the opinions and problems of their own people are. This is called propaganda analysis; in military form, it is merely an adaptation of civilian methods of public-opinion analysis.

The second form of intelligence is no less important. It consists of audience information for the propagandist. The psywar operator cannot make effective use of persuasion unless he is given concrete details about his audience. In wartime much of this information comes through espionage channels and is therefore difficult to obtain. There is a natural conflict between espionage officials who wish to keep all incoming information secret and psywar officials who wish to use the realistic parts of it to strengthen their messages. Estimates and plans are still subject to wide variations of staff procedure between different modern armies. The U.S. army had a psychological warfare branch, G-2, in 1941–42 and 1943–46 under various names. In 1951 a special staff division, the office, chief of psychological warfare (OCPW), was formed. Later this staff was made the "special warfare" portion of the deputy chief of staff for operations, the army staff division handling all command problems, when psychological warfare and warfare problems were placed under a common jurisdiction.

The communications media most commonly used in psychological warfare are the same as those used in civilian life; radio, newspapers, motion pictures, books and magazines form a large part of the output. Leaflets are more widely used than they are in civilian life. (The World War II leaflet output of the western Allies alone, excluding Russia, was at least 8,000,000,000 sheets.) Loud-speakers are often used in the front lines; both sides used them in the Korean fighting. The slow media are those in which a physical object must be transported to effect the communication: magazines, pamphlets, books, lecturers. Fast media are those which can be transmitted electronically: telegrams, radiobroadcasts, wireless messages. The media used in a mar usually reflect the capacity of the civilian economic system of each of the contestants. Whatever the medium! psywar can be successful only if it is credible, simple and properly timed.

See also PROPAGANDA.

BIBLIOGRAPHY.—W. E. Daugherty and M. Janowitz (comps.), *A Psychological Warfare Casebook* (1958) ; M. L. De Fleur and O. N. Larsen, *The Flow of Information: an Experiment in Mass Communication* (1958) ; L. John Martin, *International Propaganda: Its Legal and Diplontatic Control* (1958) ; J. R. Mock and C. Larson, *Words That Won the War* (1939); P. Davidson, *Propaganda and the American Revolution* (1941) ; I). Lerner, *Sykewar* (1949), (ed.), *Propaganda in War and Crisis* (1951) ; C. A. H. Thomson, *Overseas Information Service of the United States Government* (1948) ; Elizabeth P. MacDonald, *Undercover Girl* (1947) ; Stewart Alsop and Thomas Braden, *Sub Rosa* (1946) ; S. K. Padover, *Experintent in Germany* (1946; pub. in England under title *Psychologist in Germany*) ; E. Hunter, *Brain-washing in Red China* (1951), *Brainwashing: the Story of Men Who Defied It* (1956). (P. M. A. L.)

PSYCHOLOGISM, in philosophy, is the view that problems of epistemology (that is, problems relating to the validity of human knowledge) can be solved satisfactorily by the psychological study of the developrnent of mental processes. Locke's Essay on *the Human Understanding* may be regarded as the classic of psychologism in this sense. A more moderate form of psychologism only maintains that psychology should be made the basis of other studies, especially of logic.

PSYCHOLOGY (ARTICLES ON). The subject matter of psychology—the behaviour of man and lower organisms—receives a general overview in PSYCHOLOGY, which surveys the scope and methods of the science, its major schools of thought and fields of specialization.

PSYCHOLOGY, HISTORY OF traces the evolution of psychological theories from the speculations of the ancient Greeks to modern concepts and methods. Prior to the 19th century the content of psychology was predominantly philosophical and introspective. The radical shift to the experimental and behaviouristic emphasis of modern psychology is reflected in the section dealing with the 20th century. BEHAVIOURISM: and PSYCHOANALYSIS are primarily devoted to theory; however, the reader who wishes to obtain a comprehensive view of modern psychological theories should consult, in addition. articles on PSYCHOLOGY, ABNORMAL; ANIMAL BEHAVIOUR; CONDITIONING; EMOTION; INTELLIGENCE; LEARNING; MOTIVATION; PERSONALITY; PSYCHOLOGY, COMPARATIVE; PSYCHOLOGY, EXPERIMENTAL; PSYCHOLOGY, PHYSIOLOGICAL, among others.

The range of psychology extends from the primarily biological (the behaving organism is a biological entity and must be understood as such) to the primarily social (behaviour, particularly in the case of man, can be influenced decisively by social determinacts). Those interested in the biological basis of behaviour should consult the articles on ANIMAL BEHAVIOUR; BRAIN; ENDOCRINE GLANDS; INSTINCT; MEDICINE AND SURGERY (ARTICLES ON); NERVE; NERVOUS SYSTEM: PHYSIOLOGY; PSYCHOLOGY, COMPARATIVE; PSYCHOLOGY, EXPERIMENTAI; PSYCHOLOGY, PHYSIOLOGICAL; and ZOOLOGY. Similarly, ANTHROPOLOGY; ATTITUDE; LANGUAGE; PERSONALITY; and SOCIOLOGY. give a view of the role of social factors in behaviour. Many articles under general psychology headings and elsewhere (*e.g.*, PSYCHOLOGY. ABNORMAL; CHILD PSYCHOLOGY AND DEVELOPMENT; LEARNING; MOTIVATION; PSYCHIATRY) treat behaviour from both points of view, of necessity. because psychology sees behaviour as (1) a function of the total organism. (2) occurring in a context and not in isolation, and (3) a function of both biological and social determinants.

From its beginnings. psychology has had strong interests in methodology and has developed a variety of techniques and apparatus for experimentation and analysis—on its own and by borrowing from other sciences. New devices and methods appear regularly. Most represent elaborations upon or adaptations of general principles and facts well known and widely accepted in psychology. There are many such principles and facts; much, if not most, of the disagreement among workers in psychology is with respect to theory and interpretation rather than with respect to the facts about behaviour. Some of the techniques and devices are primarily for laboratory use (PSYCHOLOGY, EXPERIMENTAL; PSYCHOLOGY, HISTORY OF, PSYCHOLOGY. PHYSIOLOGICAL; and PSYCHOPHYSICAL METHODS). Others have been developed for the school situation, the clinic or hospital, and business and industry (ATTI-

TUDE; PERSONALITY; PSYCHOLOGY, APPLIED; PSYCHOLOGICAL TESTS AND MEASUREMENTS). Applied psychology is an actively growing field; new appiications of basic psychological knowledge emerge continuously as techniques developed for laboratory use migrate to the practical situation where they demonstrate utility for applied purposes. The distinction between applied and pure science is often less clear and categorical in psychology than in some other fields of learning.

PSYCHOLOGY. Psychology studies living behaviour with ultimate reference to human individuals alone and in groups. In so doing it impinges upon several other fields. It is possible to isolate for study living units at the levels of cell, organ, individual, group and society. Physiology and neurophysiology are concerned with the functioning of cells and organs of the body. Sociology studies the structure and function of groups and societies. Anthropology is interested in man as a species which makes multiple cultural adjustments to the world's varied environments. Biology. economics, political science and. in part, history, philosophy and theology all focus upon subject matters in some way related to that of psychology. While there are no clear-cut, universally accepted distinctions among the various sciences, it can be said that the psychologist makes statements about the individual which describe his behaviour in response to a variety of stimuli; turning to physiology and neurophysiology when he wishes to demonstrate "causal mechanisms" by which the effects are produced. Also he studies in the individual "causal mechanisms" that underlie the group and social phenomena which the sociologist takes for his subject matter. In general, the psychologist is interested in the whole individual in relation to his surroundings, his fellow beings and himself.

Since psychology is so inclusive, it encompasses numerous specialties. This diversity sometimes contributes to the impression that there are a number of disunited "psychologies." The appearance of disunity is increased by the lack of a theoretical structure applicable and acceptable to the whole field. Thus there are clinical psychologists, experimental psychologists. physiological psychologists, comparative psychologists, industrial psychologists, social psychologists, occupational psychologists. all of whom, after undergoing somewhat different training, follow separate specialties within psychology. The discipline finds unity, however, in the fact that their common interest is in organisms which are highly organized and integrated. It is thus difficult to discuss sensation without involving perception, perception separate from learning, learning without reasoning, or any of these processes apart from personality, emotion and motivation. And it is difficult to isolate the organism from the influence of the external culture. for the immediate group situation, the interaction with absent but important people and early family experiences are all transparently significant in most branches of the science of behaviour.

Psychology developed as a part of philosophy (*see* PSYCHOLOGY, HISTORY OF), appearing as a separate discipline as recently as the late 19th century and developing into an experimental science with the establishment of laboratories by Wilhelm Wundt at Leipzig, Ger., in 1879 and by G. Stanley Hall, a pupil of both William James and Wundt, at Johns Hopkins university in 1833. Both James and Wundt had had informal laboratories as early as 1875.

The fundamental philosophical questions particularly relevant to psychology are those of epistemology: What is "mind" and how is it related to the body? How does the knower know the world and other minds? What is the relation of experience to reality? These problems were dealt with well before Plato, yet are involved in current discussions of consciousness, the relation of psychological function to structure, phenomenology and the nature of the self. As physics and physiology developed, physicists and physiologists became interested in whether mental activity as well as physical phenomena followed orderly laws. Gustav Fechner (*q.v.*) performed the first experiments in psychophpsics, published about 1851, to show the relations of mind and matter by making "the relative increase of bodily energy the measure of the increase of the corresponding mental intensity.:' (See PSYCHOPHYSICAL METHODS; PSYCHOLOGY, HISTORY OF.) Hermann von Helmholtz, like Fechner a physicist, made contributions in the fields of audition and vision, and did pioneer experimental and theoretical work in perception, holding views similar to those of the English associationists John Locke and James and John Stuart Mill, that perceptions are built from experience and are not native to the mind. Wundt, trained in physiology, who first insisted upon psychology as a separate discipline, held that it is the science of immediate experience, including both subjective feelings and perceptions. and that introspection is its appropriate and primary method. He believed that mind and body are totally different universes, not necessarily parallel, and that events within the mind are subject to laws which can be studied. James, a physician and philosopher who approved of experimentation in psychology, saw mind and consciousness as a "stream." ever changing. whose primary function is knowledge and the selection of relevant data from the mass of sensations confronting the individual. E. B. Titchener, at Cornell university. Ithaca, N.Y., was one of the first psychologists to believe that the epistemological questions could be bypassed, leaving psychology a realm of sensations. .images. feelings and meanings which could be studied scientifically. He agreed with R'undt that introspection is the proper technique for this.

"Pity poor psychology," it has been said. "First it lost its soul, then its mind, then consciousness, and now it's having trouble with behaviour." This summary of its history, though facetious, is not entirely incorrect. since the entities which had served philosophers as explanatory concepts appeared unsatisfactory as data for science. Psychology moved progressively from attempts to prove something about the mind-body question, to consideration of "consciousness." to concern with unconscious processes as well. and then to the insistence that behaviour alone is available for study by public science, and that constructs like "mind" either refer to nonexistents or are irrelevant. In the second and third decades of the 20th century, the behaviourism of J. B. Watson was embraced by many psychologists. especially in the U.S., who believed they found in it a refreshing breeze sweeping out the dust of centuries of speculation and opening the way for true science. They were committed to a view of behaviour based upon the connection of the stimulus with the motor response through a nervous arc, more complex behaviour being built up by the elaborating of connections between the simple nervous elements. Thought was associated not with the brain but with the organs of speech, and experiments showed that while thought was taking place the vocal apparatus was active in a way similar to that during speech, although to a lesser degree. Thought was thus defined as subvocal speech.

The behaviourists were challenged by the Gestalt (German for "configuration") psychologists, a school which was initiated in Germany about 1912, most of whose leaders continued their work in the United States after Adolf Hitler came to power. They experimented mainly with perceptual processes and emphasized the importance of the brain in organizing sensations. They further looked upon behaviour as taking place in a "field" of forces, and they held that organized subjective experience is exactly mirrored by a comparable "isomorphic" physical process with a similar organization in the brain. The relationship of the organism to its surroundings was to Gestalt psychologists much more complex than the behaviourists pictured it. While both stimulus-response and field theories still have their proponents, they usually adhere to modified forms of the older, classical views.

In addition to the questions about mind and matter. philosophers have for centuries concerned themselves with issues of human motivation. the place of emotion in behaviour, the bases of aesthetic choice and the ethical aspects of man's nature. All of these are still live issues for psychology. Sigmund Freud was not the first to point out that many of the most potent factors in human motivation are not ordinarily available to waking consciousness. Plato. for example. in book ix of the Republic, quoted Socrates as explicitly recognizing the same fact. Freud importantly altered psychological thought, however, by developing a complex and sophisticated theory concerning unconscious determinants of behaviour and applying it, in the therapeutic process of psychoanalysis, to the care of the emotionally disturbed and mentally ill. Since the beginning of the 20th century Freud's work has had great impact on the medical and scientific world as well as on art and letters generally. (*See* PSYCHOANALYSIS; UNCONSCIOUS.)

THE METHODS OF PSYCHOLOGY

A few of the techniques which have become classical in psychology can be listed here. These methods are in general similar to those of other sciences, although some are specific, their nature determined by the subject matter. Problems about behaviour frequently involve variables which are not available for direct manipulation and measurement. Almost every act of animals and men is determined by several factors. so they are rarely identical from one to the next or from individual to individual. Psychologists! however, may observe and measure these acts; they use statistics to analyze the findings. Two kinds of statistics are used. The first, descriptive statistics, describes sets of results by various measures of how much similarity they have as well as how. much deviation individual cases display. They constitute a quick means for summarizing meaningfully many single findings on a topic. The other kind, probability statistics, is a mathematics whereby, despite ignorance of some of the related facts, one can estimate the likelihood of a certain future event, or show that a given past event did not occur by chance. If more than a chance number of cases out of a random sample of a class fall in a certain direction on a given dimension, even though all cases in the class are not observed, it is assumed with a calculable risk of error that some factor is acting to influence them in that direction. By such means it is possible to make predictions, as well as to isolate the effective elements in a situation and show how important each is.

Direct observation, in psychology as in other sciences, is the first and simplest way to gather data. Careful noting of everything that takes place in a schoolroom, the keeping of a diary for a year on the behaviour of an infant or the observation and recording of group discussions are all examples of this method.

Controlled experiment arranges the situation, chooses the subjects for certain characteristics such as age or sex or type of pathology, and controls variables that cannot be eliminated. Often this is accomplished by the use of control groups which are matched with the experimental groups in as many ways as possible in order to observe the effect of a specific difference between them, which is the aspect of their behaviour being studied. A specific type of control, the method of co-twin control: is used especially in the study of child behaviour. It is used to distinguish genetic from environmental influences on certain behaviours. such as performance on standard intelligence tests. When accidents of fate separate identical twins so that they are raised apart and given different training, tests before and after can indicate what effects favourable and unfavourable environments have on intelligence quotient (I.Q.). Foster children have also been used to study the problem, by comparing the child's performance on tests with those of his true parents on the one hand and the foster parents with whom he was raised on the other.

In comparative psychology (see PSYCHOLOGY, COMPARATIVE) various apparatuses are employed to study learning. reasoning and other aspects of behaviour, in which animals are taught to make discriminations—say between a black and a white card or a right and a left turn—by reward or punishment. Variations in performance are produced by the systematic introduction of changes in the experimental situation. Various problem boxes and mazes have been devised for such work. Comparable equipment is constructed for studying human verbal and nonverbal activities.

Some of the processes which are associated with emotion can be precisely observed. Facial expressions and gestures can be photographed. The psychogalvanometer (see PSYCHOGALVANIC REFLEX) records changes in electrical resistance of the skin nith increases in microscopic sweating caused by even slight emotion. Breathing rates, blood pressure. pulse rate and other bodily functions alter with emotion and can be measured objectively. Such methods are sometimes used in lie detection in criminology, such measures being made while a suspect is answering questions about his knowledge of a crime.

Subjects' experiences as well as their actions can provide important data. In many experiments only the subject himself can indicate of what he is conscious, and therefore the technique of introspection is used. The subject reports his experience verbally or by depressing a key or performing some other act. Efforts have been made to ensure rigour in this method, such as averaging repeated trials to diminish the effects of incidental fluctuations in awareness, and establishing rules for regarding stimuli in order to minimize subjects' personal involvement with them. Questionnaires of various sorts have been used in the measurement of subjective attitudes toward political changes, family problems and many other situations.

Of course the person being queried may not wish to divulge his true feelings, and therefore may give inaccurate answers. Or he may not be aware of his true feelings, especially if they are shameful or unacceptable to him. And he may have biased memory about many things. His actual behaviour, also, may differ sharply from his indicated attitudes, as is likely to be true in such matters as race relations and family relationships.

Interviews in which the subject is encouraged to talk at length about his attitudes, guided by questions from the interviewer, may lead to more accurate results than simple questionnaires and are increasingly used in surveys of political feeling and public opinion. In both questionnaire and interview techniques sampling is often carried out. The persons to be interviewed are chosen from the population so that all groups whose attitude is relevant will be proportionately represented. The accuracy of the sample is important in generalizing about the results. If significant groups are neglected, predictions will be in error. Such mistakes, for instance, have been made in some forecasts of the outcome of elections.

In clinical, educational and guidance applications of psychology other techniques are used. The clinical interview or psychotherapy is usually designed by the one who conducts it to learn about the patient's personality or to help him express his feelings and understand them. Hypnosis can help the patient remember forgotten material or aid him in overcoming undesirable habits or attitudes. Various drugs: such as sodium amytal, have been used similarly. Controlled and free association may also be employed. In these the patient either says what comes to his mind in response to a question or stimulus word, or is instructed to say everything that comes to mind during a period. When the latter is continued over a number of sessions, it facilitates recovery of memories of past feelings and events and is conducive to the expression of repressed or suppressed attitudes. It is a characteristic method of psychoanalysis.

Psychometric tests measure various sorts of performance as compared with previously established norms (see PSYCHOLOGICAL MEASUREMENT). These may be objective tests, designed to measure specific traits, skills or achievements; or projective tests, consisting of pictures, ink blots, lists of words, sentences or other stimuli, designed primarily to reveal unconscious emotions or attitudes. These techniques are employed widely in the diagnosis of mental and emotional illness and as aids in guidance. Factor analysis, a statistical method developed by C. E. Spearman and Sir Cyril Burt in England, L. L. Thurstone in the United States and others, has been increasingly used to derive the dimensions of behaviour and personality measured by psychometric tests.

Stress interviews and other situation tests are recent developments used in selecting personnel for special military duties or industrial assignments. These techniques are designed to create circumstances in which emotional factors are sufficiently strong or events develop with sufficient realism so that the reactions of the person being tested can be assumed to be like those he would manifest in critical situations on his assignment.

Play therapy with children too young for adult methods of psychodiagnostics and therapy ordinarily involves the use of play materials either as a sort of projective device (for instance, to see how the child treats dolls representing faniily membersj or to facilitate expression of feeling and allow the child to "act out" his conflicts in play with his therapist. Various forms of therapy through role playing have also been developed. The patient may play himself or another character, and additional actors, therapists or patients act other roles. Usually the plot is not specified and action proceeds extemporaneously. This technique often serves as an opportunity to express feelings and also to practise meeting the problems of real life.

THE CONTENT OF PSYCHOLOGY

The individual is an organized system maintaining equilibrium among the inputs and outputs of each of its constituent subsystems and over-all stability in a constant flux of inputs from and outputs to the environment. In common with others, the individual is a subsystem of larger systems like families and other groups. countries and societies. The present state of any of these behaving units is the result of its genetic constitution and the past inputs to it. In this general framework it is possible to see the interrelationships among the various areas of psychology. Sensation is the name of the area concerned with the inputs of stimuli to the sense organs of the individual. The patterning or organization of these inputs is the subject matter of the field of perception, and apperception deals with processes whereby perceptions become meaningful by being associated with memories of related past experiences.

Among the internal processes which regulate the organism, learning and memory (and its converse, forgetting) deal with the storage of experience for periods of time. Attention or set are functions which result in certain sorts of input having more influence on the organism than others. Various "higher mental processes." though demonstrable in other complex animals. are particularly characteristic of man with his intricate central nervous system—reasoning, decision making. problem solving and concept formation. Emotion and temperament concern processes related to feelings and closely associated with the autonomic nervous system and endocrine system (see ENDOCRINOLOGY). Motivation is the area which deals with the internal needs or drives which provide the impetus that makes the person act. And the complex notion of personality, which is similar to but not identical with self and ego, is used to represent the organization of all the characteristics that make the individual unique, dependable in his responses and consequently recognizable to others over long periods.

Psychology is also concerned with the outputs to the environment or larger systems of which the individual is a member These include such responses as his reflexes and his complex physical acts. Included also are his patterns of work, and the effects of fatigue, distraction motivation and social interactions on them, as well as his gestures and his speech.

The study of the development of human behaviour from infancy through the "seven ages of man" is a part of psychology. So, too, is the systematic comparison of the actions of different species and the relating of this to known facts of comparative anatomy (*see* PSYCHOLOGY, COMPARATIVE). Psychopathology, the study of abnormal states. is also part of the science. Deviation from norms produced by genetic or experimental influences and abnormal states produced by toxins. drugs. hypnosis. injury, illness and unknown factors are studied both as phenomena in their own right for the light they shed on healthy function and in the hope of learning how to cure or improve afflicted individuals (see PSYCHIATRY; PSYCHOLOGICAL MEASUREMENT).

Finally the field embraces social psychology, which is concerned with the behaviour of systems larger than individual and deals with interpersonal and group relationships, the influence of societal and cultural factors, the place of the individual in society and problems of communication among individuals.

A relatively new development is the growth of psychology as a profession distinct from the science. This development mas inevitable with the rapidly increasing number of applications of psychoiogical knowledge in business, military and political life, and since psychologists developed tools useful in the clinic in studying and treating patients, both psychiatric and medical. (See APPLIED PSYCHOLOGY.)

SPECIFIC TOPICS IN PSYCHOLOGY

Some of the most important theoretical formulations and empirical findings of psychology are summarized below under the main topics suggested in the preceding statement input, central and output processes; developmental history; pathology; and interpersonal relations.

Input Processes.—The world impinges upon us through our senses of vision, hearing, smell, taste, touch, vibration, hot and cold. The state of our body is reported to us by pain, muscle and joint sense and the vestibular balance sense. Of these the earliest to be studied scientifically and the most thoroughly understood today are vision and hearing. Impulses reaching the appropriate sense receptors are transmitted by peripheral nerves to the central nervous system. The nature of the receptors and of the neural transmission dictates which sort of energies mill be sensed and which will riot, as was recognized by Sir Charles Bell and Johannes Müller early in the 19th century. The receptors are sensitive to certain wave lengths and not to others, and these must be of sufficient intensity to cross the limen or threshold of the particular sensory subsystem involved. The eyes are stimulated by light sources whose wave lengths fall between ultra-violet and infra-red, both limits being invisible. In this limited range of all light frequencies, species differ as to which frequencies they see best. Dogs and some other species can hear high-pitched sounds which human beings cannot hear. A single nerve cell (neuron) .either reacts to the full or does not respond at all. Therefore increase in intensity of sensation is brought about in a stepwise manner by the involvement of more and more neurons in a nerve trunk, or by other means. The "just noticeable difference" is a unit of psychophysical measurement representing how much more intense a stimulus must become to produce a report of awareness of change by the subject. Donald Hebb and his associates and John Lilly reported evidence that for normal function, the nervous system needs a constant minimal input through the senses; otherwise hallucinations and abnormal behaviours may be produced.

Central Processes.—The Central *Nervous* System.—(See BRAIN; NERVE; NERVOUS SYSTEM; PSYCHOLOGY, COMPARATIVE.) More complex animals in general have larger brains in proportion to their body sizes and show encephalization, which is a tendency for the higher nervous centres to integrate functions controlled by lower centres in less complex species. In man this tendency has resulted in even those vegetative functions which are mediated by the spinal cord and older portions of the brain having representation in the cortex. The histology and neuroanatomy of the nervous system have been studied in detail and the activity of many areas is well understood. The brain is known to be incessantly alert and active chemically and electrically throughout life. even in sleep. Knowledge is incomplete, however, concerning the function of much of the brain, including the frontal lobes. Studies on animals which have undergone operation and on brain-injured and surgically treated human patients have located areas whose damage permanently impairs or destroys certain such processes as sight or speech. The neural bases for learning, memory: reasoning and perception are not clear?and the meaning of such factors as attention, will, decision making and personality organization in terms of brain activity is uncertain. There are, however, theories which account for many of the observable facts. Electronic computers and "behaviour simulators" have been viewed as models of brain mechanisms and have furthered understanding of them.

The two classical theories of brain function are those based upon the stimulus-response model and field model. respectively. In the first, the elements of sensory nerve, central process and motor nerve are assumed to be elaborated with many interconnections strengthened by repeated use, so that more complicated behaviours are built up from the same elements as the spinal reflex arc. The second, field theory, regards behaviour as related to energic changes in the whole cortex or brain rather than through the connection of elements. There is no common agreement as to which is a better way to conceptualize central processes like perception, learning and memory.

Perception is the organizing of the raw material of sensation into a constant "world of experience" in which sight, hearing and other senses are co-ordinated with each other and recognizable objects are located in space. Study of the different images on the retinas of the two eyes indicates that the images change shape and size if the object causing them moves in the visual field. Their colours change with light and shadow as backgrounds alter. The observer, however, knows that the steadily enlarging image of a car means that it is approaching; that the yellow of a lemon remains the same in sunlight or shadow; that the square has four right angles even, though its image on his curved retina has none. He is able to recognize familiar songs in any key. All this being true, it is not surprising that the question has arisen both in philosophy and in science of the extent to which the observer is responsible for the characteristics of the world which he inhabits. What is "really there" outside? Our whole experience of the world comes to us in the form of such percepts, and these cannot be observed by anyone but the perceiver himself.

The point of view known as "phenomenology," a position particularly popular among existentialist theorists on psychological issues in Europe, stresses both the privacy of experience and the activity of the perceiver in giving form to reality. The classical modern view of perception was based upon the associationist philosophy of Locke, David Hume and John Stuart Mill in the 18th and 19th centuries, according to which ideas are bonded together to form a total idea of an object. Titchener, who developed a late form of such theory. believed that a number of sensations are incorporated into a connected whole and supplemented by images from past experience in such a way that they become part of the percept. They have meaning according to the context or total situation in which they arise.

The perceptual theory of the Gestalt school developed in the tradition of Kant, who held that the mind imposes categories upon experience. The Gestalt movement began about the time Max Wertheimer published experiments in 1912. These demonstrated that "apparent movement" of a single object from one place to another is perceived when two adjacent lights are lighted sequentially at a time interval longer than those which make them appear simultaneous but shorter than those which make them appear successive. Wolfgang Kohler, Kurt Koffka and others published further research and additions to the theory. They were. as noted above, committed to a field theory of brain function and believed that innately the brain is able to perceive certain simple forms such as a square or circle. Their experiments showed that there is a perceptual tendency to "closure" in which partial figures are seen as wholes, patterns are organized from amorphous materials and unfamiliar constellations are seen as familiar. It was emphasized that in perception the whole is greater than the sum of its parts. Gestalt theory opposed the associationist theories with cogent arguments.

Hebb, in 1949, challenged the Gestalt view at least in part. He held that there is indeed some innate organization of perception but contended that a given perception depends upon the excitation of particular neural cells. He cited experimental evidence to show that congenitally blind persons who, after ophthalmic operations, are able to see, can readily perceive figures as standing out against background, but must learn to recognize and name them. Even after a training period they must sometimes count the corners to tell a triangle from a square. Objects are often not recognized against altered backgrounds until a learning period has passed. Neurologically the Hebb theory assumes that cell assemblies form which, through growth of neurons, come to be so connected as to discharge in a co-ordinated way. They are also integrated into more complicated organizations. These make possible the perception of wholes as "greater than the sum of their parts." Hebb's theories concern other psychological processes besides perception, sometimes in detailed fashion but often only sketching in general outline.

Even early theories of perception recognized that other functions are related to perception. One of these is attention and another the set or direction of activity already in process in the individual at the moment of perception. Though attention can alternate rapidly when two or more stimuli demand notice simultaneously, we cannot pay attention to every stimulus which assails our sense organs. What is chosen to be attended to is therefore partly determined by the characteristics of the stimulus—suddenness, frequency of repetition, intensity. unusual characteristics such as strange colour or unexpected motion are among these—and partly by factors within the perceiver. If he is hungry, he will pay more attention to the restaurants he passes than if this drive is satisfied. An artist will observe the play of light and shadow over a cornfield while a farmer will notice the vigour and probable yield of the crop.

Set influences perception by leading the perceiver to expect a continuation of the sort of situation which has been in progress. A picture of a red sphere will commonly be called "apple" if shown in the midst of a series of pictures representing various foods or fruits. The same sphere is a "ball" if the series is of toys or sports equipment. It is "sphere" if in company with abstract geometrical designs. Words identical in sound gain their meaning from the context in which they appear. We do not look for "flower" in a cake recipe, or "flour" in the gardener's account of his successes.

Within relatively recent years new sorts of determiners of perception have been emphasized. Not only is the present drive state of the perceiver recognized as important, but his past history, his emotional characteristics, his personality structure and his motivation can all be demonstrated to affect perception. A fearful soldier or a recruit will perceive a threatening situation in battle differently from a brave or experienced man. Emotions and past experiences determine to a great extent what things will be singled out as important. The way we perceive another person may be affected by attitudes we have had about similar persons in the past. A man whose father was overly strict. for instance, may perceive all older men as threatening. forbidding and likely to cause trouble. This, of course, is an extension of the classical sense of "perceive."

Social factors in perception are important in the theories of Jerome Bruner, Leo Postman and others, published in the 1950s. Muzafer Sherif and others have shown that social pressure can strengthen a weak conviction about what one is perceiving, or throw doubt upon a relatively strong one.

Phenomenology, as contrasted with objective theories of perception. has its greatest number of adherents among psychologists in Europe where the philosophical implications of the theory are believed to be in keeping with current thinking in literature and other fields. Albert Michotte, a leading exponent of such theory, conducted a considerable body of research relevant to his ideas. He studied the effect upon perception of stimuli which are in some way discordant—for example, when two senses, like vision and touch, seem to give conflicting information about an object. His results indicate that some subjects behave as if the object lacked unity, yet seem untroubled by the difficulty; others make a compromise of some sort. He also studied the perception of volume, finding that a plane figure with metal wires arranged in certain ways will be perceived as having volume. Perception of causality, he found, can be gained by moving objects in such a way that they appear to affect each other without doing so. For instance, a motion picture of circles going toward and away from each other in certain patterns and at certain rates is perceived by the viewers as showing billiard balls bouncing against other balls and causing them to roll. Michotte found that in perceiving distance and size, situations in which people are used to being deceived by appearances, they readily admit that an illusion is operating. However, in novel circumstances involving no previous experience of deception, adult subjects behave as Jean Piaget found children to behave; that is, they find it difficult to convince themselves that they are perceiving incorrectly. Carl Rogers in the United States championed a point of view related to phenomenology, applying it in nondirective or client-centred psychotherapy; this involves the acceptance by the therapist of the client's subjective frame of reference, including his perception or conception of himself.

Learning is a central process which has been a major concern of psychologists since the earliest days of the science. By the mid-1950s there existed a formidable bulk of experimentally demonstrated fact upon which to build theory and to base further research. It continued to grow as rapidly as scientific journals could print papers on the problem. Hermann Ebbinghaus' well-known experiments on memorizing nonsense syllables. published in 1885, were among the earliest of these studies. He demonstrated that such material, without meaning or emotional connotation, is acquired in an orderly way that, when plotted graphically, results in regular curves. Learning of meaningful material can produce such curves under certain conditions, but the process is more complex, being affected by the difficulty of the task, familiarity with its content, attitudes toward its meaning and other factors, Motor habits such as operating a typewriter are learned in similar regular fashion.

Increasingly it has been possible to specify precisely what conditions facilitate or inhibit learning. Active participation of a subject in an experiment, for instance: produces rnore rapid learning than when he merely listens passively as the material is read to him repeatedly. Motivational factors. such as expectation of reward or fear of punishment, also operate to influence the rate of acquisition of new information. The law of efiect of experimental psychology, as first stated by Edward Lee Thorndike and as modified by Clark Hull and others in terms of "reward" and "reinforcement," and the pleasure-pain principle of Freud's psychoanalytic theory agree (in spite of many differences on other points) that information and action patterns which produce pleasure or prevent pain are learned and retained while those which produce pain or prevent pleasure are forgotten or repressed. Research has also indicated that, up to a point, increasing distraction operates to speed the rate of learning, but beyond that point the process is hampered. The set or attitude of the learner, his emotional reactions to the material, his motivations, social factors such as the presence and reactions of other learners, all affect the process.

The work of I. P. Pavlov on conditioning in animals, which first appeared early in the 20th century, was classical physiological research with important implications for the psychology of learning. In this work an animal was presented with an "unconditioned stimulus," *e.g.*, an electric shock, a short time after he heard a bell ring—the "conditioned stimulus." The animal would withdraw the paw which received the shock from its position, thus ending the painful stimulus. After a number of trials of this sort the animal would begin to remove the paw upon hearing the bell ring, so avoiding the shock. This action was called the "conditioned response." It could be established by the use of reward as well as punishment. A bell ringing shortly before meat was offered to a hungry dog would set up conditioning whereby the sound of the bell would cause the dog to salivate in a way that had formerly been elicited by food alone. It was found that this response would slowly disappear unless it was "reinforced" with a meat reward from time to time, and that it could be made to disappear more rapidly if the ringing of the bell were followed by punishment instead. The investigations of Pavlov deeply affected the behaviourism of Watson, who maintained that any personality traits desired could be built up in children by proper conditioning.

We do not know exactly what goes on in the nervous system when even a simple motor habit. much less a complex idea, is acquired. But it is assumed that in some way neural connections are strengthened or organizations developed by repeated passing of impulses in given patterns. It is considered significant that for almost all learning more than one experience of a given sort is necessary. "One trial learning" is possible where the situation is dramatic or extreme—one touch of the hot stove is usually enough to make a child avoid it. In some lower species a process like learning, known as imprinting, takes place; in which the first experiences have an immediate and lasting effect. Konrad Lorenz has shown that a gosling will follow a human being who quacks at him during the first few minutes after hatching if the mother goose does not get there first. Thereafter the gosling will follow the human being in preference to the goose. According to Lorenz this effect is permanent, although this has been questioned by others. Learning differs from imprinting in involving the more gradual development of some sort of connections or restructuring over time.

The determinants of learning have been specified in great detaii for the white rat, but less fully for humans and other species. Animal learning is studied with mazes and other types of apparatus. as for instance those which permit animals to jump or press levers or make sorne other specific response to differently patterned cards or lights. (See PSYCHOLOGY, COMPARATIVE.) Human learning is investigated using finger mazes, memory drums that automatically expose cards with pictures or words, discrimination situations and other procedures.

As in other fields of psychology, there are both associationist learning theories and field learning theories. In the first class learning is regarded as proceeding from the formation of many reinforced connections between sensory events, central processes and motor events. In the second it is viewed as the organization of a field. Stimulus-response theory, in the first class, conceptualizes learning as a continuous function, proceeding as connections are strengthened in an orderly way. Field theory conceives it as discontinuous; the field is structured first according to one set of cues and then restructured to another.

Hull hypothesized that "bonds" are formed between stimulus and response, and that these are reinforced when drive reduction occurs through a reward such as food or escape from a punishing situation. He did not, however, insist that there are definite sensory-motor pathways in the nervous system, conceiving instead of "habit family hierarchies," interrelated patterns of action which can be elicited repeatedly by a specific sort of stimulus.

Edward Tolman, a field theorist, placed more emphasis upon "cognitive" factors. That is. he assumed a more active role for thinking and reasoning and less for reinforcement by the situation. He assumed that an animal learns a maze by forming a series of hypotheses as to the correct direction to take at each choice point, checking them and continuing those that are rewarded by success, so developing ultimately a "cognitive map" of the total configuration of the maze.

4 third important learning theorist was B. F. Skinner. Instead of guessing at what might be going on "inside" the animal, he tried to specify exactly and in units of detailed acts the conditions under which learning takes place. Skinner preferred as a measure the rate of response in animals as related to the degree of drive—measured by the amount of weight lost through hunger or the number of hours of fasting or thirsting. He pointed out that if a rat is trained to depress a lever in order to receive a measured amount of food, the number of times the lever is depressed during a feeding period can be considered a measure of the rat's drive.

Memory of learned material was regarded classically as the maintenance of associations established in the learning process. Sir Frederic Bartlett studied memory experimentally and his findings indicated that more is involved in memory than the storage of information or the maintenance of established bonds. He showed that as time passes the memory "trace" is modified. He asked subjects to make successive drawings from memory of an outline picture of an owl. Typically such drawings progressively dropped out details?finally losing the characteristics of an owl and ending as the more familiar outline drawing of a cat. His theory assumed that organization of memory is subject to change as ii is affected by prior experience and by later events. Ebbinghaus had found earlier that forgetting of nonsense syllables, like learning, followed a smooth curve—in this case a decay curve.

Much research relevant to memory actually deals with its opposite, forgetting. As learning mas held to be the setting up of connections! and meinory their maintenance; forgetting, to classical association theorists, involved wearing them away. Pavlov found that to keep a conditioned response lively it must be reinforced from time to time, He also found that extinction can be hastened by presenting the conditioned stimulus without the reward or punishment which established it.

Events occurring after learning or conditioning can interfere with retention. This is "retroactive inhibition." J. G. Jenkins and Karl M. Dalienbach showed that memory is better after sleep than after a comparable waking period, presumably because in sleep there are no interpolated tasks to inhibit memory retroactively. "Proactive inhibition" also occurs, whereby later learning is prevented or altered by earlier events.

Freud challenged classical views of forgetting. By hypnosis or free association he could retrieve from patients verifiable memories of long-forgotten events. Frequently these mere confused with "cover" or "screen" memories which the patient preferred to recall, but the original impressions were available under special conditions. He therefore concluded that memories of shameful or disturbing events could be repressed into an unconscious aspect of the personality. This repression mas somewhat similar to Pierre Janet's "suppression," which in extreme cases even embraced the "forgetting" of whole parts of the personality or functions of the body. Both Freud and Janet found that memories outside of awareness continue for long periods to exert an effect upon behaviour. This discovery led to the view that little is ever forgotten but that in some way the brain retains most impressions made upon it, mhich under favourable circumstances can be recalled. Evidence is accumulating that brain processes are continuously suppressing and repressing selectively various stored memories.

Problem solving has been studied in men and in animals. *(See* PSYCHOLOGY, COMPARATIVE.) Though thinking and reasoning are often held to be "higher mental processes" particularly characteristic of man, the body of experimental material on them is relatively small and theory is primitive. About the turn of the 20th century the chief argument in this field centred around the question of whether a thought was characterized by a temporal chain of conscious images, as a group at Leipzig contended, or could be carried on without such an association of images, as their Wdrzburg antagonists believed.

Later, as has been mentioned, controversy raged around the behaviourist insistence that thought is subvocal speech, minimal activity of the laryngeal muscles. Thorndike and other associationists held that the solution of problems proceeds by random trial and error, the scope of trials becoming more delimited gradually as partial solutions are achieved. Problem solving by animals has been studied in various kinds of problem boxes in which the animal receives a reward for completing the task. Multiple-choice apparatus has also been used to observe human problem solving.

The Gestalt school made new assertions about problem solving, stressing the instantaneousness of arrival at a solution as the conceptual field is restructured. They pointed to the surprise with which subjects suddenly see the answer, calling this the "aha experience." Karl Duncker published research on such cognitive reorganization in 1926 and 1935. He made use of difficult problems whose answers were not immediately apparent from past experience. He found that solutions were not reached in a single step, but proceeded by one or more restructurings of the problem so that it was viewed differently, and this process led to the final correct ansaer.

Norman Maier also gave difficult tasks to human subjects and analyzed the solution process. He believed that it occurs by the formulation of a theory as to what should lead to solution, testing of it and eventual confirmation or rejection with the consequent statement of another hypothesis. This is neither the trial-and-error process of Thorndike nor the insight of the Gestalt group. Maier held that only problems that were easy for the subject were solved by insight, but he recognized that when they could be grasped at once and structured readily the solutions were "seen" with the "aha experience."

In ways somewhat similar to the problem-solving process, the central process of *decision making* has been increasingly investigated. In some region of the nervous system, many inputs from the environment, from other parts of the body and from the memory must be resolved in order to give rise to a single output, or a limited number of them. In neurophysiological terms, a "final common path" must be selected. Psychologically and psychoanalytically this is classed as a "self-" or "ego-function." Many influences, both external and internal, impinge on us—sensations and perceptions of the outer environment; social factors; motivational conditions and somatic needs involving physiological states of the "internal environment" within our bodies; feelings, emotional states and aesthetic preferences; memories, both conscious and unconscious; the resultants of learning, thinking and reasoning; ethical values and religious beliefs. All these must be reduced to a common denominator before one behaviour occurs in a given situation rather than another. This is decision making, and it is being increasingly investigated by psychologists, sometimes with the assistance of a new branch of mathematics known as "theory of games," which was introduced by John von Neumann and Oskar Morgenstern.

Emotions such as fear, rage, sorrow and love are central reactions which involve visceral and emergency mechanisms of the body *(see* EMOTION). The autonomic nervous system, which controls functions like respiration, digestion, circulation and glandular secretion, mediates through its sympathetic branch various states of excitement and preparedness for action which characterize emotion. Digestion may stop, heart and respiration rates increase, adrenaline be excreted into the blood stream and the blood sugar content be increased. Measures of blood pressure, breathing rate, blood sugar and the psychogalvanic skin response *(see* PSYCHOGALVANIC REFLEX), among others, have been used in experiments as indicators of emotional states.

Psychologists have asked what are the relations between the physiological conditions of emotion and the concomitant introspectively reported feelings. James in 1884 and Carl Lange in 1885 independently proposed that emotions are the conscious awarenesses of the bodily changes which occur as direct responses to emotion-provoking situations. Thus, "we feel sorry because we cry." A revision of this theory, by Walter Cannon and Philip Bard, held that the hypothalamus, a midbrain centre, is the seat of emotional response, sending impulses both to the cerebral cortex, where awareness of them probably arises, and to various internal effector subsystems of the body, producing visceral, glandular, muscular and other responses.

Charles Darwin, in 1872, wrote about the distinctive gestures and facial expressions which characterize the different emotions, and suggested that at least some of these behaviours are inherited from lower species. The human sneer, for instance, may be related to the carnivore's baring of its canine teeth in rage or in preparation for attack.

Continued emotional stress, conscious or unconscious, is recognized to have a role in causing many "psychosomatic" diseases, although the mechanisms by which these effects are produced are poorly understood. The relief of the underlying tensions may alleviate symptoms when other sorts of therapy have been ineffective. Mental diseases such as schizophrenia have a profound effect not only on cognitive processes but also on the emotional state of the patient, characteristically producing an apathy or "flatness" of affect. Manic-depressive psychosis results in either excited or depressed emotional states or cyclical alternations between the two.

(See ABNORMAL PSYCHOLOGY.)

Also there are *feelings,* somewhat but not exactly like emotions and consequently often classed separately. Among these are anxiety, which has been given many diverse definitions and explanations by experimentalists and clinicians, but which is most commonly considered a subjective state of discomfort signalling an unresolved internal tension or apprehension about a potentially harmful input from the environment. Anxiety neuroses are moderately severe emotional disturbances characterized by such feelings, which are often overuhelmingly powerful and which frequently swell into acute "anxiety attacks" associated with sweating, trembling. palpitation and other autonomic responses *(see* ABNORMAL PSYCHOLOGY).

Pleasantness and unpleasantness are also feelings, rarely occurring together, which characterize the "hedonic tone" or degree of satisfyingness of subjective experience. They are studied experimentally as determinants of preference among various objects or events in the environment. Since satisfaction of drives is usually pleasant and frustration of them unpleasant, they also are related to motivation.

An associated problem was mentioned in the section on learning, in discussing the lam of effect.

Personality is the characteristic organization of the individual's traits which makes him unique and which to a large extent remains constant throughout his life. If it is to claim completeness, any theory of personality must deal in some way with such questions as the following: What is the self? What drives the individual? What relative importance have various influences upon the development of adult personality? How can one account for the temperament, or characteristic emotional climate, of a person? What are the bases for individual differences in capacity, perception and reaction? What are the causes and nature of extreme deviations in these? And what is the effect upon personality of interpersonal relations and cultural influences?

There are a number of current theories of personality. Some of the theories dealt with above—particularly under perception and learning (*e.g.*, those of Hebb, Bruner, Hull and Tolman)—have been extended into the realm of personality. Other theories were derived chiefly from clinical observations. A moderate amount of experimental work in this field has been carried out, but in general it is characterized by a wealth of words amid poverty of reliable evidence.

Foremost among the clinical theories of personality, the psychoanalytic system of Freud (see ABNORMAL PSYCHOLOGY; FREUD! SIGMUND; PSYCHOANALYSIS) presents a coherent body of concepts which has had deep influence on personality theory as well as other fields of psychology. The results of efforts to test experimentally the psychoanalytic formulations based on observations with patients have been difficult to interpret and, taken altogether, still are inconclusive.

To Freud the ego is the conscious, socialized, directing part of the personality and is distinguished from the unconscious, antisocial, libidinal or id forces which exert their influence through evasion of the repressive mechanisms of the censoring superego. The energy for psychic functions comes from instinctual drives, mainly sexual and aggressive. The ego employs such mechanisms of defense (see DEFENSE MECHANISMS) as rationalization, sublimation, projection and repression in making adjustment to the changing environment on the one hand and the libidinal drives on the other.

The explanation of individual temperamental differences lies in the importance of divergent infantile experiences and the differential enforcement of societal demands for repression of instinctual behaviour by the parents or others who care for the child. The way in which feeding and nursing care are given, the amount of frustration the child experiences through having its cries ignored, the ability of the mother to express love for her child, the sternness or gentleness of the father, the presence or absence of competing brothers and sisters, the effect of others who map be in contact with the child—all combine with genetic influences to mould him into the unique individual that he becomes. Freud's use of characters and situations of the classical Greek stage—Oedipus, Electra—to symbolize the "family drama" in which the developing child is enmeshed have become an integral part of western culture. Relationships between father and son, mother and son, and so forth, which are basically similar in most families regardless of individual differences, are seen as expressions of repressed instinctual drives.

Throughout life we tend unconsciously to react toward unrelated people as if they were playing roles of members of our family. Thus a child of a stern father might in adulthood unconsciously expect similar behaviour from his employer even though actually he was not that sort of person. Extremely deviant early relationships and experiences lead to psychopathology later.

Freud's theories have been criticized and extended since his death. An important trend is the introduction into modern psychoanalytic thought of cultural relativism. It is pointed out that Freud was familiar only with western culture and that the psychosexual development of children in other cultures is clearly different. So typical personalities will also differ.

Alfred Adler and Carl Jung (*qq.v.*) were associated with Freud early in their careers, but later deviated importantly from him. Adler emphasized the drive for power and control over others as well as the "inferiority complex." Jung stressed the importance of the racial heritage historically represented in myth, art and symbol. He recognized relatively less significance in unconscious sexual drives than in the will to wholeness of the individual. He also originated the concept of the complex and the distinction between introverted and extraverted personality traits.

Other personological theories centre around the dynamic interplay of needs or drives. Examples of these are the systems of William McDougall and H. A. Murray. They included both the fundamental physiologic needs of living organisms and many socially derived needs such as gregariousness or need for affiliation with others. Murray recognized repetitive themas of fantasy and behaviour which characterized specific persons. He had a major role in devising the widely used Thematic Apperception test which identifies and measures the strength of these themas. (See PSYCHOLOGICAL MEASUREMENT.)

Theories dealing specifically with temperament include the ancient description of personality in terms of the four humours, a preponderance of one of which gave the person his characteristics. Thus individuals were sanguine (for blood), phlegmatic (for phlegm), choleric (for yellow bile) or melancholy (for black bile). Ernst Kretschmer in 1921 held that the shape of the body influences personality characteristics and determines what sorts of mental illness a person may develop. He measured large numbers of mental patients and found significant relationships between body type and the important mental diseases. This theory was extended to normal people by linking types of normal personality with the most nearly similar mental disturbances; thus the introverted person with a thin, flat-chested, long-limbed body he called "schizothymic." somewhat like "schizophrenic." William Sheldon later attempted to correlate personality characteristics and body build, using a complex measurement system chiefly on normal individuals. He found three basic components of physique and could rate any subject's body on how much of each component was present. His equating of these components with personality types is based more upon impressions than upon experimental demonstration, although some objective data have been gathered.

An important extension of Gestalt theory into the realm of personality m s made by Kurt Lewin, a mernher of the original Gestalt group whose early work concerned problems more typical of that school. Later he employed notions from the mathematics of topology, which deals with nonmetric spaces, in conceptualizing the personality as divided into "regions"! or "systems" separated by more or less permeable "boundaries," within which dynamic exchanges of energy are going on in the general direction of equilibrium or reduction of tensions.

Objects and people in the individual's psychological field or environment are assumed to have positive or negative "valences," power to cause him to approach them or withdraw from them. Conflicts occur when valences of almost equal strength are in opposition or when "barriers" exist to stop progress in the direction of strong forces. A toy may have a strong positive valence to a child, but his approach to it may be stopped by a barrier; *e.g.*, a store window or a stronger child who holds it. Many such forces act upon the person, and his behaviour is the resultant of them.

Personalities differ in the degree to which the boundaries of the component subsystems influence one another. as well as in other aspects. An infant has a relatively unstructured personality in which the self is not well differentiated from the world and other people. With maturation distinctions become firmer, but may shift from time to time as the personality is reorganized, as by education or psychotherapy. Lewin's theory provided confirmable hypotheses for experimental testing and there is some empirical literature in this tradition, particularly in the fields of child behaviour.

Output Processes.—The output of the organism, aside from secretions and excretions resulting from physiological processes! is produced through the "effector system," the subsystems of motor nerves and muscles which control bodily actions. All responses, from the reflex knee jerk to the most complex verbal communication, are included, and of course preceding sections of this article have mentioned reactions and responses as necessary in describing input and central processes. For example, the learning of motor skills and habits has been discussed.

Work is another sort of output which has been investigated experimentally. Time and motion studies, studies of conditions favouring and interfering with working efficiency, studies of optimum length of work periods have become usual in industrial psychology. All concern aspects of motor output.

The finger ergograph, a device which records the performance of the finger muscles in pulling a weight, has been used to do research on fatigue. Other devices, such as treadmills, have been employed to study larger muscle action. The resulting work curves show a characteristic rise in output as the muscles first "warm up" and then a decline with fatigue. The effects of rest pauses, interpolated activity, various drugs and different motivations have been studied by these means. Fatigue in industrial settings, however, depends upon more complex factors than the ability of muscles to do work. Boredom, the feeling of tiredness which may precede real fatigue, variations in motivation, changes in morale—all alter output. Change of task, even though the same muscles are still used, for instance, may result in improved output. The effects of distraction upon work are complicated. Some distracting sound seems to improve performance, but too intense or too prolonged or too unpleasant distraction, noise or confusion reduces output significantly.

Speech is another sort of output. The neural and muscular mechanisms of speech, its efficiency and its pathology in such conditions as stuttering and aphasia are being increasingly investigated. Information theory, derived from physics, is providing new concepts and measuring units for research on the linguistic and communication behaviour of man. Throughout the history of psychology there has been a tendency to minimize the output activity of the organism, putting primary emphasis on input and central processes, although the output is the overt evidence that the other processes have occurred. Much of the work in output processes is recent.

Developmental History. — The study of the development of animals (see PSYCHOLOGY, COMPARATIVE) and human beings from the embryo state to old age is called the longitudinal approach. Studies of embryonic and infant motor development indicate that the earliest movements are unco-ordinated, involving the whole body. Reflexes such as the sucking response and the Babinski sign (fanning upward of the toes when the sole of the foot is scratched) are present in human infants at birth. Controlled voluntary actions begin to develop within the first weeks of life, as the nervous system matures, proceeding in general from the head downward.

The progression of development of muscular activity is from larger movements involving a whole limb to fine motor adjustments and complex co-ordinations, as between the eye and the hand. Mary Shirley published detailed reports on motor development in infants. Arnold Gesell observed and tested a large number of children from birth to adolescence and provided norms for each age. His studies include not only the appearance of physical skills and characteristics, but of speech and of typical psychological adjustments, interests, fears and preoccupations. He has described characteristic behaviour at each age level, reporting changes from week to week in infants and over longer periods in older children.

Alfred Binet and Théodore Simon in 1905 published the first intelligence scale for children. A need for this had been felt in the crowded schools of Paris as there had been no precise procedure for distinguishing those children who could profit most from school. Such intelligence tests were adapted for English-speaking children by Frederick Kuhlmann and Lewis Terman, among others, and construction of tests measuring other aptitudes and abilities followed (see PSYCHOLOGICAL MEASUREMENT).

A number of long-term developmental studies have followed children from infancy through the school years, measuring physical growth, mental development and, in some, emotional progress. In addition many researchers investigated these factors at various stages of life.

Piaget, for example, made extensive observations of the reasoning processes, thought and language of young children. In them he demonstrated a growth in the use of conceptual material that was related to age. He found that certain sorts of explanations of natural and physical phenomena characterize certain ages and are not found in normal children of more advanced age—for example, younger children make more use of animistic and magical explanations than do older ones. His method was to ask children questions such as "What makes the wind blow?" or to perform a simple experiment which illustrates natural lams and ask the child to try to explain it. He has also studied the child's growth in understanding of social concepts.

With the increase in life expectancy there has been an increase in interest in the physical, psychological and social effects of aging.

Psychopathology. — (For a full discussion, see ABNORMAL PSYCHOLOGY; PSYCHIATRY; and PSYCHOANALYSIS.) The most important problems in this field relate to understanding the cause, mechanisms and possible treatment of deviations from behaviour considered pormal and acceptable by the culture in which the patient lives. The relation of neurosis to psychosis is still in the realm of theory. It is not entirely clear whether they are, respectively, mild and severe manifestations of the same essential processes, as some theorists have believed, or are qualitatively different.

There is probably a genetic causal factor in schizophrenic and manic-depressive psychoses, and there is increasing evidence that there are changes in body chemistry in them. On the other hand, pathological interpersonal relations with members of the family and others are commonly found in the early developmental and later histories of mental patients, which indicate that environmental stresses are also important in mental disease.

Psychotherapy is commonly considered most likely to be effective in mild or fairly recent illnesses. Some severely disturbed patients have been helped by such procedures alone. Among the most popular schools of psychotherapy are those following the techniques advocated by Freud, Jung, Adler, Karen Homey, Harry Stack Sullivan and Rogers. Experiments with the tranquillizing drugs, psychosurgery (or prefrontal lobotomy) and insulin, metrazol or electric shock treatments indicate that these can affect the course of even severe mental disease.

Interpersonal Relations. — The interactions among individuals in such larger behaving systems as groups and societies are studied by several disciplines including psychiatry, psychology, sociology and anthropology. The study of small group dynamics, initiated by Lewin and significantly advanced by the prolific research of his followers and others, became important in both psychology and sociology. This basic research has been applied to group psychotherapy, found to be of value in treating mental illness; group interactions in the fields of labour relations, race relations and politics; committee functioning; and behaviour of clubs and small civic organizations.

There have also been social psychological studies of whole communities, such as those done by Lloyd Warner, Robert Havighurst, Roger Barker and others, in which the complexities of intergroup and interpersonal relationships are analyzed by interviews, analyses of statistical and economic reports on the community and observation. Warner found that there is an important element of class structure in U.S. society and investigated the factors that place a person in a given class in his own eyes and those of the community, as well as the mobility of Americans in moving from one class to another in various rural and urban locales.

There are also important recent theories of social interaction, that of Talcott Parsons and Edward Shils for instance. They view the interpersonal and social processes as the interaction of "action systems" in which an individual participates through the "roles" in which he is cast by circumstance and the people around him.

He may be, for instance, a father, a Protestant, a plumber, a member of the middle class, a Republican and so forth. He participates in different ways in the social structure depending on these various roles. The groups to which he belongs interact with other groups according to the decisions of their members or other social forces. Communication and information theory are increasingly important to the study of interpersonal relationships. Many fundamental disturbances in focal, national and international social processes have been shown to arise from distortions of communication or psychological and political barriers to the free flow of information.

BIBLIOGRAPHY.— *The Harvard List of Books in Psychology,* rev. ed. (Cambridge, Mass., London, 1955); E. G. Boring, H. S. Langfeld and H. P. Weld (eds.), *Foundations of Psychology* (New York, London, 1948); E. G. Boring, *A History of Experimental Psychology,* 2nd ed. (New York, 1950); Leon Festinger and Daniel Katz (eds.), *Research Methods in the Behavioral Sciences* (New York, 1953; London, 1954); C. T. Morgan and E. Stellar, *Physiological Psychology,* 2nd ed. (New York, London, 1950); S. S. Stevens (ed.), *Handbook of Experimental Psychology* (New York, London, 1951); C. G. Jung, *Psychological Types,* trans. by H. Godwin Baynes (New York, 1923); L. Carmichael (ed.), *Manual of Child Psychology,* 2nd ed. (New York, London, 1954); Gardner Lindzey (ed.), *Handbook of Social Psychology,* 2 vol. (Cambridge, Mass., 1954); R. L. Thorndike and E. Hagen, *Measurement and Evaluation in Psychology and Education* (New York, London, 1955); A. P. Hare, E. F. Borgatta and R. F. Bales (eds.), *Small Groups* (New York, 1955); D. O. Hebb, *The Organization of Behavior: a Neuropsychological Theory* (New York, 1949; London, 1950); J. M. Hunt (ed.), *Personality and the Behavior Disorders,* 2 vol. (New York, 1944); Ernest Jones, *The Life and Work of Sigmund Freud,* vol. i, ii (New York, London, 1953, 1955); Abram Kardiner, *The Individual and His Society* (New York, London, 1939); C. Kluckhohn, H. A. Murray and D. M. Schneider, *Personality in Nature, Society, and Culture,* 2nd ed. (New York, London, 1953); Wolfgang Kohler, *Gestalt Psychology* (New York, 1947); K. Lewin, *A Dynamic Theory of Personality,* trans. by D. K. Adams and K. E. Zener (New York, 1935); Carl R. Rogers, *Client-Centered Therapy* (Boston, 1951); Sigmund Freud, *The Basic Writings of Sigmund Freud,* trans. by A. A. Brill (New York, 1938); G. W. Allport, *Personality: a Psychological Interpretation* (New York, 1937); J. B. Watson, *Psychology From the Standpoint of a Behaviorist,* 3rd ed. (Philadelphia, 1929).
(JA. G. M.)

PSYCHOLOGY, ABNORMAL. Psychology is the study of behaviour, and abnormal psychology is the study of deviations from normal behaviour. Under the term behaviour is included not only attitude and action but also such functions as motivation, perception (*qq.v.*), imagination, thought and memory (*q.v.*). Abnormal behaviour is classified today under the psychoneuroses, psychoses and psychosomatic disorders, the personality and sociopathic disorders, and the disturbances occurring in intoxications, brain damage and brain disease.

Certain basic phenomena, not in themselves pathological, are dealt with more extensively in abnormal than in normal psychology because of the central role they play in human psychopathology. Among these are anxiety and the defense mechanisms used to control it; unconscious motivation and the drives; the differentiation in early childhood of ego, id and superego; the significance of conscious, preconscious and unconscious processes; and the part played by frustration, conflict and regression in precipitating and maintaining abnormal behaviour. In addition, it is customary to include the study of normal dreaming and hypnosis, as well as such obviously pathological phenomena as hallucinations and delusions. Much attention has been focused upon the effects of extreme deprivation, found among concentration camp victims and hospitalized infants, and, under experimental conditions, among volunteer subjects isolated from normal sensory stimulation.

This article is organized as follows:

I. NORMAL AND ABNORMAL

A distinction between normal and abnormal behaviour is of considerable practical importance not only in psychology and medicine but in all studies of social interaction among individuals, groups, social classes, communities and nations. Problems of communication, for example, are fundamental to all social interaction. These problems cannot be met effectively without knowledge of the distortions of perception, interpretation and decision which personal factors introduce, many of them lying close to or within the borders of the psychopathological. In another area, the legal profession is beginning to deal with the stupendous task of revising some of its fundamental orientations in the area of crime, responsibility and punishment, so as to bring these into closer relationship with modern knowledge of normal and abnormal motivation.

Unfortunately, it is extremely difficult to work out a definition of normal behaviour that is generally acceptable — far more difficult than to define normal business conditions or normal weather. Human beings are infinitely complex and they live in a complex social environment that is continually changing. The average naive person tends to consider himself the standard of normality and to regard as signs of abnormality any actions, attitudes or experiences of other people that differ markedly from his own. Such a criterion, however reasonable it may seem to the person employing it, is obviously useless. For one thing, it begins by assuming that each person is the sole competent judge of his own conduct, an assumption that no one else will accept in practice. For another, it implies that every person's behaviour is at all times normal, which is also absurd. Millions of neurotic and psychotic persons consider themselves normal, and everyone at some time or other acts or thinks a bit strangely.

An alternative to the naive individualistic approach is clearly one of judging each person's behaviour in relation to that of others in his culture who are of the same sex, belong to the same age group and live under similar socioeconomic conditions. To make such judgments exact and incontrovertible, a system of well-defined, established norms is needed with which any given sample of behaviour may be compared and its degree of conformity or deviation determined. There are, however, formidable obstacles to the construction and use of rigidly specified behaviour norms. The most serious of these are. (1) the heterogeneous composition of contemporary industrial society; (2) the increasing social mobility of individuals and groups, which inevitably increases the incidence and complexity of cultural conflict; (3) the rapid changes in accepted standards of behaviour within recent generations; and (4) the enormous accumulation of 20th-century knowledge concerning human motivation, which has not yet been assimilated into our major social institutions.

Because of these difficulties, and the existing limitations in available techniques, a strict differentiation between normal and abnormal is still out of the question. We must be satisfied for the present to work with rough approximations. Bearing this in mind, we can take as the most useful criterion of normality the relative adequacy of a person's behaviour, including his actions, attitudes, perception imagination, thought and memory, as compared with the behaviour expected of other persons who share his status in his society. Such a criterion begins not with the fiction of the perfect or ideal personality but with the fact of a relatively wide range of culturally acceptable behaviour It allows us to include as normal the many variations and fluctuations that can be found in the everyday experience of ordinary persons.

It is important to recognize that, in this context, adequacy of behaviour is not necessarily the same as work efficiency or social conformity. Efficient work sometimes involves the compulsive exploitation of oneself or of others, and may stem from a deviant need to display personal power, to punish oneself or to eliminate irresistible temptation by eliminating one's leisure. Likewise, social conformity is not always a sign of health. Sometimes it expresses extreme social timidity or fear of one's own antisocial impulses, in which case it can lead to severe personality impoverishment. In short, behavioural adequacy as a mark of relative normality must be viewed not only from the point of view of an outside observer but from the inside of the personality system as well.

With this dual orientation. behaviour may be called abnormal under the folloning conditions: (1) if a person, otherwise in good health. shows himself incapable of establishing and maintaining mutually satisfying interpersonal relationships; (2) if his behaviour, including perception and thoughr, is or becomes strikingly inappropriate in terms of prevailing social norms; (3) if, in order to carry on ordinary activities, a person is obliged to expend disproportionate effort, in comparison with others of his own age, physique, intelligence and training; (4) if he is unable to obtain satisfaction from his activities, his memories and his prospects; (5) if he experiences chronic lack of feeling, sense of isolation or emotional instability; (6) if he suffers from high levels of tension, anxiety or conflict for prolonged periods, or must defend against such suffering through pathological symptom formation.

II. RISE OF MODERN PSYCHOPATHOLOGY

Mankind has shown profound concern over abnormal behaviour from ancient times. Attempts to account for the phenomena of abnormal psychology have varied all the way from ascribing them to demoniac possession and loss of the mind or soui to blaming them upon hereditary taint and organic disease, chiefly of the brain but by no means exclusively so. Galen, for example, ascribed hysteria to malfunction of the ovaries; the medieval philosophers related melancholia to an excess of black bile, which the word actually means.

Treatment over the ages has fluctuated irregularly over a correspondingly wide range, especially with respect to insanity. At one extreme are found drastic medical and surgical interventions; purging and bleeding were extensively used and the ancients as well as many moderns relied upon "mind drugs" and cranial operations. At the other extreme are found the use of incantation and exhortation, of flogging and cold-water shock, and for centuries the use of capital punishment, as in the world-wide witch prosecutions.

The emotional origins of abnormal behaviour and the crucial part often played by interpersonal relationships have been implicitly or explicitly recognized for millenniums. But it remained for Franz Anton Mesmer (*q.v.*) to demonstrate, consistently and on a large scale, that emotional crises and pathological symptoms can be deliberately induced and cleared up through the influence of one person upon another. He thus ushered in the modern era of psychopathology.

Mesmer rose to fame and fell to disgrace in Paris during the latter part of the 18th century. His theory that the influence of one person upon another was due to "animal magnetism" sounds strange to modern ears and his therapeutic methods were highly theatrical and even orgiastic. Nevertheless, there is no reason to doubt his sincerity, the genuineness of what he demonstrated and his tremendous influence. Because of the tempest of controversy he raised, his methods were shunned by reputable persons. and for a long time his positive contributions were overlooked. A gradual revival of mesmerism, renamed hypnotism, developed during the middle third of the 19th century and led to a second public controversy. This time it was betneen J. M. Charcot (*q.v.*), the great neurologist in Paris, and H. Bernheim, professor of medicine in Nancy. Charcot maintained that only the potentially hysterical could be successfully hypnotized. while Bernheim insisted that anyone could be. Each was partly right; it is known today that most adults can be hypnotized. and that many hysterical symptoms can be hypnotically induced in apparently normal people. By far the most important outcome of this celebrated quarrel. however. was a greatly increased interest in the origins and characteristics of psychopathology. *(See* also HYPNOSIS; PSYCHIATRY: *History: Hypnosis and Hysteria.)*

Two of the men who came directly under Charcot's influence during the last quarter of the 19th century became themselves internationally famous psychopathologists. Pierre Janet (*q.v.*), who ultimately succeeded Charcot, began a long series of contributions to abnormal psychology in 1889, devoting his attention first to obsessions and then to hysteria. His early writings have some of the germs of modern psychodynamics and his later clinical descriptions were brilliantly clear. Nevertheless, his influence upon the field has steadily declined, both because of the limited scope of his descriptive studies and his lack of theoretical originality and fruitfulness.

Sigmund Freud (q v.) spent the year 1885 in Charcot's clinic while Janet nas there, but he also looked into the other side of the controversy by visiting Bernheim in Nancy for a few months in 1889. He translated the writings of both Charcot and Bernheim into German soon after his visits. Unlike Mesmer, Freud shunned public controversy, worked with the utmost self-critical care, for many years almost in isolation, and met the condemnation of others largely by piling up further incontrovertible clinical evidence. Unlike Janet, he ranged over the whole field of psychopathology and invaded normal psychology as well, and his theoretical contributions were daring, revolutionary and of such fruitfulness that their importance seems still to be growing. In his *History of Experimental Psychology* (1950), *E. G.* Boring lists Freud as one of the "four very great men in psychology's history." Certainly no one else has influenced the development of abnormal psychology so profoundly and extensively as Freud. (For an evaluation of the related but divergent views of Alfred Adler, Erich Fromm, Karen Horney. Carl Jung, Otto Rank and H S. Sullivan. *see* R. L. Munroe. *Schools of Psychoanalytic Thought*, 1955.)

Largely as the direct result of Freud's brilliant contributions, the major emphases of modern abnormal psychology are placed upon the following factors: (1) the overnhelming importance of early childhood in laying the foundations for normal and abnormal behaviour in later life; (2) the differentiation of functional subsystems nithin the personality organization, called ego, id and superego; (3) the prevalence of unconscious motivation, especially in relation to sexual and aggressive drives; (4) the development and operation of unconscious defenses in relation to anxiety; (5) the basic role of frustration, regression and conflict in precipitating and maintaining abnormal behaviour.

III. ORIGINS OF PSYCHOPATHOLOGY

A. Early Childhood

At birth the infant is separated physiologically from his mother, but for years he remains dependent upon her, or upon her substitute. for his very existence from day to day. His interrelationship nith the mother figure is the most important factor in his earliest cycles of need and satisfaction, in his earliest experiences of security and anxiety, in the comforting and disturbing aspects of bodily care, in his development of love and hate, in what he learns to expect from the world around him and how he learns to handle it.

1. Symbiosis. — Even the child's differentiation of his own body from his surroundings, and of himself from other people, depends upon a healthy maturing of the mother-child relationship. At first the relationship is normally symbiotic, that is, one in which mother and child form an interdependent unit, each individual being of great importance to the other. There is much clinical and observational evidence to suggest that the infant in a symbiotic relationship does not distinguish between his mother, or her substitute. and himself. He makes such a distinction slowly, over a long period, by means of the normal maturing and use of his equipment for independent action. Under ordinary conditions this process of growing independence and differentiation goes on progressivcly and at an accelerating rate, especially with the development of walking and talking.

Whatever interferes with the gradual evolution from a symbiotic relationship to one of eventual independence may lay the groundwork for abnormal behaviour later on. An obvious source of difficulty is a mother's inability to give up her child's dependence because of the personal satisfactions she derives from it or because of the anxiety aroused in her by the child's attempts at independent activity.

Such a mother is often called overprotective. Her protection may take the form of overindulgence, which tends to leave a child always infantile in what he expects and demands. even after he grows to adulthood; or it may take the form of domination. which prevents him from developing initiative and enterprise. In either case, he is likely to remain a dependent person, even in adulthood. either expecting privileged treatment without earning it, or looking continually for guidance and approval from everyone. Needless to say, the presence of a strong father and of siblings in the home can offset to a considerable degree the stunting effects of maternal overprotection.

A less obvious but no less fruitful source of difficulty lies in an unsatisfactory symbiotic relationship, particularly one which fails to foster infant trust. This may be the result of maternal coldness or resentment toward the child. It may come from mothering which is carried on with unusual tension and anxiety, or from mothering that is grossly inconsistent and unpredictable. It may also develop because the child has behavioural characteristics. whatever their cause. which make him an unwelcome or uneasy partner for his mother. Apparently if an infant for any reason cannot enjoy a satisfactory symbiotic relationship when he is helpless he cannot later develop into a satisfactorily independent person, for if he does not experience a high degree of infant trust he will not be equipped later to experience the basic trust in others which is the foundation of normal emotional relationships. He is likely to grow into a lonely, emotionally withdrawn or suspicious adult

2. Identification. — One of the most important means whereby a growing child develops psychologically is called the process of identification. Unlike the simpler forms of learning and problem solving, this process involves taking over the behaviour of other people on a large scale and becoming in some important respects like them. Early in life identification seems to be relatively massive. rapid and indiscriminate, but also relatively unstable. It occurs in relation to members of the family mith whom the child is in close contact. As time goes on identification grows less complete. slower and more discriminating, as well as more stable. The child takes over certain aspects of the people around him and ignores or rejects other aspects (partial identifications). Eventually the process of identification leads to a recognizable patterning of child personality, and this patterning influences not only what the child is like but also the direction of his further identifications and therefore of his ultimate character structure.

It is a peculiarity of personality organization that the effects of early processes seem never to be wholly lost. The earliest wholesale identifications may be profoundly modified by later experience; and many shifts in the general direction of identifications may occur during maturation. But in a crisis some of the apparently lost infantile patterns may reappear and create serious disturbances of function. This is especially true of the deep and massive regressions seen among psychoses, but it is also responsible for many psychoneuroti'c symptoms in which regression is more limited in scope and less deep. Failure to establish adequate stable identifications, because of defective parental relationships or the absence of basic security, is especially obvious in sociopathic personality disturbances.

3. Rivalry. — Rivalry is an inescapable element in family living. Living together means sharing; and sharing means giving something up as well as getting something. The birth of a sibling is an unfailing source of rivalry for a first child, and a common source for any child. Not only may it provoke anger and a sense of being unloved in the older one, but it also may lead to retaliative aggressions against the younger one which disturb his development. Such retaliations at first may be quite open and direct, but in the face of parental disapproval they become disguised and indirect, although still effective. Most children survive the common experiences of rivalry without noticeable harm. The lives of many adults, however, are overshadowed by excessive competition, envy and jealousy, or by reactive inability to compete and to be envious, which turn out to have their roots in unmastered sibling rivalry.

A small child's rivalry with one parent for the love of the other is potentially the most serious interpersonal conflict in early life. The mere intensity of his own feelings, and the tremendous size and power of his adversary, can conjure up a situation of unreal but frightening danger. And this oedipal conflict is further complicated by the fact that, as a rule, the child also loves his rival parent and needs his rival's love. The eventual resolution of this problem is at best slow and painful. Out of it comes the mature form of the normal superego and a new-found freedom for the child to turn with self-confidence to active mastery of the world of people outside the home. Failure to resolve the oedipal conflict optimally can be found in a majority of persons showing abnormal behaviour.

4. Maturational Sequence. — A final point of importance is the factor of maturational sequences. Success in any phase of childhood development is in part dependent upon success in preceding phases. A boy, for example, who remains too long in a symbiotic relationship with his mother may lose early opportunities for handling rivalry with his siblings and for resolving rivalry with his father. He begins late. and with less than optimal freedom, to develop initiative in adapting to external reality and mastering its problems. The child with good early identifications is better equipped to make good ones later on than a child whose early identifications are distorted and confused.

Moreover, a child who is insufficiently emancipated from close infantile ties with a parent is not free to take advantage of close friendships and group ties as these become available outside the home when he is six or seven. These relationships are critical for his development into a socially adequate person who is capable of mature emotional experience. A child who does not enjoy these maturing relationships will be poorly equipped to enter the turbulent period of adolescence and work out his self-identity in early adulthood. It must be said, however. that a good start does not guarantee freedom from serious difficulty in later emotional maturation; and, on the other hand, it is not impossible to overcome the handicaps of a bad start if a later phase of development provides unusually favourable conditions.

B. Development of Ego, Id and Superego

On the basis of extensive clinical and genetic studies. it may be assumed that during early childhood certain groupings of psychological functions are differentiated into permanent, organized systems called ego, id and superego. If these systems are incompletely differentiated from one another, the result may be a personality with an abnormal defensive organization, with serious difficulties in controlling impulses and with inadequate reality relationships. All of these appear, for example. in the symptomatology of schizophrenia. On the other hand, exceptional strength in the operation of one or another system also may result in serious distortions, such as those seen in depressions. where a dangerously powerful superego may drive a person toward self-destruction.

1. Ego. — The earliest differentiation is that into id and ego. This differentiation begins with the infant's earliest explorations, through which he learns to distinguish between his own body and his surroundings. Through his experiences of tactile, visual and kinesthetic stimulation, as well as his internal organ sensations, the child develops a body image. The body image is the nucleus around which subsequent ego development crystallizes. As the child's experiences expand and multiply, and as processes of mental representation and symbolizing develop, his ego organization grows in complexity. It develops both adaptive functions and defensive functions.

The ego adaptive functions, which come to include the maturing perceptual, motor and glandular co-ordinations, lead to more and more effective performance in relation to the realities of the environment. The adaptive ego becomes organized, during this process, in such a way as to make possible the complex kinds of interpersonal feeling, action, imagination, remembering and thinking nhich characterize human beings. Most ego adaptations function automatically and unconsciously in the mature adult. Processes of childhood identification, mentioned above, make indispensable contributions to ego organization. They lay the groundwork for the eventual internalization of culture and for the evolution of social attitudes, value orientations, role taking and self-identity.

Ego defensive functions are also as a rule automatic and unconscious. It is through these defensive functions that the ego maintains its integrity as a system in the face of potential intrusions from three directions: (1) the ego sets up functional barriers against being overwhelmed by stimulation from the environment and from internal activities of the body; (2) the ego maintains other functional barriers against being disorganized by id activities and primitive fantasies, such as those normally experienced only in dreams; (3) as superego functions begin to differentiate from ego functions, the ego defensive organization is modified in such a way as to protect ego processes from being disrupted by superego pressures also. (The ego is discussed more fully in the separate article EGO.)

2. Id.—The id consists of the most primitive, loosely organized and potentially disruptive psychological activities. Its impulses push forward constantly for immediate discharge or gratification, without regard for the demands of external reality. It is completely unconscious in the adult. Its existence and its modes of operation are inferred from certain peculiarities appearing in preconscious and conscious activities, such as the puzzling characteristics of manifest. dreams, of slips of the tongue and of wit. the nature of symptom formation in neuroses and of delusion and hallucination in psychoses. Whereas the conscious and preconscious ego operate in accordance with the secondary process, which corresponds more or less to the logic of ordinary conversation, the id operates in a manner called primary process.

Some of the more important characteristics of the primary process follow directly from the nature of id activity. The id is perpetually seeking immediate discharge or gratification, even during sleep. How the discharge is achieved is not important so long as it takes. place. Thus, in the id's primary process, energy from blocked impulses can be displaced to other impulses which have access to discharge, no matter how illogical or inconsistent the relationship between them may be. Several different impulses may be condensed to form a single symbol or a single symptom. The primary process is also timeless and devoid of negatives. Contradictions operate side by side without mutual interference or compromise. It is more fluid than the strangest, most unstable manifest dream. Certain acute psychoses give fleeting glimpses of the mode of operation of the primary process.

3. Superego.—The superego reaches the climax of its differentiation from the ego during the third to fifth year of life. Its familiar conscious form is called conscience. This we experience as a part of us that at times criticizes, reproaches or condemns the rest of us, and at other times seems to approve, justify or praise the rest. In the first case we feel guilty, bad, inferior or worthless; in the second case we feel worthy, good or superior. This conscious split into two functional systems is based upon a permanent split at unconscious levels into an evaluating system, which praises or blames, comforts or threatens (superego), and an evaluated system which receives the praise, blame, comfort or threat (ego).

The superego is largely unconscious. In normal adults it is less responsive to current reality factors than is the ego. A great deal of its activity is primitive and irrational. This is because it crystallized during the first three to five years, in relation to powerful infantile emotional conflicts and long before logic or realistic thinking had evolved. Evidence of prirnitive superego magic is seen in obsessive-compulsive symptoms. The clearest evidence for irrational, infantile superego function, however, appears in depression and in mania, the one expressing consciously the most cruel and hateful attitudes toward the self and the other expressing extravagantly unrealistic self-adulation and self-will.

The general effect of superego development is to increase psychological stability. In organizing a superego the child acquires his own internal system of moral control. He can regulate his own behaviour without having to watch his parents continually to see if he is right. He builds up his own standards and ideals which he can carry with him wherever he goes. The superego is also a potent source of conflict. Since it is inside a person, it can condemn not only his acts but his thoughts, impulses and intentions. Even unconscious fantasies can stimulate the superego to arouse unconscious guilt. This is seen in the gnawing sense of inferiority that troubles many neurotics and in the projected unconscious fantasies which make up delusions and hallucinations.

4. Interdependence.—These three psychological systems are interdependent, interacting parts of an integrated whole. No one system makes any sense without the other two. Impulses and fantasies derived from the id are modified and channeled by ego defensive and adaptive functions into realistic thought and action, into daydreams, make-believe and recreation. Interaction with superego functioning provides value orientations and moral qualities for action, thought. daydream and play. The fact that most of the interaction among these systems is unconscious and preconscious means that much human activity cannot be accounted for on the basis of strict conscious rationality, that it has richer meanings and goes much deeper than is realized at the time.

C. CONSCIOUS, PRECONSCIOUS AND UNCONSCIOUS

In modern abnormal psychology three levels of mental activity are distinguished: conscious, preconscious and unconscious. The conscious level is familiar to everyone and need not be discussed here. It includes whatever a person is aware of at a given moment and constitutes only a small fraction of mental activity.

1. Unconscious.—The unconscious includes all id activity, most of the ego defensive organization and the greater part of superego functioning. Its purest form is in id activity. which, as stated above, operates wholly in terms of the primary process. The clearest evidence of unconscious id, ego and superego functioning comes from the study of manifest dreams, with their related feelings. fantasies and thoughts, which find expression during free association (see ASSOCIATION, MENTAL). Usually the person who is free associating does not recognize the evidence of unconscious processes in what he is saying, but a person trained in observation often can do so. Other normal expressions of unconscious activity appear in poetry, painting and sculpture. In the abnormal field psychotic symptoms are sometimes found reflecting unconscious thinking and feeling more or less unchanged. Neurotic symptoms, on the other hand, are as a rule more realistically adaptive. so that their unconscious origins may be, and remain, obscure for a long time, even during intensive therapy.

2. Preconscious.—The term preconscious has two meanings, one quite simple, the other complex. (1) The simple form of preconscious consists of all mental activity which is not conscious at a given moment but can easily become conscious by a shift of attention. Its organization is presumably the same while it' remains out of conscious awareness as when it becomes conscious. (2) In addition to this, there are other preconscious processes whose organization seems in many respects different from that of conscious awareness and that can become conscious only with considerable effort. These include relatively well-organized daydreams which are realistically organized but whose material contradicts present reality and manifest dreams which. although they reflect unconscious processes, can be experienced consciously after waking and can be described in words to someone else. Obviously it is impossible to make sharp distinctions among conscious, preconscious and unconscious.

I). NEED, DRIVE AND MOTIVATION

It is generally agreed that unsatisfied or frustrated need is of prime importance in shaping behaviour from the moment of birth. The newborn is at once made dependent upon satisfying his need through his own efforts, as in breathing and suckling, and upon the good offices of his mother, who is now a separate person who can gratify his needs at will. It is through his prolonged dependence upon older persons that the human infant and child becomes progressively socialized. His parents and parent substitutes at first can control virtually all of a child's need satisfactions. By means of this control they gradually assimilate him into the family unit and lead him in the direction of ultimate independence. During the early phases of this process the broad foundations are laid for personality development, normal as well as pathological.

While it is generally agreed that need is a basic factor in determining behaviour, there is still confusion over the use of the term. Some experts, for example, speak of need and drive as though the two were synonymous, but most show a strong preference for one term and slight or neglect the other. There is actually a difference in emphasis involved. Need stresses what is wanted (*e.g*, need for food, for love, for mother), whereas drive stresses an internal force or push which seeks an outlet. There is also some lack of agreement as to the number of basic needs or drives, which varies in psychological literature from one to a dozen.

The prevailing psychodynamic trend in abnormal psychology shows a preference for the concept of drive (also called instinct) as the most fundamental. This view may be summarized as follows: Empirical evidence indicates two basic drives, sexual and aggressive, whose derivatives impinge upon the unconscious ego through activities of the id. In controlling, channeling and discharging these drive derivatives, the ego develops its complex system of defense mechanisms which modify the drive derivatives before these reach the preconscious or emerge in consciousness. The ego at the same time develops adaptive organizations in relation to external reality and, later on, in relation to superego functions also. This ego organization of drives in relation to reality and the superego leads eventually to the formation of complex systems of motivation which have their own hierarchies: *e.g.*, a man's love of country may take precedence over love for his children, whereas a woman's love of her children may reign supreme over everything else.

The factor of unconscious motivation is of prime importance in abnormal psychology, and the empirical evidence for it is overwhelming. Of course. as long as life goes reasonably well, it need not be of great significance that a person does not really know why he does many things or has certain fixed attitudes, that he sometimes feels pushed to do unreasonable things and avoid doing reasonable ones. or that his troubles seem always to follow the same genera! pattern no matter where he is. If, however, life goes badly, if a person's actions grow unmanageable or his satisfactions are overshadowed by anxiety, doubts or gloom, the unconscious origins of his behaviour can become of major importance. It should be said, however, that contrary to a widely held public opinion, therapy does not necessarily mean rendering unconscious motivation conscious to the patient. Often it is best kept unconscious. The question of what procedure is best to follow must be left in skilled, experienced hands. (See also INSTINCT; MOTIVATION.)

E. EGO DEFENSE AND ANXIETY

Most ego defenses are directly related to the control of anxiety, which an adult may experience in two major forms. The more primitive form, called traumatic anxiety. is that of feeling in danger of imminent destruction. The less primitive, called signal anxiety, is in effect an anticipation of such danger, experienced in a much attenuated degree.

1. Traumatic Anxiety. — Traumatic anxiety is what an adult may experience when he is overwhelmed by a sudden catastrophe for which he is wholly unprepared. His response may be panic and headlong flight, a violent reckless assault or a sudden trance state in which he nanders aimlessly about or becomes paralyzed and mute. Dramatic examples of such responses were reported from the battlefields of World War IT; and in civilian life similarly violent and often maladaptive behaviour may be seen. for example, in theatre or school fires. Traumatic anxiety is especially common when flight and attack are both impossible, as when a soldier is isolated and pinned down in extreme danger by enemy fire.

Traumatic anxiety also is experienced when id derivatives break through ego defenses and threaten to disorganize ego function. This occurs in normal and neurotic persons during sleep if for any reason id derivatives threaten a breakthrough and produce a night terror from which the frightened sleeper is glad to awake. It also occurs in psychoses when a defective ego organization proves incapable of coping aith direct id derivatives. Acute psychotic episodes sometimes include panic reactions like those seen on the battlefield and in fires.

2. Signal Anxiety. — Signal anxiety is a relatively mild experience of impending danger. If it is conscious. and its source seems outside, the anxious person becomes vigilant, cautious and defensive. If there seems to be no source, he feels uneasy, tense and anxious aithout being able to understand why. In most neurotic and psychotic disturbances there is at least some conscious anxiety. Much more commonly, however, the experience remains chiefly unconscious, and the threat comes from inner processes. The immediate automatic result is to increase ego defensive action, which also takes place at unconscious levels.

Increases and shifts in ego defense as a result of signal anxiety. are assumed to occur automatically throughout the 24 hours of every normal person's daily life. What defensive pattern prevails at any moment, and what the commonest changes in ego defense shall be. depend upon the internal economy of the person, upon his personality structure and upon the nature of the experienced threat. (See DEFENSE MECHANISMS.)

F. FRUSTRATION, REGRESSION AND SYMPTOM FORMATION

1. Frustration. — Disturbances of behaviour are usually precipitated by a series of frustrations. Frustration is experience of strong need acconipanied by a sense of being prevented from satisfying it, What prevents satisfaction may be (1) an external obstacle—physical, social or personal; (2) an internal conflict, conscious or unconscious; or (3) the absence of facilities for satisfaction, in the environment or in oneself. These factors of course can be understood only in relation to each individual person. Though some obstacles, conflicts and lack of facilities affect everyone. even these affect diiferent persons to different degrees. What seems an insuperable and intolerable obstacle to one person does not seem insuperable to another, or else does not seem especially important to him. Conflict and lack of facilities likewise are tolerated differently.

Additional variables are the strength of the drive and the character of the need involved. A frustrated powerful drive, especially one that is not successfully warded off by unconscious defenses, is more likely to precipitate a disturbance than a frustrated weak or well-defended one. Also, a need that involves too much physical, social or psychological danger is almost sure to be frustrating, because each attempt to satisfy it will arouse intolerable anxiety. The closer one comes to its satisfaction the more intense the anxiety grows, and the less possible it becomes actually to achieve satisfaction.

Two of the commonest normal responses to frustration are aggression and withdrawal; *i.e.*, fight and flight. The aggression may be directed against the frustrating obstacle or it may be directed against a substitute, as when a person shouts at his child after he has been humiliated by his employer, whom he fears. The withdrawal may be in the form of physical retreat or merely of passive withdrawal of interest. This last is the most important in abnormal psychology, because it is the most likely to result in regressive fantasy and symptom formation.

2. Regression. — Passive withdrawal of interest is not in itself pathological. When a normal person is bored. or when he is in a relaxed state before going to sleep; he automatically loses interest and turns to daydreams and fantasies. These imaginings are usually less realistic than are his thoughts about what he plans to do or remembers doing when he is more alert. It is not difficult to demonstrate that unconscious processes play a large part in such normal daydreaming and fantasying. Anyone who examines his thoughts immediately after he has been deeply preoccupied or dozing will find some elements that certainly do not belong to his ordinary logical thinking.

This lowering of the level of functioning. from more to less realistic, is called regression. It is a movement away from logically ordered thought toward more primitive forms. An effective contact with reality and processes of logical thinking tend to prevent the appearance of such primitive functions, although these latter seem always to be potentially present. We see what happens when we withdraw as much as possible from the environment and go to sleep. Dreams eventually appear which are obviously regressive. They seem unintelligible when we wake up because their logic is not realistic logic but a reflection of regressive unconscious logic. Wishes. fears and conflicts that are expressed in dreams often surprise or shock the dreamer mhen he awakens and make him feel that he has been wandering in strange places with a different kind of reality and different moral codes. Nevertheless, it is usual for manifest dreams to exhibit some degree of superego function and ego defense. as well as to reflect raw id impulses and their fantasy derivatives.

3. Symptom Formation.— Symptom formation in neuroses is the result of processes much like those resulting in a manifest dream, but the neurotic person withdraws a part of his interest in objective reality to escape frustration while he is awake. and not merely to enable him to go to sleep. In neuroses this withdrawal is never total as it is in sleeping and in some psychoses. A more or less effectual contact with external reality is always maintained Likewise, regression is neither so sweeping nor so profound as that in normal dreaming and in psychoses. Usually a neurosis is precipitated not by one frustrating experience but by a long series of them. each leading to some withdrawal and partial regression. Eventually the succession of withdrawals and regressions leads to the reactivation of a primitive conflict whose origin lies in early childhood. This reactivated conflict now tends toward becoming conscious.

As in dreaming, so in neurotic symptom formation the superego and the unconscious ego defenses are hard at work. The id impulses and derived fantasies, which help make up the reactivated conflict, do not erupt in their naked, primitive forms. They are subjected to defensive transformations more radical than most of those suffered by manifest dreams and. since the adaptive ego is wide awake and most of it attuned to external reality, the erupting impulses are subjected to further transformation until they harmonize more or less with reality. Thus a phobia based on an irrational childhood fear of one's father becomes transmuted into an adult fear of dogs which the adult finds easy to rationalize and accept. It is only when, during therapy, a frightening father figure appears in a dream or free association reveals a stil! more direct relationship, that the substitution may become apparent and the road cleared toward working through the basic conflict. (*See* also NEUROSES.)

Symptom formation in psychoses is similar to the process in neuroses. A major difference is that ego organization is fundamentally unstable. Defects in ego adaptation stem largely from defective early identifications and from early interference nith the development of reality testing and initiative. Defects in ego defense consist mainly in the overuse of such primitive defenses as denial, projection and introjection in situations which normal persons would handle through repression. A succession of frustrations, or sometimes a single severe frustration, leads to massive withdrawal from reality and sweeping regression.

The functioning that emerges in psychosis is typically that of an adult who is trying to deal nith the world around him by means of delusion and sometimes hallucination. These delusions and hallucinations are constructive attempts to rebuild external reality. The reconstructed reality must be made to correspond to primitive id, ego and superego activities nhich have become conscious with relatively little defensive and adaptive transformation.

In this may be seen one respect in nhich a psychotic solution may be the opposite of a neurotic one. Whereas the neurotic transforms his emerging conflicts adaptively, to make them conform as much as possible to external reality. the psychotic tries to transform reality. by delusion and hallucination, to make it conform to his emerging conflicts. The relative ineffectuality of ego defense and ego adaptation in psychoses renders it impossible to make an extensive transformation of unconscious material before it erupts into consciousness.

G. Individual Susceptibility to Psychopathology

Sex differences. physiological age and relative biological competence, especially of the brain, may all enter into the determination of psychopathology. When it comes to individual differences in susceptibility. however, the major factors seem to be differences in frustration tolerance. in ego adaptive and defensive development, in superego maturation and in the adequacy of object relations and self-representation.

Wide variations in tolerating frustration are to be found not only in comparisons of one individual with others, but also in comparisons of the same person's tolerance level at different times and under varying conditions of stress. Moreover, one person may exhibit low general frustration tolerance (i e., he reacts maladaptively to almost any frustration) while another may exhibit low specific frustration tolerance (*i.e.*, he reacts maladaptively to some particular kind of precipitating factor but not to others). 'This multiple variability in frustration tolerance helps account for the great range found in both intensity and variety of precipitating factors in abnormal psychology.

Ego adaptive and ego defensive development are directly related to a person's ease of regression under stress, to the completeness of his regression and to the depth to nhich his regression goes. In general, the more realistically a person has adapted to his social environment and the richer his psychological resources, the less likely he is to lose his grip on reality mhen frustration forces him into a withdrawal. The stronger and more mature his ego defensive organization and the less it is dominated by denial, projection and introjection. the less likely is regression to bring the sudden eruption of primitive processes. Thus, mildly defective repression and the ready use of projection may result in a neurotic phobia that is not at all disabling, whereas severely defective repression and the ready use of projection may lead to a paranoid psychosis.

Defective superego maturation goes hand in hand with defective ego development. but its effects are sometimes more striking. Thus, susceptibility to severe inferiority feelings an unfailing indicator of superego pathology. often appears in persons who adapt well to reality in most important respects, even though with greater than average effort. Likewise. susceptibility to psychotic depressions often appears in adults nho have managed to handle their lives responsibly and well. It is only when frustration becomes acutely intolerable and such a person grows seriously depressed that one realizes how powerful a fixation in primitive superego functioning he has been hiding most of his life.

Object relations and self-representation have their origins in the symbiotic mother-child relationship and its resolution. As the infant learns to differentiate himself from his mother and from other objects, he develops relationships with these objects and becomes able to represent them to himself and to distinguish a self that is more or less distinct from them. These basic differentiations, relationships and representations will determine the effectiveness of his conception of reality, his emotional interaction with other persons and his recognition of himself as an entity. There are infinite possibilities of defect in object relations and self-representation, and many of these are implicit in the various forms of psychopathology described below (*See* also PSYCHIATRY: *Diagnosis: Predisposing and Precipitating Factors*)

IV. ABNORMALITIES OF BEHAVIOUR

Abnormalities of behaviour are divided into a number of groups having similar characteristics. The task of classifying in the field of abnormal psychology has always been difficult because, no matter how the groupings are formed, each actual case will exhibit some symptoms belonging to a different group. A compulsive person may have a sudden phobia, or a phobic person may show minor compulsive trends A schizophrenic may be subject to depressions and a depressed person may have brief periods of temporary disorganization. The most useful procedure in classification is to determine what seem to be the dominant pathological characteristics, name the disorder accordingly and bear in mind constantly that such naming is a convenience and not a final judgment.

The current official classificat on is oriented primarily toward mental hospital diagnosis and statistical recording. Consequently, it stresses heavily the illnesses characteristic of a mental hospital population rather than those most commonly seen in office consultation and therapy. Brain disorders and psychoses, for example, make up 50% of its listed illnesses. whereas the psychoneuroses make up less than 10%. In what follows, a few of the most typical varieties of abnormal behaviour encountered in the community outside mental hospitals will be described using, insofar as possible, the terminology of the official classification.

A. Neurotic Reactions

Four of the chief pathological reactions seen in neurosis are discussed fully in the article on neuroses, and hence will not be dealt with here. For anxiety reactions, phobic reactions, conversion reactions and obsessive-compulsive reactions, see Neuroses: Types of *Psychoneurotic* Disorders.

A fifth reaction seen in neurotics is that of psychosomatic disorders, called also organ neuroses or somatization reactions. What all these names refer to is a variety of disorders in the functions of internal organs, blood vessels and glands. The disorders are either the direct product of continued emotional disturbance or at least an intensification of symptoms by emotional disturbance.

Recognition that internal organs, blood vessels and glands are affected by strong emotion is by no means new, but the systematic study of their emotional disturbances, the field of psychosomatics, is relatively recent. So is the realization that many chronic organic disorders may have primarily an emotional origin and that structural changes may result from prolonged emotional stress. Among the disorders that have been most emphasized are stomach ulcer, colitis. vascular hypertension, aching in postural muscle systems and joints, allergies. asthma and skin rashes.

As so often happens when a new field opens up, there was at first a great wave of enthusiasm and speculation regarding psychosomatic disorders, and for a time the nonemotional origins of dysfunction in these areas were in danger of being overlooked For example. there is direct evidence that the stomach lining is sometimes much more easily injured by abrasion during emotional disturbance than during emotional calm, and that such injury can lead to ulcer formation. But there is no justification in assuming. as many enthusiasts did, that all stomach ulcers are produced in some such manner. In another direction there have been concerted attempts to tie up definite personality types with definite psychosomatic disorders; but most of the conclusions drawn in this relationship have still to be confirmed.

To understand psychosomatic disorders it is necessary to bear in mind three things: (1) that emotional expression normally involves widespread changes in internal organs (*e.g.*, diarrhea or loss of appetite during fear). in blood vessels (*e.g.*, flushed face during anger or love) and in glands (*e.g.*, sweating and urinary hypersecretion in anxiety); (2) that intense emotional expression can continue for long periods of time with little relief; and (3) perhaps most important of all, that a person may be unaware most of the time that he is emotionally disturbed. He is most likely to concentrate on his somatic symptoms and to seek help on this basis; he may resent any nonorganic interpretation of them as an insult. Although dramatic and lasting improvement sometimes rewards psychotherapy in psychosomatic disorders, the results may not be so gratifying if the disorder is of long standing. It should be added that sometimes a psychosomatic disorder is a person's best defense against neurosis or psychosis (*e.g.*, a stomach ulcer may substitute for a serious depression), and it is sometimes in the patient's best interest to avoid intensive psychotherapy.

There is still some controversy as to whether or not psychosomatic disorders can be clearly differentiated from anxiety reactions and conversion reactions. A distinction between psychosomatic disorders and anxiety reactions is attempted on the grounds that the former focuses on one organ or one system in any given person, while in the latter most or all visceral systems are involved. As for conversion reactions, they stress perception and voluntary motor functions rather than internal organs, blood vessels and glands. Moreover, conversion reactions seem to free a person from anxiety, and they tend not to result in structural lesions. The position of psychosomatic disorders in relation to the psychoneuroses has been the subject of controversy for many years, and must still be regarded as unsettled.

B. Psychoneuroses and Psychoses

Turning to a discussion of the psychoses, the question of their relationship to the neuroses or psychoneuroses arises. In the past this relationship was conceived in two different ways. According to one view. psychoses are fundamentally different from psychoneuroses in origin and in dynamics. They are basically manifestations of brain defect or disease, or of disturbances in physiology or biochemistry, whereas psychoneuroses are products of personal stress. According to the other view. psychoses are only graver manifestations of the same fundamental psychodynamic processes as those underlying psychoneuroses.

The first view was much more generally accepted by experts during the 19th century than it came to be in the 20th. All psychoses were assumed to be expressions of some constitutional defect. in the form of a hereditary taint or a brain disease. During the 1890s and early in the present century it became fashionable to ascribe psychoses to the presence of toxic substances in the blood, to changes in blood chemistry. to endocrine imbalance or to faulty metabolism. Even today the press shows an eagerness to report research in these general areas as if it were new and revolutionary and as though for the first time a hopeless illness had become treatable. Such reports, however earnest, succeed in misleading the public. Actually the approach by way of physiology and biochemistry is old and conservative. and the many promising leads it turned up after the turn of the century had not, by the 1960s, fulfilled their promise.

A major source of confusion comes from the fact that such symptoms as delusion, hallucination, stupor and excitement are common in known states of intoxication. They also occur in fevers. infections, starvation. anoxia and other forms of physiological disturbance. The superficial resemblance between these states and schizophrenic, paranoid and affective reactions is so impressive that it has taken thousands of years to recognize that symptomatic resemblance does not mean identity. Today even an undergraduate medical student can learn to make the distinction reliably. Further, a patient's active behaviour during a known intoxication is likely to be a function more of his own personality organization than of the chemical properties of whatever toxic substance is used. Additional light on the problem was shed by studies of sensory deprivation. Normal adults who are as completely isolated as possible from normal sensory stimulation develop striking hallucinatory experiences without being exposed to any form of intoxication or other artificial physiological disturbance. Mere isolation from the normal environment allows primitive processes to dominate mental activity.

When it comes to heredity the evidence can neither be fully accepted nor simply dismissed. Originally. of course, a belief in the prime significance of hereditary taint for psychoneuroses was also widespread, but the field has come to be restricted to controversy over the psychoses. There is statistical evidence of a significantly higher incidence of schizophrenia and affective disorders in certain families than in the general population. Among identical twins the incidence of schizophrenia in both members, if one member is schizophrenic, is higher than for fraternal twins; and the incidence is higher among near than among distant relatives. On the other hand, the more closely psychotic persons are studied in psychotherapy, and the better their family structure is understood, the more important the home setting becomes as a source of psychosis. Further, the fact that both schizophrenia and affective disorders develop in families with no record of previous psychotic members is unquestionable.

The trend among experts is strongly in the direction of accepting psychoses in accordance with the view that they are manifestations of the same fundamental dynamic processes as those which underlie psychoneuroses. This does not exclude the possibility that physiological or biochemical malfunction may be demonstrated some day in some psychoses. It means only that as more experience is gained in studying psychotic persons, intensively and individually, there is steadily mounting evidence that the predisposing and precipitating factors in their illnesses do not differ basically from those in the psychoneuroses. With this increased understanding has come an important change in general attitude on the part of therapists. Whereas in the 1930s intensive psychotherapy with psychotic patients was unusual, by the 1960s it had become commonplace.

The traditional belief that adults who develop a psychosis suffer from some basic personality defect seems to be justified, but not on the assumption of brain disorder or hereditary taint Evidence points to personality defects whose origins are to be found in the early mother-child relationships. These defects leave a person vulnerable to deep and extensive regression when he is severely frustrated, and it is the type of regression he suffers that leads to the psychotic symptoms. Like neurotic persons, the psychotic lives by means of ego defenses and ego adaptations which represent compromises with respect to reality. id impulse and superego pressure. Unlike neurotic persons. he is liable to lose these defenses and adaptations, sometimes suddenly, and to fall back upon primitive unrealistic ways of handling his situation, such as hallucination and delusion.

C. Psychotic Reactions

1. Paranoid Reaction. — This illness is characterized by persistent delusions, usually persecutory but sometimes grandiose, without the presence of hallucinations. General behaviour and emotional response are consistent with the patient's ideas, and there is little or no impairment of intelligence aside from the delusions Paranoia is a rare form of paranoid reaction in which there develops, slowly and progressively, a complex, intricate and logically elaborated delusional system. The commoner paranoid state is not so highly systematized and elaborate, is sometimes of brief duration and often ends in symptomatic recovery.

Paranoid states are most likely to arise in tense, insecure persons who are basically mistrustful of others and of themselves and nho are ill at ease in interpersonal relationships. The paranoid illness is precipitated by a person's regressing in the face of serious frustration.

In the common persecutory variety, the patient begins to see signs of aggression and evil intent in the actions of people around him His vigilance grows in such a way that he becomes increasingly alert to further evidence that he is in personal danger. Regression has reduced the effectiveness of his reality testing to a point where he can accept only evidence that confirms his delusional suspicions. His need for an explanation leads him to believe that the signs of hostility he sees are part of a plot of which he is the focus. The more fixed this belief becomes the more difficult the patient is to treat.

The paranoid reaction illustrates clearly tivo defense niechanisms, denial and projection. When the patient regresses, his already defective repressive defenses become still more ineffectual, and he experiences a breakthrough of id derivatives, especially aggressive ones. To escape ego disintegration he denies and projects the impulses he can no longer repress, and he misperceives in other people (real ones and imagined ones) the aggressive intentions which are actually his own. His persecutory delusion is thus a reconstruction of his human environment in such a way thnt what actually threatens to destroy him from within seems to threaten him frorn without. It goes without saying that this achievement neither gets rid of the threat nor leads toward a happy solution, (*See* also Paranoid Reactions.)

2. Schizophrenic Reactions. — Schizophrenia, or dementia praecox, seems to include a nurnber of psychotic disorders which have in common certain basic disturbances in reality relationships. thought processes and emotional response. Delusions are commonly less well organized and more fantastic than in paranoid reactions, and hallucinations are usually present. Schizophrenic patients show a marked tendency to nithdraw frorn contact aith other people, to regress deeply and disorganize.

It is convenient to distinguish four general types of schizophrenia on the basis of symptomatology. (1) If delusions predominate, the condition is called paranoid schizophrenia. The delusions, characteristically vague and fantastic may be of persecution, grandeur, magical influence or body change. (2) If, instead, the patient's most prominent symptoms involve motility, the condition is termed catatonic schizophrenia The catatonic patient postures, gestures, shows great excitement, or grows mute, motionless and sometimes stuporous. (3j If the patient behaves in a silly, giggling way, with peculiar mannerisms and evidence of hallucination, the disorder is called hebephrenic schizophrenia. (4) If there is an insidious, progressive withdrawal and personality impoverishment, a general deterioration without dramatic symptomatology, the term used is simple schizophrenia. It must be emphasized, however, that patients seldom correspond exclusively to one of these general types. There is much overlapping, and a patient may shift from one type of symptomatology to another.

Controversies over the origin and nature of schizophrenic reactions were touched upon above. There is an additional point of interest. Earlier in the 20th century, experiments with mescaline demonstrated that florid hallucinations and weird distortions of the body image could be produced in normal adults mhich resembled those reported by schizophrenics. Later the use of lysergic acid and other toxic substances resulted further in the production of schizophreniclike symptomatology. The majority expert opinion, however, including that of some of those who have carried out such experimentation, does not accept the intoxication or its symptomatology as representing a form of schizophrenia.

In the most advanced therapeutic centres; psychotherapy is the preferred form of treatment for schizophrenics, and is considered the most successful. Close study of individual schizophrenic patients reveals as good evidence that their illnesses are precipitated by stress and frustrations as in the case of psychoneuroses. The high incidence of recovery under competent therapy weighs heavily against purely physiological and biochemical theories. In a university community, for example, 50% of those students who developed schizophrenic reactions serious enough to demand hospitalization were able to return to college, continue their work and graduate without further mishap. (See also Schizophrenia.)

3. Affective Reactions. — This group is characterized primarily by a severe mood disorder, either depressive or elated, with disturbances in thought and general behaviour in keeping with the mood. Psychotic depressions are either agitated, in which case sustained tension, overactivity, despzir and apprehensive delusions predominate, or retarded, in which case the patient is slowed up, his activity is reduced, he is sad and dejected and he suffers from self-depreciatory and self-condemnatory delusions. Suicidal attempts are common and often successful. Manic excitement is a circumscribed psychotic episode of elation or self-assertive aggression, usually with grandiose delusions.

Although most patients who suffer a depression do not ever develop a frank manic attack, and few with mania ever become frankly depressed, there is a close relationship between the two illnesses. While recovering from a depression, many patients go through a brief period of overoptimism and mild euphoria; and manic patients sometimes have transient episodes of gloom and self-depreciation. A minority of patients actually do pass from a depression into an elation, or vice versa, and some of these go through whole cycles of mania and depression. This close relationship has been recognized ever since the ancient Greeks wrote about it. Even the current. term, manic-depressive psychosis, is derived from *folie maniaco-mélancolique,* introduced in the 17th century.

Statistical studies are often cited in support of hereditary predisposition to affective disorders. but they are more inconclusive than for schizophrenia. It is tempting to postulate a large-scale metabolic disturbance to account for the dramatic contrast between a slowed-up! retarded. depressed patient and an excited manic; this is what Emil Kraepelin did. One is quickly disillusioned, however, when comparing the commoner agitated depression with a manic, for between these two there are no differentiating metabolic measures. The differences boil down to differences in level of activity and not in basic mood.

Significant environmental precipitating factors can be demonstrated in a great many affective reactions? but not in all. The official classification provides for a major class of reactive psychotic depressions. It is believed that a predisposition to affective psychoses lies in abnormal fixations at an oral, dependent level of development. This is thought to leave a person especially vulnerable to deep regression in adulthood, but not to the disorganization characteristic of schizophrenia. The controversy over the origins of affective reactions is far from settled. Its literature is much more sparse than that on schizophrenia.

4. Brain Disorders.—The official classification includes under this head what used to be called toxic and organic psychoses. About 20 different varieties are distinguished. The commonest changes in mental function found in brain disorders are (1) impairment of intellectual abilities, memory, judgment and orientation; (2) shallowness or instability of emotional response; and (3) alteration in general personality or character.

Brain injury, brain disease and brain intoxication can result in such changes, either gradually or acutely. So also can general systemic disorders if they interfere with the supply of nourishment and oxygen to the brain or interfere with the removal of waste products. Only one type of brain disorder will be discussed here, that occurring in old age. In old age the brain gradually shrinks in size, certain types of cells disappear and the blood vessels harden. If the blood vessels suffer serious damage, the brain changes may be extensive and may come on suddenly.

Among persons with aging brains will be found all the basic characteristics of brain disorder. The aged person grows forgetful, and he unintentionally distorts what he does recall. He becomes unable to continue at his usual level of work, especially if it involves meeting new situations and making new judgments. He may grow confused about his surroundings, particularly at night and in strange places. He tends to become tearful easily, but he can often be cheered up quickly and even made to laugh through his tears. He is easily annoyed and he may have temper tantrums. Sometimes striking changes in general character develop. Usually these are only exaggerations of previous personality traits. but occasionally they appear as something new. A kindly, considerate person grows selfish, harsh and vindictive; a morally strict person becomes involved in taboo or even antisocial activities; an honest, reliable person steals, equivocates or embezzles.

It is disconcerting to find that even in brain disorders, where organic damage is easy to demonstrate, the causation of behaviour disturbances is still far from simple. The brains of senile persons have been microscopically studied, and attempts made to correlate the anatomical findings nith the clinical pictures. A surprising lack of close relationship has been found betneen the extent of cerebral degeneration and the degree of behavioural disturbance. Some patients with widespread cellular destruction show relatively little behavioural deterioration or character change during life. Others with only moderate cellular destruction show considerable behaviour pathology.

In general, old people who live in a peaceful environment. where they experience reasonable satisfaction of their emotional needs, seem to suffer much less deterioration than those whose lives are frustrating, empty or in turmoil. The patterns of functional change which develop with senility seem usually to correspond more to the patient's previous personality, and to the structure of his social environment. than to his pattern of senile brain decay. Eventually. of course, if the brain grows sufficiently incompetent as an organ. its owner mill decline to a vegetative existence no matter nhat his present situation or his personality structure. But the point is that this can occur without psychotic episodes or emotional storms. It is probable that, as we grow better able to understand the ordinary emotional needs of the aged, we shall find the incidence of psychopathology lower than at present and the task of providing for their last years less onerous. (*See* also DEMENTIA.)

See also PSYCHIATRY; NEUROSES; PSYCHOSES.

BIBLIOGRAPHY.—J. Hunt (ed.), *Personality and the Behavior Disorders* (1944); R. Grinker and J. Spiegel, *Men Under Stress* (1945); K. Menninger, *Human Mind*, 3rd ed. (1945); R. Hoskins, *Biology of Schizophrenia* (1946); N. Cameron, *Psychology of Behavior Disorders* (1947); G. Murphy, *Personality: a Biosocial Approach to Origins and Structure* (1947); N. Cameron and A. Magaret, *Behavior Pathology* (1951); American Psychiatric Association, *Diagnostic and Statistical Manual: Mental Disorders* (1952); S. Freud, *Interpretation of Dreams*, trans. by J. Strachey (1953); S. Arieti, *Interpretation of Schizophrenia* (1955); C. Brenner, *Elementary Textbook of Psychoanalysis* (1955); O. Kaplan (ed.), *Mental Disorders in Later Life*, 2nd ed. (1956); R. Rlunroe, *Schools of Psychoartalytic Thought* (1955); T. Parsons and R. Bales, *Family Socialization and Interaction Process* (1955); S. Brody, *Patterns of Mothering* (1956); H. Selye, *Stress of Life* (1956); R. White, *The Abnormal Personality*, 2nd ed. (1956); R. Sears, E. Maccoby and H. Levin, *Patterns of Child Rearing* (1957); J. Dewan and W. Spaulding, *Organic Psychoses* (1958); A. Hollingshead and F. Redlich, *Social Class and Mental Illness* (1958); S. Arieti *et al.* (eds.), *American Handbook of Psychiatry* (1959). (N. A. CN.)

PSYCHOLOGY, ANIMAL: *see* ANIMAL BEHAVIOUR; PSYCHOLOGY. COMPARATIVE.

PSYCHOLOGY, APPLIED, represents the use of the findings and methods of scientific psychology in solving practical problems of human behaviour. A more precise definition is impossible because the activities of applied psychology range from laboratory experimentation through field studies of specific utility to direct services to troubled persons. Its practice is not fully controlled by professional or legal methods; there is a zone in which charlatans operate for personal gain. The intelligent layman's major protection against fraudulent practitioners lies in his general knowledge of psychology and in investigating the qualifications of the psychologist whose heip he seeks.

This article, which attempts to make reference to all the major areas of applied psychology, is organized as follows:

I. THE FIELD

Psychology deals with the origin, development and modification of behaviour. These concerns define the specialized knowledge of the field: the genetic and physiological bases of behaviour; the social and cultural setting in which behaviour occurs; learning theory and the modification of behaviour via learning: personality theory and the motivational forces producing normal and abnormal behaviour; measurement theory and methods for the quantification of behaviour; experimental and statistical methods for the assessment and prediction of behaviour under defined conditions. The applied psychologist is trained first in these areas of knowledge; to them is added a period of specialized research or apprenticeship in the area of his particular interest.

A. History

The same intellectual streams whose confluence produced psychology as an independent science of behaviour in the latter part of the 19th century led to the later development of an applied psychology. Philosophy, physiology, evolutionary theory, naturalism and measurement concepts borrowed from the natural sciences contributed to the new discipline. Self-analysis, as a basis for speculation about behaviour, gave way to controlled observation and study. In Germany, England and France these ideas took shape in laboratories, technical journals and books. *(See* Psychology, History of.)

1. Early History.—Francis Galton's publication in 1883 of *Inquiries Into Human Faculty* foreshadowed the entire field of measurement of individual differences. In 1896 Lightner Witmer established at the University of Pennsylvania, Philadelphia, a clinic that was the forerunner of the broad field of clinical psychology. Intelligence testing began with the work of Alfred Binet and Théodore Simon in the Paris schools; the publication of their classic scale for intelligence in 1905 was followed in 1908 by H. H. Goddard's translation of the French mental age scales and in 1916 by the U.S. standardization of the Stanford-Binet scale by Lewis M. Terman and his associates. On *the Witness Stand* (1908) and *Psychology* and *Industrial Efficiency* (1913) by Hugo Münsterberg extended the new science into two additional areas of application. Sigmund Freud's writings gave major new insights into the motivations of behaviour *(see* Psychoanalysis). In 1913–14 E. L. Thorndike published his *Educational Psychology.* At the Carnegie Institute of Technology a division of applied psychology was established as a teaching and research department in 1915 by Walter V. Bingham. The *Journal of Applied Psychology* appeared in 1917 along with the first applied psychology text, by H. L. Hollingsworth and A. T. Poffenberger.

Broad application of psychology occurred during World War I, particularly in the U.S. army. Over 2,000,000 men were tested and classified for military service, and the Army Alpha test became the forerunner of a group-testing movement that spread through education and industry in the next two decades. In the period 1919 through 1921 four applied psychology organizations independent of universities were established: the Scott company (U.S.). founded by Walter Dill Scott; the Psychological corporation (U.S.), founded by J. McKeen Cattell; the National Institute of Industrial Psychology (Great Britain), headed by C. S. Myers; and the Personnel Research federation (U.S.), directed by Bingham.

Between World Wars I and II the basic findings of general psychology and the special techniques of practitioners came to be applied in courts, clinics and hospitals, classrooms, libraries and museums, factories and offices, social service agencies and government bureaus. Even the great depression of the 1930s was a period of expanding activities; vocational counseling was extended to the unemployed, buying habits of the public were analyzed and opinion polling became an aid to government policy formulation.

2. World War II Period.—Many problems related to the war involved the understanding, prediction and management of human behaviour. To select and assign persons for military duty, psychologists devised or adapted tests that resulted in efficient and rapid classification. Since learning time was short, psychologists worked on problems of efficient and rapid learning at all levels of military training. With manpower in short supply, persons judged to be illiterate or undereducated had to be brought to a minimum level of literacy; psychologists worked with such groups. At the point of induction, those whose personalities would probably break under the strain of military service had to be screened out; psychologists worked with medical specialists in devising more effective screening methods.

Polling methods mere developed for evaluating the morale and attitudes of military personnel; psychologists were members of research teams working on studies of physiological and psychological stress, as in flight, submarine, espionage and combat operations. to determine which persons might best be assigned to these functions and what stress conditions would create dangerous decrements in human functioning. As new machines of war were developed, psychologists studied the man-machine relations in order to increase speed of training, increase equipment effectiveness and simplify and improve the design of military equipment.

As the number of physical and psychological casualties of war increased, rehabilitation and reassignment to limited duty became problems to which psychologists—as clinicians, as rehabilitation specialists and as co-workers with specialists concerned with restoration of lost bodily function—turned their attention. Leadership, group effectiveness and survival under stress were major concerns and psychologists conducted field studies of leadership, morale and combat operations. In cases of military discipline and delinquency, the methods of clinical psychology, counseling and rehabilitation of offenders were employed in corrective programs.

In civilian life, psychologists concerned themselves with the most effective methods for war bond sales; assisted in developing child-care and day-care centres for families temporarily disrupted by civilian employment or military service; and concerned themselves with spread of rumour, use of propaganda and psychological warfare and collecting intelligence data. With the end of the war, civilian readjustment and veterans' benefit programs required great increases in clinical and counseling services, and government training programs for specialists in these fields of applied psychology were established. The political climate of the postwar years required continuation of applied psychological research and services and accounted in part for the rapid growth of all fields of psychology. In the United States, for example, each of the military services maintained specialist groups of psychologists, and each supported both contract and in-service research programs on a wide range of military problems related to human behaviour.

3. Period After World War 11.—Many of the trends in applied psychology were accentuated by the demands of the "space age." Educational psychology is applied to the task of early identification and discovery of talented persons as it has become recognized that trained intelligence is an important national resource. Such activities are linked with the work of counseling psychologists, who seek to help persons clarify and attain educational, vocational and personal goals. Counseling services sponsored by government agencies, social service organizations, schools and colleges and offered by private practitioners are widely available; referral to competent service may be obtained from most college or university departments of psychology. Concern for the optimum utilization of human resources also has increased the importance of industrial psycholcgy in business and industrial organizations. The aviation industry and the various space agencies and organizations have been important factors in the rapid development of the field of engineering psychology; as machines and engineering systems have grown in complexity it has been necessary to study man-machine relationships. In response to society's concern for treatment of the mentally ill and for preventive measures against mental illness, clinical psychology has shown the greatest absolute growth rate within psychology; it also has produced some of applied psychology's major professional problems, involving as it does relations with older medical specialties.

B. Applied Psychology as a Profession

Until about 1940 the majority of psychologists held academic appointments, but after World War II there was a great increase in the number of psychologists engaged in work outside institutions of higher education. Support for such activities, including research, came from the military services, government agencies and business and industry.

In the United States, where this development was most marked, the American Psychological association was active in developing a code of ethics for practitioners, examining relationships with other professions and supporting through consultation the licensing or certification of psychologists in many states. In 1947 the American Board of Examiners in Professional Psychology was independently incorporated to grant diplornas representing special competence to experienced psychologists in the clinical, counseling and industrial fields; by the latter part of the 1950s the cumber of diplomates was about 1.500. Great Britain, with an early emphasis on educational and industrial psychology. was a leader in engineering psychology and in applied social psychology in industry. Australia and New Zealand were particularly active in industrial psychology, as were the Scandinavian countries. Counseling received much attention in India and Japan as well as in France, which was particularly important in the historical development of clinical psychology. Industrial and educational applications were characteristic of German psychology. (A. H. Br.)

II. PSYCHOLOGY IN TREATMENT

A. Clinical Psychology

Clinical psychology is concerned with the assessment and alleviation of the problems of persons who are mentally distressed or disturbed. It can be understood properly in any one of three ways: as a type of personal service performed by psychologists; as a professional subgroup of psychologists having commonly recognized and self-imposed standards of training and practice together with sanctions designed to ensure compliance with those standards; or as a special area of scholarship within the main body of psychological knowledge.

1. History. — Clinical psychology emerged at the beginning of the 20th century mith the establishment of individualized treatment programs for disturbed or handicapped children. At first the emphasis was upon sensory handicaps and basic defects in muscular skills. The clinic established by Witmer in 1896 had such an emphasis and, moreover, it dealt with children whose problems arose primarily in school.

The practice of clinical psychology in hospitals and in collaboration mith physicians dates also from the turn of the century. A psychological "laboratory" was established by Shepherd Ivory Franz at the McLean hospital in Waverley, Mass., in 1904 and was continued under Frederic Lyman Wells. In 1909 William Healy. a physician, founded the Juvenile Psychopathic institute — later the Institute for Juvenile Research — in Chicago. At the beginning Healy, a psychiatrist who also had had psychological training under William James at Harvard, and Grace M. Fernald, a psychologist, constituted the entire professional staff. Clinical psychology as practised in the tradition established by these two ventures has been characterized both by its mutually supportive collaboration with advanced medical practice and by its attention to the so-called dynamic or motivational factors in the human personality.

Another current in the stream of clinical psychology started with the publication of the first successful intelligence scale by Binet and its subsequent adaptations by Goddard and Terman. Through these events the practice of clinical psychology came to be characterized by use of precise and objective measures of psychological traits and capacities with, nonetheless, continued emphasis on dealing with troubled persons one at a time and taking into account those personal factors still requiring, in large measure, the psychologist's judgment.

At the beginning of World War II there were between 400 and 600 trained clinical psychalogists in the United States. In other countries, except for the fact that the numbers are disproportionately smaller, the figure is difficult to estimate, primarily because in other countries the clinical psychologist is more difficult to identify. By 1943 the armed services of the United States were employing 1,500 persons as psychologists, a third of them in assignments that might be called clinical; a large proportion of these persons, however, had had inadequate training. At the end of the war the U.S. Veterans administration adopted a policy of employing clinical psychologists in all its hospitals and clinics; the U.S. public health service and the various state mental health authorities moved in a similar direction; and child guidance clinics, as well as public and private schools, created new positions. By 1958 clinical psychologists in the United States numbered more than 7,000.

In addition to the types of positions mentioned above, there are also places for clinical psychologists in industry, where some specialize in services to emotionally disturbed employees and others in services for managerial officials who need psychological consultation to help them cope with work stresses and interpersonal problems. Other clinical psychologists serve the courts in assessing psychological factors that bear upon judicial decisions; others serve prisons; some are employed by the armed services; and some teach. Many, in all types of positions, are engaged in research. A small proportion are in private practice.

2. Activities. — Clinical psychologists generally classify their essential activities under three headings: psychodiagnosis, psychotherapy and research. In psychodiagnosis emphasis is placed on skill in the administration and interpretation of psychological tests, particularly those administered to one person at a time. Such tests are described in the article Psychological Tests and Measurements. Less formal diagnostic procedures also are employed. including the psychodiagnostic interview. In psychotherapy a variety of methods is used (see Psychotherapy). Research generally is considered to be a further obligation for the clinical psychologist, but it is often crowded out of his schedule; in some cases, where research is undertaken as a primary service to the client, it continues to be, because of the skills employed, a clinical service.

A considerable number of clinical psychologists perform their services in hospitals and clinics. The patterns of collaboration between clinical psychologists and their colleagues in medicine and social work vary greatly among such institutions. The variations are most marked with respect to psychotherapy; some institutions assign most psychotherapeutic duties to clinical psychologists, others to psychiatrists only. Institutional collaboration with pediatricians follows a more regular pattern. the clinical psychologist being more likely to be held responsible for services requiring his clinical skills.

3. Professional Aspects. — Clinical psychology gradually is assuming organized responsibility for its own-standards of training and practice. This development was considerably delayed because of the conviction, widespread among psychologists, that the sanctions and restraints of a profession are antitheticai to liberal scholarship and that they would impede the advancement of psychology as a science. Because of the threat of restrictions imposed from organized psychiatry, however, clinical psychologists were reluctantly joined by their colleagues in an effort to establish standards of training and practice and to provide legal refuge for the continuing development of psychology as a whole. Thus U.S. psychology, and especially clinical psychology, sought to achieve what no profession previously had achieved, a body that was at once both science and profession.

British clinical psychology, in contrast, assumed a more ancillary role, the certification of clinical psychologists being at the discretion of physicians.

4. Training. — The pattern of training for clinical psychologists in the United States was established by a committee headed by David Shakow during the 1930s. A broad training in psychology as a science and in related disciplines, as well as demonstration of research competence, was recommended for the doctor of philosophy degree, to which were to be added practicum courses and a fourth year of graduate training to allow time for internship in an interdisciplinary setting.

The American Psychoiogical association, through its Education and Training board, annually identifies the universities and internship agencies that meet its standards. The American Board of Examiners in Professional Psychology, established in 1947, certifies selected advanced specialists in psychological practice, including clinical psychologists, after examination. As a general guide to the practice of professional psychology the association developed a code of ethical standards, which was accepted by its membership and is used as a basis for disciplinary action against those who fail to conform. (G. A. Ke.)

In Great Britain the training of clinical psychologists is divided between the departments of psychology in universities, which assume responsibility for the purely academic aspects of psychological training and for the awarding of degrees, and medical institutions, directors of which individually certify the clinical competence of psychologists who have worked under their supervision.

B. Counseling

In psychological counseling a psychologist participates in interviews with a client for the purpose of increasing the client's level of self-unification or personal integration. This definition emphasizes (1) that treatment proceeds through communication; (2) that the motives and personality structure of the client are the focus of interest; and (3) that the help offered is nonspecific. This latter means essentially that total personality organization is dealt with. Such issues as marital, sexual, job and educational problems and symptoms are not the main concern of the counselor, although they may be resolved as part of the counseling process. Influence rather than guidance is the aim; adjustment of the client, in the sense of fitting in or of conforming to the environment, is not a goal of the counselor.

1. History and Philosophy. — Before 1940 the emphasis in counseling mas the reverse of that described above. The goal of the counselor would have been to help his client to find some educational or occupational environment conceived to be optimal for the client. The main function of the counselor was to assess personal and environmental possibilities so that the client might make reasonably realistic educational and vocational decisions.

Counseling psychology has its roots in two distinct traditions, both established at the turn of the century. The first is that of mental testing, the second that of vocational guidance *(see* below), as influenced by Frank Parsons and others, with emphasis on matching person and environment. Originally interests, aptitudes and abilities were given great weight in the counselor assessment of the client. Later, after successful use of intelligence tests and personality inventories had been demonstrated in World War I, the assessment came increasingly to be based upon the results of mental tests and psychometric methods. Since psychometric methods required considerable sophistication in the psychology of individual differences and statistics. the "professionalization" of counseling began under the influence of the mental test movement.

During the period between World Wars I and II great emphasis was placed upon scientific quantitative assessment of the person and also of his educational and occupational environment, and considerable progress in the study of individual differences and of occupational psychology occurred as a result. The main goal of the counselor'remained constant, however; the person was to be matched to the environment and helped to decide upon one of a set of educational or occupational environments. The textbooks of the period, abounding in discussions of tests, individual differences, etc., discuss personality structure and dynamics, if at all, only in terms of their relation to environments; personality was considered relevant to possible milieus but not to vocational or educational counseling. If the client was too maladjusted to discuss and make decisions rationally, he was referred to a psychotherapist; the counselor's client was required to be sufficiently integrated to have vocational and educational problems only through misinformation or lack of information.

World War II brought to the attention of counselors the importance of personality structure and dynamics. In 1942 Carl R. Rogers published *Counseling and Psychotherapy,* in which he stressed the counseling process rather than diagnosis and assessment; he presented a radical new approach to counseling and psychotherapy; and, most important for counseling psychology, he brought together two traditions with different origins but in many ways similar purposes: the traditions of counseling and guidance and of psychotherapy.

2. Activities. — While Rogers' recommendations with regard to treatment have deeply influenced professional practice in many ways, his emphasis upon personality development and psychological growth processes has been even more influential. The great difference in emphasis can be seen by comparing a textbook such as E. G. Williamson and J. G. Darley's *Student Personnel Work* (1937) with E. S. Bordin's *Psychological Counseling* (1955) or with J. Hadley's *Clinical and Counseling Psychology* (1958). In the first text "psychotherapy" does not appear in the index; in the latter two counseling and psychotherapy are used as virtual synonyms, the distinction being one of degree only. The tendency to identify counseling and psychotherapy, however, is not so significant as the tendency to think of counseling and psychotherapeutic processes in terms of the general psychology of behaviour. Whereas formerly counseling and psychotherapy were discussed in, for example, the specialized terms of individual differences, mental test theory and psychoanalysis, there has come to be a distinct tendency to relate them to the general psychology of learning, behaviour and perception.

The shift in interest from specific vocational and educational problems toward personality integration and unification, with educational, vocational and other problems remaining as important but derivative, has still broader implications. The client usually has immediate and specific problems he wishes to solve; from the counselor's point of view the solution of these problems often must await the resolution of personal deficits that brought them into being. Initially, therefore. the goals of the counselor and the client are different: the client wishes to make a satisfactory adjustment, the counselor wants to modify the personal organization that created the problems. Because of this initial difference in goals the establishment of a suitable counseling relationship becomes a matter of prime interest.

3. Counseling and Psychotherapy. — In focusing on the modification of personality, the psychological counselor approaches the field of the psychotherapist. Are there useful differentiations to be made between counseling and psychotherapy? With regard to the psychological processes involved the answer is probably no; they are identical. Counseling and psychotherapy are indistinguishable with respect to their primary goal, modification of personal organization in the direction of increased personality integration. Psychological counselors usually, however, assume more of a distributive function. Assessment of aptitudes, abilities and interests in relation to educational and vocational goals occurs much more often in the counseling than in the psychotherapeutic situation.

A useful distinction between counseling and psychotherapy can be made in institutional terms. Psychotherapy has been confined largely to medical settings, hence psychotherapists have developed points of view on personality derived from medical experience; the language of health, disease, pathology and hygiene is used in their approach to treatment and to the understanding of personality. In the approach of psychological counselors, on the other hand, deriving as they do from the academic and scientific discipline of psychology, concepts of theory of perception, behaviour theory, learning theory, theory of individual differences and of mental testing and research methods dominate.

Besides the difference in approach, psychotherapists and counselors serve a somewhat different clientele, although there is a very large overlap. Psychiatrists and psychotherapists, by custom and often by law, tend to serve persons whose lack of personal integration is severe enough to be incapacitating or to render them dangerous to themselves or others. Counseling psychologists seldom work with persons so severely ill; when they do so, they conventionally place themselves under medical supervision. In sum, the distinction between counseling and psychotherapy is essentially one of degree, not of kind.

4. Professional Aspects. — In the United States the trends discussed have resulted in an increase in professionalization, and with this has come an increased demand that psychological counselors have the Ph.D. degree and increased emphasis within graduate training programs on the psychotherapeutic aspects of the counseling process and upon mastery of projective psychology and projective tests. In other countries, such as Great Britain, the emphasis continues to be upon the distributive aspects of counseling. However, it is becoming clear that the trends on the American side of the Atlantic are having some effect on the European

side. In Japan a deep interest in psychoanalysis, Rogerian psychotherapy and counseling has developed. The Japanese seem not to make the intellectually arbitrary distinctions forced upon Americans by their history; consequently interaction and mutual influence between counselors. clinical psychologists and psychotherapists is possible and evident to a degree not realized in the United States and Europe. See also PSYCHOTHERAPY.

(J. M. Bu.)

III. VOCATIONAL GUIDANCE

Vocational guidance is based upon theories and methods derived from the social sciences, mainly psychology. economics and sociology. It assists the person (1) to obtain accurate information about his abilities, aptitudes. vocational interests, skills and personality characteristics; (2) to learn about the world of work, kinds of jobs available, training required and duties. responsibilities and rewards of jobs; (3) to integrate this iniormation about himself and about available alternatives so that he can arrive at a realistic and reasonable vocational decision; (4) to make sensible educational and vocational plans that eventually mill lead to his vocational objective; (5) to acquire the skills and attitudes requisite for success in his chosen occupation; (6) to obtain a job that provides adequate opportunities for him to express and use the skills he has acquired; and (7) to develop further skills that will lead to advancement and promotion once he has started his career.

1. History and Scope.—Systematic vocational guidance in the United States had its origins in Boston about 1905, in Parsons' book *Choosing a Vocation.* It began under the sponsorship of community agencies. and such organizations have maintained their interest in it. The schools however, soon began to express interest. and gradually vocational guidance became largely a school function. Most vocational guidance in the United States is provided by school and college counselors trained in adolescent and developmental psychology, psychological testing and measurement. occupational information and guidance and counseling methods. In addition, vocational counselors in many state employment offices use the comprehensive system of vocational aptitude tests, the General Aptitude Test Battery developed by the United States employment service. The U.S. Veterans administration expanded its vocational rehabilitation program started for disabled veternns of World War I and, in its advisement and guidance program, provided vocational guidance to millions of World War II and Korean war veterans through counseling centres located throughout the country. Most states, in conjunction with the U.S. office of vocational rehabilitation, provide vocational guidance to physically disabled persons.

In Great Britain vocational guidance is provided to school-age youth primarily through government employment agencies. In Australia and Canada schools have assumed major responsibility for vocational guidance. Vocational guidance in France was officially made a responsibility of the ministry of education in 1522. and since 1928 the national counseling service has been known as the Institut National d'Étude du Travail et d'Orientation Professionnelle; in 1953. 500 counselors were employed in 209 guidance centres in France. The first Belgian vocational guidance centre was established in 1912, and in 1937 a national system of vocational guidance was established under the jurisdiction of the minister of education; in the early 1950s between 50,000 and 60,000 persons were provided with vocational guidance yearly in more than 80 local counseling centres. The first vocational guidance bureau in Japan was opened in 1920, and in that country the program has been sponsored by the ministry of education, ministry of welfare, ministry of labour and the Japanese Vocational Guidance association.

2. Methods and Functions.— The methods used in vocational guidance include those of both teacher and counselor. In order to help the person better understand his own potentialities. many methods for appraising personality are utilized. Psychological tests provide information useful in predicting success and satisfaction in various occupations. Tests of general intelligence frequently are used. Following World War II increasing use was made of batteries of ability tests, such as the Differential Aptitude Tests and the General Aptitude Test Battery. which provide measures of general intellectual ability and such special aptitudes as clerical speed and accuracy, mechanical comprehension and form perception ability. Other tests of special abilities. such as the Minnesota Clerical Aptitude test and the Bennett. Mechanical Comprehension test, frequently are used. Tests of skill and achievement, particularly academic achievement, include the Cooperative Achievement test and the Iowa Tests of Educational Development. Vocational interest blanks, such as the Strong Vocational Interest Blank or Kuder Preference Record. identify occupations that have the greatest probability of providing satisfaction. At times other tests of personality. temperament or character are used for purposes of vocational guidance, such as the Minnesota Multiphasic Personality Inventory or the California Psychological Inventory. *(See* also PSYCHOLOGICAL TESTS AND MEASUREMENTS.) The results of these psychological tests are supplemented in interviews by additional information about the person's previous experience and achievement.

Use of psychological tests in vocational guidance requires skill and training. and in most states vocational counselors employed in schools must have completed a minimum of a year's work in a graduate school of a university, specializing in guidance, counseling and psychological measurement.

As important in vocational guidance as test information is occupational information, obtained from a variety of sources including government departments. colleges. universities, professional associations and commercial firms. Gertrude Forrester's *Occupational Literature*, an annotated bibliography published in 1954, listed approximately 3.200 selected references to occupational literature.

In vocational guidance. relevant occupational information is provided in individual interviews and group meetings. Courses in occupations are taught at the secondary school level, and frequently units in other courses. particularly in the social studies, are devoted to the study of occupations.

Helping persons obtain jobs, or placement, is another important function of vocational guidance. Persons are taught how to locate jobs. write letters of application, behave during employment interviews and evaluate job alternatives. In a few organizations. counselors and personnel workers are available to assist employed persons in meeting problems encountered on the job. Personnel workers also discuss with employees on-the-job training programs leading to advancement and promotion. relationships with other employees and supervisors and other matters affecting the worker's vocational adjustment. Thus, vocational guidance is a continuous process. (R. F. BE.)

IV. ENGINEERING PSYCHOLOGY

Engineering psychology—also called human factors engineering or ergonomics—seeks to ensure that the tools and machines man uses and the work he performs in a technological society. are congruent nith his own characteristics. capabilities and preferences. Such aims are as old as the field of engineering. However. past efforts to achieve them rested chiefly on the ingenuity of inventors and on the application of practical experience rather than on scientific knowledge of human performance and other characteristics. The accelerated pace of modern technology, the increasing complexity of modern machines and the trend toward automation have led to increasing emphasis on a scientific approach to the design of efficient man-machine systems and to the adaptation of machines to fit man's characteristics and preferences. This emphasis resulted in the rapid growth of engineering psychology.

Work in engineering psychology was greatly accelerated in response to demands arising during World War II. particularly in the field of aviation. Questions concerning the design of aircraft instruments for ease of interpretation, the design of flight controls for accurate manipulation and the matching of man's dynamic response characteristics to the dynamic characteristics of aircraft were among the many critical human-factor problems encountered in military aviation Similar problems arose in designing other types of military equipment. It was found that some of these problems could be solved by the application of data already available from research in experimental psychology, and that existing experimental methods could be used to solve still others.

One of the oldest problems of engineering psychology is the design of signs and symbols—*e.g.*, alphabetic symbols, the signs used on highnays, the codes used in telegraphy and the symbols used in printing for the blind—so as to increase speed and accuracy of information transmission. As new display media, such as radar and television, were developed, new problems of visibility, legibility and ease of interpretation arose, and research on display problems continues to be an important topic.

Another class of problems of historical importance involves the design of tools and various types of controls so that they are adapted to man's capabilities in respect to strength, dexterity, speed and accuracy of movement. As new types of machine controls are designed, new questions of this sort also arise.

The scope of engineering psychology has broadened to include consideration of the proper functions to be performed by men in large man-machine systems. Such questions as "How far is it advisable to go in eliminating people and making manufacturing processes completely automatic?" fall in this area. Answers to such system-design questions obviously should be based on quantitative analysis of the relative capabilities of complex machines, such as electronic computers, versus the capabilities of human beings in performing comparable tasks. Thus the role of people in future man-machine systems. as well as more specific questions regarding the design of displays and controls, can best be settled on the basis of knowledge of human behaviour characteristics.

Engineering psychology applications thus depend heavily on knoaledge of human performance characteristics and on theory that predicts the levels of performance and ranges of human variability and reliability that can be expected in various types of tasks. especially the effects of variables that engineers can manipulate in designing new machines. Engineering psychology also seeks scientific knowledge of individual differences, learning and human motivation, with a view to understanding how such variables affect performance in man-machine systems.

In summary, engineering psychology is concerned with improving efficiency, with increasing reliability and safety. with simplifying jobs and the learning of new tasks and with increasing motivation, job satisfaction and user acceptance, especially insofar as these objectives can be achieved through the design of machines and human tasks. **(P. M. Fi.)**

V. INDUSTRIAL PSYCHOLOGY

Industrial psychology is concerned nith the utilization and conservation of industry's human resources. This is accomplished by the study of people at work and by the development and application of principles designed (1) to increase production; (2) to promote individual satisfaction and adjustment; and (3) to establish a basis for harmonious relations between management and workers.

Emphasis on human welfare is to be found in the first detailed program of industrial psychology as formulated in 1913 by Münsterberg (*q.v.*), then serving as director of the Psychological laboratory at Harvard university. In Great Britain the Health of Munition Workers committee, organized in 1915, and later the National Institute of Industrial Psychology also based research and practice on the view that it is necessary to give the worker greater ease at work—both mental and physical—as well as to raise output.

A. Personnel Selection, Placement and Training

1. Selection and Placement.—Application of scientific procedures for matching jobs and workers involves (1) an analysis of the requirements of each job in terms of aptitudes, interests, personality, etc.; and (2) the development of techniques for measuring the capacity of applicants for employment or transfer to meet these requirements. In the main, such measuring devices take the form of psychological tests.

Many industries have reported striking results from the use of psychological tests, as have the military services. During World War II failures in the U.S. air force pilot training program were reduced from 65% to approximately 35% following the introduction of tests for the classification of candidates for pilot training. A remarkable development in the air force program was the use of a single battery of tests for the differential classification of candidates as pilots, navigators and bombardiers, respectively. Increasing use of such differential aptitude test batteries in placing applicants for employment, and also in the vocational guidance of young people, represents one of the most significant developments in psychological testing in the third quarter of the 20th century. This approach contributes to the most effective utilization of the capacities of each person at the highest occupational level he is capable of achieving.

Another significant trend is the application of psychological techniques for appraisal and development of supervisory and executive personnel. Not only psychological tests but also rating scales, patterned interviews and biographical inventories show promise in this area. In fact, such traditional methods, refined and validated, have proved to be more effective in selection for some types of jobs, such as insurance salesmen, than have psychological tests. (See also Psychological Tests and Measurements.)

2. Training.—The person who is fully qualified for the job may become inefficient and even maladjusted in the absence of proper training. Principles derived from research on the learning process (see Learning) are applied to increase returns from training in the way of improved quantity and quality of output; to reduce training time; to enhance ease; to increase safety at work. Such research has focused attention on the need for supplementing repetition or routine practice by positive reinforcement. In industry this can be provided most easily and cheaply by giving the trainee immediate and frequent knowledge of results. As an example. in one case a revised program for training radio code operators, in which the correct symbol was given immediately after the trainee had written down each signal as he understood it, reduced by about 25% the time taken by trainees to reach a speed of five groups per minute. The effectiveness of training also can be improved by telling the worker why a job is done in a particular way, as well as how to do it. Principles mentioned above and others have been introduced into programs for teaching supervisors to give better instruction on the job. Notable among these is one known as Job Instruction Training (JIT), developed by the U.S. War Manpower commission, which has been advantageously used throughout the world.

A highly crucial problem in industry is that of reducing the frequency and severity of accidents. Although some progress has been made, it generally has been found that little can be done in this direction through the use of tests for measuring accident proneness. On the other hand, training programs in which supervisors make sure that each worker uses only correct methods of work can contribute much to the reduction of accidents.

B. Hours of Work and Physical Environment

1. Fatigue.—One of the significant psychological and physiological costs of work is fatigue, which is discussed at length in the separate article **Fatigue.** The term fatigue has been used to characterize three interrelated phenomena: (1) a decreased capacity for work, known as work decrement; (2) modifications of the physiological state; and (3) tiredness and related feelings.

Work decrement is reflected in a reduction in output toward the end of a work spell. The quality of performance also suffers as the worker becomes fatigued. Physiological changes occurring during work provide clues to the amount of energy expenditure. commonly known as effort, required to do the work. Measurement of oxygen consumption and carbon dioxide discharge, pulse rate, frequency of blinking, muscle tension, urinary excretions and many other functions have been used to assess the expenditure of physiological energy. Feelings of tiredness, weariness, etc., which appear with prolonged work are another expression of fatigue. A feeling of fatigue plays a protective role in preventing exhaustion, but it does not provide an index of either the physiological state of the body or of the capacity for continuing work. Nevertheless, the subjective constituents are significant characteristics of fatigue. In fact, investigators view these not merely as symptoms but as basic expressions of an aversion to continued activity. which is in itself fatigue.

Though it is not possible to avoid fatigue altogether, it is possible to eliminate unnecessary fatigue by adjusting the work situation. However, increase in output cannot properly be used as the sole criterion for measuring the effects of changes in the work situation. It cannot be said that fatigue has been reduced when increased output is achieved only at the cost of an increase in effort or energy expenditure, or of adverse effects on feelings of fatigue and adjustment. Involved here is a psychological concept of efficiency differing markedly from the narrower economic concept, which overlooks the risk of physiological and psychological impairment to man.

2. Hours of Work.—During the 19th century a work schedule including a minimum of ten hours per day and six days per meek was predominant. Opposition to reducing hours of work has been overcome by the discovery that production is not adversely affected, indeed is frequently increased, by shortening the working day and the length of the working week. Output does not fall off with a shortening of the work week because of a tendency for the human being to adapt his rate of mork to the length of the work spell and to the total amount of work to be done.

There is no single best pattern of work hours uniformly applicable to all kinds of jobs. British investigators have shown, for example, that a sortie of four to six hours in a piston-engined plane produces no appreciable fatigue effect, although deterioration in pilot performance occurs after about eight to ten hours of flight. By contrast, two or three one-hour flights in a jet-engined airplane appear to produce as much fatigue as ten or more hours in a conventional plane.

While there is no "optimum work schedule" suitable for all of industry, there is considerable evidence that, on the whole, a five-day week and an eight-hour day are more efficient than a work schedule with longer hours, especially where the worker. rather than the machine, sets the pace. Further shortening of the work schedule may be economically feasible and of psychological advantage in some instances, but built-in human limitations in the way of rate of work and also the time required to "warm up" at the beginning of each work shift may make it impracticable to shorten the work periods radically without adverse effects on total output.

3. Scheduled Rest Pauses.—It is advantageous to break up a spell of work by scheduled rest pauses. Rest pauses are desirable because they may heighten motivation and combat boredom as well as reduce fatigue. Furthermore, they may involve no actual loss of time, since workers will take equivalent time off, sometimes surreptitiously, and unauthorized "breathers'! do not provide the equivalent of scheduled rest pauses in the way of relaxation and release from tension. Support for well-controlled coffee breaks; tea breaks or "elevenses" is found in studies showing that the intake of food during a rest pause contributes to its beneficial effect.

4. Illumination.—Unsuitable lighting accelerates the onset of fatigue, chiefly by increasing the muscular activity involved in seeing. A major requirement of good lighting is adequate brightness, associated with intensity of illumination. Low intensity continues to present a problem in many factories and offices, where the level of illumination is lower than 5 foot-candles, as contrasted with the 1,000 to 1,500 foot-candles characteristic of the outdoors even on a cloudy day. Difficulties in measuring the physiolcgical cost of work under varying levels of illumination and other factors have led to disagreements as to applicable minimum standards for different jobs. Nevertheless, those listed by organizations such as the Illuminating Engineering society, illustrated below, represent widely accepted guides to the establishment of lighting specifications.

Type of work	Foot-candles (30 in. above floor)
Assembly (rough)	10
Bookbinding (cutting, punching, stitching)	20
Clothes pressing (hand)	50
Electrotyping (blocking, tinning)	30

Proper diffusion and distribution of illumination. designed to eliminate glare and undesirable shadow effects. are also necessary for clear vision and easy seeing. Brightness contrast (*i.e.*, the ratio between the brightness of the object and that of the background) must be considered in determining the quantity and quality of illumination. Colour may play a part; it has been shown that ease of seeing is increased through the use of contrasting colours on machine tools and that this serves to emphasize danger points on the machine as well as to increase efficiency. (*See* also LIGHTING.)

5. Atmospheric Conditions.—According to a study conducted by the American Society of Heating and Ventilating Engineers, 50% of people engaged in light work in the United States find air temperatures of 63° to 71° F. comfortable in winter, and temperatures of 66° to 75° F. suitable in summer. The same percentage select 30% to 70% as the desirable level of relative humidity. However. people vary widely in their reactions to these atmospheric conditions and also to the rate of air movement, which is another important factor in maintaining efficiency and comfort at work. Much depends also upon the nature of the task.

For the exact study of human reactions to atmospheric conditions. use is made of an index, known as Effective Temperature (ET), which shows the combined effect of air temperature and humidity on the sensation of warmth or cold for a specified rate of air movement. In general, studies indicate that human performance is impaired to a serious degree with effective temperatures in the middle 90s or above, and that incentives do not offset the effects of high temperatures. At temperatures below 50° F. the precision of hand and finger movements is reduced. There are no materially adverse effects on mental activities even at temperatures below 0° F.. although impairment occurs in the performance of manual tasks. Furthermore, both physical and mental processes suffer and feelings of fatigue are increased under conditions of anoxia, or oxygen deficiency, such as occur moderately at an altitude of 10,000 ft. or less and critically around 20,000 ft. and above (*see* HYPOXIA).

Careful selection of personnel, provision of protective clothing and oxygen equipment, adjustment of the work spell. etc., can help to ameliorate the effects of atmospheric conditions characteristic of extreme climates and also of work around blast furnaces, in mines and submarines, in flying, etc. However, atmospheric conditions create negligible human problems in modern, well-ventilated, properly heated, air-conditioned plants. (See also HEATING AND VENTILATION.)

6. Noise.—Adaptation takes place in the case of regular exposure to expected and continuous noises of high intensity in the work situation; especially in the presence of high incentives. Prolonged exposure, however. to high noise levels and certain types of noises—as, for example. those experienced by boilermakers and airplane pilots—contributes to hearing loss. On the question of direct fatigue effects there is considerable disagreement among research workers. Thus K. D. Kryter states that there is little evidence of damage to health, either psychologically or physiologically, from intense noise: even though it may be annoying. Other investigators maintain that available evidence tends generally to show that noise detracts from efficiency and well-being. Underlying this controversy are deficiencies in experimental methods and also limitations in methods for measuring the physiological cost of work. It is not safe to disregard the possibilitv that. excessive noise acts on the human organism as excessive friction acts on the machine; that it wastes energy.

C. WORK METHODS AND MACHINE DESIGN

1. Efficient Methods of Work.—Waste in the use of human resources in industry can be curtailed by the elimination of awkward and unnecessary movements in doing the job. A comprehensive program for doing this, including time-and-motion study procedures. mas first developed at the beginning of the 20th century 'This and a variety of subsequent programs undertake basically to eliminate unnecessary movements and to combine selected "best" motions into a standard method frequently designated as the one best way of mork. The concept of the one best way of work has been a matter of concern to psychologists. Involved, in part, is a question as to whether any single rigid pattern of work is uniformly applicable to an entire group of workers, since these differ from one another in physical and mental make-up. There is need to make allowances for the personal equation of the individual, so long as departures do not result in a reduction of output or in increasing work hazards.

Modern programs designed to improve work methods, generally known as methods engineering or work simplification. reflect these newer outlooks. There is an increasing tendency to make use of general rules of motion economy—dealing with such factors as symmetry, continuity, smoothness and rhythm of movement—as a substitute for rigid patterning of so-called basic motions. Furthermore, many supervisors and also workers are being taught how to apply these rules. Such an approach embodies a concern for individual differences. Participation of this kind also contributes to a psychological climate conducive to harmonious industrial relations.

2. Posture and Distribution of Load.—Fatigue is increased when a static posture must be maintained. Furthermore, the energy cost of work is increased by departures from normal, erect positions in carrying loads. In general, it appears that a load should not be in excess of 40% of the body weight in continuous work of this kind. In such activities as pushing wheelbarrows, a normal, brisk walking pace without stopping appears to be most efficient in terms of energy expenditure. While of decreasing importance in highly industrialized countries, excessive fatigue induced by improper posture and excessive burdens can represent a major human problem where the task of carrying loads is still primarily a human rather than a machine job.

3. Alleviation of Boredom.—Highly specialized. repetitive work, widespread in modern industry, leads to a feeling of boredom; as indicated by both U.S. and British studies, considerable boredom is experienced by approximately 25% of factory workers. Boredom produces a change in the shape of the daily production curve which, contrary to the situation when fatigue is experienced, tends to fall in the middle and to rise at the end of the work spell. Furthermore, employees who experience boredom are responsible for a considerable number of complaints and frequently exhibit low morale.

Efforts to develop tests of susceptibility to boredom and assign to repetitive work only those who are not highly prone to it have not been successful. As a result, attention has been turned increasingly toward modifying aspects of the work environment that contribute to the arousal of boredom. Research conducted from this point of view has shown that appropriately spaced rest pauses, freedom to engage in conversation, music and the social environment of the plant, especially as reflected in the formation of closely knit small work groups, contribute to the alleviation of boredom.

A high degree of specialization in work has been favoured in the belief that this tends to increase over-all production. However, it has been shown that redesigning jobs so that the worker can perform a variety of tasks reduces the incidence of boredom and improves general attitudes without adversely affecting production. Thus job rotation and also job enlargement are being used increasingly as ways of alleviating boredom and its attendant effects in the way of unrest, low morale and possibly impaired social adaptation.

4. Machine and Instrument Design and Man-Machine Systems.—With the growth of mechanization in industry. it has become increasingly necessary to view man and his machine as an integrated functional unit. There is continuing need to approach the design of machines with full consideration of basic patterns of human perception, communication and motor response, and also of built-in limitations in the speed, accuracy and co-ordination of these and other human functions. Failure to consider the human element in the design of machines has led to the construction of mechanical monstrosities, such as a mine hoist that requires the operator to read a dial tilted 30° upward and sideward while standing spread-eagled with his weight resting on one foot. Many machines and tools tax the capabilities and energy of human operators.

Since approximately 1940 there has been growing acceptance of the principle that machines should be made for men rather than men forcibly adapted to machines. This view finds expression in specialized research and practice most frequently described as engineering psychology (see Engineering Psychology, above).

Visual Indicators.—The widespread use of instruments such as pressure gauges, tachometers, voltage meters, etc., has led to extensive studies of visual indicators. An example of poor design is found in a control panel 17½ ft. in width where all major gauges were 2 to 3 ft. above eye level. Operator complaints of eyestrain and fatigue led to the redesign of the control panel to a width of six feet with better positioning of instruments for seeing.

Poorly designed instruments can cause accidents as well as produce unnecessary fatigue. Thus a survey of 270 "pilot errors" showed that 13% of aircraft accidents investigated resulted from a misreading of the altimeter by 1,000 ft. There is evidence that the substitution of a numerical counter for the conventional type of altimeter reduces the percentage of errors in reading from 11.7 to 0.4 in the case of experienced pilots. Studies of many kinds of visual indicators have led to the formulation of principles designed to improve both the ease and accuracy of instrument readings, covering such characteristics as intervals between scale markings, size and style of figures, shapes of pointers, conditions of illumination. etc.

Controls.—The placement, shape and direction of movement of controls represent important factors in the design of mechanical elements of the system. Wide separation of controls leads to reduction of output and to increase of effort in the operation of machines; by contrast, too close proximity of major controls may produce accidents. The latter has been demonstrated in the case of aircraft. where the nearness of the flap control to that used in operating the landing gear has contributed to accidents because of accidental operation of the wrong control.

Coding.—Strain can be reduced and safety increased by coding or associating differently shaped controls with distinctive operating functions. Certain basic principles with respect to direction of movement have been developed, including the rule that for adjusting a lever or control knob the movement should be in the same direction as the perceived adjustment. Thus toggle switches should move upward for "on," "go" or "increase" and downward for "off," "stop" and "decrease."

D. Psychological Climate

In many instances, hours of work and physical conditions play a less important role than the psychological climate of a plant or office in determining the output. satisfaction and attitudes of the working force. Psychological climate is determined by the personnel policies and practices of the company, the attitudes and behaviour of supervisors and executives and the multitude of interpersonal and social relationships in which people are involved at work.

1. Social Situation.—Studies conducted in the Hawthorne, Ill., plant of the Western Electric company between 1927 and 1932 attracted attention to the significance of such aspects of the work situation. These studies included extensive observations of the effects of changes in number and distribution of hours of work, illumination, rest pauses, wage-payment plans, etc. Such changes were accompanied by increased production, but the upward trend did not disappear when the favourable physical conditions were eliminated. It was concluded that the production increase was the result of a change in the social situation. The conditions of the experiment created a friendly and closely knit working team and a relationship of confidence between the employees and their supervisors which did not exist in the ordinary work situation in the plant. Employees did their best not primarily because of wage incentives, reduced fatigue or similar factors but because the psychological climate was conducive to maximum co-operation by the work group.

Subsequent research by different investigators in many plants has clearly confirmed the view that the way the person acts, the way he feels about his job, the level of his morale — in the sense of willingness to strive for the goals of the company — are very much affected by the sentiments and attitudes of his co-workers. Of particular significance is the influence of the small work group or team to which he is assigned by management. and of the small informal organization which develops spontaneously as a function of the work situation. The influence of the social situation is intensified because the employee is simultaneously a member of many groups. and because some of these, *e.g.*, the company and the union may be competing for his interest and his loyalty.

2. Incentives. — This emphasis on the influence of the social situation does not mean that workers' behaviour and attitudes are determined only by "social motives" or drives derived from group membership. Other and even more fundamental motives, associated with basic drives for the satisfaction of needs for food, shelter, job security, self-expression, etc., play a tremendous role.

Research has thrown considerable light on the sources of motivation (*q.v.*)—on the variety and strength of needs and desires that must be gratified in the work situation. There also exists a wealth of information concerning factors in the industrial situation that operate as incentives to production and in promoting high levels of employee satisfaction and morale.

There is evidence that executives, and also union leaders, err in their judgments of workers' perceptions of their needs and the potency of financial incentives. In a survey conducted in 1947, 75% of executives and of labour leaders and less than 30% of employees included compensation among five factors rated as most important to workers. In a later study workers listed "full appreciation of work done" as first and "good wages" as fifth on a list of morale factors. By contrast. supervisors predicted that "good wages:' would turn out to be the most important item looked for on the job by the workers. and that "full appreciation of work done" would rate in eighth place.

Desire for money is only one of many factors in motivation and morale. This does not mean that the pay envelope is unimportant in satisfying workers' needs; a low nage scale is a significant source of dissatisfaction and lack of co-operation. Nevertheless, voluntary restriction of output in plants using wage incentive systems and strikes in plants with high wage scales show that wage schedules and nage incentive systems have limited power as incentives. A nage incentive may have no efiect if the work operation is disliked, if elements of the psychological climate produce frustration or are perceived as barriers to the satisfaction of basic needs. Furthermore, as wages rise above the subsistence level, other needs and wants. satisfied by plant conditions other than pay, become more influential. In addition to material rewards. workers seek such mental and spiritual returns as the opportunity of doing something worthwhile; the feeling of being recognized as somebody; a sense of belonging; a chance to get somewhere; approval of work done; a safe future; guidance by a strong and understanding leader in establishing goals and learning how to achieve them; the opportunity of contributing from their knowledge in dealing nith their own problems.

The question has arisen as to whether union or management carries the prime responsibility for satisfying such needs. There is evidence that the worker has strong attachments to the union and sees it as a powerful agency for the increasing satisfaction of material nants through higher wages and job security. It is not so clear that he views the union as the primary medium for the satisfaction of other wants. On the contrary, many studies show that employees at all levels look to management for the establishment of policies and practices conducive to the satisfaction of these needs.

3. Work Groups. — A study conducted in two British automobile factories showed that higher production and greater satisfaction occur in smaller than in larger nork teams. Observation of four gangs engaged in repairing railroad passenger cars in Great Britain shoned that, under a group wage incentive, productivity increased at a higher rate in gangs of small size and with a particular pattern of stability than in larger work gangs. These and other studies also yielded evidence of higher levels of satisfaction and morale in smaller work groups.

The explanation of such findings is to be found in the social structure of the groups. Smaller working groups tend to be more cohesive than larger groups do. Under appropriate conditions, especially in the presence of a high quality of leadership, such cohesiveness leads to higher work standards, to acceptance of technological change and to better achievement of other goals important to management.

A conscious effort to combine in a work team members who like and are friendly toward each other is conducive to the development of such positive attitudes and behaviour. The advantages of using such sociometrically organized work groups are illustrated in an experiment conducted in the construction industry; total production costs were reduced by 5% when carpenters and bricklayers were permitted to select their own workmates instead of being required to work with arbitrarily assigned teammates.

4. Democratic Leadership. — A number of studies covering many occupations and many countries — ranging from telephone operators in the state of Michigan to textile workers in India— have demonstrated that an atmosphere of democratic leadership, which provides opportunities for employee participation in setting goals and in other aspects of decision making. results in higher production, greater job satisfaction and improved morale. Evidence of such returns was first demonstrated clearly in a study conducted in a garment-manufacturing plant, where there was considerable resistance of production workers to necessary changes in jobs and work methods. Providing opportunities to the workers to participate in planning the details of the change and in setting production goals led to higher output, decreased turnover and a more harmonious relationship between workers and supervisors. Such benefits appear not only nhen small job changes are involved but (as was shown in later developments in a garment-manufacturing plant and in the Indian studies) also where a widespread program of modernization or reorganization of the plant as a whole is required.

Experience of companies introducing electronic office equipment and other forms of automation shows further that industry can profit from permitting workers to participate in decision making, without any abdication of the responsibility of management for the operation and growth of the business. In fact, the extent to which the worker is involved in participation may determine his reaction to management when demands are made for loyalty to tno overlapping membership groups: the company and the union. A study conducted in an automobile-manufacturing plant showed that, uniformly, where the foreman is active in involving men and the union steward is not, the workers are more likely to be high on an index of management affiliation and low on an index of union affiliation, and vice versa.

5. Supervision. — Many studies, including that cited above, have demonstrated that the quality of supervision exercises a tremendous influence upon employee motivation and morale. Studies of nork groups, including insurance office workers, labourers in railroad gangs, linemen, etc., conducted by the Survey Research centre of the University of Michigan, showed that employees who perceive their supervisors as "employee centred" have better production records than do groups working under "production centred" supervisors. There is evidence that absence rate is inversely related to quality of supervision.

Analyses of finding:, from studies conducted in the 1940s and 1950s show that the quality of supervision is good (1) when workers feel free to discuss their problems with their supervisor; 12) when norkers know what he thinks of their work; (3) when workers feel that the supervisor supports them nhen they have a complaint; (4) when the supervisor uses general rather than close supervision; (5) when the supervisor frequently conducts group meetings where work matters are discussed.

Recognition of the central role of good supervision has led to the formulation of programs to select for supervisory jobs those persons nho are most capable of meeting such requirements. More important and more widespread are numerous and extended training programs designed to help the supervisor develop proper perception of workers' needs, feeiings and attitudes, and skill in dealing nith employees on the job.

6. Communication.— Evident in much of the discussion above is the important role played by communication in determining the quality of interpersonal relations. Small groups become cohesive, in part, because in them information can be passed along quickly. Employees look to supervisors for opportunities to discuss what is of importance to them. Adverse attitudes toward company pension plans and other benefits change for the better when facts concerning them are properly communicated to employees.

The need for adequate communication exists at all levels. Supervisory personnel often complain of the failure of higher management to keep them informed about matters that are of interest to them and their employees. Formal channels of communication following the lines of the organization chart may not be sufficient for full dissemination of information.

7. Management Atmosphere.— Basic principles of good supervision cannot or will not be put into practice unless the climate is such as to stimulate supervisors at all levels to perceive themselves and to act as members of the management team. Along with keeping the supervisor informed, it is necessary to define the scope of his responsibility and to delegate to him the authority to use it. A study made in 1954 showed that 79% of foremen with high morale and only 37% of foremen with low morale had a clear understanding of their duties. Similarly. 79% of the former and only 30% of the latter claimed that they had adequate authority to deal with employee and other problems. In addition, the supervisor is at a disadvantage on the job unless his status is made clear by the wage scale and by such physical symbols as desk, office space. etc., and unless he is permitted to play a role appropriate to his rank in policy administration and even in policy making. *See* also INDUSTRIAL RELATIONS. (M. S. VI.)

VI. MOTIVATIONAL RESEARCH

Motivational research is the branch of applied psychology that is concerned with the deep-lying and often hidden motivations of human beings, and with the influencing of their behaviour through understanding of these motivations. It finds its chief uses in business. solving, by studies of mass behaviour, problems of sales, advertising and merchandising. Motivational research resembles —and some of the basic fact-gathering methods it uses are similar to those of—public-opinion polling (*see* PUBLIC OPINION; STATISTICS). Public-opinion polls, however, are concerned mainly with how people behave. Xfotivational research attempts to find out why people behave as they do and, further, it acts on the assumption that many human motives are unconscious or not readily admitted because they do not always represent desirable aspects of behaviour.

The methods employed to uncover underlying motives for human behaviour are borrowed from the general fields of psychiatry, psychoanalysis and depth psychology (*see* PSYCHIATRY; PSYCHOANALYSIS). They include such devices as the depth (nondirective or open-end) interview, projective tests, laboratory experiments and psychodrama. The depth interview is one in which the subject rarely is asked a direct question; for example, the researcher will not ask him why he bought a particular make of car, but will attempt to discover this from his answers to indirect questions. In using projective tests, pictures illustrating specific situations are shown to subjects who are then asked to project themselves into these situations; this often reveals their true motivations (*see* also PSYCHOLOGICAL TESTS AND MEASUREMENTS: *Projective Methods*). Laboratory experiments seek to measure the relationship between people and objects—including products, services and mass media. In psychodrama, people are asked to act out on a stage a purchase. interpersonal relations or emotional problems; in doing so. they often discover insights into their own behaviour, and the researcher gains understanding of their motivations.

Motivational research, since it attempts to change such activities as voting. buying and national and international attitudes toward various issues, has exposed itself to a question regarding the ethics of using social sciences to influence people, often against their will. Motivational researchers answer that people always have tried to influence each other and that the real issue is one of determination of goals. (E. D.)

VII. FORENSIC PSYCHOLOGY

Part of the scientific research on human behaviour carried out by psychologists and other social scientists is pertinent to a wide range of legal problems. At one time or another, psychologists have studied detection of guilt and deception, distortions of perception and memory in relation to testimony, the behaviour of juries, problems related to the determination of competence and sanity, personality and motivational factors related to crime, factors influencing success and failure on parole, the sociopsychological organization of prisons, the psychology of drug addiction and the like.

In addition, a number have served as clinical psychologists or guidance counselors affiliated with juvenile and criminal courts, prisons and other legal agencies. Further, psychologists sometimes serve as expert witnesses in cases involving determination of mental deficiency or "insanity" or other problems in which technical psychological knowledge may be of use.

In the main, however, the application of psychology in relation to the law has not emerged as a clearly delineated, professional field. Few psycliologists have obtained sufficient legal training to make them familiar with court procedure and to enable them to adapt their findings to the general rules of evidence. Most of the practical application of psychoiogy to legal problems is carried out by specially trained police officers and attorneys. (H. F. HT,)

BIBLIOGRAPHY.—*The field:* the most extensive single reference is D. H. Fryer and E. R. Henry (eds.), *Haizdbook of Applied Psychology*, 2 vol. (1950). A popular treatment of applied psychology may be found in E. Ogg, "Psychologists in Action," *Public Affairs Pamphlet 229* (1955). *See* also L. E. Tyler, *The Psychology of Human Differences*, 2nd ed. (1956); A. Anastasi, *Psychological Testing* (1954); L. J. Cronbach, *Educational Psychology* (1954); M. Blum, *Industrial Psychology and Its Social Foundations* (1956); H. Hyman, *Survey Design and Analysis* (1955); D. B. Lucas and S. H. Britt, *Advertising Psychology and Research* (1950); L. A. Pennington and I. A. Berg (eds.), *An Introduction to Clinical Psychology*, 2nd ed. (1954).

Clinical psychology: V. C. Raimy (ed.), *Training in Clinical Psychology* (1950); American Psychological Association, *Ethical Standards of Psychologists* (1953); R. I. Watson, "A Brief History of Clinicai Psychology," *Psychol. Bull.*, 50:321–346 (1953); E. A. Rubinstein and M. Lorr (eds.), *Survey of Clinical Practice in Psychology* (1954); R. I. Watson, *Psychology as a Profession* (1954); W. A. Hunt, *The Clinical Psychologist* (1956).

Counseling: Frank Parsons, *Choosing a Vocation* (1909); E. G. Williamson and J. G. Darley, *Student Persoiznel Work* (1937); Carl R. Rogers, *Counseling and Psychotherapy* (1942); John M. Brewer, *History of Vocational Guidance* (1942); F. P. Robinson, *Principles and Procedures in Student Counseling* (1950); C. Gilbert Wrenn, *Student Personnel Work in College* (1951); H. B. and P. N. Pepinsky, *Counseling: Theory and Practice* (1954); E. S. Bordin, *Psychological Counseling* (1955); Milton E. Hahn and Malcolm S. MacLean, *Counseling Psychology*, 2nd ed. (1955); J. Hadley, *Clinical and Counseling Psychology* (1958).

Vocational guidance: D. E. Super, *Appraising Vocational Fitness* (1949); C. L. Shartle, *Occupational Information*, 2nd ed. (1952); L. E. Tyler, *The Work of the Counselor* (1953); *Personnel aizd Guidance Journal* (formerly *Occupations*).

Industrial psychology: M. S. Viteles, *Industrial Psychology* (1932), *Science of Work* (1934), *Motivation and Morale in Industry* (1953); E. Mayo, *The Human Problems of an Industrial Civilization* (1933), *The Social Problems of an Industrial Civilization* (1945); F. Roethlisberger and W. Dickson, *Management and the Worker* (1939); H. E. Burtt, *Principles of Employment Psychology* (1942); T. A. Ryan, *Work and Effort* (1947); K. Lewin, *Resolving Social Conflicts* (1945); N. R. F. Maier, *Principles of Human Relations* (1952); A. M. Rose, *Union Solidarity* (1952); W. F. Floyd and A. T. Welford (eds.), *Symposium on Fatigue* (1953), *Symposium on Human Factors in Equipment Design* (1954); G. Friedmann, *Industrial Society* (1955); R. Stagner, *The Psychology of Industrial Conflict* (1956); E. J. McCormick, *Human Engineering* (1957); T. W. Harrell. *Industrial Psychology*, rev. ed. (1958); C. G. Browne and T. S. Cohn (eds.), *The Study of Leadership* (1958); *Journal of Applied Psychology* (U.S.); *Personnel Psychology* (U.S.); *Occupational Psychology* (Great Britain); *Journal of the Institute of Personnel Management* (Great Britain); *Personnel* (U.S.); *Human Relations* (U.S.-Great Britain); *Journal of Personnel Practices* (Australia); *Le Travail Humain* (France).

PSYCHOLOGY, COMPARATIVE, concerns the study of similarities and ditierences in capacities for environmental adjustment and for behavioural organization among the important types of living beings, from plants and unicellular organisms to the primates including man. A view of the subject held earlier by W. Wundt and others included human comparisons now generally studied under the titles of genetic or child psychology, abnormal psychology and ethnology or folk psychology. The present article is concerned with an examination of the psychological nature and capacities of lower animals and man in comparison with one another.

Comparative psychology is studied because the behaviour of animals is in itself interesting, because of important applications in fields such as medicine and animal training, and also because of significant bearings on human psychology. With the rise of an experimental comparative psychology in the latter half of the 19th century and its rapid growth during the 20th century, the scientific study of lower animals has cast increasing light on questions in human psychology, such as the development of individual behaviour, motivation, the nature and methods of learning and many others. Psychologists often employ lower animals as subjects in their experiments because these are easier to obtain in numbers and can be much better known as to background and better controlled under experimental conditions than human subjects. and because of relationships in behaviour. Much can be learned about man by studying lower animals; moreover, the discovery of differences illuminates the similarities.

In primitive times man had to learn about animals because of his constant struggle with them for existence. Animals became familiar members of human households, and many cultures used animals as totems or worshiped them as magical beings. The common-sense tendency to endow lower animals with human capacities always has been strong. People often talk to animals, appealing for action or for sympathy as though dealing with human beings. An extreme development of this tendency is the doctrine of metempsychosis (*q.v.*), or transmigration of souls, which holds that after death the human soul may reside either in another person or in a lower animal.

In recorded history two different views have developed concerning man's relation to the lower animals. One, termed for convenience the man-brute view, stresses differences often to the point of denying similarities altogether; the other, the evolutionary view, stresses both similarities and differences. Aristotle formalized the man-brute view, attributing a rational faculty to man alone, lesser faculties to the animals. On the other hand, from the 19th century Darwinism led scientists to look for relationships between man, considered a highly evolved animal, and the other animals. This has come to be the modern view in science. Scientific evidence indicates that continuity in the evolution of organisms provides a basis for essential psychological similarities which exist, together with differences, between lower and higher animals.

This article is organized as follows:

I. METHODS

1. Gathering Evidence. — The evolutionary position, which has been substantiated in its main contentions concerning mental relationships among animals, has its basis in experimental evidence. Fact gathering, whether by observation or by experiment, requires, beyond a keen interest in animals, special training in the scientific methods of investigation for which personal feelings are no substitute. An animal story, even when reported by a person of repute and veracity, carries no automatic guarantee of its soundness. All reports. whether from laboratory experiments or from studies of animals in their natural habitats, must be evaluated for reliability according to what investigative conditions prevailed and what precautions were taken against error in gathering the facts.

In comparative psychology, as in science generally, the soundest method of study at hand is used. An observer of nesting behaviour in birds constructs a hide-out or blind to minimize disturbances resulting from his presence. Binoculars, a camera and special mechanical means for recording the bird's reactions may further increase the reliability of his investigation.

Experiments in the laboratory are designed to obtain the maximal control over conditions. There it is possible to regulate general factors such as age and physiological condition of the subjects, to exclude disturbances, to change environmental conditions or keep them constant, according to the experimental plan, and to introduce apparatus designed to ensure accuracy both in the test itself and in recording results. Thus animal psychology has employed the maze method as one means of testing learning, special problem boxes to test intelligent behaviour and a variety of other techniques planned to increase the significance of the evidence obtained.

2. Interpreting Evidence. — No theory can be sounder than the validity of its evidence or the logic of its construction. To illustrate the necessity of checking evidence at the source and logically examining theory, a famous case in which humanlike abilities were claimed for a performing animal may be cited. Late in the 19th century, several horses owned by a Herr von Osten of Berlin, particularly one named Hans, became renowned for purported mathematical capacities. When a problem was written on a blackboard before him, Hans, by tapping first with right forefoot and then with left, indicated the answer in digits and tens respectively, with such success as seemingly to support the owner's claim for mental calculations by the horse. Although skepticism was expressed by many, and some alleged trickery, others asserted that the owner must be honest and his claims therefore valid. Scientific surveys of the case, particularly by the psychologist O. Pfungst, supported the following analysis. The horse performed well whether the owner was present or not, apparently ruling out trickery due to the owner's presence. But Hans failed unless the trainer or someone else was present who knew the answers; hence success depended somehow on human influence. The fact that the horse failed when blindfolded excluded telepathy while indicating some other effect from persons present. Observing the audience carefully, the psychologists found that when a problem was written down, someone who knew the answer would bend forward very slowly, whereupon the horse would begin tapping. After the correct number of taps the person mould relax, usually nith a iittie movement, as of the head. and the horse would stop. Slight movements of this kind were known to psychologists as inadvertent activities accompanying acts of close attention. From these facts, Pfungst concluded that, without the owner's knowing it, the horse had learned to start and stop his taps according to appropriate sensory cues. This interpretation was favoured by still other facts. The horse was equally successful nhether the problem was in simple arithmetic or in calculus; also. his responses to easy and to difficult problems alike often were incorrect by only one or two digits, suggesting a direct control of the tapping that could operate now early, now late. rather than mental operations. Supporting this conclusion was the fact that Hans typically began tapping mechanically nhen all was ready. without even looking at the figures.

This case brings out some important principles of interpretation in comparative psychology. The investigator selects a likely hypothesis, but considers it tentative until it is supported by experiments in which all factors of possibie importance are controlled. (In the Clever Hans case, the roles of sensitivity and habit in the horse, the factors of audience knowledge and of subtle motor aspects of attention. and still others were tested.) After his experiments, the scientist sifts and organizes the available evidence logically, using mathematical techniques when possible, to find what theory best fits the facts. These safeguards are elementary, whatever the nature of the behaviour problem.

3. Anthropomorphism. — There is an irresistible human tendency to ascribe human attributes, emotions and capacities to other beings. Thus it is said that moths and other insects fly to the light out of curiosity; the rattlesnake sounds its rattle in order to warn intruders; pets and domestic animals are noble or sly and deceitful according to conditions; and so on. The practice of interpreting behaviour on the basis of selected stories is called anecdotalism. Thus Plutarch in ancient Rome, La Fontaine in 17th-century France and countless other writers have busied themselves in narrating stories about mental feats in lower animals.

Although valuable literary works may be created by authors attributing human traits to animals, anthropomorphic literature risks two fundamental flans which make it an undependable source of evidence. First, it typically involves the implicit assumption that any person is well acquainted with his own behaviour and thoughts and even understands their causes. About this belief modern psychology is seriously doubtful, advising caution to writers about behaviour and particularly those unskilled in observation or interpretation. Another difficulty is that a scientifically untrained person, however well intentioned, may rest content with a single outstanding occurrence in the life of an animal as a basis for his interpretation, especially one nith dramatic features making its telling and retelling a gratifying act. But a single observation has low reliability, as have any number, when perception is influenced by prejudices and preconceived notions. Furthermore. with each narration, new features are usually introduced and old ones changed so that the report becomes increasingly unreliable.

4. Adaptive Behaviour or Purpose. — Unnecessary complexities often arise in interpretation because of the interpreter's point of view. Under natural conditions. for example. animal behaviour generally conforms to what a human observer might call "appropriate" or "best" in the given situation. Thus the Venus's-flytrap closes its hinged leaf when a fly alights upon it. but not when stirred by a breeze; the scallop closes the valves of its shell as its common enemy, the starfish, approaches; the octopus frequently remains secluded until its common prey, the crab, is nearby; the chimpanzee, attracted by food out of reach, may attain it by piling hoxes. Acts that seem well adapted to the given animal's welfare under particular conditions are often described as purposive. For those interested in obtaining valid explanations, this generalization of purposiveness in behaviour raises difficulties.

The above cases are typical—what can be said about them? First. these acts occur as described: the reports are reliable. Also, the acts have in common one characteristic: each of them furthers the life processes of the animal and fits it to its surroundings. In this respect they are all adaptive, and indeed, animal behaviour tends to be adaptive. Although many theorists mean only this when they use the term purposive to describe behaviour, a distinction seems desirable between what is adaptive and what is purposive in behaviour.

The names of H. Driesch and W. McDougall are associated with a view in the nature of teleology (*q.v.*), through which all animal behaviour of the type termed above adaptive is endowed with directive forces comparable with human volition. When a man behaves purposively, with the assistance of thought processes he strives for an end which he anticipates or expects. If all animals actually performed their adaptive behaviour on the basis of such a process, the theoretical problems of comparative psychology would be relatively simple! for the same type of solution would apply to all cases. But the danger exists that the teleological type of explanation may arise from the theorist's preconceived notions rather than from reliable supporting evidence.

5. Morgan's Canon. — A useful rule in scientific interpretation is the principle of parsimony, which may be stated as follows: of alternative expianations for a given phenomenon, choose the simplest, that requiring the fewest assumptions, provided it meets the facts adequately. This principle was stated for comparative psychology by C. L. Morgan *(An Introduction to Comparative Psychology, 1894)* as follows: "In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale."

The purposive type of explanation for the above examples would be that the Venus's-flytrap needs food, hence closes when touched by insects but not by inedible objects; the scallop recognizes the starfish as an enemy and closes its valves to avoid destruction; the octopus hides so that its enemies cannot see it and its prey may come close; the chimpanzee stacks boxes in order to obtain suspended food. Although at first sight these purported explanations all may appear simple. actually they are all complex and no one of them should be adopted until alternatives have been considered in the light of Morgan's canon. Each hypothesis assumes that the animal anticipates the consequences of one action or its alternative (*e.g.,* the scallop anticipates death if it does not close) and can weigh the possibilities somewhat as a reasoning man might. Humanlike capacities, such as understanding meanings, anticipating results and choosing between alternatives, are thereby implied by these purposive explanations. The evidence, however, favours a purposive explanation in only one of the described instances, the case of the box-stacking chimpanzee. W. Kohler and others have shown that this animal can anticipate success when jumping from the ground to suspended food, can understand the significance of a box as a means of reaching food and can solve problems by reasoning. Conversely, to account for the flytrap's reaction, only a simple reflexlike reaction to stimulation need be assumed, for the leaf closes when its delicate filaments are touched by a foreign object. As for the scallop, experiments show that it closes in response to any sufficient chemical effect, as to starfish broth released in the water nearby, but not to a starfish presented behind glass (visual control). In the case of the octopus, an intent to hide is excluded by J. A. Bierens de Haan's finding that the animal slips between plates of glass, where it remains in full sight, as readily as between pieces of slate. The simpler explanation consistent with the facts is that the octopus comes to rest when its body touches between surfaces, not because it understands hiding.

These cases illustrate the value of investigation in comparative psychology to test assumptions and reach an adequate explanation. Too frequently a purposive account rnerely names the gains of an activity (*e.g.,* protection, food) without clarifying the process involved. But a name alone is no explanation, and may in fact suggest an incorrect interpretation. Adaptive acts must be explained through evidence from investigation rather than by analogies between lower animals and man, for activities which lead to similar adaptive results (*e.g.,* both the leaf closing of the flytrap and the box stacking of the chimpanzee are "food-getting behaviour") may be very different psychologically.

6. Objective Attitude. — Early in the 20th century the view gained ground that careful experimentation on behaviour under controlled conditions should produce evidence improving psychological theories of animal capacities. A chief contribution of this movement to comparative psychology was its emphasis on objective techniques as against subjective procedures for evaluating and comparing the psychological resources of different animals. To appraise any animal activity, the psychologist must consider its nature and adaptive value, the situation and what factors in the species' organic make-up and in individual experience may have contributed to it.

The first task in comwarative studv is to discover the characteristic capacities and resources of behaviour in each animal type; the next is evaluation. It is not sufficient to assign positions in a series, classifying some animals as inferior and others as superior; the presumed inferiority or superiority must be clarified through comparisons. Neither the stability nor the adaptive efficiency of behaviour are as indicative of superior psychological status as are modifications of behaviour to fit new conditions. The principal weakness of a topical study is the implication that capacities such as "memory" are much the same wherever found. But any given capacity, such as learning, overlaps others and may also differ greatly according to the animal type involved. Higher animals do not necessarily repeat the make-up of lower animals with the addition of certain new abilities. Rather than a recapitulation of the characteristics of lower animals in the higher, research discloses similar properties and others which assume new psychological significance. These matters may be illustrated by passing in review some outstanding differences observed among various types of animals.

II. PSYCHOLOGICAL STANDING

1. Psychological Levels. — The earliest formal statement of psychological levels was the scheme of Aristotle, endowing plants with a nutritive faculty alone, the lowest animals with sensory faculties also, higher animals with an appetitive faculty also and man alone with a rational faculty. Descartes's ideas embodied a simpler scheme: a lower level of animals, viewed as automata, and man as the sole rational being, on a higher level. In 1905 R. M. Yerkes differentiated levels on the basis of functional criteria and experimental evidence: (1) discrimination, a general form of reaction, shown by lower invertebrates; (2) docility, or modifiable reactions, shown by rodents; and (3) initiative, or variability in reaction, shown by primates.

One objection to such systems is that they are speculative and may restrict the experimenter's viewpoint. Another is that they tend to oversimplify animal nature. even in the lowest animal forms, and encourage categorical interpretations of animal capacities. Distinctions of psychological levels are rejected by those who believe that capacities such as perception and learning exist in all animals. Experience, however, favours the concept of psychological levels to usefully represent transitions from lower to higher psychological stages and validly summarize knowledge of animal relationships, so long as complete discontinuities from level to level are not assumed.

2. Consciousness. — Attributing consciousness to any lower animal and speculating as to how it must feel to be that animal is a popular tendency which has its formal counterparts in speculative philosophy. When we see another individual behaving more or less as we do under comparable conditions. that being, whether man or lower animal, is assumed to have an experience similar to our own. Thus Montaigne, from occurrences such as the starting and barking of dogs in their sleep, thought that brutes must possess the power of imagination. Late in the 19th century when experimental comparative psychology began to develop, the prominence of introspective methods in general psychology encouraged a strong tendency to analogize consciousness. This tendency weakened in time, mainly through objective tendencies succeeding the failure of attempts to use consciousness as a criterion of animal mentality. The chief objections mere, first. that introspection. a method considered low in validity for human psychology, could not be valid for studying lower animals, which lack speech; and, second, that if inferences concerning the subjective aspects of even the simplest mental states in man are held doubtful, little justification exists for applying the method of anthropomorphic analogy to lower animals. In the words of M. F. Washburn (from *The Animal Mind*, 3rd ed., 1926, Macmillan Co.):

> We speak, for example, of an "angry" wasp. Anger, in our own experience, is largely composed of sensations of quickened heart beat, of altered breathing, of muscular tension, of increased blood pressure in the head and face. The circulation of a wasp is fundamentally different from that of any vertebrate. The wasp does not breathe through lungs, it wears its skeleton on the outside, and it has the muscles attached to the inside of the skeleton. What is anger like in the wasp's consciousness? We can form no adequate idea of it.

Comparative psychologists have thus come to favour objective procedures for understanding lower animals, and to mistrust analogies from human states when these stand alone.

A. Critical Points of Change in the Animal Series

1. Protozoans **and** the Concept of **"Simplicity."**—Protozoans frequently are termed the simplest animals. This cannot mean that their activities are few, for H. S. Jennings and F. Alverdes found that the reactions of the ciliate *Paramecium*, for one, are many and varied.

This organism is propelled forward, rotating about its long axis, by the beating of minute, hairlike cilia covering its ovoid body. When stimulated, it pauses momentarily, rotating narrowly or widely before continuing in a new direction, or backs away at an angle varying from acute to obtuse. Specific properties of the stimulus, particularly its intensity. may be critical; for example, weak contact typically elicits slight interruptions of forward movement, strong contact a pronounced backing reaction, and physicochemical properties of stimulation directly influence the extent and the duration of modifications in forward swimming. Although the protoplasmic changes underlying the many variations of ciliary stroke in these different reactions doubtless are biochemically complex, this behaviour is simple in the sense that it can be understood in terms of psychologically simple concepts. for a dictation of response by the physical properties of stimulation is the lowest order of psychological process.

Protozoan behaviour, nevertheless, is adaptive. When Jennings dropped a stream of carmine particles upon the disc of the attached trumpet-shaped ciliate *Stentor*, there occurred a series of reactions from a slight contraction of the oral disc to increasing general contractions which at length broke the animal free from the substratum. Jennings characterized these variable reactions to conditions of repeated stimulation as a series of "trials." More objectively considered, such behaviour is the product of protoplasmic changes forced by repetitive stimulation. At first only the funnel end reacts; then as internal excitation spreads, the stalk contracts progressively toward its attached base. Behaviour thus changes successively through a progression of physiological summations producing new results as they reach more remote localities. Although the notion of .'trials" emphasizes the adaptive aspects of these processes, it misrepresents the acts. which are forced by stimulation rather than arising as attempts to attain expected results.

This case illustrates how, in the simple psychological system of the protozoan, variable reactions widen an animal's adaptation to surrounding conditions. Jennings demonstrated that paramecia collect around a drop of acid in their medium not through direct approaches to the acid but because they first swim readily into the area. then recoil from the acid-deficient border zone on each encounter. Since, in the ciliates, stimulus changes typically interrupt forward swimming differently according to their intensity and other physicochemical properties, the organisms thereby can avoid injurious and approach beneficial agents in their environment. The adaptability of such reactions in unicellular organisms, through the gaining of optimal conditions thereby, stems from the persistence of variable swimming until conditions favour normal locomotion.

The status of behaviour changes in protozoans has been much discussed. As examples, amoebae, repeatedly exposed to bright light, put forth fever pseudopodia before each further reversal of direction; *Paramecium*, introduced successively into a capillary tube from uhich it can escape only by doubling around, reverses with increasing promptness. Some nriters consider such changes equivalent to the "learning" of higher organisms, pointing to graphic records of reduced time or movement in these cases. Others. conversely, stress the limited duration of such changes in protozoans, also that many of them have been duplicated (as by chemical treatment) without putting the organism through "trials." Thus. although F. Bramstedt reported that repeatedly cbmbining light (generally ineffective) with heat (generally avoided) caused *Paramecium* to avoid light in tests, J. B. Best found that light avoidance came about in *Paramecium* through experimental exposures to high temperature alone. Best therefore interpreted Bramstedt's results not as "conditioned responses" but as hysteresis, or a general sensitizing of the protoplasm to the action of one physical agent through the effect of another. Perhaps the most relevant point favouring the latter, simpler interpretation is that, the described changes soon disappear without evidencing any lasting alteration of the species behaviour pattern.

2. Psychological Limitations of Lower Invertebrates.—Significant for determining the psychological level of an animal is its behavioural organization. Perhaps least endowed in these respects are lon multicellular animals such as adult sponges. The sponge is a bottom-attached organism of the colonial type that feeds by filtering organic substances from water drawn through chambers in the body wall. The reactions of sponges are simple, local and sluggish. As G. H. Parker *(The Elementary Nervous System,* 1919) found. sponges lack integration among their parts except that resulting from structural unity and a crude transmission of mechanical impulses through certain primitive cells around the opening to the body cavity, combining sensory and motor properties. Such limitations may have characterized the early ancestors of multicellular animals prior to the appearance of neural tissue.

In the coelenterates, behavioural organization has improved so that a measure of integration exists in activities such as feeding, locomotion and withdrawal from intense stimulation. These gains were found by G. J. Romanes and by Parker to be attributable to a generalized conduction system. with a nerve net. a continuous conduction network permeating the body wall and transmitting impulses from specialized sensory cells to specialized muscle tissue. Activities here, although far better integrated than in sponges, are still relatively sluggish and considerably below the level of cephalopods, for example. One limitation is in the low-grade centralization of the conduction system, which distinctly handicaps behavioural organization.

Activities are better integrated in echinoderms such as starfish and sea urchins. In normal behaviour, local activities are so effectively combined that J. von Uexküll, who investigated the neurophysiology, was led to characterize the echinoderm in action as a "community of reflexes." In a reflex, stimulated sensory cells transmit impulses to association cells in the neural system. which arouse muscular contractions. Thus, the tube feet. small fingerlike muscular structures capable of adhering to the substratum by their terminal sucking discs, when stimulated lightly, bend toward the affected side through one muscular action; when stimulated intensely, they bend away through another action. An appreciable local autonomy is indicated by the fact that the characteristic echinoderm structures, tube feet, pedecillariae (nippers) and spines, when cut from the animal and appropriately mounted. react to stimulation much as before. To be sure, throughout the animal series, reflexlike actions enter into the normal functioning of internal organs (*e.g.,* the vertebrate heartbeat), controlled reflexly in a more or less automatic manner. Even in mammals, reflexes may intervene in general behaviour, as in scratching or sneezing, but with a very different significance than in loner invertebrates. For the latter. the community-of-rcflexes concept has some validity for a behaviour in which somewhat autonomous local activities are combined differently according to the conditions of arousal.

Yet the behaviour of lower invertebrates such as coelenterates and echinoderms is more than a chain-reflex combination of functions, as sense organs and motor structures are linked functionally together by the nerve net. Thus, soon after pedecillariae have caught prey, the tube feet extend, attach and "walk" the object toward the centrally located mouth. which meanwhile everts and folds around the victim. The simplest nerve nets (as in the coelenterate *Hydra)* have a minimal polarization related to the growth gradient. and conduct according to the strength and localization of external stimulation without strict directionality. Such nerve nets exemplify the function of primitive conduction systems, joining local operations without specifying the behaviour pattern. Although in mammals nerve-net functions are visceral and local (as in co-ordinating intestinal activities in digestion), in the lower invertebrates nerve-net correlation is the main agency unifying behaviour.

Echinoderms advance materially in behavioural organization as compared with coelenterates. A more versatile integration of local function exists in the righting response. aroused when the animal is turned on its back. In the inverted starfish, with previous stimulation and handling equalized, two or three rays twist about, and when the ventral surfaces of these rays touch the ground, tube feet progressively closer to the central disc attach. These rays thereby swing the body of the starfish, overbalance and right it. For this reaction to occur. it is necessary that the rays of one side become dominant.

A. R. Moore demonstrated that this organization normally depends on impulses through the nerve ring interconnecting the radial nerves of the five arms. When this nerve ring is sectioned, all rays attach, behaviour is unco-ordinated and righting occurs slowly and abnormally. Through nervous impulses, therefore. the normal unitary behaviour of echinoderms involves the temporary subordination of certain local activities to others dominating general action. The studies of J. E. Smith on the starfish nervous system reveal new complexities, including ganglion-cell mechanisms involved with the nerve net, advancing behavioural organization beyond that of the coelenterates.

An improved organization of behaviour thus enters with the subordination of local, reflexlike functions to wider patterns, as when scratching is inhibited as a dog sees food. The local activities themselves are then not only more elaborate and diversified. as in the reflex-cleaning activities of insects, but also better related to other behaviour. Echinoderm behaviour is more than a community of reflexes; sponge behaviour is far less.

Although echinoderm adaptive activities are impressive, they are sluggishly performed and their level of organization should not be overestimated. Jennings endowed the starfish with the capacity to learn, on the basis of tests in which individuals shortened the time required to right themselves. One pair of rays was prevented from attaching by a glass rod used to disengage the tube feet from the substratum, and after 180 trials these arms attached less readily than before the trials. Although Jennings interpreted this as "habit formation," Moore produced similar results merely by rubbing the tube-foot surfaces of particular rays with a glass rod or treating them nith weak acid. He therefore attributed Jennings' results not to "learning." or changes in central organization through experience, but to injury of restrained arms through continuous friction with the rod which altered sensory and motor function in further trials. These results are therefore equivalent to the impairment of action through motor fatigue. or its reduction through sensory adaptation or injury, not ordinarily classed as learning in higher animals.

B. Cephalization and Centralized Control

1. Functions of a Simple Brain.—Improvements in both organization and capacities of behaviour appear in norms, mollusks and particularly insects. Basic advances are illustrated in a simple form in the earthworm Whereas echinoderms are radially structured, and any of the body sections can lead in locomotion or other activities according to circumstances. worms have an anterior specialized end, which is not only the most sensitive and mobile of all body sections but also the dominant one by virtue of a superior ganglionic centre or brain. Cephalization, or head dominance, improves organization basically, nidens the range of environment and action. and carries behavioural organization beyond the conditions prevailing in protozoans. coelenterates and echinoderms. The significance of specialized head receptors and a brain for efficient behaviour in a marine norm is indicated. after the brain has been destroyed, by irregular crawling about, by turning much more clumsily on contact and burroning less readily than a normal worm.

The animal after operation cannot extend from its burrow (on chemical stimulation) and seize prey as does the normal individual. Removal of the worm's brain, although not preventing normal reactions altogether, materially reduces their directness and precision. This is therefore a primitive type of brain, a collector and a transmitter of impulses from the most sensitive parts of the organism, presumably also an amplifier, but not a major organizing centre. The brain of insects, in contrast, is an indispensable organizing centre. Although a bee or ant with its brain destroyed may stagger about for a time before dying, with a degree of locomotor coordination, only scattered reflex acts such as stinging occur and the complex normal repertory (*e.g.,* foraging, building) is gone.

2. Advances in Orientation. — Regulation of locomotion and way finding under changing external stimulation improves in worms, mollusks and arthropods over its status in lower invertebrates. J. Loeb emphasized that the evolution of a specialized anterior and bilateral symmetry opens the way for new patterns of orientation in space. These improvements admit more appropriate changes in adjustment to external stimulation, as when an octopus turns toward the side on which a crab is seen but does not pursue if the object moves too swiftly. At this stage the crude energic properties of stimulation are dominant, as when a worm or snail approaches the source of a weak chemical but withdraws from the source of an intense stimulus, with variable behaviour at intermediate concentrations. The directive effect of stimuli of different intensity acting on receptors of the opposite sides of the body is shown by experiments in which a fly with its right eye covered turns toward the right under strong light but toward the left under weak light.

Progress in the organization and variability of orientation is indicated from the Norms to insects, depending on the complexity and specialization not only of receptors but also of the central nervous system. The octopus, for example, has eyes much better fitted than those of marine worms for general vision, with accommodation to distance, and can inhibit its dash at a crab until within range. Social insects such as ants and bees have compound eyes, admitting versatile reactions to visual movements as well as movement with reference to changing visual stimuli. Although the evolution of orientation in space involves receptor specializations, advances in this capacity are especially correlated with the nervous system. Operative longitudinal sectioning of the brain introduces progressive impairments in the orientation of animals from worms to insects. Z. Y. Young demonstrated that the octopus, through experience, can master conditioned responses to a crab, or to visual forms experienced with food. In such functions the octopus, far superior to worms, loses correspondingly much more through brain operations. Although in the lower'invertebrates quantitative aspects of stimulation such as intensity, size and rate of change basically control the timing and precision of orientation, in the cephalopods and insects, as compared with the worms, the patterns not only become more complex but also more changeable according to experience.

3. Simple Learned Modifications. — Clear evidence for learning appears first in the worms, in which conditioned responses have been demonstrated. H. B. Hovey found that, although light ordinarily keeps the marine flatworm *Leptoplana* active, presenting a light together with head contact (which stops movement) trained the worm within 20 five-minute periods to stop moving in light. Comparably, M. Copeland conditioned the marine worm *Nereis* to emerge from a tube in response to iight or to dark, whichever condition had been paired with meat juice in training. A more complex habit was acquired by earthworms in Yerkes' experiment, in which turning to the left at a T junction led to electric shock, to the right into a dark box. Within 160 trials some of the worms regularly turned right on reaching the junction. This habit does not depend on specific sensory or muscular changes; when L. Heck reversed the electrodes and dark box after the habit was learned, worms which required more than 120 trials to acquire the right turn now reversed it within 75 trials. Such modifications indicate a basis in central nervous organization rather than in peripheral function. No learning comparable to this adjustment in worms has been demonstrated in coelenterates or echinoderms.

The organization of behaviour is greatly enhanced by a capacity for learning. Worms, through simple learned changes, can alter their normal activities, though not as much as higher invertebrates. In learning, illustrated by the conditioned response. through experience a specific reaction is given to a stimulus previously incapable of eliciting such behaviour. In Copeland's experiment, light (the conditioned stimulus) initially did not bring the worm from its tube. Meat juice (the unconditioned stimulus) mas effective, however, and pairing these two stimuli brought for light a new control over reactions. In the worm's T-maze behaviour, through comparable changes, stimuli near the junction control the right-turning reaction, rendering contact with the electrodes unnecessary. An adequate basis for such changes is afforded by a central nervous system with ganglionic centres and interconnections admitting appropriate new sensory-motor organizations. The mere presence of ganglion cells is not enough, for the starfish despite such equipment seems incapable of true learning. In arthropods, neural evolution admits further advances in the learning capacity. See also NEUROLOGY, COMPARATIVE.

III. EVOLUTION OF BEHAVIOUR

1. Behaviour and the Processes of Evolution. — Modern science interprets behavioural differences in animals, from protozoans to man. as the outcome of long and complex evolutionary processes. The role of behaviour in evolution is by no means obvious, however, as inferences from fossils must be validated by evidence on the relationships of structure and behaviour in existing organisms and these, rather than forming a linear series, represent different branches of a complex related system of which many sections have vanished. Also, the relations of structure and behaviour not only resist unraveling, but seem to have very different properties in the principal types of existing animals. Despite these and other obstacles, behaviour has clearly evolved.

There is little question that behaviour has played a critical and major role in organic evolution. Efficiency in widely different activities, from foraging to defense and shelter getting, has much bearing on the success of reproductive processes and hence on species survival. In many ways, behaviour must have influenced intimately the selective processes underlying evolution.

The initiatory mechanism for evolutionary change, biologists conclude, involved mutations in the chromosomes, effected through the action of radiation on the organism through chemical, mechanical or other extrinsic agencies. Mutations (see EVOLUTION. ORGANIC) may have involved any aspect of structure in the organism, thereby altering behaviour in diverse ways from the specific to the general. Widespread effects of structural mutations on behaviour probably were commoner in higher animals such as mammals, with more complex interrelationships between structures and functional systems, than in phyletically primitive organisms such as echinoderms. As further mutations affected existing structures, modifying function from its previous basis, behaviour may have changed in different directions from the patterns of the principal ancestral types.

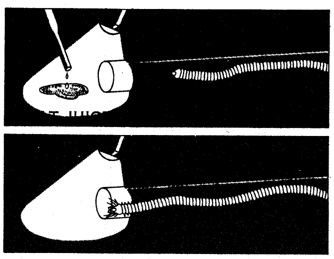


FIG. 1.—COPELAND'S STUDY OF CONDITIONING IN THE MARINE WORM NEREIS

At first, light is ineffective, but after having been combined several times with meat juice, light alone brings the worm from the tube

According to conditions, success in behaviour affecting reproduction must depend on what responses are made both in everyday existence and in critical or marginal situations. Because behaviour results from the interactions of functional systems (sensory, neural, secretory, motor and others), a mutation affecting structure locally can often influence functions in the organism a a whole. For example, a more sensitive eyespot may improve directed responses to light so that orientation and foraging become more efficient, and adding a lens to the system widens the range and efficiency of adaptation still more.

Structural changes through mutations therefore admit behavioura! specializations giving surviving species distinctive habitats or "niches." Within any period, the relative success of behaviour affecting reproduction determines which strains and species can adapt to appropriate niches and survive and which types perish through mutations leading to detrimental or inefficient behaviour. As accumulating mutations favour diversity, successful animal types tend to expand into lineages differing increasingly in their adaptive patterns. The survival of a species then depends on its possessing a set of genes contributing under appropriate conditions to the development of a behaviour pattern adequate to maintain the reproducing population in its species niche.

2. Evolution, Structure and **Behaviour.**—Structure, physiology and behaviour are intimately related in all animals, and the principles of evolution therefore apply to all three. The course of evolution does not reinstate earlier conditions, but transforms and adds to them in new phyletic settings. The fate of species and species relationships in evolution depends primarily on the relative efficacy of structures rather than on purposive considerations, which involve a basic misconception of species-typical acts and their dependence on structures. Thus a dragonfly which ordinarily lays her eggs on water may lay them on a freshly tarred roof, not by mistake, but because she responds to the sensory characteristics of any shimmering surface.

At early stages in evolution, structure bears rather directly on behaviour, favouring stereotyped patterns. Invertebrate activities thus are dominated by the functional characteristics of specific sensory, motor or other equipment or of particular physiological conditions. These relationships can be misunderstood, particularly when they are complex. Thus J. H Fabre believed in an "inflexibility of instincts" in insects. attributed to inherited nervous patterns, arguing from cases in which performance presumably could occur only once, as he reported the callow mason bee able to escape only once from the paper cell of pupation. But L. Verlaine found that in this case the critical matter was strength of the jaws, for when the cell wall was not too tough, the bee could escape more than once even on the first day. Dependence of behaviour on particular organic conditions is ilicstrated by the fact that spiders can repair their torn nebs or not according to the supply of secretion in their different silk glands. As we shall see. structure is much less directly related to behaviour in mammals.

Throughout evolution, and particularly at times of crisis and other turning points, there evidently was a premium on mutations increasing the complexity and functional relationships of structures favouring nider and more versatile environmental adjustments. Significant sequences thus are indicated, as when local specialization of the skin of early vertebrates added a lens to the primitive eye, increasing the efficiency of space perception, which increased still further when specializations in retina, eye muscles and brain admitted binocular vision and an augmented depth effect.

New adaptive levels were achieved in evolution not just through added complexity of existing structures affecting function but through qualitative changes as well. In a succession of adaptive radiations from the acellular to the multicellular, and from the primitive vertebrate ancestor to the reptilelike mammalian ancestor. basic changes occurred in the conduction system with important consequences for behavioural organization and for new behaviour. The result presumably was not so much that mechanisms of lower levels were repeated on higher levels as that they were modified in relation to the new context. Accordingly, it is probable that in vertebrate evolution from fish to man the "old brain" was not merely retained in a more complex form, but was progressively repatterned correlatively with increasing cortex In mammals, as compared with invertebrates, not only are structural mechanisms much more versatile in their functional relationships but limitations of action by specific structures relax increasingly, widening the breadth and plasticity of behaviour in its bearing on species adaptation.

3. Ancestry and Behavioural Resemblance. — In the animal series, behaviou: patterns tend to exhibit similarities in proportion to the degree of phylogenetic relationship and dissimilarities in inverse proportion. All animals are similar in the general sense that behaviour is adaptive and that each type, in characteristic ways, behaves so as generally to attain beneficial and avoid injurious conditions. This similarity depends on the fact that all species have mechanisms favouring approach to stimuli of weak intensity, withdrawal from stimuli of strong intensity. In phyla from bacteria to man, however, these reactions differ in their structural bases and in their ontogeny.

In principle, existing animals represent parts not so much of a linear series as of a multibranched system, hence discontinuities as well as continuities prevail among them. Body form exerts a basic influence on general type of behaviour, as in the head-first progression and bilaterality in orientation of all bilaterally symmetrical animals. Superimposed on such general patterns are disparities among groups from phyla to species, roughly proportional to ancestral affinities.

Striking differences among the specific adaptive patterns of surviving phyla show that the principle of continuity in evolution must be qualified in view of different branch lines in ancestry. For example, arguments, on grounds of evolutionary continuity, that a learning capacity exists in protozoans analogous to that of mammals oppose the fact that since unicellular and multicellular animals diverged in remote geologic times they have differed progressively, and the advent of mechanisms basic to the learning capacities of multicellular organisms may well have postdated the common ancestry.

Because structure may influence function very differently on different animal levels, both in the relative directness and in the nature of its effect, the principle of structural homology (*i.e.,* basis in common ancestry) cannot be generalized directly to behaviour. A different reservation concerns resemblances through convergence, or adaptations evolving independently, whereby similar niches are occupied or similar activities arise. Owls and bats, for example, have analogous adaptations for flight and the nocturnal capture of prey; termites and ants have similar patterns in nesting and other social activities.

0. Heinroth, particularly. and later K. Lorenz stressed behavioural characteristics as an additional clue to evolutionary relationships. Thus similar activities in closely related species often exhibit gradations evidently corresponding to the relative recency of the species. For example, in the mating patterns of empid flies prior to coupling, in one species the male presents to the female a freshly killed insect, in another species he presents the booty within a cocoon he has spun and in still another he presents only an empty cocoon. The last pattern is presumably the most recent.

Striking similarities, not convergences, are often found between related species living in widely separated habitats, as, for example. both English and South American thrushes line their nests with mud Comparisons are complicated, however, in the similar patterns of related species which are sympatric (*i.e.,* live in the same habitat) by the rise of specialized differences through competitive processes influencing natural selection. Thus two closely related species of army ants in the genus Eciton, sharing the same tropical forest habitat. differ strikingly in the patterns of their predatory raids. with colonies of one species pillaging in large swarms, colonies of the other in complex systems of columns. These species also differ in the booty they capture, with the first taking mainly hard-bodied arthropods, the second soft-bodied brood of various insects, and significant differences are also found in the properties of their cyclic nomadic acrivities.

4. Phylogeny, Ontogeny and "Instinct." — The traditional view that ontogeny recapitulates phylogeny, questioned for structure by G. R. de Beer and others, is even more doubtful for behaviour. What individuals in each species inherit are their chromosomes, influencing ontogeny in species-characteristic ways provided development occurs under species-typical conditions Under other extrinsic conditions, different phenotypes (developmental forms) appear, diverging from the species-typical pattern not only structurally but often also behaviourally. Species-characteristic behaviour patterns, considered in relation to species genetics, constitute the problem of "instinctive behaviour."

A useful way of stating this problem is to say that although heredity influences all behaviour in all animals, its influence is more direct in some animals (evidently the more primitive) than in others and may be very different on different phyletic levels. This interpretation contradicts the traditional view that the "instinctive" and the "learned" may be clearly distinguished in animal behaviour, with the latter increasingly prominent in higher animals. It is more likely that behaviour evolves through new and increasingly complex reorientations, with the old rebuilt and extended in terms of the new, than through the replacement of the "innate" by the "learned."

On each phyletic level, striking differences appear in the relationships between genes, species-typical structures and physiology, situational conditions at successive developmental stages, and the predominance of species-typical behaviour as against genotypical patterns. In the sense that the activities of invertebrate animals are more directly dominated by structure than are those of mammals, invertebrate behaviour is more instinctive. Accordingly, agencies mediating among genes, organic mechanisms and behaviour are fewer, with less numerous and less involved interrelationships, in protozoans and sponges than in insects, with insects in turn below rodents and rodents below mammals. In this succession, the role of heredity in behavioural development is not decreased, but rather becomes increasingly indirect and plastic as further and more diverse intervening variables are added. Consequently, contrasting behaviour patterns arise which are not only increasingly complex but also qualitatively progressive. For understanding these differences, the classical nature-nurture dichotomy is not only too simple but also misleading. Psychological superiority must have emerged in higher animals not through less nature and more nurture but through increasingly complex and qualitatively new properties of nature and nurture, inextricably interrelated in development in ways characteristic of the level.

As an example, function varies strikingly with age both in invertebrates and in mammals. In honeybees, G. Rosch attributed such differences to growth-conditioned organic changes. Young workers emerging from pupation tend to specialize in feeding larvae, but when the salivary glands atrophy at about the 15th day the main function becomes comb construction. The wax glands seem influential in the latter work, as building drops off sharply when these glands end their active phase at about the 25th day. Foraging outside the hive then typically begins. In mammals, however, ontogenetic changes in function usually cannot be correlated readily with specific structural changes.

It is therefore probable that the relationship of behaviour to survival, always important in evolution, is very different on various phyletic levels. As it is realized that assumptions of innateness in apposition to the acquired can explain no activity, increasing emphasis is placed upon the need for analytical investigation.

Although geneticists often state that the genes impose species-characteristic limitations on development, even after the mid-20th century this generalization lacked proof for behaviour. Actually, the influences of the genes are not direct or exclusive in determining behaviour in any animal but are exerted through diverse interrelationships between organism and developmental medium. The gaps between genes and somatic characters are great; those between genes and behaviour, which are far greater, can be bridged only through investigations directed at disclosing the intervening variables and their interrelationships.

In all phyla, the functioning of organic factors underlying the rise of instinctive activities requires a developmental situation typical of the species. Frequently, certain conditions of stimulation (*i.e.,* experiences) can be detected as critical for the development of the species-typical pattern. Thus J. E. Harker found that the normal day-night activity rhythm of the adult May fly does not appear when developing individuals have been subjected to continuous light or darkness, but only when eggs or larvae have been exposed to at least one daily light-dark cycle. Comparably, species patterns such as the spinning of characteristic cocoons by caterpillars result from a close relationship between structural growth and features of the developmental situation. G. van der Kloot and C. Williams found that if a Cecropia larva cannot attain an upright posture against a support such as a twig, no cocoon is spun. Instead, the thread is arranged, as, for example, a cone around a peg or a sheet lining a balloon, according to prevalent physical conditions. In the parasitic ichneumon fly *Nemeritis,* responses to the host upon which eggs are laid are influenced by larval experience, as such responses can be modified by changing the type of insect on which the individual feeds as a larva. indicating the possibility that conditioning influences insect development, although in a secondary and obscure role, is evidence that the act of following odour trails arises in many ants on the basis of individual habituation to nest chemicals beginning as early as the period of larval feeding.

In lower vertebrates, species-typical behaviour such as mating and nesting have the characteristic of stereotypy, as in insects, but with a different aspect relevant to the level. The claim of Lorenz and others that certain critical acts called "instinctive movements" arise through innate neural patterns determined isomorphically by the genes lacks effective support. Rather, Z. Y. Kuo, from his significant studies on pecking in chicks, concluded that intimate relationships exist between factors in growth and in the extrinsic situation. Comparably, D. Lehrman found that adult ringdoves experimentally injected with the hormone prolactin did not feed their young. Instead they underwent organic changes such as the production of "pigeon's milk" by the crop and an increased thoracic sensitivity, contributive to action although not specific action. The characteristic pattern of feeding the young did not occur unless the adult had experienced a sequence of reciprocal stimulative exchanges with nestlings. Therefore, although such patterns are species typical and involve genetic influences, they are not predetermined neurally, but result from a development in which organic processes interact intimately with situational factors. In vertebrates, the development of behaviour involves more diverse and plastic relationships between organic and extrinsic factors than in any of the invertebrates.

5. Ontogeny of Vertebrate **Behaviour.**—Vertebrate behaviour patterns characteristically exhibit essential differences from those of invertebrates, evidently due not only to organic differences basic to perception and motivation but also to the potentialities of a nervous system with a fundamentally different central pattern. Although certain functions, such as locomotion and equilibrium, are well developed even in fishes, in mammals these too may vary according to the conditions of individual development.

6. "Maturation."—The concept of maturation, emphasizing the role in behavioural development of organic changes through growth and differentiation, has been focused by many upon the nervous system. In the study of G. E. Coghill on the salamander *Ambystoma,* successive stages in action were observed with correlated histological changes in the nervous system. In this tailed amphibian, an early nonmotile stage was identified when, with sensory surfaces still unconnected nervously with muscles, the only action was an anterior bending to the side of direct muscular stimulation. At about 30 hours of age, the head bent away from the stimulated side, paralleling the appearance of crossed nerve connections from the skin of the head to muscles on the opposite side. Then S movements of the body and, later, rapid swimming movements were correlated with further growth changes in the nerve tube. Coghill concluded that in the development of swimming in this vertebrate, the status of neural growth is critical. This conclusion found support in the research of L. Carmichael, who immobilized salamander embryos with Chloretone during the period in which swimming normally appears, yet found that when later released from the drug, these animals apparently swam as well as undrugged normal specimens. The conclusion that organic neural growth alone is sufficient for development of normal swimming in this amphibian is tentative, however, in view of evidence obtained by A. Fromme. His results indicate that opportunities for action and stimulation at certain stages in development also contribute to the swimming pattern, since embryos immobilized then, when later released from the drug, swam less well than normals.

Maturation, as defined; seems basic to the behavioural development of lower vertebrates from fishes to birds. The concept needs revision, however, in view of evidence cited below, bearing on the interaction of processes within the developing organism and between organism and external situation, characteristic of growth stage but extending beyond the specific bounds of growth and differentiation.

Although the development of behaviour patterns is often held to depend on an innate central neural control, this question is still controversial. Certainly. neural growth limits behaviour at any stage (*e.g.*, the salamander cannot bend its head until crossed neural connections have grown). Other factors also are involved. The characteristic head lunge of lower vertebrates probably requires sensory maturation as well as neural maturation. Several such mechanisms evidently contribute to the adult lunging response, which, as in many fishes. amphibians and birds. occurs on weak stimulation. Thus the characteristic lunge is elicited by objects below a certain size if these are in motion at not too rapid a rate. Presumably, in lower vertebrates, tissue growth promotes adult patterns such as feeding and mating in distrete mays as through sensory-threshold factors in visual-movement responses. To understand the ontogeny of behaviour, however, the study must be broadened. Although, for example, gonadal hormones are basic to the appearance of mating behaviour in all vertebrates, evidence suggests that they may function in diverse ways beyond their possible neural effects, as by increasing local sensitivity.

7. Factors in Organization. — Against the traditional predeterministic view that instinctive behaviour is organized neurally on a native basis, the alternative epigenetic view holds that such behaviour develops through co-ordinations of many organic resources in the organism interacting with the developmental medium. Experience, definable as the effect of stimulation on the organism, participates in all development, and in diverse forms, including learning.

From the same genotype (see HEREDITY), variations in the conditions of development may result in phenotypes differing behaviourally as well as organically. Under different temperature conditions in development, M. H. Harnly obtained fruit flies which were flightless, limited and eccentric, or species typical in flight; and K. Moore in a comparable experiment obtained rats differing in both body form and learning ability.

For the organization of instinctive behaviour, evidence for invertebrates and for vertebrates shows that species-typical factors both of maturation and of experience in the standard developmental situation are essential. Certain poecilid fishes, raised apart from species mates in neutral surroundings in which, for example, they never saw their own reflections from the water film or other surfaces, scored much lower than normals in mating tests at maturity. That the role of experience may involve learning in amphibian larvae is suggested by the fact that N. L. Munn found the early swimming stages of certain amphibians capable both of being conditioned and of learning a simple T-maze habit.

Although the roles of maturation and of experience are fused in all behavioural development and resist experimental separation, certain generalizations are possible. Thus organic factors seem relatively more determinative of behavioural development in lower vertebrates than in mammals. In the former, accordingly, naive responses to stimulation are less readily modified through experience than in the latter. The lizard Lacerte, studied by H. Ehrenhardt, gave its forward (feeding) lunge most readily to the movement of figures such as circles with even outlines, least readily to figures such as crosses with irregular outlines. When a circle was presented with a quinine-treated meal worm, a cross with an untreated meal worm, initial responses were virtually unmodified aithin 850 trials. In comparison, mammals such as rats normally change their initial responses readily according to the conditions of training. In lower vertebrates, discrete properties of the stimulus such as movement. size and brightness characteristically dominate behaviour, evidently as a result particularly of correlated factors in sense organs and nervous system. N. Tinbergen and others use the term "releasers" for stimuli which typically elicit certain types of response; however, this concept has been criticized as too simple and as obscuring ontogenetic processes. For example, the gaping (mouth-opening) response of nestlings in passerine species such as thrushes is first aroused by mechanical stimulation, as by vibrations of the nest, later by the movement of any object (*e.g.*, a black disk) of sufficient size presented above the nest edge. The facts suggest that, through conditioning, naïve responses (*e.g.*, to nest vibration) become attached to specific features of the external situation, such as first the parent bird's bulk at the nest edge, then the parent's head. The organization of such responses in birds is a complex matter in which experience may figure in various ways.

In this sense, birds have a far more extensive and complex repertory of instinctive, organically determined activities than have mammals. In the organization of activities such as migration, the role of maturation seems predominant. that of experience secondary. The investigations of W. Rowan and others show that the northward spring migration of birds such as juncos is set off through the excitatory effect of internal changes (*e.g.*, pituitary and gonadal secretions) caused by a progressive increase in daily illumination. How these factors relate to those influencing the direction and the course of migration (*e.g.*, temperature gradient; angle of the sun) requires further investigation.

For activities such as homing, in contrast, the influence of organic factors, although undoubted, is difficult to discern; the role of experience, clearer. Whereas the studies of E. Schiiz and others show that some species on release in strange territory may be oriented as in migration, homing in birds such as the pigeon is known to be strongly dependent on experience with landmarks and topography.

The organization of species-typical activities such as pecking in fowl is known to have a complex individual history, starting in the egg. Kuo showed that, with maturation in sensory, nervous and muscular tissue, the embryo's head lunge to touch modifies under the influence of self-stimulation through its own actions. Crude conditioning processes are evident before hatching. Shortly after hatching, the significant activities of the head lunge, bill opening and closing and swallowing are crude and essentially separate. Head lunging occurs, however, on the appearance of small. moving objects and (limited by maturational properties such as muscular strength) within a few days an organized and discriminative pecking at edible objects comes about. Thus it appears that whereas maturation dominates the development of individual components of pecking such as the head lunge, experience factors are required even for the early appearance of these components and are heavily involved in organizing the eventual efficient act. The influence of maturation is emphasized by the fact that, when chicks are kept in the dark and hand-fed for varying times after hatching, the process of improvement leads sooner to efficient pecking than in normal chicks; *i.e.*, experience is more advantageous when strength and other organic factors have advanced. The influence of experience is emphasized by the fact that chicks fed artificially for longer than two weeks after hatching learn only with great difficulty to peck at food, since they have learned to feed otherwise than through pecking. The greater predominance of stereotypy in lower vertebrates than in birds seems attributable to the greater influence of experience in the behavioural development of the latter.

8. Nervous Systems and **Behaviour.**—An important approach to understanding psychological differences between lower animals and mammals is through the role of the nervous system. Although in worms the appearance of a dominant brain permits definite advances over the radial pattern of the starfish, this centre is of a low order, mainly a transmitter rather than an organizer. Insects, much advanced in organization, still reflect a strong influence of sensory and other local components in behaviour.

As comparative neurologists have shown, the anterior nervous system of lower vertebrates is not only more sparsely supplied with interconnections than is that of mammals, but the brain exerts only a rudimentary control over lower centres and is not equipped to influence general behaviour in terms of numerous changing sensory factors in a situation. The olfactory system, dominating the forebrain, and the visual system, in the midbrain, are best equipped for integrations within the status of reflexes. Such characteristics go far toward accounting for the characteristic stereotypy of behaviour in these animals and for their shortcomings in modifying naïve responses based on specific stimulus aspects such as intensity.

With the appearance of cerebral cortex, correlation among the principal centres of the vertebrate brain improves greatly. Cortex, although restricted in reptiles to a small area in the upper forebrain and obscure in birds, covers the entire forebrain in mammals. Cortex interconnects the principal centres of the nervous system both directly and indirectly, admitting new types of organization which override specific sensory effects and local activities according to the animal's experience. The evolution of cortex, particularly. admits for mammals their psychological superiority.

IV. PSYCHOLOGICAL SUPERIORITY OF MAMMALS

In mammals, from marsupials to man, the psychological limitations of lower animals are overcome progressively. Through more versatile capacities and better organization of behaviour, the world of the individual increases in content and in variety. The general superiority of mammals shows itself particularly in their resources for developing new behaviour. For example, reptiles, although they can be tamed so that they become docile, do not form attachments or take the initiative in play with the person who satisfies their needs, as do mammals.

A. Development of Behaviour in Mammals

1. Maturation. — Correlated with the longer developmental period typical in mammals, their resources admit a greater weight for experience and a greater variety of behaviour appropriate to changing circumstances than in inframammalian animals. In general, higher mammals require a longer time than lower to develop. Accordingly, whole-body adaptive behaviour appears earlier in lower mammals, which often fend for themselves sooner after birth than the young of higher mammals. For example, the young opossum, just 12–15 days after development begins, crawls from the mother's cloaca over her abdomen to the pouch, moving along by a reflex hair-clutching and forelimb progression. At 60 days it leaves its nipple in the pouch on occasional excursions to the outside, where it runs and climbs about. The young of ungulates, such as the goat, are capable of upright progression shortly after birth; the human infant, in contrast, is incapable of self-progression until it crawls at about eight months of age.

Most mammals are relatively more immature at birth than the young of lower vertebrates, and hence cope less effectively with their environments. Young marine turtles, on emerging from the egg, crawl toward the moonlit sea (in response to reflected light). Newborn kittens and puppies, however, accomplish only a highly variable, nonvisual locomotion to the mother, and in specific activities have little more than crude sucking and righting responses. These mammals improve very slowly from birth in orientation and locomotion. At one week (before vision enters) the kitten returns slowly and inefficiently to the nest when set down nearby, mainly requiring tactual guidance. Although in the appearance of crawling in kittens and walking in human infants maturation is basic, limiting the rate of development somewhat as in lower vertebrates, in mammals the factors of experience have increasing weight.

Man's adult behaviour pattern appears later than that of any other animal and is the least specifically influenced by maturation. When a chimpanzee and a human infant were raised from birth in the same household, with similar treatment, the advantages of more rapid maturation were at first all in the chimpanzee's favour. At five months it exceeded the average one-year performance level of human infants in climbing, manipulating objects and responding to companions. Although the chimpanzee's motor superiority continued, soon the human infant excelled in other respects. At one year, in acquiring word sounds, object meanings and social meanings, the human infant far surpassed the chimpanzee. Man's psychological superiority over other animals rests on his greater capacity for profiting from experience and not simply on his longer infancy and childhood.

2. Genetics of Behadour. — Although genetic factors underlie ail animal activities, heredity seems to influence behaviour more directly in the lower mammals than in the higher. Sexual patterns, for example, are less stereotyped in chimpanzees than in rats, as a result of evolutionary advances in the primate cortex which admit new relationships between structure and behaviour and make experience and learning more influential.

The study of correlations between genetics and behaviour, in psychogenetics, offers techniques for comparison. For example, the trait "wildness" appears to be dominant in the offspring when the gray Norway rat is crossed with the docile albino rat, and the behaviour of future generations as well as that of backcrosses of the hybrids indicates the opposed influence of different gene combinations (see Genetics). With this knowledge the organic basis of such behavioural differences can be studied in different strains. The increasing difficulty, as maturity approaches, of taming the young of genetically "wild" strains of rats, much greater than in domesticated strains, indicates that glandular secretions contribute to strain differences of this type. Supporting evidence is found in the fact that the adrenal glands of wild strains are larger than those of domesticated strains.

3. Influence of Experience. — Traditionally, species-typical activities appearing soon after birth, in isolated animals, have been considered inborn. But experience is not excluded thereby, as conditioned-response learning is demonstrated prior to hatching in certain birds and before birth in certain mammals, including man. Furthermore, under equivalent developmental conditions, experience may influence different individuals similarly and its role therefore may be overlooked. For example, Kuo found that the appearance of mouse-hunting behaviour in kittens depends upon a situation in which organic equipment is utilized. The kitten's first pounce is not "hunting," but darting toward a moving object. This response resembles the forward lunge of certain lower vertebrates, except that in the kitten the new stimuli that enter and the patterns that eventuate are largely matters of experience. In the typical feline environment, pouncing soon leads to tasting blood, since the kitten inherits sharp claws capable of piercing the mouse's skin; tasting blood stimulates biting, and with experience the kitten becomes a mouser. Kuo obtained different results by varying developmental conditions. By always shocking kittens with mice present, he displaced pouncing with a fear reaction; by raising kittens with mice, pouncing was inhibited and social companionship developed. Thus, although certain species-typical equipment favours pouncing, drawing blood and other events essential for mousing, mouse killing as a pattern requires certain interactions of organism and developmental field most likely to occur in the normal species environment.

4. Drive and Motivation. — Certain classes of behaviour once called instincts are related by modern psychology to drives. Drive is a term for physiological processes energizing individual behaviour. Examples are the thirst, sex and hunger drives. Each of these patterns has its basis in physiological processes; for example, the sex drive emanates irom complex conditions centring around glandular secretions, the hunger drive from both gastric processes and changes in blood chemistry. The influencing of changes in general behaviour by internal drive fluctuations has been established experimentally for many different animals. A classical example is G. H. Wang's demonstration of relationship between the ovarian (egg-maturation) cycle and periodic fluctuations of general activity in the iemale rat. Organic examinations showed that oestrous or heat periods recurred at four- to five-day intervals, and at corresponding times striking increases occurred in the daily amount of activity. Wang concluded that the activity rhythm depended on glandular changes incident to oestrus, as it disappeared in mature females after spaying and during pregnancy and was absent in immature females.

Some broad differences exist in the responses of different types of animals to drives. On maturing sexually, invertebrates and lower vertebrates tend to behave in more stereotyped ways than do higher vertebrates. A female solitary wasp of certain species, fertilized and with mature eggs, stirs about and excitedly stings a spider or other characteristic prey when it is encountered; an egg-laden jewel fish is particularly attracted by objects having certain general properties of movement, coloration and size. The effective stimuli are species typical. In contrast, the incentives or stimuli governing the drive-impelled responses of mammals, increasingly broadened and individually more variable than in lower vertebrates. seem related to superior capacities for learning through experience.

A related difference exists between lower and higher mammals in the ability to satisiy or change a drive tension through conditions related only indirectly to the original incentive. Thus a pat on the head stimulates a properly trained dog to intensive efforts but affects a rat much less. Chimpanzees can learn to work for poker chips which are then inserted into a food-delivery slot, whereby an inedible object acquires a measure of drive satisfaction for the animal. A comparable mammalian superiority in motivated behaviour is seen in the individual's ability to initiate the secondary stimulus, as when a dog "ready for a walk" brings out his leash. Such behaviour has not been established reliably in reptiles or other lower vertebrates. (See also INSTINCT; MOTIVATION; PSYCHOLOGY, PHYSIOLOGICAL).

5. Sensitivity and **Perception.**—Von Uexkull and others have undertaken to describe the world of lower animals in terms of what is known about sensitivity. Thus one might speculate that for the honeybee in flight a flower patch is a flickering mosaic of colour with a glimmer of ultraviolet here and there; for the bird skimming low the patch has a distinct colour geometry without ultraviolet effects; for the house cat the scene has a washed out, colourless appearance. Such descriptions, from subjective inferences, are in the class of rudimentary speculation.

Only the first step toward understanding an animal's effective environment is accomplished by exploring its sensitivity. The chief problems are: what types of physical effects the animal is equipped to sense, what upper and lower limits (thresholds) hold for the various aspects (*e.g.,* intensity) in vision and other modalities, and nhat the acuity is in each field. In the sensory properties of animals, striking differences are found. Among the insects, the housefly, honeybee and others. although blind to the long nave lengths of light seen by man as red. are visually sensitive to very short rays (the ultraviolet band) not seen by most vertebrates including man. Carnivores such as dogs, cats and rats are insensitive to wave-length differences in light which man sees as colours; whereas bees, many fishes and most diurnal birds and primates have a distinct wave-length sensitivity. Although these animals may not see hues as does man, they have colour vision, since under experimental conditions they can discriminate between wave lengths and between wave lengths and grays of corresponding brightness.

Important differences also are found in the ranges of corresponding types of sensitivity. Most fishes can discriminate among intensities and pitches of sound; many crickets and other insects possess receptors known as chordotonal organs, sensitive to high frequencies of sound; many lower animals react to auditory frequencies above the human limits. The hunter's dog responds to the tone of a whistle near 30.000 cycles per second. soundless to the hunter, whose upper threshold lies below 18.000 cycles.

Striking sensory adaptations, important for orientation, are common. In bats, insect-feeding species and certain others have remarkable aptitudes for flying in the dark, long attributed to tactual sensitivity but found to depend on a keen perception of the bat's own ultrasonic utterances reflected from objects. When D. R. Griffin releasec! bats in a dark room they flew skillfully among wires strung close together, but when hearing mas eliminated by plugging the ears, or when the sounds mere stopped by fastening shut the mouth, the skill disappeared. The work of K. von Frisch shows that honeybees and other arthropods can orient with reference to the plane of polarization of light, a visual capacity still undemonstrated for any vertebrate animal. In primitive vertebrates, such as sharks, olfaction tends to be a highly developed and dominant sensory field; in higher vertebrates, and especially in primates, the dominant field is vision. In most birds, taste is acute but smell is poor; in honeybees and many other insects, olfaction through antenna1 reception is exquisitely acute but taste seems poorer than in man.

An animal's sensory equipment fundamentally influences its way of life. Bats and oilbirds can live in dark cares because of their delicate ultrasonic auditory sensitivity; mammals with keen olfaction can track prey by scent and tend to become night foragers, particularly (as in the cats) when dark adaptation processes favour dim-light vision. In contrast, animals with superior bright-light vision and inferior smell, as the diurnal monkeys, settle into a routine of daytime activity and nighttime sleep. Interesting relationships are often found between the fields of sensitivity and differences in habitat. There are species such as cave fishes living in complete darkness that have poor vision or are blind with tactual and chemical sensitivity highly developed. Comparable inverse relationships between vision and olfaction prevail in many insects. Most diurnal birds have excellent vision but are low in olfaction. Sensory equipment basically defines the limits and the nature of an animal's world.

6. Sensing v. Perceiving.— Sensory data, although indispensable for behaviour, are not the best indicators of an animal's psychological standing. Many birds, for example, approximate man and are far superior to most lower mammals in visual acuity. Yet. in the critical matter of using sensitivity to master object meanings and their relationships, in which sensory factors are secondary, birds are inferior.

An animal's capacity for perception, definable as sensing in terms of meanings, is best judged according to how it deals with objects under varying conditions. The relatively stereotyped responses governing food-getting activities in cold-blooded vertebrates seem best interpreted in terms of "taxis" types of relatively direct stimulus-response relationships (see ANIMAL BEHAVIOUR). For these vertebrates, object-organism relationships evidently depend mainly on specific characteristics, such as intensity and rate of movement, and not object meanings, and feeding depends essentially on what stimuli are adequate in their physical properties to elicit a reflexlike combination of forward lunge and mouth opening. These animals seem to behave far more in terms of seeing than of perceiving.

7. Simplest Perceptual Relationships.— The organic basis of capacities for response to sensory change and for perceiving is evidenced in the lowest vertebrates. Minnows trained by P. Schiller to snap at the movement of a small bar of light presented with food then reacted to the light when it was presented twice within $\frac{1}{20}$ sec. in closely adjacent positions. The fish evidently perceived a movement, somewhat as would a human subject under comparable conditions. Experiencing "apparent movement" thus may be present throughout the vertebrate series. Many psychologists, and especially Gestaltists, consider this class of phenomenon an index of capacity for relationships, basic to perception.

It is probable that such capacities are essential to a meaningful sensing of objects. G. Révész presented chickens with successive pairs of circles, triangles and arcs differing in size, the smaller one of each pair bearing food, thereby training the bird to peck only at the smaller figure in grain-free test pairs. Then two identical arcs were presented, one directly above the other, both with grain. The trained chickens pecked mainly at the upper figure, apparently seeing it as smaller than the lower arc, thus evidencing an illusion of size similar to that of human subjects under comparable conditions. Correspondingly, chickens trained by Kohler to peck at the brighter member of a training pair pecked mainly at the brighter card in new test pairs of different brightnesses. Similar results were obtained in equivalent tests of a chimpanzee and a human child, except that the training was more quickly accomplished.

Thus widely different vertebrates have a capacity for reacting to successive visual situations as unities in which the members are bound together reciprocally. An organization of this type may be termed a relationship, although in the simplest cases the unity seems due to processes on a physiological level rather than to qualitatively superior functions involving intelligence.

8. Contrasts in Perceptual Capacity.— Social insects normally accept members of their own colony but attack nestmates bearing the odour of another colony. That the perceptual capacities of lower vertebrates are comparably low is indicated in tests with species mates. Male Siamese fighting fish. for example, respond similarly to femsles and to artificial objects such as clay plugs, unless size is too great or movement too rapid, whereupon

the artifact is attacked as are other males. Hence the male's responses to species mates evidently depend on physical characteristics but not meanings such as "mate" or "enemy." In pigeons, kittiwakes and numerous other birds, a parent which feeds young regularly on the nest will neglect them when they are off the nest even if close by. Evidently the young have a very simple meaning for the mother bird, rigidly dependent on the nest locus (at least in the early stages of incubation) and much below the level of maternal perception in monkeys, in which mothers feed and protect their young under a variety of conditions.

Sensory Discrimination.—Critical for evaluating perceptual levels is the extent to which experience brings more versatile adjustments to objects under changing conditions. The first step is sensory discrimination, a learning to distinguish sensory differences and respond appropriately. As far as sensitivity permits, stimulative discriminations in every sensory field can be learned with appropriate responses by insects and other higher invertebrates, and by vertebrates from fish to man. The learning is relatively simple for a mammal, which characteristically requires fewer trials than lower vertebrates; the critical matter is nhether the animal is sensitive and reactive to stimulative differences under the conditions. Thus dogs discriminate tones more readily than do rats because of better reception as well as superior sound localization and learning capacities. A hunting dog must first discriminate among types of animal scents (*e.g.,* raccoons and rabbits), then he must learn to set himself for the one aspect of scent emphasized by his master.

Complex *Discriminations.*—The next degree is mastering complex discriminations, forming schemata in which successful response under experimental conditions depends on two or more characteristics of the positive pattern (*e.g.,* brightness and size), two or more characteristics of the negative pattern, or on relationships between the positive and negative patterns. Correspondingly, the tracking dog at this stage distinguishes the "correct" scent from similar "false" scents depending on different combinations of characteristics.

Conditional Discrimination.—A qualitative advancement is that of conditional discrimination, which demands intelligence well beyond that required for simple discriminations and schemata. This step is not indicated for reptiles and birds, and may exceed the capacities of rodents. Problems requiring conditional discrimination arise when similar schemata are encountered in many situations with important differences in their relevance. For example, not all pet dogs can learn that unless the master also wears his hat he does not necessarily intend to go walking when he holds the leash. When an animal can give the critical response to the essentials of related schemata without mistakes due to conflicting details. he has mastered a set of contingent relationships termed an abstraction. For example, white rats after long training can jump to a triangle, however it stands, rather than to a circle; whereas chickens, having learned to differentiate these two figures in set positions, are lost if the triangle is tilted.

For success in conditional discrimination, aspects such as complexity in the combination of critical details from experience to experience are crucial. Discerning patterns in varying circumstances, in which confusing differences may obscure key details, is an accomplishment in the discrimination of relationships excluded to all but higher mammals. In contrast to the rat, whose limits for abstraction are soon reached, chimpanzees progress well in matching-from-sample tests, as N. Kohts found, and can single out a schema such as a triangle even when it is presented with others matching it in details such as colour and size. Monkeys, although less apt pupils than chimpanzees, as H Harlow has shonn can advance from simple discriminations of objects to very complex discriminations involving a number of characteristics.

Very different attitudes have been taken in animal psychology toward the subject of perception. Some would use this term for any reaction to sensory effects, others would reserve it (as above) for grasping meaningful patterns through sensitivity. The former practice seems to have its basis in implicit analogies between any animal sensitivity and human "consciousness of environment." On this view, the simplest sensory processes indicate perception. Such analogies, however, are vague. Modern experimenters prefer objective methods in mhich judgments of perceptual capacities depend on data from systematic object-discrimination tests under controlled conditions. The critical matter is not sensitivity alone, but how the animal organizes sensory data in adapting to new conditions. For this, resources for learning are critical.

B. Learning Capacity

The rich endowment of lower animals in species-typical adaptations related to structural specializations is well balanced in mammals by superior capacities for modifying behaviour. Writers such as E. Hering believe, however, that all organisms have "memory," in that the action of a stimulus on protoplasm always leaves traces which influence further responses. In this very general sense, the term learning would be extended to the simplest types of behaviour changes through stimulation, as in plants and protozoans. An alternative view is that such changes should be classed as equivalent to the general kinds of trace effect termed hysteresis (*q.v.*) in physical systems rather than to learning as in higher organisms. For comparative psychology, the primary fact is not just the production of some trace effect through stimulation, but nhat class of trace is involved and what its relevance to the organization of behaviour may be.

1. Varieties **of** Learning.—Adaptation and *Fatigue* Phenomena.—The simplest types of trace phenomena are based on processes akin to sensory adaptation or muscular fatigue. A dog or a man kept in the dark for even a few minutes undergoes chemical changes in the retinas of the eyes increasing the sensitivity of the rod cells so that dark vision is good, but on release to bright light, vision is poor and orientation inefficient. A worm, after circling counterclockwise inside a dish, is likely to turn left when transferred into a T maze; a dog after running all day scratches himself weakly, because chemical products of action and associated phenomena (fatigue) have temporarily changed muscular contraction. Similar instances based on changes in receptors or muscles are common throughout the animal series. They are not classed with learning because they centre around peripheral changes and not directly around central-nervous traces altering individual behaviour in persistent ways.

Sensory Integration; Habituation.—Certain classes of experience may arouse neural trace effects influencing behaviour without altering it specifically. For example, the larvae of many ants and other social insects, through feeding on substances characteristic of the species (chemical stimulus I) in the nest situation of the colony (chemical stimulus 11), may accomplish a sensory integration with neural traces influencing adult behaviour in varied ways as in trail following and in foraging. In a comparable phenomenon in mammals, termed "sensory preadaptation," after different stimuli such as a light and a buzzer are experienced together repeatedly without any specific action being involved, a response then conditioned to one of these stimuli also is elicited by the other without further training. In a similar phenomenon, generally termed hzbituation, commonly experienced disturbing stimuli lose their initial effect, and may even facilitate ongoing behaviour. Thus snails in an aquarium, bumped and otherwise disturbed for weeks by fish, then carry out their activities without the initial stoppages; a clerk becomes able to work in a noisy office. In such cases, through common experiences, nervous traces are set up which influence behaviour in general ways. These phenomena seem related to conditioning because new integrations are formed; they are, however, distinguishable from other types of learning in that specific behavioural changes are not primarily essential.

Conditioned Responses.—In conditioned-response learning, the gain is a new stimulus-response connection, the nature of mhich depends on what specific stimuli are experienced together. To take an example from the lowest animal in which learning has been demonstrated, a flatworm moves about in response to stimulus A (light). hut halts at stimulus B (head contact); stopping occurs to A, however, after the stimuli have been combined many times. Conditioning, therefore, depends on what stimuli are combined under appropriate conditions, through everyday experience or the plans of an experimenter or animal trainer. With each repetition, an "unconditioned stimulus" (B) which arouses the critical resonse (B_R) at the outset is experienced by the animal together with a conditioned stimulus (A) which initially does not arouse this response. Through experiencing the combination, the animal forms both an A-B integration and neural traces permitting A to control the critical response B_r. In the pioneering experiment of I. Pavlov with dogs, A was a bell sound; B, meat powder in the mouth, was a stimulus arousing B_R, a reflex salivation. Through repeated combinations of bell and meat powder, at length A-B_R was accomplished and the bell controlled salivation.

In vertebrates, and in the invertebrates including worms, probably most reflexes and other local reactions may be conditioned if stimuli are appropriately paired. Although at first young dogs scratch only in response to local skin irritation (*e.g.,* flea bites), appropriately pairing this unconditioned stimulus with the smell of flea powder, hearing "scratch!" or seeing his collar normally conditions the dog to form the corresponding A-B, pattern. The potentialities of the conditioning principle for practical animal training depend mainly on ingenuity and patience, as is illustrated by a popular Russian film of the 1950s portraying an animal enterprise in which dogs run trains, rabbits behave excitedly on missing them, cats punch tickets and theatrical doings are also represented convincingly, although evidently without understanding, by the actors.

In the mammals, particularly, aspects of the situation other than the focal stimuli can control behaviour through conditioning, thus serving as secondary conditioned stimuli. In Pavlov's work, stimuli incidentally seen and heard in the test room (*e.g.,* hearing experimenter's movements) at length elicited the critical response in the absence of the experimental stimuli. This enlargement of the habit was indicated also by a reduced responsiveness when the animal was tested in another room or without his harness. In such ways, in laboratory experiments or with pets at home, stimuli considered incidental or even overlooked come to control a habit, as in the Clever Hans case.

Conditioning is not the same in all animals capable of it but varies considerably in its internal pattern and relations to other behaviour. For this fact, differences in neural resources are critical. In invertebrates capable of it, and in lower vertebrates! conditioning is largely restricted to combining simple stimuli with reflex or stereotyped responses, and naïve responses to potent stimuli are reversed only with difficulty if at all. Examples are the difficulty of conditioning an inhibition of the snail's foot retraction to intense contact or the lizard's snapping at figures of complex but not smooth outlines. Mammals can form. systems of conditioned. responses in which a wider range of responses may be controlled by the same stimuli, the responses themselves varying more than in lower animals. The traditional milkman's horse, starting and stopping skillfully according to combinations of footstep-and-bottle sounds, is an everyday example. The significance of such learning is illustrated by the great variety and flexibility of combinations possible through systematic training in almost any mammal, compared with the limitations of turtles, toads and fish, increasing in that order.

From the lowest to the highest mammals the ability expands to modify conditioned responses according to prevailing conditions. It is difficult to condition a fish to move one fin alone to a light combined with shock, but with a dog, in time a light paired with shock to one leg controls not only the flection of that leg, without the shock, but other changes also. Reduced forms of the conditioned stimulus and subtle secondary stimulus effects enter, and the response is curtailed and modified until at length the paw alone moves just enough to avoid the shock. Cases of learning in this class, in which both stimulus and response undergo precise modifications according to motivation and the consequences of action (*e.g.,* obtaining food or evading shock), evidently represent the merging of the conditioning type with the selective type of learning (see below). The inferiority of lower vertebrates to mammals in such learning doubtless corresponds to differences in neural equipment. Thus, although normal dogs can be conditioned to withdraw a specific paw skillfully on signal, dogs deprived surgically of cerebral cortex advance little beyond the stage of general excitement and variable responses to the conditioned stimulus. The limitations of dogs without cortex remind the experimenter somewhat of lower vertebrates with their inferior neural equipment. (See also CONDITIONING.)

Operant Learning. — Variations of conditioning are possible depending on the animal and technique used. A method known as operant learning approximates conditioning by routinizing stimuli and other conditions, but differs from it in that initiating the response depends specifically on the animal. In the classical experiment of B. F. Skinner, a rat learns to approach and press a bar for a food reward. If the reward is given only in the presence of a signal, say a light, the rat will tend to press the bar during presentation of the light and not in the dark. If his hunger is reduced, he stops pressing, and so on. This method is very useful for research on the properties of sensory discrimination, reaction and drive; however, it may not be suited to the comparative study of learning. In the operant method, the experimenter plans the situation for the animal so that the successful response is sure to occur, thereby greatly reducing the time and variable behaviour for solution (if indeed the "solution" otherwise could be learned at all). Despite the specific utilities of this method, the fact remains that by selecting nhat action is to be "correct," and by maneuvering the animal's behaviour so that this action occurs, the experimenter substitutes his own role for unexamined selective processes otherwise dependent upon the animal. By this method, therefore, similarities are obtained for pigeons, rats and men which may be very misleading as to how far the basic processes of learning may actually be similar or different through the animal series. (See LEARNING.)

Trial-and-Error or Selective *Learning.*—This complex form of learning, not clear below arthropods, reaches its peak in the mammals. It is illustrated by the behaviour of a hungry dog outside a food box that can be opened only by pulling a cord. The first responses of dogs to such problems are highly varied, and include nearly all activities possible under the conditions, from pawing and sniffing at the box and at the floor nearby to running about at intervals and also, finally, sitting and howling. At length the dog, in the course of biting and pawing at objects, happens to pull the cord and enters the door to food. The first trial, particularly, is likely to be very long, but, as E. L. Thorndike found in his pioneering work with cats. random activities decrease and the cord is pulled more and more promptly in further trials. From these characteristics. such learning is called trial and error. Because the animal improves by working more frequently in the correct locus and adapts more efficiently through organizing appropriate responses from initial variable behaviour, the process may be termed selective learning. When D. K. Adams prehabituated animals to the general situation, thereby reducing initial disturbance and emotional excitement, random behaviour decreased and the correct solution was more promptly and efficiently acquired than in naïve animals.

Many kinds of problem situations have been used in studying selective learning, including types in which escaping shock or getting food depends on pressing a pedal or pulling a string, combinations of these and other devices. Higher mammals such as the chimpanzee can solve problems involving latch combinations which are difficult for the monkey and insoluble for rats and lower mammals, not merely because the chimpanzee excels in manipulative ability but because of his superior capacity for organization in learning. Birds, in contrast to mammals, are limited to easier problems. which they learn more slowly. Sparrows are slow, pigeons much slower, in learning to press a string admitting them to a food box, then do not relate the string response to the act of entering the door. The bird's inferior organization of the habit is shown by the fact that, nith the habit learned, if the string is moved he tends to work in the habitual place instead of directing his efforts at the shifted string, as most dogs would. The inferiority of lower vertebrates to mammals in problem solving, as W. Fischel has shown, lies especially in their shortcomings for interrelating the critical act (*e.g.,* string pulling), the object acted upon (*e.g.,* the string) and the goal (food).

A method much employed in studying selective learning involves the maze, in which establishing a correct route despite blind alleys makes possible investigating both the elimination of errors and the organization of a complex orientation habit. Animals from earthworm and crab to chimpanzee and man have been tested, and striking differences are found. To learn a T maze with only one blind alley the crab *Cambarus* needed more than 60 trials, chimpanzees only a few. In about half the trials needed by the crab for its simple learning, Formica ants master mazes containing six blind alleys. Rats, on the other hand, given this pattern used for the ant in an appropriate scale, need only 12 runs or less.

As T. C. Schneirla found, submammalian animals require more trials to learn comparable problems, commit far more errors than mammals and accomplish an inferior habit in a different and more limited way. The ant, to learn the six-blind maze mentioned, first became habituated, next mastered local difficulties, finally a general organization of the habit, all very gradually. The rat, in contrast, exhibited no distinct stages but mastered local difficulties and organized the general route simultaneously. The superiority of the rat's habit is shown by its facile modification when maze changes shift the correct route through a former blind alley. The rat reverses maze habits readily when required to start at the former exit, whereas for the ant this is a very difficult problem. The ability to reorganize behaviour in new situations is a particular mark of the mammal's superior capacity for selective learning.

Tests requiring modifications in learned habits reveal even more clearly than do studies of initial learning how strikingly different the capacities of ants and rats are for organizing solutions of comparable tasks. To compare fish and rat in this respect, M. E. Bitterman and J. Wodinsky used a technique requiring successive reversals to the stimuli of a discrimination habit. Although in these experiments the rats improved steadily from day to day in shifting between two similar alternative habits, the fish usually failed to improve except within given days, and in successive reversals their habits seemed to interfere with each other. Differences thus are indicated between ant and rat and between fish and rat, with the rat excelling not only in its method of acquiring habits but also in changing mastered habits.

When learning is reviewed comparatively (as in the foregoing discussion) the possibility arises that the chief difference between invertebrates and lower vertebrates, on the one hand, and mammals on the other may not so much involve the formation of neural traces, emphasized by S-R learning theory, as in capacities for organizing traces, emphasized by other theories. Thus. using food or shock in training techniques may be important in inframammalian forms mainly for the rate of forming the neural traces themselves, although in mammals its influence on the course and organization of selective learning can be much greater.

For good results in training mammals, although conditioned-response procedures may be held basic, the use of punishment or reward to control what is learned must be tempered by a broader conception of the role of incentives and motivation than would be necessary for lower animals. Accordingly, for mammals, punishment is advisedly used only in mild forms (as intense stimuli emphasize avoidance reactions to trainer and situation) and reward, similarly, to encourage desirable responses and their efficient organization.

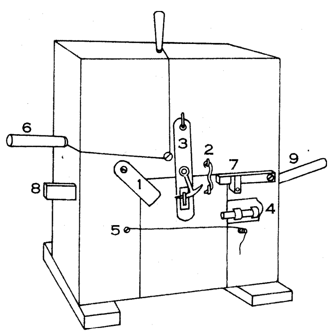
2. Experience and Capacities in Learning. — Mammals surpass invertebrates and lower vertebrates not only in learning new problems but also in reorganizing habits adaptively. Adapting to this comparison the neurophysiological theory of D. O. Hebb for the ontogeny of perception, one would say that rodents and higher mammals, with further related experiences, advance much more readily than lower forms from trace effects to linkages to complex neural patterns. Mammalian learning is typically more efficient in familiar situations, not only because the animal is less excited and behaves less erratically than under strange conditions, but also because mammals can extend habits progressively to better effect than can lower animals.

Virtually any type of problem is mastered more readily by mammals, not only because of their superior organic equipment for original learning. but because experience is brought more effectively to bear on further problems. Harlow investigated these matters at length with monkeys given long series of discrimination tests with problems of increasingly difficult natures. Results showed that monkeys master more complex discrimination problems of the same general type with progressive facility. Harlow applied the term "learning sets" to the successive stages of the monkey's progress in "learning to learn." He was inclined to emphasize the similarity of learning at successive stages and to doubt that qualitatively new processes enter at the advanced stages. But, as N. R. F. Maier and Schneirla suggested, the discrimination method may not be adequate to reveal qualitative differences in learning. This problem seems to require other methods more appropriate for the investigation of similarities and differences in learning and intelligence at different animal levels.

C. Intelligent Behaviour

1. Criteria. — Intelligence (*q.v.*) is definable as the capacity to utilize experience in adapting to new situations. Intelligence is not efficiency in adaptive behaviour, a quality shared by all surviving animals. Furthermore, although intelligence depends to some extent on the organism's aptitude for conditioning, and more so on its capacities for selective learning, the crucial matter is how readily the gains of past experience are adapted to new problems.

It is difficult to diagnose any solution correctly without adequate knowledge of the animal's background. Morgan described a case in which, after he had observed a dog in repeated erratic attempts to pull a crooked stick through a paling fence, the animal finally yanked the stick through when the crooked part accidentally broke off. A passer-by, who saw only the last and successful part of the series, remarked, "Clever dog that, sir, he knows where the hitch do lie." Whether success results through accident, a gradual process of selective learning or an efficient reorganization of experienc'es appropriate to the problem may depend on (1) species capacities, (2) the capacities and experience of the individual and (3) the conditions under which the difficulty is encountered.



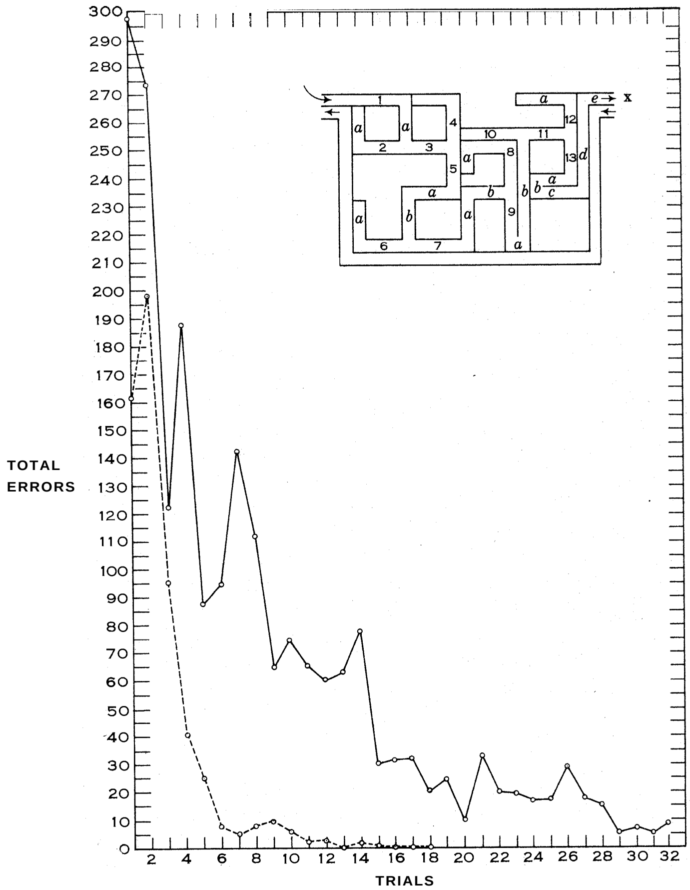
FROM J. A. KINNAMAN IN "AMERICAN JOURNAL OF PSYCHOLOGY," VOL 13, P. 112 (1902)

FIG. 2.— COMBINATION PROBLEM BOX USED IN TESTING MONKEYS. TO ENTER THE BOX AND OBTAIN FOOD. THE ANIMAL MUST DEAL WITH THE ITEMS IN THE SEQUENCE INDICATED BY THE NUMBERS

2. Insight. — Commonly accepted as an index of intelligent behaviour are short-cut solutions known as insight, in which the animal appears suddenly to "see the point." Calling such solutions insightful does not of course explain them but may only analogize success with a hypothetical process of seeing into something. The mere rate of accomplishment does not indicate insightful solution, for insects in certain problems occasionally achieve rapid but noninsightful improvements. Insight involves a kind of organizing ability not demonstrated in insects or lower vertebrates, superior to both conditioning and selective learning for overcorning new difficulties.

Pioneer studies by M. Haggerty and others shortly after 1900 revealed that problem solutions by monkeys are often better than would be expected through trial-and-error processes alone. For example, a monkey, after having watched another, in four successive trials, climb the side of a cage and reach into a chute to obtain fruit, when given the problem himself soon solved it by working directly around the chute until he reached the fruit. Later, in the research of Kohler and Yerkes particularly, similar abilities were demonstrated for chimpanzees, superior to those of monkeys.

In these experiments, chimpanzees were presented with problems such as food overhead or behind a fence, unobtainable by direct responses such as reaching or jumping but obtainable only by indirect procedures. Although there were failures and some animals never did well, some of the chimpanzees reached distant food by means such as stacking boxes or raking it in with a stick.



FROM T. C. SCHNEIRLA IN "INSECT PHYSIOLOGY"; REPRODUCED BY PERMISSION OF JOHN WILEY & SONS, INC.

FIG. 3.— SIX-BLIND MAZE PROBLEM USED FOR TESTING BOTH ANTS AND RATS. SOLID LINE INDICATES TOTAL-ERROR SCORES OF EIGHT ANTS. BROKEN LINE. THE TOTAL-ERROR SCORES OF EIGHT RATS

One of Kohler's chimpanzees, which had previously used only single sticks as rakes, was shown food beyond reach, requiring a stick longer than any available. First there were actions such as merely reaching out with the arm, or using one bamboo piece alone or to push out another, for getting at the incentive. Even though inappropriately! the animal in such behaviour was using foreign objects as a means to an end—in other words, as crude tools. After an hour, the goal was unattained and the animal sat facing away from the food, idly handling two bamboo sticks. Then a change appeared, as follows:

> Sultan . . . picks up the two sticks, sits down again on the box, and plays carelessly with them. While doing this, it happens that he finds himself holding one rod in either hand in such a way that they lie in a straight iine; he pushes the thinner one a little may into the opening of the thicker, jumps up and is already on the run toward the railings, to which he has up to now half turned his back, and begins to draw a banana towards him with the double stick. (W. Kohler, The *Mentality* of Apes, Eng. trans., 1925, Harcourt Brace.)

That the sticks were perceived as a useful tool and not combined by accident mas indicated by the fact that when the pieces happened to separate, the animal straightway recombined-them in a manner impossible without some understanding of their function together.

3. Relative Capacity for Indirect Solution.— Solutions of such types resemble the pattern recognizable in mammals as "perception of relations." Much evidence indicates that lower mammals are inferior to primates in this respect. Cats and dogs can learn to manipulate levers, but neither can assemble a tool or use it as chimpanzees can in solving problems.

Kohler emphasized the superiority of primates over lower vertebrates in correcting their initial direct responses to the incentive! when necessary, with indirect ones. A hen separated from food by a wire fence persists in zigzag running against the fence, opposite the food, whereas dogs in time abandon direct responses for a detour to the food. and monkeys do so sooner than dogs. Fischel demonstrated that although dogs can respond to one of two incentives with the direct or indirect action that is appropriate, thus solving a task failed by turtles and by birds, they master the critical relationships less effectively than primates do. Chimpanzees clearly surpass monkeys at solving the type of problem requiring the subject to push food away from him around a barrier before raking it in, indicating a superior mastery of the relationship of the subject's position, the barrier and the goal.

4. Reasoning as Reorganized Learning.— Indirect or insightful solutions are frequently differentiated from patterns acquired directly through selective learning in that the former type of solution often appears suddenly, after a period of apparently fruitless trial and error. Sudden improvements in progress toward or in attaining a n e type of solution are notable in the problem-solving behaviour of higher primates such as chimpanzees, less prominent in monkeys, still less in dogs, cats and rats in that order. This fact does not mean that insightful solutions occur independently of previous learning.

Insightful solutions have not been clearly demonstrated in any inframammalian animal, and various anecdotal claims for such processes, as in insects! seem attributable rather to uncontrolled possibilities for direct responses. What is unique about insightful solutions is that they are attained by reorganizing two or more patterns of response available from experience in similar situations, although previously independent of each other. Thus, perceptual adjustments such as jumping to food and handling a box may exist separately in the animal's repertory until he combines them in solving a new problem. In one of the experiments of Maier. who studied simpler forms of this type of solution in the rat, the subject was first habituated to the elevated pathway shown in fig. 4, passing between each two tables frequently, without receiving food. In the test, the rat was first given food on one of the tables, *e.g.,* no. 3, then was transferred to no. 1, for example. On the basis of his specific habits, the rat in this case would have turned with equal readiness to tables no. 2 and no. 3; the results, however, showed that adult rats were able to return with better than 80% success to the one food table correct in the particular test. Achieving correct solutions when a direct recall of learned responses would have led to chance scores indicates a capacity for combining learned items which had been separate in previous experience.

Maier emphasizes the qualitative similarity of such solutions to reasoning in man. As an example of a solution by reasoning, not demonstrated in mammals below primates, the joining of short sticks when a longer one is needed has been mentioned. As H. Birch found, however, chimpanzees cannot solve this stick-combination problem by reasoning unless they have previously handled sticks as in play and appropriate unitary perceptual adjustments are thereby made available. The feat then is to combine these elements insightfully in an intelligent adaptation to new difficulties.

5. Relative Independence of **Stereotypy.**—*Nonsoluble Tests.*—Mammals differ greatly in their freedom from stereotyped behaviour in problem situations, as G. V. Hamilton found. In his nonsoluble test, the subject was presented with four doors, one door unlatched on each trial, but never that unlatched on the preceding trial. This fact was discovered by the human subjects, but not by any lower animal. Sext in complexity of response were monkeys, the other primate tested, which often tried all four doors successively and distributed their efforts without trying any one door repeatedly on any one trial. Stereotypy of response. or repeating particular reactions frequently: occurred often in dogs and cats and very often in horses. Significantly. the tendency for stereotypy and persistent repetition of errors is marked in the

maze learning of rats in which 20% or more of the cerebral cortex has been destroyed. Maier found partially decerebrate rats very inferior to normal subjects on reasoning problems, much as lower mammals are distinctly inferior to primates on such problems. Superior cortical endowment thus inhibits stereotypy in mammals so that new adaptations become possible.

Multiple-Choice Test.—The Hamilton situation was adapted by Yerkes in further studies of plastic behaviour in his multiple-choice test. Here the subject faced nine doors in an arc, with a sequence of five doors unlatched on each trial, but (to eliminate simple position habits) always a different set. Food was to be found behind just one door each time, and the problem was to discover how the correct door was systematically related to the others. Sample problems were: (1) always first at the right; (2) always second from the left; (3) always the middle door. The aim here was to compare the levels of intelligence in different animals. In the above problems (1), presumably the simplest, was solved both by the crow and the rat, which both failed (2). Problem (3) was solved by the monkey but not by the pig. Chimpanzees solved problems more difficult than (3), in which success may have depended on capacity to abstract a significant pattern from among complex settings, or on what Yerkes called "ideational processes." To the claim that the multiple-choice method is valid for testing animal intelligence comparatively, critics object that the method affords no basis for clearly appraising such processes; also that this situation handicaps some animals unduly by admitting irrelevant features such as emotional reactions, which may have caused gorillas to fail problems solved by chimpanzees.

6. Representation as a Secondary Factor in Reasoning.—Attaining solutions by combining previously independent experiences, demonstrated in lower mammals including rodents, represents the reasoning process in simpler outline than in man. Animal psychologists have studied "mental processes" in lower mammals, in comparison with man, to find what other factors are contributive. One interesting method is that of delayed response, an outcome of earlier attempts to test capacities for "ideas." In the form developed by W. S. Hunter: this method involved first training the animal to go through the one of three doors marked by a light; then, in tests, the lamp over one of the doors was first lit briefly and after a given delay the animal had to respond without the light. In modifications of this test by others, the animal was first shown food under one of several cups or saw iood buried. and after a delay had to locate it.

The general result of such experiments, although specific results differ according to procedure and situation, is that lower mammals require more preparatory training for success and in general rely more on specific bodily orientation during certain types of tests than primates do. In food-concealment tests, monkeys and chimpanzees can delay successfully over intervals of 24 hours or longer. The general interpretation is that success depends on a capacity to represent the absent object or the appropriate adjustment to this object as a cue for recalling its location after the delay. Ability to delay the correct act over an interval is often interpreted as centring around an abbreviated form of the actual adjustment; lifting a box, for example, might be represented by a slight tensing of the arm muscles as in raising the box. In comparison with man's great advantage of symbolizing experiences verbally, lower mammals are handicapped by having to represent their adjustments in much less versatile ways.

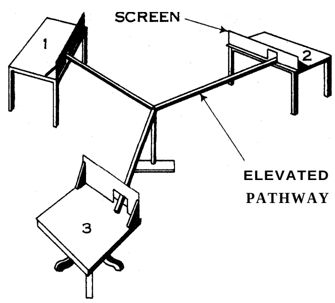
A related capacity indicated in lower primates and certain other mammals is the anticipation of particular absent objects. In one delayed-response experiment with monkeys, in which banana was used in some of the trials and lettuce (less preferred) in others, the subject became disturbed and refused a piece of lettuce surreptitiously substituted for the banana he had seen concealed before the delay. Evidently the animal then specifically anticipated banana, for lettuce was accepted readily in delayed trials preceded by the showing of lettuce.

The ability to represent absent objects and situations may be considered a contributory factor in reasoning. This type of process is suggested by trials in which a chimpanzee, aiter having worked at suspended food for some time without success, suddenly rushes around the corner for a box previously seen there, then promptly uses this box in a solution. The ability to represent absent objects, although it aids solutions by reasoning, cannot alone account for such solutions, for merely representing an experience without change or recombination would constitute a direct recal! rather than a new solution. In the primates. the newness of solutions achieved through reasoning is far more striking than in other mammals.

V. MAN COMPARED WITH THE LOWER ANIMALS

Although man is not structurally the most highly evolved animal. he is psychologically the highest. His superiority is not absolute, however, for most of his advantages are also possessed, though to lesser extents, by mammalian relatives.

1. Time, Reasoning and Foresight.—Although reasoning is found in mammals down to rodents, in the lower orders it is simpler and evidently plays a far smaller part in adaptive behaviour than it does in man.



ADAPTED FROM N. R. F. MAIER AND T. C. SCHNEIRLA, PRINCIPLES OF ANIMAL PSYCHOLOGY. REPRODUCED BY PERMISSION OF MCGRAW HILL BOOK CO.

FIG. 4.—MAIER THREE-WAY APPARATUS FOR TESTING REASONING IN THE RAT (see TEXT)

One of man's psychological advantages is foresight, or reasoning with reference to problems in the more distant future. Time, for lower primates, is largely restricted to the present and is much less extensive and meaningful for the past than it is for man, who lives in the future as well as in the past and present. The anticipations of lower animals can be conditioned within limits to coming phases of recurrent events, through internal or external stimuli characteristic of given times of day. In rodents, discrimination of short intervals of time in terms of action has been demonstrated; however, their anticipations are held to shorter times and simpler processes than they are in primates. Even in apes, anticipation is far shorter than it is in man, and largely involves more familiar occurrences. The capacity to think far forward in time requires a wider reorganization of the traces of experience than is found in any lower animal.

Man's intelligence is capable of systematic sequential reasoning. or planning, organizing into systems the traces of very different experiences nith reference to future goals. Foresight in the chimpanzee is typified by his food expectancies, anticipative of specific episodes only a day or two off. If lower primates are capable of utilizing reasoning to obtain goals or forestall hazards expected in the more distant future, these abilities remain undemonstrated.

Planning for future needs requires not only foresight but also reflective thought, or reasoning about one's own condition in relation to the past, present or future. Differentiating and identifying the self in thinking, marked typically by the first significant use of personal pronouns such as "me" around two years of age, is a major event in human mental development. This symbolic accomplishment is far superior to reacting emotionally about one's own behaviour or appearance, as might a monkey observing himself in a mirror or a growling dog preparing to fight.

Foresight involves taking note of one's own status or condition, in reference to that of other individuals, objects and situations, to achieve appropriate measures. This type of self-reactive reasoning expresses man's superiority over the lower primates better perhaps than any other aspect of development. The comparison is weakened neither by subnormal human intelligence nor by the fact that any man at times uses his mental capacities poorly. The best human foresight infinitely surpasses the best in subhuman primates.

2. Verbal Language and Communication.—Although language and communication are often confused, the former constitutes a special case of the latter. In communication the behaviour

(or related processes; *e.g.,* odours) of one animal influences the behaviour of others; in language, a special system of symbolic processes is used with the expectation of influencing others in given ways. Odours produced reflexly from an excited bee's scent gland or vibrations produced in a termite colony through the head rapping of excited individuals on gallery walls are communicative events but not language. Processes such as the flashing of fireflies, the chirping of crickets and the colour changes, movements and sounds of mating animals are by-products of excited behaviour rather than language symbols initiated in view of expected effects on other individuals.

Communication approaches closer to language when social responses advance through conditioning, as in groups of birds or mammals when the excited cries of one individual throw others into flight. Another advance is made mhen a general activity is modified through experience into a special device used to influence the behaviour of others, as when barking and biting in a dog change into baring fangs and growling as means of intimidation. When merely beginning the act often causes flight, the abbreviated form is learned as a special social device. Instances of simple, discrete communicative processes of this sort are not uncommon in the everyday life of mammals, as in the "begging" of hungry dogs and the mewing of cats before closed doors. When 'used with even a limited anticipation of their social effects, such acts approach the stage of language.

Infrahuman primates seem not to develop systems of symbols in the class of language. Yerkes, however, from his extensive experience, indicated in the chimpanzee a variety of sounds and movements which influence other individuals, keeping them in touch with and informed about the presence and attitude of one another as well as about significant features of their environment. To be sure, these sounds and movements of lower primates more often appear as incidental features of the first animal's excitement (*e.g.,* the "hunger cry") than as intentional means of informing others of something. Although proof is lacking that chimpanzees use sounds symbolically, S. Crawford and H. Nissen demonstrated experimentally that these animals can use gestures as language symbols, as in tapping the shoulder of a lagging companion when food can be obtained only with his co-operation.

Man alone has the capacity for systematic codes of language symbols. Nonmimetic, conventional types of symbols, particularly, qualitatively distinct from the acts or objects they represent, account for the great efficiency of human language. In contrast. the communicative activities of lower mammals are essentially mimetic in that the sign or signal is a specific part of a series of experiences which represent the whole. Even the chimpanzee, which has a facility for vocal utterances and an intelligence that makes it perhaps the best candidate for language next to man, falls short of achieving verbal language symbols. Attempts to teach chimpanzees true words attain only the stage of stereotyped responses given under set stimulus conditions. Parrots can learn to repeat frequently heard sound patterns, which, however, constitute skilled acts largely devoid of any meaningful association uith the objects or situations eliciting them and are not manipulated with anticipation of the results; hence, not language.

3. Conceptualization and Intelligence. — The psychological deficiencies of chimpanzee as compared with man, and of monkey as compared with chimpanzee, relate significantly to the elaboration of cerebral cortex. In the mammalian series rat-dog-monkey-chimpanzee-man, there is not only a progressive increase in the proportion of cerebral cortex to body weight but also an increase in the number of cortical cells and the complexity of their interconnections. Such increases parallel improvements in capacities for complex functions centring around learning and its reorganization in perceptual, conceptual and language processes. This is validated by findings such as K. Lashley's of a high positive correlation in rats between amount of intact cerebral cortex and performance in learning problems, and Maier's that losses exceeding 20% of cortex abruptly reduce to a minimum the scores of rats in reasoning tests. Limitation of symbolic behaviour by the amount and pattern of cerebral cortex is emphasized for man by the deficiencies of imbeciles and by the degeneration of symbolic functions in step with progressive cortical loss as in tumours. In the final stages of such disorders, the patient may see once familiar objects without being able to name them or recall their meanings.

Mastery of verbal language symbols evidently requires a foundation in object meanings beyond the resources of subhuman intelligence. To be sure, a chimpanzee can be taught human activities such as using utensils, yet the circumstances of training and of use indicate a limited perceptual and conceptual command over the adjustments and a performance more rigidly bound to specific sensory properties and motor routines than in man. The chimpanzee thus can learn to ride vehicles without forming the abstraction "ride" and using it verbally to initiate the act as does the human child through mastering the common properties of vehicles. Although human infants in their first symbois are bound to particular situations and concrete uses, later they progress steadily with verbal symbols whereas chimpanzees remain in the nonverbal stage.

Chimpanzees are not sufficiently intelligent to attain the level of perceptual development essential for human conceptual processes. Their concepts do not reach the stage of conventional symbols such as words, and are too simple and rigid to be combined in symbol sentences. Correspondingly, their adult problem-solutions are simple and discrete and, like their tool concepts, cannot be interrelated into systems to form progressive principles. From the lower primate's episodes of reasoning, discontinuous as compared with man's, the gains therefore are not consolidated as communicable knowledge or social heritage.

4. Emotion. — In higher and lower animals alike, a relationship may hold between outer causes and the individual's initial excited, emotionalized responses. Although in the higher mammals these processes progressively involve perceptual states of variable stability and psychological complexity characterized as pleasant or unpleasant, they are grounded in visceral conditions. Primitively. strong stimuli elicit withdrawal and an interruptive visceral condition, neak stimuli approach and a vegetative visceral condition. What may be called the strong emotions, characterized by interruptive visceral changes such as hampered digestion, quickened heartbeat, secretion of adrenin and impulsive responses such as flight or fighting, are aroused by intense stimulation. W. Cannon identified equivalent interruptive physiological reactions of these types as accompaniments of strong emotional excitement in both lower mammals and man, "putting the organism on a war footing." Conversely, weak stimulation promotes vegetative changes such as facilitated digestion, and the related overt response is an approach toward the stimulus source, naïvely in mammals a general relaxation and reflex extension of limbs. The interruptive condition seems inherently episodic, the vegetative condition relatively continuous and potentially basic to social life. In mammals, however, nith their capacities for psychological plasticity, which of these becomes dominant in personality and society seems increasingly dependent on the prevalent development conditions. Lower mammals and very young children readily tend to perceive objects and situations in terms of their general emotional associations, as conditioned-response learning prevails first. Under severe environmental conditions, with punishment and strong stimulation frequent, interruptive emotional tendencies may become dominant, as in the trembling, cringing, uhining behaviour of a frequently punished dog when the whip, his master or a stranger is encountered. In contrast, an emphasis on approach tendencies and selective learning in development brings intelligence to the fore and contributes to social rather than asocial behaviour.

In man, visceral processes play a far more indirect and delicate role in emotional reactions which are much more influenced by the perceptual significance of the situation than they are in lower mammals. Because man's emotional development is dominated by his perceptual and conceptual processes. according to circumstances, it is unsafe to infer experiences of "fear" in the human sense in the excited flight of insect or fish from a suddenly moved object or "maternal love" in the queen ant licking her first brood. That the difference depends particularly on the intimate involvement of cerebral function in man's emotional development is indicated by lapses in emotional specialization and social restraint with cortex-inhibiting agents such as alcohol or more lasting deficits when brain tumours or injuries reduce cortical function. Comparably, in cats and other lomer mammals, when the cortex and brain stem are disconnected surgically there are marked increases in activities such as snarling, biting, panting and other signs of interruptive visceral disturbances normally episodic and associated with high emotional excitement. Man's cortical equipment admits an emotional specialization comparable with his intelligence and involved with it in an intimacy well beyond the range of lower mammals in general.

The temperamental resemblance of lower primates to man appears much closer than their intellectual resemblance to him. Although %ell-domesticated dogs are frequently very sensitive to subtle differences in human behaviour, acting almost as members of the family, domesticated chimpanzees seem far more delicately and complexly attuned both to man and to chimpanzee companions. Hebb, by simulating the approach of a "timid man" and of a "bold man" in successive tests, obtained significant chimpanzee responses, with one animal friendly in the former situation but aggressive in the latter, tno others interested but aggressive and unafraid in both. The first animal may have been hoodwinked by the act, the other two not, as the experimenter was known to them.

Experienced observers report patterns meriting terms such as confidence and discouragement. bluff, suspicion and others, appearing under comparable conditions in the ape and the human child. These responses involve rough similarities in external signs of emotionality, including facial expressions and general tensional changes, reliably interpreted as indicating emotional attitudes. A common difference is that, in excited emotional responses, overt processes tend to emerge more readily in adult lower primates, with the whole body involved as in stamping and shrieking when rejecting something. and in this sense they are much more "dominated emotionally" than adult man.

5. Aesthetic Perceiving. — The capacity for perceiving objects or situations in emotional terms such as distress or reassurance appears first in mammals. Although in lower vertebrates and some invertebrates stimuli such as body colours or characteristic sounds may be excitatory or calming, repellent or attractive, evidence suggests that specific effects such as intensity (controlling physiological changes), and not their perceptual significance, dominate such responses. Neither simple conditioned responses nor naive responses to stimuli are truly aesthetic, in that emotional effects accompanying attraction or repulsion reach the level of appreciating object significance, object qualities and emotional effects as related.

Simple aesthetic perceiving, so defined, is indicated in the subhuman primates. Kohler observed chimpanzees hanging material such as plants or fruit skins about their necks or shoulders or applying clay or other substances to their bodies or to surrounding objects. Other behaviour was seen which Kohler considered rudimentary dancing, as when animals pranced around a circular path in single file or stood in pairs, one stamping the feet alternately as the other rotated with outstretched arms. Such actions are accepted as primitive types of aesthetic perceiving both because individuals evidently derive an emotional gratification from manipulating object qualities with reference to themselves and because these actions exert an emotional effect on others. D. Morris, from studies of finger painting by chimpanzees in the London zoo. suggested that free-choice and project methods often reveal indications of aesthetic appreciation in selecting and combining colours, somewhat comparable to the tendencies of human infants. B. Rensch thought that the preferences of *Cebus* monkeys for certain combinations of colours and grays, and certain geometrical patterns, express processes resembling some of the simpler aesthetic tendencies in man.

The capacities of lower primates for aesthetic perceiving are slight in comparison with the potentialities of man, uho alone seems able to create systematically visual patterns such as thematic paintings, auditory patterns such as symphonies or dances worthy of choreography with the expectation of exciting appreciative emotional responses in himself and others. Not only are the chimpanzee patterns vague and lacking in subtlety, but their significance apparently involves only a momentary emotional appreciation, as capacities are lacking for the intellectual synthesis of emotional effects and patterning of material essential for a wider orientation in time. The human artist, with an appreciation of his own relationship to the theme and resources for planning his work to play upon the emotional susceptibilities of others, can treasure and recreate aesthetic experiences. Through his foresight, experiences remote in time and space and with disparate meanings are continued creatively to enrich the environment for himself and others.

6. Personality and Abnormal **Behaviour.**—Normal behaviour is definable as the developmental pattern characteristic of the given animal group. The major animal forms have been compared here in terms of their normal or typical patterns. Although this is justified, it is also true that every species presents individual differences in all characteristics of behaviour. Individual differences in organic characteristics and in adaptive behaviour constitute an important fact in evolution. Generally such variations are predictable, in that correspondingly fewer individuals deviate from the species norm in more radical ways. Some ants or bees are superior and others inferior to most of their colony mates in orientation, foraging and nest activities; chimpanzees differ widely in capacities from reaction time to reasoning, and so on for every psychological property of every animal species.

Individual differences that are matters of degree in sensory acuity or in the efficiency of learning may be considered regular or ordinary. Radical psychological deviations from typical species behaviour are uncommon in the lomer animals, although special departures may result from extraordinary conditions as in development. Pathological and disease conditions affecting the nervous system can produce behavioural eccentricities. Thus the signs of rabies in dogs and other mammals are extreme emotional excitability with indiscriminate running and biting; brain tumours produce sleepiness, reduced sensitivity, irritability or depression and other extraordinary signs according to their locus and extent. In these disorders, however, psychological disturbances are secondary results rather than causes. Man seems to be the one animal frequently plagued by psychological complications arising through disrupted organization of personality and behaviour rather than primarily through organic defects.

Under special stress, lomer vertebrates may exhibit emotional disorders resembling those of man. Gun-shy dogs tend to be extremely fearful in specific situations, and perhaps generally, because of emotional conditioning. Disturbances resembling neuroses have been produced in mammals and also birds with Pavlovian conflict technique, in which an animal, trained, for example, to respond to a circle but inhibit response to an ellipse, is then forced to respond to a figure intermediate between these two. As the animal cannot both respond and inhibit response simultaneously, a conflict condition results, with tension, excitement and even violent movements, and usually great difficulty in repeating either habit (*see* NEUROSES, EXPERIMENTAL). Under marked frustration in problem situations, with strong hunger but with no response adequate to get food, chimpanzees and other mammals become emotionally disturbed, negativistic and neurotic. Frequent experiences of this sort cause lower primates and human children alike to exhibit symptoms such as temper tantrums or chronic sulkiness with evasion of or dependence on others rather than attempts at direct solutions. By frustrating chimpanzees from infancy, with frequent stress and blocking of strong motivation (as many human parents treat their children). one may obtain abnormal personality trends resembling human neuroses.

One important reason why types of personality disorganization common in man are less prominent in his animal relatives centres around their deficiencies for redirected motivation. perception and reasoning and their consequent freedom from morbid anxieties about unobtainable goals. When a chimpanzee is away from the scene of its frustrations, its limited capacities for symbolism hold down related emotional stress in other situations. The effects of frustration are thereby reduced for the animal and it is freer to recuperate than is a man, who can recreate the situation with its tensions and even enlarge on these.

Lower animals are protected from mental illnesses in still other ways, also related to their psychological inferiorities. Not so dominated as man by remote goals or dangers or by attitudes of personal prestige, they can leave the frustrating situation outright when this is possible, or hit on some irrelevant response as an escape. Even so, similar personality defects frequently arise, with some resemblance to human reactions in frustrating work situations, as in caged mammals persistently circling their enclosures. Stereotyped habits arising under these conditions tend to reduce emotional tensions from conflicts between escape motivation and the necessity to remain. Although such behavioural fixations, as a rule, neither satisfy the dominant motivation nor resolve persistent emotional difficulties, they help the animal to survive frustration without excessive emotional tensions; hence they are adaptive. Similarly, in man, characteristic delusions and other fixations in behaviour and thinking may save the individual from more serious personality disorganization and thus permit survival in society.

7. Contrasting Social Patterns.—Aggregations are fairly common among all animals. Cells of sponges and other colonial organisms are unified organically, members of general associations remain together temporarily through common responses to the same extraneous stimuli. Social groups as in insects, birds and men are unified and organized on the basis of interdependence among the individual members and their responses one to another.

Natural selection has placed a premium on mechanisms making for interattraction and grouping of species members. As W. C. Allee demonstrated. even the biochemical products of death facilitate survival of others in various invertebrate associations. In insects and mammals, secretions and other processes have evolved which attract members of the species one to another, facilitating unity in local groups while repelling strangers. In various animals, and particularly birds, specialized visual and auditory mechanisms have a comparable function. Variously, the conditions of development favour the effectiveness of such processes and in many ways grouping contributes to species survival.

Striking similarities in social patterning, as between insects and man, encourage analogies as in A. E. Emerson's stress on the social group as supraorganism and his argument that natural selection affects different animal groups in the same ways. Such views can usefully attract attention to comparable organic factors ensuring social life in very different animals, but they also may obscure major differences. In social insects, cuticular secretions, tactual and other factors promote reciprocal stimulation among workers, queen and brood, unifying the colony; in mammals, including man, the organic products of parturition assure the female's attention to and licking of young; suckling and approach to the female by neonates strongly promote the development of a parent-young bond basic to individual socialization. Yet Schneirla has emphasized the significance of differences in the socialization process itself on different animal levels, terming the insect patterns biosocial, the mammalian patterns psychosocial.

Analysis shows that. on different levels, comparable biological factors promoting specialization can differ greatly in their developmental consequences, according to phyletic psychological differences such as those discussed in this article The abiding characteristic of the biosocial level, as exemplified differently by insects and birds, is that organic processes exert their effects rather directly on group behaviour; that of the psychosocial level is plasticity and diversity of outcome according to conditions in development and in the social situation. Whereas the many types of insect social pattern over the world had reached substantially their present forms by Tertiary times. more than 60,000,000 years ago, man has passed from the Stone Age to the space age, producing complex cultural systems, civilizations, science and recorded knowledge, within the past 50,000 years. Insect social evolution was achieved through organic evolution, whereas man has developed socially within a period when his organic make-up, particularly his cerebral cortex, seems not to have changed in any important respect. Insects have fixed communication patterns, men have plastic symbolic languages; insects have structurally canalized caste functions, men only those fixed circumstantially, through social heritage or through differences in intelligence; insects have organically stereotyped forms of co-operation but men are capable of intentional forms of concerted goal striving or of competition, according to upbringing and prevalent conditions.

It is valid to speak of a "worm nature," an "ant nature" or even a "bird nature" but not of a "human nature," for man can have whatever nature the conditions of his rearing and social situation permit. He may be tolerant or intolerant, with narrow prejudices and violent hatreds or broad interests and congenial attitudes dominant, depending on developmental, social and cultural background. The resources of his maturation may be directed either to avariciousness and cruelty or to charity and kindness, but none of these patterns is inherent in him. If one tendency seems more convenient for man than another, it is to discover or create a habitat in which interruptive, excited emotional disturbances are minimized most of the time. He shares this tendency with most of the other animals, but as a psychosocial being he has his own conventional, sophisticated ways of achieving it. Man stands on the psychological pinnacle not only intellectually but also emotionally, and the struggle for social conditions of peace and quiet has predominated in his history despite frequent disturbed, noisy exceptions.

It is not only through his intellectual but also through his emotional capacities that man has succeeded in merging small groups into widespread integrated societies as against the local groups to which all lower animals are held. He has achieved not only vast unitary social organizations, but true *internationales* in art, literature, music and science. Perhaps the most important task of comparative psychology is to show in what respects these achievements are unique and in what respects they are equivalent to the various ways in which lower animals adapt to their worlds.

Bibliography.—*Colloque internationale sur l'instinct animale* (1956); J. Dembowski, *Tierpsychologie* (1955); W. Fischel, *Die Seele des Hundes* (1950); D. O. Hebb, *The Organization of Behavior* (1949); H. Hediger, *Wild Animals in Captivity* (1950); F. Hempelmann, *Tierpsychologie* (1926); H. S. Jennings, *Behavior of the Lower Organisms* (1906); N. R. F. Maier and T. C. Schneirla, *Principles of Animal Psychology* (1935); C. L. Morgan, *An Introduction to Comparative Psychology* (1894); A. Roe and G. G. Simpson (eds.), *Behaviour and Evolution* (1958); S. S. Stevens (ed.), *Handbook of Experimental Psychology* (1951); C. P. Stone (ed.), *Comparative Psychology*, 3rd ed. (1951); C. J. Warden, T. N. Jenkins and L. Warner, *Coiizparative Psychology*, 3 vol. (1935–40); J. B. Watson, *Behavior: an Introduction to Comparative Psychology* (1914); H. Werner, *Comparative Psychology of Mental Development* (1940). *See* also the journals *Animal Behaviour; Behaviour; Journal of Comparative and Physiological Psychology; Journal of Genetic Psychology; Zeitschrift für Tierpsychologie.* (*T. C.* S.)

PSYCHOLOGY, DIFFERENTIAL: *see* Differential Psychology.

PSYCHOLOGY, EXPERIMENTAL, is a method of studying psychological problems, but the term has come generally to be used to connote all those areas of psychology which use the experimental method to obtain their data. The experimental method as it applies to psychology is a systematic attempt to discover the conditions which determine human and subhuman behaviour by manipulating, one at a time, the variables that enter into the situations which give rise to the behaviour under study; it may also investigate the behavioural effects of modifying the organism. rather than manipulating the conditions external to the organism. Like other sciences, it is thus primarily concerned with discovering causal laws.

The areas of study in psychology which embrace the experimental method exclusively. or almost exclusively, include those of sensation and perception, learning and memory, motivation and physiological psychology. Other areas utilize the experimental method in some of their branches or subareas, and thus there are experimental child psychology, experimental clinical psychology, experimental educational psychology and experimental social psychology. Usually the experimental psychologist deals with the behaviour of the normal, intact organism, but in the area of physiological psychology, studies are conducted with organisms modified by brain or other nervous system surgery, radiation, drug treatment, induced convulsions or long-standing deprivations of various kinds. The experimental psychologist often finds that his problems overlap with those of physiologists, neurophysiologists, radiologists, biochemists, zoologists, pharmacists, physicists and geneticists. The main line of demarcation between experimental psychology and the closely related fields is the psychologist's emphasis on the behavioural products of his various experimental manipulations.

EARLY PERIOD

Origins. — Experimental psychology as a systematic study grew out of the work of physicists and physiologists who were compelled to recognize the important part played by the human observer in the results which they obtained from their experiments. Thus it was at first almost entirely concerned with the measurement of reaction times (*i.e.,* the time elapsing between the giving of a stimulus and the making of a prescribed response by the observer) and with a study of the special senses. In a brief survey it is impossible even to mention the names of many pioneers whose work gradually developed modern methods of experiment in psychology.

A very great amount was due, however, to Gustav Theodor Fechner, appointed professor of physics at Leipzig in 1834, who elaborately endeavoured to obtain exact quantitative statements of the relation between the intensity of a stimulus and of the sensation which it evokes. His reasoning never commanded wide assent, but the actual methods of observation mhich he initiated were developed in many ways and became the foundation of a large part of modern experimental procedure. In 1885 Hermann Ebbinghaus published the results of a long series of experiments mhich he had made upon himself in the memorizing of nonsense syllables. He claimed that the use of this kind of material made it possible for the first time to experiment successfully on the "higher mental processes." Although, as in the case of Fechner, there is reason for doubting the validity of many of his claims, his work undoubtedly inspired a large quantity of further research. Near the beginning of the 20th century Oswald Kiilpe took a further step by encouraging a number of researches upon judgment and volition, while throughout the whole period, from Fechner onward, experimental work on feelings and on certain specific psychophysical problems, such as fatigue, were continued.

In England the approach to experimental work in psychology—from the time of Francis Galton—was, in general, by a biological route. The importance of statistics as a method of dealing with experimental results received special attention and in many ways experimental psychology was closely in touch with neurology and medicine.

It is curious that the genuine experimental study of animal behaviour (*q.v.*) is a modern growth. With a few exceptions, and those for the most part resulting from the interest of comparative anatomists in the localization of various bodily functions, the anecdotal method of Aristotle remained predominant in the study of animals till the 20th century. That there arose a flourishing school for the experimental study of animal behaviour was due in the main to U.S. psychologists and in particular to Edward L. Thorndike, Robert Yerkes and John B. Watson.

The study grew until every important university in the world in some way recognized the right of experimental method in psychology to a position in the scheme of higher education and of scientific research. Most of the leading universities provided actual experimental laboratories. A considerable number of journals were established for the publication of the results of experimental research in psychology. Apart from university teaching there arose flourishing organizations for the practical application of psychology in various directions, particularly those of education and industry.

Recognition of the importance of psychological teaching and research in relation to the practice of medicine and law and to the organization of military services grew rapidly. It would be easy to show that the development of this practical aspect of psychology was made possible directly and almost entirely by the use of experimental methods.

Sensory Processes. — The earliest experimental psychologists were physicists and physiologists and consequently a great amount of work in the psychological laboratory became concerned with the special senses of touch, temperature, taste, smell, vision, hearing and movement. Let us select t\\-o groups of these for a somewhat more careful description: those dealing with visual and those dealing with auditory reactions. Here, then, are colour wheels on which disks of different colours may be rotated so rapidly that the resulting sensations combine and the effects of mixing colours in varying proportion can be accurately determined. Special apparatus demonstrates the aftereffects of continued light and colour stimulation and the occurrence of colour-blind or colour-weak zones in the normal eye. A darkroom is provided, designed to show clearly the differences between vision in daylight and in twilight and to bring out some of the theoretically and practically important facts connected with abnormalities of colour vision and with night blindness.

All of these may be seen in the physics laboratory or in the physiological laboratory. But the psychologist came to realize that his main problems and his methods of approach are his own. The physicist is chiefly concerned with an analysis of the stimulus, the physiologist with the mode of reaction of the eye itself, for instance, and with its connections with the central nervous system. The psychologist must be concerned with these also but has all the time to keep clearly in view how the accuracy of the observations themselves is determined. Thus he has to be particularly careful to study the effects of the method and order of presentation of the stimuli. He knows that these and numerous other factors, some of which may be extraneous to the particular experiment involved, determine the observer's attitude toward what is set before him, and that this general attitude, for which there is no obvious or immediately available physical or physiological expression, in turn may powerfully influence his observations.

With the same aim the psychologist carries out experiments on sound. He notices a man's normal reactions to sounds of different pitch, intensity and complexity, studies the results of combining tones in various nays, measures the acuteness of an observer's reaction to sounds of given character and demonstrates how the ears make it possible to judge where a sound has its source. He shows how all these apparently simple responses are in reality exceedingly complex and how an important part of their conditions often has to be stated in terms of what are called the "higher mental processes."

Perceptual Processes. — Obviously the world in which men live is not mainly a world of shifting patches of light and shade. of colour, of isolated sounds, tastes. smells and similar sensory characters. It is a world of things identified, named, referred to some position in space or apprehended as moving in some direction. So the experimental psychologist must try to show the conditions, not only of the relatively abstract sensory response, but of the more concrete perceptual processes that men are constantly carrying out. He has apparatus for the controlled exposure of objects: stereoscopes and devices for the study of the perception of solidity or of distance, and of the various optical illusions; means by which he can demonstrate how sensations of differing kinds may all come together into a single complex perception.

A little study of these perceptual processes is enough to demonstrate that in many instances what is actually perceived at the moment is only a little of what a person reports that he has observed. We fill up the gaps of perceptual data by using images or relying upon some form of recollection of past events, as when a person traveling at high speed in a train sees only parts of things through the window and then reports his observations with much more detail than could possibly have been discriminated at the time. Considering this, the experimental psychologist is led to arrange special situations with a view to the production of mental imagery and to study the types and functions of the imagery produced. Once more employing his exposure apparatus, so that the conditions of reaction can be at least partially controlled, he presents common objects incomplete in some respects, or material arranged in a series which gradually approaches a climax, or material directly designed to produce ambiguous or alternating reactions, or material conflicting with some other simultaneously presented perceptual data, and in these and other ways seeks to arouse mental imagery and so to discover what functions it fulfills. *(See* also PERCEPTION.)

Choice and Feeling. — Throughout the whole range of psychological experiment an observer frequently has to judge, to choose, to decide and he often reports that his reaction processes are accompanied by feelings and emotions. How can these functions of judging. choosing, deciding and feeling be themselves experimented upon? As regards the first three the essential method is to place an observer in some situation nhich presents him with an interesting problem. The solution has to be effected by judgment, choice or decision. Thereupon the experimentalist brings into play apparatus by which he can record some of the physiological changes which accompany these mental processes, such as variations in respiration, in pulse rate or in glandular secretion. At the same time the observer, acting throughout under relatively controlled conditions, gives a verbal report of the processes which seem to him to have led up to the judgment, or the choice, or the volition. The problem situations may be indefinitely varied in complexity, from the simple judgment as to which of two weights is the heavier to decisions upon controversial questions of great difficulty. In regard to feeling, also, some exciting stimulus or situation is presented, and the observer reports verbally the factors which appear to induce his feeling, while changes of respiration, pulse beat, glandular secretion, resistance to passing an electric current through the observer's body, etc., are recorded automatically on polygraph tape. *(See* also FEELING, PSYCHOLOGY OF.)

Reaction Time. — As a part of practically all of the general fields of investigation already mentioned it is often of interest to measure the speed at which the combination of physical, physiological and psychological processes involved takes place. For this purpose the psychologist developed elaborate and delicate reaction-time apparatus by which he can determine accurately the time elapsing between the occurrence of a stimulus and the response to that stimulus in some prearranged manner.

Abnormal Conditions. — Especially interesting questions arise in the investigation of abnormal conditions. What, for instance, are the effects of glare or of flicker in the visual field; of excessive and continued noise or vibration in the auditory and tactual fields; of drugs and fatigue upon psychical processes generally? The study of muscular and mental fatigue (*q.v.*) in particular developed a mass of special apparatus and methods of research and had an immediate practical application.

Learning and Memory. — After 1920 more experimental psychologists devoted their efforts to studying the intricacies of learning and memory, or retention, as later psychologists have generally termed it, than to any other area. The experimental laboratory reflects this interest. For human learning experiments there are tachistoscopes, apparatus for brief exposing of limited amounts of verbal or pictorial material'at a time, with the length of exposure controlled automatically. There are memory drums for presentation of consecutive learning materials at a fixed, but adjustable, rate. There is a wide range of apparatus for learning of motor skills; *e.g.*, the pursuitrotor, complex reaction-time apparatus, a variety of assembly tests and the tno-hand co-ordinator. In soundproof darkrooms there are highly complex apparatus for conditioning eyeblink response, with both photographic and electronic equipment for continuous recording of the stimulation and responses.

A substantial proportion of the modern laboratory is devoted to animal quarters and test rooms. Apparatus for animal learning is extremely diverse. There are mazes, ranging from the straightaway, a single, straight alley with a starting box at one end and a goal box at the other, through mazes shaped like T's or Y's, which require a single choice of path, on through complex mazes having from 3 up to 10 or even 20 sections arranged with cul-de-sacs or blinds. Some of these mazes may be immersed in water so that the animal must swim through the pathways to reach the goal. There is jumping apparatus for training animals to discriminate betneen visual stimuli. the subject being required to jump from a platform at one of two cards. If the animal jumps correctly, the card swings back and the animal drops into a box containing food; if it errs, it hits an unyielding card and drops into a net. There is apparatus for conditioning animals to withdraw a leg to avoid electroshock. There are revolving drums to record activity and shock apparatus for delivering convulsion-inducing electroshocks. There are Skinner boxes, which are cages containing a lever which, when operated, delivers pellets of food or drops of water. And each laboratory has additional special apparatus peculiar to the research interests of the experimenters working there and adapted to the species of subjects being investigated. *(See* also LEARNING: MEMORY.)

Social **Behaviour.**—In one direction in particular experimental psychology advanced rapidly. A great many of the conditions of human behaviour are directly social in character and source. Many attempts were made to observe these under experimental conditions, and the task was by no means hopeless. Experiments were arranged to allow observation of at least some of the effects of such socially derived motives as competitiveness, pugnaciousness, assertiveness, submissiveness, friendliness, liability to suggestion, leadership and co-operation.

The earliest success in the social experimental area was with children in college and university demonstration schools, both in nurseries and elementary grades, which, from about 1920, served frequently for research purposes as extensions of the psychology laboratories. Later, successful research in social relationships was conducted with older subjects through clubs. high school, college and adult extension classrooms, and even special interest and social groups of mature and aged individuals.

Helpful aids in this area have been the combination of a microphone and earphones and a one-way vision window built into one wall of a room which permits observers to sit in another room behind the window and observe activity in the experimental room without detection. Motion-picture and sound-recording equipment also have been extensively used in this area and have facilitated the collection of data. Results obtained in this way inevitably reacted upon the experimentalist's study of the individual, forcing him to investigate not only the operations of the intellectual, cognitive mechanism, but also the extremely important play of temperament and character. One striking achievement of the experimental psychologist was the development of exact methods of studying and ranking "intelligence." Many of the ideas and devices which proved fruitful for this purpose were taken over into the wider field of the study of the social determination of conduct and the influence of individual temperament.

LATER PERIOD

The chief aim of experimental psychology in its early days was to render a description of certain experiences as they were experimentally produced and controlled. On the one hand, the interpretation of the results obtained was dominated by theories taken over from general psychology according to mhich all complex experiences were regarded as made up of unitary elements of a sensory order which had been built together in the course of individual life by the principles of association. On the other hand, the actual methods employed were, as nearly as possible, copied from other experimental fields. Particular forms or varieties of experience. whether of a sensory or of a "higher" order, were, as far as possible, cut off from other kinds and correlated with their immediate physical stimulus. The result was often artificial in the extreme and experimental psychologists were constantly doing or initiating work which could be done much better by physiologists, with their specific training in the technique of the study of relatively isolated bodily activities. The view that complex experiences and reactions are nothing but aggregations of simpler forms practically disappeared. In consequence the problems of the experimental psychological laboratory were brought much nearer those of real life.

Behaviour.—A powerful influence in bringing about this change was the movement known as behaviourism (*q.v.*). Men have always been interested in the study of the behaviour of animals but formerly their interest led them either to' the descriptive type of study attempted by the field naturalist, or to the collection of remarkable animal stories interpreted in the light of human conscious experience. The development of an experimental approach to biology made behaviourism possible. At first, as in the field of general human psychology. experiments were mainly concerned with the special senses, and in particular with an anatomical study of the parts of the central nervous system in which various special sensory reactions of sound, vision, taste. balance and the like may appear to be localized.

Then experimenters began to try to observe exactly how various species of animals learn to discriminate one object from another, or to run successfully more or less complicated pathways in a maze. They decided to avoid explaining animal behaviour in terms of human experience and to limit themselves strictly to relating the conditions of their experiments. as any competent observer mould describe them, to the behaviour of the animals, as that, again, could be described by any instructed onlooker. It seemed possible to do a great amount, and perhaps the whole of this. without once using the notion of consciousness as a causal factor, for these experimenters rightly held that to attribute consciousness to an animal is to go beyond directly observable fact. Their success led them to put forward an exactly similar program for experimental work in general human psychology.

Most experimentalists in psychology. however, maintained their right to include in the conditions of the reactions studied many that are incapable of being expressed in physiological terms. Many continued to try to hold themselves free from any systematic theory about the nature of human experience and, taking up certain specific problems of reaction in human beings, insisted that such reactions must be regarded as partly determined by "attitudes," both conscious and unconscious, by "tendencies" whether instinctive or of a higher level, and by the accumulation of the results of past experience which appear or which function in the form of images, ideas, sentiments and so on. For example, much work continued to be done on the minimal intensity of stimuli of varying quality which mill produce a reaction. The experimental psychologist showed that these threshold values of stimuli of all kinds can be shown to depend in part upon "attitudes," images and like factors occurring during the course of ·the experimental investigation. He held that, independently of any discussion as to their ultimate character, it is impossible to reduce these to physiological and much less to physicochemical terms. Such a vien being admitted, experimental laboratories came to investigate problems over the nhole field of human response. There was a revived interest in the psychology of the special senses, particularly those of vision and hearing. Memory was investigated less as an isolated type of response and more as falling into place in a whole complex learning process which may continually involve also the higher mental activities of judging, choosing, reasoning and the like. On the side of feeling and emotion increased interest in experiment grew out of work on the effects of the secretions of endocrine glands. Methods of registering emotional expression through metabolic change were developed. Encephalography was developed in the physiological laboratory and was much exploited by psychologists.

From 1900 to 1930 experimental psychology and experimental psychologists tried to establish an independent science of behaviour, as indicated above. William McDougall emphasized the fact that purposive or goal-directed behaviour could be studied objectively. but he failed to establish an experimental program bearing out this point of view. John B. Watson stressed the importance of objective measurement in psychology, and his book Behaviorism (1925; rev. ed. 1930) had a great influence on subsequent experimentalists. Watson conducted some rather limited researches on emotional responses and emotional learning in children and maze learning in the rat, but he failed to establish an experimental program. Furthermore, he stressed the importance of the study of isolated responses, and he placed more emphasis upon the biological correlates of behaviour than upon behaviour itself.

By 1920 the research of the Russian physiologist Ivan Pavlov was becoming well-known in Europe and America, and his influence was doubtless greater than it could otherwise have been because of the groundwork laid by Watson. Pavlov's great lasting contribution was the demonstration that learning could be studied objectively in the dog. A second contribution mas the concept of the conditioned reflex, or conditioned response, as it came to be called later. This model of learning dominated the subhuman learning research for several years and remains a formidable method in psychological research. Pavlov chose to investigate a limited kind of learning, the salivary reflex. and his attempt to generalize this specific learning to more complex phenomena, such as those involved in problem solving and thinking, ended in complete failure. Thus, Pavlov remained a neurophysiologist unable to interpret conceptually the problems of the behaviour of the total organism. (See also CONDITIOXIXG; REFLEX.)

Theory. — Theory, of course, played a role in the work of all the early experimental psychologists. The attempts to integrate and explain their data gave rise to hypotheses, and these in turn led to further experiments to check their hypotheses. As the data increased and the scope of experimental psychology broadened, the need for comprehensive theories developed, and this need resulted in the rise of formal systems which attempted to embrace large areas of behaviour.

A number of systems or theories arose and subsided between 1900 and 1930, and all played a part in determining problems to be investigated and the approaches to these problems, and the resulting data led to the development of new systems with new approaches. After 1930 theory became ever more influential in experimental psychology, doubtless because of the maturing of the science.

Thorndike. — Important advances in experimentation and theory were being made by Edward L. Thorndike at the same time Watson and Pavlov were at work. Probably Thorndike's most important contribution was his analysis of the role of motivation in both animal and human learning. His work in this area was to have great influence on a later theorist, Clark Hull, but Thorndike's interpretation of learning as the formation of specific bonds or connections represented a position of limited generality and, thus, was short lived.

Tolman.—In 1932 Edward C. Tolman published his Purposive Behavior in Animals and *Men,* which must be regarded as the first systematic treatise of experimental psychology as it was considered in the late 1950s. Tolman stressed the fact that experimental psychology must be objective and that the only acceptable behavioural data are those that result from direct measurement and recording, whether by observation or mechanical devices. He pointed out that experimental psychology per se was the study of the behaviour of the total, intact organism rather than the investigation of isolated reflexes and the underlying neurophysiological processes. He named the first type of behaviour molar and the second molecular. His view that the psychologist's particular domain lay in the study of molar behaviour later received wide acceptance. Tolman also taught that the behaviour of the total organism is commonly directed to the achievement of objectively determinable ends or goals, and for this reason he used the term purposive behaviour. He mas the first theorist to emphasize the importance of intervening variables in a psychological system, these being processes which intervene between the measurable stimuli which are presented to the subject and the overt behaviour which is directly measured. Tolman's intervening variables included demand, correlated with some maintenance schedule such as food deprivation; appetite, correlated with appropriateness of the goal object such as a particular food incentive; motor skill, correlated with the type of motor response required; and hypotheses, correlated with the cumulative nature and number of training trials. He also established the principle of determining the value of the intervening variable through experiments which systematically varied the correlated environmental variables while holding all other conditions constant.

Tolman and his co-workers were the first to demonstrate the importance of appropriateness of incentives, showing sudden changes in learned performance when a preferred reward was substituted for one of lower preference and when an incentive appropriate for a particular drive state, such as food for hunger, was substituted for one inappropriate, such as water. Furthermore, converse effects were demonstrated under converse conditions. One of his more notable 'discoveries was that of latent learning. In these studies the animal was allowed to explore an apparatus, usually a complex maze with a number of blind alleys, under a particular drive state, *e.g.*, 23-hour food deprivation, in the absence of any extrinsic incentive. After a predetermined number of days food was presented at the end of the maze, and a sharp improvement in performance was found to occur on the subsequent day. Tolman interpreted these data as supporting his position that learning is a process of relating sensory or perceptual processes and that demands and appetites do not affect learning but only performance. In other words, the introduction of an incentive in the latent learning situation does not produce learning but merely provides purpose for the use of previous learning to achieve with minimum effort what has become a desirable goal.

Hull. — Probably no theoretical system has had as great an influence on experimental psychology as that formulated by Clark Hull over a period of 20 years beginning in the early 1930s. He chose the science of physics as a model and developed what was ostensibly a rigid theoretical system based on 16 postulates and the derived axioms. Unlike Tolman, he did not believe that learning was the result of new stimulus-stimulus connections; rather he conceived of learning as the formation of new stimulus-response connections. Also. contrary to Tolman, he assumed that the operation of incentives and drive states was essential to learning per se and not merely to periormance. Indeed, Hull clearly stated that habit strength (*i* **e.,** learning) resulted only in the presence of the need reduction which folloned reinforcement; reinforcement was defined as the attainment of a reward or the reduction of some deprivation state such as hunger.

In actual operation Hull tended to follow the Tolman research model. He placed great emphasis on intervening variables, and he tried to quantify each of these by determining experimentally the effects of systematic manipulation of the independent variables (*i.e.,* the experimental conditions) on the dependent variables, the directly measured responses. Hull differed from Tolman in that his primary intervening variables represented a chain of symbolic and complex interacting constructs.

Hull's system stimulated a large group of research projects employing both subhuman and human subjects. The animal research, mostly conducted with rats, confirmed that it was possible to establish the effect of many variables such as length of deprivation, delay between presentation of the conditioned and unconditioned stimulus. amount of reward and amount of effort required to obtain the reward. Generally, simple response measures were used, such as speed of running down a straight alley or rate of lever pressing in an otherwise barren box. Hull and his associates believed that the results supported his position that learning is fundamentally the formation of new stimulus-response connections arising from need reduction.

Tolman-Hull Controversy.—Because the Tolman and Hull positions appeared to differ drastically, various attempts were made to establish experimental situations demonstrating that one or the other had the greater predictive power. One of these attempts resulted in the continuity-discontinuity learning controversy. Hullian theory would predict that all learning is a gradual, continuous process whereas Tolman had predicted that some learning, at least, was saltatory. Neither group, however, was able to control adequately the conditions essential for a definitive test,

A second attempt to establish a definitive test centred around the latent learning controversy, because latent learning is similar to sudden saltatory learning, at least so far as performance is concerned. One of Hull's associates, Kenneth Spence, argued that the apparent phenomenon of latent learning was the result of inadequate experimental controls and that the phenomenon could not be demonstrated if all controls were adequate. The large number of experiments which resulted from this controversy demonstrated that the latent learning phenomenon existed under limited and prescribed conditions but was voided in similar test situations by such unexpected variables as any condition involving intense deprivation. One of the most heartening results of the latent learning controversy was the realization that even rats were motivated by conditions other than internal, biological drives and that wandering around a maze might of itself represent some need reduction.

Hullian theory led to a series of experiments involving study of the effect of serial position in memorization of nonsense syllables, analysis of the reminiscence effect (improvement in performance after practice has ceased) and the influence of massed and distributed practice on the serial-position effect. In all cases Hull made predictions on the basis of certain of his postulates. and he tested the plotted theoretical curves against those obtained empirically. The general similarities were such as to indicate that Hull's system, primarily established on the basis of subhuman animal experimentation, had considerable power in predicting limited but important aspects of human learning. Another important application of the Hullian theory is found in the researches conducted by Spence and Janet Taylor on the effect of anxiety on the conditioned eyeblink response. Making the assumption that anxiety, as measured on a paper-and-pencil test. would function to raise drive level, they predicted that high anxiety would improve performance on simple learning tasks and lower performance on more complex learning tasks. Again, the results gave general support to the predictions.

Others. — In addition to Tolman and Hull. Edwin R. Guthrie developed a comprehensive theory of learning based on conditioned-response principles, and even though he did not develop the theory to the point at which many specific predictions could be made, the theory did stimulate the collection of experimental data. Also in the same period, Kurt Lewin developed a topological theory using geometric models and physical field theory as illustrative and predictive devices; his technique received attention particularly in experimental social and experimental child psychology. Kurt Goldstein, Max Wertheimer and Norman R. F. Maier independently developed two-factor learning theories which differentiated between so-called conditioned-response type learning and a so-called creative type of learning which has been called reasoning. Another entirely different approach after World War II was the statistical learning theory presented by William Estes and Cletus Burke, and by Robert Bush and Fred Mosteller.

Laboratory Methods. — During the period of 1930 to 1957, B. F. Skinner devised and conducted a series of experiments using a technique by which rate of response is measured instead of errors or latency. Basically this technique involved use of the Skinner box. which is an experimental chamber bare except for a lever (or multiple levers) and an incentive delivery mechanism. After the animal has been trained to depress a lever and receive a reward, it is subjected to various reinforcing schedules, such as a fixed- or variable-interval schedule, in which rewards are given at predetermined periods of time regardless of the number of lever presses, or a fixed- or variable-ratio schedule, in which rewards are given after a predetermined number of lever presses. regardless of time.

The Skinner technique proved useful both in the analysis of the effect of motivational states! such as food or water deprivation, and in the analysis of simple learning phenomena; it was, for example, used extensively by Hull and his associates. In the late 1950s researches were conducted on the ability of the subjects to respond to multiple schedules.

Although the technique was used primarily in analyzing rat and pigeon behaviour, it was also used with monkeys and chimpanzres, The breadth of the method was illustrated by the fact that Skinner adapted it for the study of arithmetical instruction of elementary-school children and behavioural analysis of institutionalized mental patients.

The early comparative psychologists had been quite eclectic in the range of animal species studied, but a tendency later developed in many laboratories to limit researches to the albino rat. Fortunately, however, another trend arose, starting with the establishment of the Anthropoid Experimental station by Robert Yerkes in 1929 (later renamed the Yerkes Laboratories of Psychobiology). There was initiated a comprehensive series of experiments on the psychobiology of the chimpanzee, including collection of data on development, basic sensory capacities, motives and emotions, social behaviour and a wide range of learning abilities. Although the Yerkes laboratories have studied other primates only in incidental researches, a beginning was being made early in the 1930s in the study of other primate species. Carlyle Jacobsen published his ingenious studies on the effect of prefrontal lobectomy on the learning perforinance of the rhesus monkey; W. Trendelenberg and W. A. Schmidt, in Germany, presented their research on colour vision in monkeys; and in 1933, Heinrich Kluver summarized his search on perception and learning in a wide range of monkey species.

At the same time a primate laboratory for the study of monkeys was developed at the University of Wisconsin, Madison, under the direction of Harry Harlow, who by 1945 had developed a series of standardized techniques for measuring a wide range of learned behaviours in monkeys. The research of this laboratory made it quite clear that, at least in the case of the rhesus monkey, it was practical to use primates as subjects in the same kind of formal, rigidly designed experiments that had been popularized in researches nith rats. After 1950 there was an upsurge in the establishment of primate laboratories in the U.S.; and psychological research was undertaken at Yale university, Johns Hopkins university, Baltimore, Md., Emory university. Atlanta, Ga , the University of Texas, Austin. the University of Oregon, Eugene, the University of Pittsburgh, Pa., Stanford university, Calif.. the University of South Dakota, Vermillion, and the National Institutes of Health.

The advantages of using monkeys instead of rats in a wide variety of psychological studies became apparent. The monkey possesses a far wider range of trainable behaviours. It is quite capable of solving complex problems on a level of difficulty unapproached by any subprimate form, and its speed and proficiency in learning simpler problems make possible far more detailed analysis of the mechanisms and developmental processes underlying learning than is possible with subprimate forms.

Studies at the University of Wisconsin on manipulation motivation and on the rhesus monkey's almost insatiable urge to explore its environment visually made it clear that the monkey's motivational structure is far closer to man's than is that of any other animal except the great apes. This does not imply that other animals lack an exploration drive. Such motives were demonstrated in the rat by David Berlyne in Scotland and by Kay Montgomery in the U.S. The differences betneen primates and rodents in the form and range of these behaviours is striking, and the limitations of the rat appear to be as pronounced here as they are in the area of learning.

Areas **of** Interest. — Learning. — In the area of human verbal learning there was continuous research on both serial learning, the learning of a series of words or syllables, and paired-associates learning, the learning of pairs of words or syllables. Among the many investigators in this field may be cited the systematic work of Benton Underwood on the effects of distribution of practice. Underwood found that distribution of practice had a beneficial effect on serial lists of both nonsense syllables and meaningful materials, but that no such effect could be demonstrated for paired associates. Similar research found no evidence for reminiscence with serial lists of nonsense syllables, although this phenomenon had been reported in the past both with serial lists of nonsense syllables and with paired associates.

Thus, the historical inconsistencies from experiment to experiment and from one situation to a similar situation continued to arise. On the basis of 'a detailed review of the literature, Underwood concluded that there was no single theory such as the reactive-inhibition theory or differential-forgetting theory adequate to account for the existing data. One of the most intriguing contributions in this area in many years was a study by Underwood in which he devised a technique for equating associative strength of both fast and slow learners at the termination of practice. He then tested retention 24 hours later and found no differences between the two groups in terms of response probabilities at recall. If this finding proved to be susceptible to generalization, we would have a solution to the problem of relation between speed of learning and amount retained.

Motor Skills. — During and after World War II major emphasis was given to the development of motor skills tests, particularly as devices predictive of pilot proficiency. A large number of specific tasks resulted, such as the pursuitrotor, the two-hand co-ordinator, reversed alphabet printing and block turning, and the effects of multiple variables upon the performance of these tasks have been studied. Investigators found that there are multiple variables influencing performance on all these tests, but no new integrating approach to these problems mas devised.

From the theoretical point of view, most of the work on motor skills revolved around Hull's concepts of reactive inhibition (*i.e.*, inhibition produced by work) and conditioned inhibition, arising from the fact that stimuli associated with the cessation of a response became conditioned or learned inhibitors. A vast array of experiments was conducted dealing with various motor skills performances under conditions of distributed and massed practice, including the phenomenon of reminiscence. Information on the locus — peripheral or central — of the inhibitory effects was provided by a number of investigators. Their findings of significant post-rest gain when subjects shift from the active to the passive hand after rest give support to a central locus.

Unlike the results obtained from verbal learning studies, the differences produced by massed and spaced practice on motor skills are enormous, and the phenomenon of reminiscence appears nith unfailing regularity. The goal of many investigators was to obtain such precise control over their experimental conditions that they could evaluate precisely the role of reactive inhibition and of conditioned inhibition. Both Underwood and Estes doubted not only the ability of investigators to achieve this, but the theoretical possibility of its being done. Indeed. Underwood expressed skepticism about the existence of the Hullian postulate concerning conditioned inhibition.

Children. — Attention to the experimental study of children, normal and abnormal, was focused during this period on learning studies, and attempts were made to integrate the experimental data uncovered in research on subhuman animals with the developing learning abilities of the child. Most of these studies, such as that of transposition in nursery school children by Margaret Kuenne and the studies by Charles Spiker, emanated from Hull's theory or from Harlow's concept of "learning to learn."

Social Psychology. — A renewed interest in experimental social psychology stemmed from the original work of Alex Bavelas, a student of Lewin, on the effects of various communication links on group behaviour. The theory assumes that co-operative action by a group is dependent upon the number and kind of communication links. Various patterns of communication links can be arranged according to definable principles, and their efficiency can be tested on a wide range of task performances by groups of varying size. The effects of different kinds of links on the attitudes of the group members also can be assessed, and the influence of a wide range of conditions, including problem difficulty, distribution of problem-related information, kind of leadership by selected group members, drug states and the efficacy of various types of information feedback were investigated. This communication-pattern model became an instrument for the experimental study of the interactions of small- and medium-sized groups.

Perception. — A new approach to the psychology of perception was provided through the researches of Jerome Bruner and coworkers. They were based on the assumption that perception is a selective process and that it will be influenced by the values which the individual places upon selected perceptual objects, whether these values are determined by past affective experiences or by existing internal states. Specific experiments suggested that favourable values accentuate the physical characteristics of objects, such as the size of coins, and that they selectively sensitize the subject's perceptual system and selectively lower his recognition threshold. Unfavourable values, on the other hand, result in perceptual defense, which elevates his perceptual thresholds and increases his latency response. Furthermore, drive conditions (*e.g.,* prolonged periods of food deprivation) may enhance perceptual selectivity.

Many of these experiments were subject to criticism on the basis of inadequate experimental controls and failure to control the past experience of the subjects.

In whatever realm and with whatever general background of theory he works, the modern experimental psychologist is definitely committed to a biological method of approach. He regards mental processes as falling into their place in a biological adaptation of the organism to its environment, and his problems are thus becoming more and more an inquiry into the functions which such processes carry out, and less and less merely a description or analysis of the processes themselves.

Modern Practical Applications.—The possibility of applying experimental psychological methods to the solution of practical problems, especially in education, was early realized. The movement gained momentum and extended into many fields of human achievement during World War I when almost every belligerent country called upon its psychologists for advice in the organization and training of its military. In industry psychologists devised and widely applied special techniques for vocational guidance, selection and training. Time-and-motion studies made notable contributions to human productivity and industrial organization. Fatigue, accidents and the particular effects upon work of special environmental conditions were studied intensively in a variety of practical fields.

In education the intelligence-test movement grew to enormous dimensions. Medical applications were everywhere exploited. though they were mainly, in this period, confined to the approach through what were called abnormalities. There was even a beginning of experimental investigation of broad problems of industrial management, and there was a burst of interest in the development of new methods for determining the distribution and evaluation of the influence of public opinion.

World War II vastly increased both the amount and the scope of psychological experiment as applied to practical problems. The striking increase of mechanization both in the fighting services and in their attendant industrial processes introduced problems new in magnitude though not in their basic character. In a rapidly increasing number of directions the human operator became an indispensable link in some variety of electrical or mechanical system. Such systems. therefore. had to be devised, and the general and specific conditions of their application determined in accordance with what the normal human individual could reasonably be expected to do with the highest efficiency and the smallest strain.

Experimental psychology became of enhanced interest to the physicist and engineer. Further, since mechanization on the whole tends to increase skill requirements. many hitherto unsolved problems concerned with skill training and skill fatigue were effectively studied. With skill training went a tremendous development of synthetic trainers, the principles in the design and use of which had to be considered as never before from the psychological point of view.

Side by side with all this increased interest in problems of the design and control of the instruments and conditions of work was an increase of activity and scope in vocational and professional selection. Even the broader problems of group and individual morale and of the results of the contact of differently organized social groups began to be approached less from the point of view of dogmatic opinion and more from their factual and partially experimental aspects. (*See* also PSYCHOLOGY, APPLIED.)

Specific major journals include: *American Psychologist, Journal of Abnormal and Social Psychology, Journal of Applied Psychology, Journal of Comparative and Physiological Psychology, Journal of Consulting Psychology, Journal of Experimental Psychology, Psychological Monographs, Psychological Review, Behaviour, Journal of Social Psychology, Journal of Genetic Psychology* and the *Journal of General Psychology.*

See also PSYCHOLOGICAL TESTS AND MEASUREMENTS; PSYCHOPHYSICAL METHODS; ANIMAL BEHAVIOUR; PSYCHOLOGY, COMPARATIVE.

BIBLIOGRAPHY.—E. G. Boring, *A History of Experimental Psychology,* 2nd ed. (1950); S. S. Stevens (ed.), *Handbook of Experimental Psychology* (1951); C. E. Osgood, *Method and Theory in Experimental Psychology* (1953); R. S. Woodworth and H. Schlosberg. *Experimental Psychology,* rev. ed. (1955); C. P. Stone (ed.), *Annual Review of Psychology,* 1–6 (1950–55); P. R. Farnsworth (ed.), *Annual Review of Psychology,* 7–8 (1956–57); for list of psychological journals, *see* American Psychological Association, *Psychological Abstracts,* 29:841–837 (1955). (F. C. BA.; H. F. H.)

PSYCHOLOGY, HISTORY OF. The history of psychology is the history of thought about human consciousness and conduct; that is to say, about reason, perception and memory, and also about action, motives and the other determinants of action. On the one hand. the history of psychology merges with the history of philosophy whenever psychology is regarded as dealing primarily with reasoning, thinking. feeling and perceiving; on the other, it merges with the history of physiology when psychology is considered to be the science of that behaviour which is regarded as a function of the action of the nervous system.

GREEK PSYCHOLOGY

Early Theories.—In the 6th century B.C. the development of medical thought had led to recognition of the importance of the brain and the sense organs in reasoning and in perception, two functions which were distinguished from each other. There also appeared quite early the doctrine of the four basic temperaments, dependent on the admixture of the four bodily humours—the blood, the phlegm, the black bile and the yellow bile. Centuries later the temperaments corresponding to these humours were named, respectively, sanguine, phlegmatic, melancholic and choleric. In early Greek thought there was no recognition of a soul which is an agent in the activities of reasoning or perceiving.

The idea of a soul as something resident in the body but capable of existence apart from it came into Greece with the Pythagoreans about the end of the 5th century B.C. Plato developed it, distinguishing between the nutritive, sensitive and rational functions of the soul, and assigning them, respectively. to plants. animals and men. He held that these functions represent a developmental hierarchy, each higher level including the lower, and that the development of reason in man may introduce conflict between reason, which is possessed only by man: and desire. which exists also at the animal level. Thus we find in Plato the conception of the soul's activity as constitutive of its basic functions? and the notion that simpler activities develop into more complex, sometimes giving rise to conflict. Such conceptions reappear from time to time in the history of psychology, notably in the psychology of G. W. Leibnitz (1704), J. F. Herbart (1825) and Sigmund Freud (1900), the line of development that led eventually to what is called dynamic psychology.

The Greeks also introduced the doctrine of empiricism into psychology, the doctrine that all the contents of the mind are derived through the senses. Heraclitus (5th century B.C.) held that all knowledge comes to man "through the door of the senses," and Protagoras (c. 484–411 B.C.) that the entire psychic life is made up only of sensations. The Stoics used the figure of the *tabula rasa,* the blank wax tablet of the mind upon which experience writes. This is the doctrine that was taken up later in the British school of empiricism.

The Greeks had also a theory of perception. Empedocles (c. 490–435 B.C.) supposed that objects give off from their surfaces or pores effluvia, which act upon the senses to furnish knowledge of the external world. Democritus (5th–4th century B.C.) and Epicurus (*c.* 341–270 B.C.) described these projections as faint images, simulacra or eidola of the objects which. being conducted to the mind, give it acquaintance with the objects which they represent. This view that perception represents an object by being similar to it is so simple and attractive that it continued to persist. in spite of opposition, having been contradicted by Johannes Müller

(1801–58) and by various critics in the 20th century.

Aristotle.—Aristotle (384–322 B.C.) has been said to be the greatest mind in the history of thought. Certainly his recorded wisdom influenced the scholarly thought of Europe more completely and for a longer time than have the writings of any other one man. He was both philosopher and scientist, theorizer and empiricist, and the psychology found in his De *Anima* and other writings determined accepted psychological doctrine down to the end of the 18th century.

In Aristotelian doctrine the body has a pneuma, which is connate with it and pervades it. This pneuma (animus, spirit) effects the integration of the organism by its appropriate movement within the body. Aristotle seems to have believed that the pneuma moved within the blood vessels, for he knew nothing about the nerves. Later psychologists substituted "animal spirits" for the pneuma and assumed that the nerves were their conductors, but the basic idea of integration by an internal pervasive agent was Aristotle's. The soul, according to Aristotle, is the entelechy of the body; that is to say, it is the perfection of unity toward which the functions of .the body are directed. This stress upon the unity of the soul and the importance of considering the total organism in the understanding of perception and action persisted through the ages into modern psychology and is the chief means of distinguishing psychology, which deals with total action, from physiology, which deals with the functions of parts.

Aristotle localized the psychic functions in the heart. That was an error. Plato and Pythagoras had been correct in placing them in the brain. Much later, Galen (*c.* A.D. 130–*c.* 200), one of the greatest physicians of antiquity, synthesized the two views by arguing that the animal spirits are stored in the ventricles of the brain, flow thence to the ventricles of the heart, whence they are distributed to the body by the arteries.

The specification of five separate senses is due to Aristotle. External forces, he held, act upon the body and their effects are transmitted by the pneuma to the sensorium, where the unity of the senses is preserved, as can be seen in such perceptions as those of shape and size: which are common to both sight and touch.

Aristotle distinguished clearly between the cognitive and conative aspects of the soul. On the one hand, he noted a cognitive series of functions from sensation to reason; on the other, a conative series from simple desire through wish to will. The basic conative drive Aristotle called *orexis*. In terms of it he derived a dynamic psychology, which for him included ethics.

Hellenistic Period.—After Aristotle there ensued the Hellenistic period, which was distinguished. among other things, by the brilliance of Alexandrian science in the 3rd century B.C. Herophilos (4th century B.C.) and Erasistratos (c. 304–258 B.C.) discovered the nervous system, the nerves leading to the brain and spinal cord. They even distinguished between motor and sensory nerves, a distinction that was not validated until 2,000 years later. In general, however, Alexandrian science did not promote psychology, for the mind was not then supposed to be understood in terms of natural law, and psychology and physiology became during the course of many centuries more and more widely separated.

The Stoics (c. 300 B.C.) contributed both the notion of instinct and of conscience, the latter signifying an inner sense of conformity with innate reason. In general. the Christian schools took over the pagan philosophy and with it Aristotle's psychology. By the 3rd century A.D. Plotinus (c. A.D. 203–270), promoting a return to Platonism, established psychology as a pure science of experience based upon introspection described without regard to underlying physiological processes. Augustine (A.D. 354–430) continued this tradition, establishing what came presently to be the accepted psychology of the Christian Church. Thereafter, through the middle ages! psychology consisted largely of a repetition and elaboration of the dicta of Aristotle and Augustine.

EARLY MODERN PSYCHOLOGY

All through the history of psychology we find a dichotomy in respect of which the various views and theories about mind and the definitions of psychology can be organized. In the absence of accepted terms, we may call the one the phenomenological approach and the other the mechanistic approach. The phenomenological approach to the problems of mind includes the description of immediate experience, directly as it comes to the observing person. It tends to regard mind as separate from the body and to get along with only minor reference to physiology. It is often an unexperimental psychology, being available to philosophers by their own introspection. The modern representatives of the phenomenological approach are Franz Brentano's intentionalism, Wilhelm Wundt's introspectionism, and Gestalt psychology. The mechanistic approach, on the other hand, deals more with causal relations than description. It is thus forced to look to bodily functions and physiological processes in order that it may subsume psychological events under natural law. Its modern representatives are U.S. functionalism, behaviourism and operationism. In general, up to the year 1910 and even later, the British and German traditions were phenomenological, the French and U.S. mechanistic.

Seventeenth-Century Psychology.—Plotinus and Augustine had left psychology phenomenological and descriptive. In the 16th century, with the tendency to recognize that causal principles determine behaviour, occurred the beginnings of a dynamic psychology. Niccolo Machiavelli (1469–1527) had effectively expounded the thesis that men are controlled more by their passions than by reason, and various other less well-known writers had developed that theme. Still later we find Francis Bacon (1561–1626) promoting a naturalistic view of man's conduct.

Thomas Hobbes (1588–1679), who published his Leviathan in 1651, was essentially a mechanist, a dynamic psychologist. He was primarily concerned with the conduct of man, especially his social conduct. Hobbes distinguished between innate motives and those that are acquired in experience. He observed how pleasure and pain, pride and fear, determine human action. He is perhaps, before John Locke, the originator of British empiricism, because of his stress upon the role of experience in establishing the nature of man; but mostly he was a social dynamic psychologist.

The great founder of the mechanistic tradition in psychology was René Descartes (1596–1650), a philosopher who also performed anatomical dissections and physiological experiments. He established in the common sense of the next three centuries the dualistic notion that mind and body are separate, that mind is unextended substance and body extended substance, the mind occupying the body and interacting with it at a determinate point in the brain. Thus, body affects mind, and mind body. Animals, who have. Descartes thought, no rational souls, are automata, machines which behave in accordance with their properties and the forces which act upon them. Thus, the history of reflex action. as basic to the mechanistic conception of mind, must be dated from Descartes. He called the total motion of the animal spirits along the nerves through the valves of the brain and out again along other nerves to the muscles *undulatio reflexa,* since the nervous system, in redirecting the course of the animal spirits to produce movement, may be regarded as "reflecting" them.

The mechanistic tradition was continued in France during the 17th century by the contributions of Nicolas de Malebranche (1638–1715).

Scientific cognizance was also being given at that time to some of the problems of visual perception. Leonardo da Vinci (1452–1519) had already discussed some of these problems—colour contrast, the relation of light and shade and of aerial perspective to the perception of the third dimension, the problem of the transparency of near objects in binocular vision (caused, of course, by the different angles at which the two eyes view the scene) and the similarity of the eye to a camera. In 1604 the astronomer Johann Kepler (1571–1630) noted that the crystalline object in the eye must be a lens and not the percipient organ, and that it must throw an inverted image on the retina. He, therefore, decided that the retina must be the percipient organ. Kepler then raised the question as to why we see right side up when the retinal image is upside down, falling into the common error of thinking that external objects must be represented by similar patterns in the brain. Later Descartes demonstrated, using the excised eye of a bull, that the inverted image is actually formed by the lens at the back of the eye.

The century saw two other important discoveries in the field of sense perception. In 1638 Galileo (1564–1642) showed that the pitch of tones depends on the frequency of vibration of the air, that the ratio is two to one for the octave and three to two for the fifth. In 1672 Isaac Newton (1642–1727) presented to the Royal society his first paper on colour theory, in which he showed by experiments with a prism that white is a mixture of colours. a discovery that was at first met with incredulity by his scientific colleagues. Newton worked out the laws of colour mixture, and his *Opticks*, after a long delay, was published in 1704.

Eighteenth-Century Psychology.—The French mechanistic tradition was continued by J. O. de Lamettrie (1709–51), who published his *L'homme machine* in 1748; by E. B. de Condillac (1715–80), who is noted for his analogy of the human organism to a statue, which, provided with a single sense, acquires through experience the attributes of a human mind; and by P. J. G. Cabanis (1757–1808), who extended the knowledge of reflex action and argued—he was interested in the reflexes of victims of the guillotine—that consciousness is dependent only on the action of the brain and not of the spinal cord. Contemporaneous with Cabanis was M. F. X. Bichat (1771–1802), who has been called by some the founder of physiological psychology.

The important events of the 18th century occurred, however, on the phenomenological side of psychology, especially in connection with the development of British empiricism and associationism.

In a sense, British empiricism began with Hobbes, but its formal initiation was the publication in 1690 of the *Essay Concerning Human Understanding* by John Locke (1632–1704). Locke's argument was that the mind is constituted of ideas. all of which are gained from experience, most of them by way of the external senses, some of them by reflection, which is the inner sense by which the mind becomes aware of its own operations. Although Locke added a chapter on association of ideas to a later edition of his *Essay*, the doctrine of association became of importance only with his successors.

Bishop George Berkeley (1685–1753), famous for his subjective idealism, inverted Locke's proposition. The problem, he thought, is not how the ideas get into the mind from outside by way of the senses, but rather, since the mind knows nothing other than the ideas of which it is constituted, how we ever obtain a belief in the existence of the external world. Berkeley undertook to answer this question and many other related ones by an appeal to experience and a principle which is essentially that of the association of ideas. He also wrote a *New Theory of Vision* (1709), which contributed both to the systematic theory of empiricism and to the psychology of visual perception.

David Hume (1711–76) comes next in this line of descent. He differentiated impressions, which depend upon a present stimulation, from ideas. which are "faint copies" of the impressions. This is the distinction between sensation and image in later terminology. Hume also undertook to explain the concept of causation as resulting from the habitual sequence of the impressions of two events, thus reducing causation to association. Because Hume lent his great influence to the conception of ideas as mental elements whose compounding explains all of the more involved mental phenomena, he is often regarded as the chief enemy of holism. as it is found in the modern school of Gestalt psychology.

David Hartley (1705–57), while less important than his predecessors in this school, stands out because of the clear, simple and emphatic associationism which his *Observations on Man* of 1749 presents. Taking association from Locke and the notion of transmitted vibratory motion from Newton, he built up a system in which the laws of association of ideas were paralleled by laws of association of vibrations (correlated with sensations) and diminutive vibrations (correlated with ideas. images) in the nervous system. This sharp and uncompromising presentation of the associationistic principles. combined with a simple psychophysical parellelism of mind and nervous action, served to make the nature and implications of associationism clearer than could the more subtle exposition of an abler mind, like Hume's.

The French tended to take over associationism and combine it with their mechanistic psychology. Condillac's statue (*see* above) was supposed to build up its sensations in experience by means of associative principles.

Meanwhile in Germany there was G. W. Leibnitz (1646–1716), Locke's contemporary. Leibnitz's chief contribution to psychology was his insistence on the active nature of the mental units, his "monads," which are forever striving for development according to their pre-established nature. The association of ideas in the British school tended to create the picture of fixed mosaics of mental elements which make up the complexes of the mind. Leibnitz, on the other hand, remained on the side of a dynamic psychology, which insists that activity and purpose are basic in mental life. He believed that his monads develop independently, and that the results of their interrelations are simply coincidences resulting from a harmony pre-established among them and not from causal interaction. The conception of psychophysical parallelism between mind and body grew out of this Leibnitzian notion. Leibnitz also contributed to psychology the concept of apperception, which he held to be the consequence of the summation of many little perceptions. His notion that the apperception of the roar of the sea is the sum of the "petites perceptions" of the noise of every falling drop of water is well known. It gave rise to the concept of the threshold of consciousness as it is found in the writings of Herbart, in G. T. Fechner and psychophysics, in Freud and psychoanalysis.

After Leibnitz the development of German psychology passed into the hands of a number of less well-known men in the Berlin academy, of whom J. N. Tetens (1736–1807) is perhaps the best known. The chief contribution of these philosopher-psychologists was to stress the importance of feeling as a third primary category of psychology. Heretofore cognition and volition. knowing and acting, had constituted chief subdivisions in systematic psychology. Now the affective life was added as a third, and this threefold division of the subject matter of psychology—thinking, feeling and doing—continued as the standard classification all through the 19th century and well into the 20th.

PSYCHOLOGY IN THE 19TH CENTURY

The history of psychology in the 19th century can be viewed as a history of schools of systematic thought about the mind (associationism, introspectionism, intentionalism, evolutionism, functionalism) and of fields of experimentation and research (physiological psychology, experimental psychology proper, phenomenological observation, abnormal psychology and the mental tests in conjunction with the functional psychology of individual differences).

Associationism.—While the Scottish philosophers—Thomas Reid (1710–96), Dugald Stewart (1753–1828) and Thomas Brown (1778–1820)—are not properly classified as associationists. the theory of perception that developed under their thought contributed to the importance of associationism. Bronn's theory is the culmination of the discussion. He distinguished between sensation and perception, holding that perception, unlike pure sensation. refers to or intends an external object. In perception the sensations that first arise suggest—by association. but Brown preferred the word "suggestion" to "association"—other sensations which specify the object which is intended. For example, the smell of a rose suggests the sight of a rose, which is enough to identify the object as a rose. In other words, meaning arises in perception by the compounding of two or more sensory elements, and that theory is really the core of associationism: meaning is given in consciousness by the associative compounding of ideas.

It was James Mill (1773–1836) who expressed this view in simplest and clearest terms in his *Analysis of the Human Mind* in 1829. In fact, he reduced the theory to an absurdity by carrying it to its logical conclusion. At the end of his chapter on association of ideas, he noted that the idea of any object is a fusion of the ideas of its components. "Brick is one complex idea, mortar is another complex idea: these ideas. with the ideas of position and quantity, compose my idea of a wall." Finally, he asked: "How many complex ideas are all united in the idea of furniture? How many more in the idea of merchandise? How many more in the idea called Every Thing?" That was the difficulty: the associationists thought that the idea of everything must be a compound formed by association of every idea of a thing.

John Stuart Mill (1806–73), James Mill's son, made no such error. He avoided the difficulty by noting that a combination of elements often generates something totally new in the compound, so that the parts are lost and the new product gained. This is the theory that Wundt called creative synthesis, that others much later called emergence, that became still later the basis of Gestalt psychology. J. S. Mill also argued that the unrealized potentialities of association play their role in the mental life: an object is, he argued, the "Permanent Possibilities of Sensation"; that is to say, the sensations that it could arouse. As an object, it is believed to be permanent, in spite of the evanescent nature of experience, because these possibilities of sensation are permanent.

Alexander Bain (1818–1903) is the representative of associationism in the latter half of the 19th century. He combined with associationism the growing interest in physiological psychology. Herbert Spencer (1820–1903) represents an influential evolutionary associationism, a doctrine that worked in with the trend of thought in England after Charles Darwin's influence had become dominant. From this point associationism passes over into the introspectionism of Wundt and his followers.

Introspectionism.—Wilhelm Wundt (1832–1920) has been called the founder of the new scientific psychology of the 19th century. Certainly he was its vigorous promoter. He called it physiological psychology and experimental psychology. His *Grundziige der physiologischen Psychologie* was a systematic text and also a general handbook of the new science: and it ran to six editions from 1874 to 1911. Wundt founded the first formal laboratory of psychology at Leipzig, Ger., in 1879. He started the first journal devoted to experimental psychology in 1881. For 40 years he was the most important and influential figure in German psychology.

As a systematist he was an elementist and an associationist, for he described the sensations and feelings that are the mental elements of psychology, and showed how they are compounded by association into ideas and perceptions *(Vorstellungen)* which are meaningful and refer to objects. The turn of events, however, put more emphasis upon Wundt's insistence that introspection—the verbal description of the immediate data of experience—is the chief method of psychology. Although Wundt called the new science physiological psychology, he was insistent that physiological processes parallel and do not constitute the psychic processes. The phenomena of consciousness, he held, are observable without reference to the body to which they belong.

Wundt's position was continued by Oswald Külpe (1862–1915) and E. B. Titchener (1867–1927). They were both his students. Külpe is best known for his attempt to apply the introspective method to the study of thought in the researches of his Würzburg school (1901–09), which showed—this appears to be the verdict of time—that introspection is inadequate to the observation of the unconscious directive tendencies which preserve the purposive nature of thought. Titchener went to the United States in 1892 and there upheld the Wundtian position for 35 years. There can be no doubt that U.S. functionalism was more clearly understood because it contrasted so strongly with Titchener's unyielding introspectionism. Titchener hoped that psychology could eventually get along without any relation to physiology.

J. F. Herbart.—The influence of Herbart (1776–1841) was so great during the first half of the 19th century that separate mention must be made of him. He defended a psychology founded upon experience, metaphysics and mathematics, and denied the possibility of experimenting upon mind. He conceived of ideas as active and struggling, one with another, for a place in consciousness. Thus, as we have already noted, he provided, in following Leibnitz, both psychophysics and psychoanalysis with the concept of the threshold of consciousness and also with the notion of unconsciousness that lies below the threshold. Much of Wundt's work was clarified by his opposition to Herbartian ideas.

Intentionalism.—The traditional psychology that had come down from Aristotle and Augustine was reformulated by Franz Brentano (1838–1917), a Roman Catholic priest and a psychologist of aide influence, as what is called act psychology or intentionalism. The contrast between Brentano's and Wundt's psychologies was heightened by the fact that both men published their crucial systematic texts in 1874. Brentano contended that the conscious mind is constituted of acts—ideating, judging, feeling ("loving-hating"). Wundt had divided mind into more static elements—sensations and the feelings. The acts, Brentano held, have objects which they "intend" or are directed upon, and these objects "inexist" within the act. If I see a green, then the act of *seeing* is the mental datum and the *green,* the object of the act, exists intentionally within the act, thus in part determining its nature.

Brentano's psychology claimed many followers in the late 19th and early 20th centuries, especially in Austria. Kiilpe's later systematic views were affected by Brentano's thinking, as was also the system of Carl Stumpf (1848–1936), who, holding the chair at Berlin, found himself in opposition to Wundt on many occasions.

In England, James Ward (1843–1925) was markedly influenced by Brentano. Ward distinguished between cognition, feeling and conation, finding all three present in the representative psychological act. G. F. Stout (1860–1944) followed the tradition of Ward, and William McDougall (1871–1938), who in 1919 transferred from England to the United States, upheld a purposive psychology that showed this same influence.

Evolutionism.—One effect of Charles Darwin's theory of evolution was to interest psychologists in mental inheritance and in the phylogenetic development of mind. In 1869 Francis Galton (1822–1911) published *Hereditary Genius,* a study which showed that men of eminence in England tend to be related. In those days the data were taken as demonstrating the biological inheritance of mental ability, although later it became evident that these great men owed their eminence at least in part to their education and their socioeconomic status. Darwin himself argued for the phylogenetic development of mind in his *Expression of Emotion in Man and Animals* (1872). Thereafter the versatile Galton conducted other studies on mental inheritance among persons of ability and on the resemblances of twins. He advocated the inventorying of the abilities of the British nation, inventing some simple tests whereby such an inventory could be made (or so he thought). He coined the word "eugenics," meaning by it the improvement of the race by selective parenthood.

G. J. Romanes (1848–94) carried on this interest in England by his studies of animal intelligence and his books on mental evolution in both animals and man. He coined the term "comparative psychology" for the study of the relationships between the minds of different animal species. C. Lloyd Morgan (1852–1936) carried comparative psychology further, and this field of endeavour was then taken up in the United States *(see* PSYCHOLOGY, COMPARATIVE).

British evolutionism also found support in the United States. J. M. Baldwin (1861–1934) was the Romanes of the U.S.. with two important books on mental evolution. G. Stanley Hall (1844–1924) admitted that his many interests in the different phases of human capacity were held together by his abounding faith in the importance of evolution. James McK. Cattell (1860–1944), directly influenced by Galton, coined the term "mental test" in 1888 and lent his support to the development of the psychology of individual differences. In the United States evolutionism formed the background of functionalism.

Functionalism.—In the 1880s and 1890s the United States had the temper of a young nation, a nation still imbued with the practical spirit of conquering a continent. It sent its psychologists to Wundt at Leipzig that they might learn the best of what was new in psychology, but U.S. psychology never accepted the pedantry of the German approach to the subject. The Americans were bound to be practical and functional, to see mind in terms of its use for the survival of the organism in the struggle of the race for existence and in the social competition of the individual for success. Hence, the United States accepted evolutionism enthusiastically and created its own psychology, which was functional.

William James (1842–1910), pioneer of psychology in the United States, introduced the functional approach to the problems of the mind in his *Principles of Psychology* of 1890. Cattell, as has just been noted, supported a functional psychology in his advocacy of the use of mental tests in the 1890s and later. The formal school of functionalism was, however, founded by John Dewey (1859–1952) about 1896 and was continued at The University of Chicago by James R. Angell (1869–1949) and his associates.

Functional psychology admits the data of both consciousness and behaviour to its domain, for it is primarily concerned with what enables the organism to adapt to the varying conditions of its environment. Functional psychology is the psychology of the "Is-for," as Titchener remarked, the psychology of how to be successful, and thus it is appropriately American. The school disappeared after Dewey and Angell left Chicago, and behaviourism was ready to replace it (c. 1916). Nevertheless, the spirit of functionalism, since functional psychology is a natural medium for physiological psychology, animal psychology! differential psychology, normal psychology and applied psychology, came to stay and has characterized most of the psychology of the United States from the beginning. *(See* section on *Functional Psychology* below.)

Physiological **Psychology.**—The century saw great progress in nerve physiology. In 1811 Charles Bell (1774–1842) distinguished between sensory and motor nerves, showing that the two kinds of nerves have separate roots at the spinal cord. François Magendie (1783–1855), the French physiologist, discovered independently in 1821 this same fact, which is called the Bell-Magendie law. As electrical currents and galvanometers became available in the 1840s, the electrical properties of nervous conduction came to be investigated, and the mysteries of the animal spirits were dissipated by the accumulation of observed facts. In 1850 H. L. F. von Helmholtz actually measured the velocity of the nervous impulse along a nerve, a discovery which met at first with as much incredulity as Newton's report in 1672 that white is a mixture of colours.

There was also a great deal of work on the localization of functions in the brain. F. J. Gall (1758–1828), a brain anatomist of considerable ability, formulated the theory of phrenology about 1800, the theory that temperament can be assessed from a study of the conformation of the skull. since the development of crucial areas in the brain would be reflected in the shape of the skull. The popularity of this view was not readily destroyed by the scientific opposition which it received. Pierre Flourens (1794–1867) undertook experiments upon animals to determine more exactly the functions of the various parts of the brain, discovering about 1825 that certain gross areas are essential to certain functions but that fine localization is often (perhaps always) missing. In 1861 Paul Broca (1824–80) discovered the speech centre in the left cerebral hemisphere, and then in 1870 G. Fritsch and E. Hitzig localized motor centres precisely by electrical stimulation of the brain. The last quarter of the century saw the growth of a firm belief in exact cerebral localization, a belief somewhat weakened by the discoveries of the 20th century.

Johannes Müller (1801–58), sometimes known as the father of experimental physiology, affected psychology by his doctrine of specific nerve energies. which he first published in 1826. The doctrine was really a theory of sensory quality, for Müller sought to demonstrate that the sensory quality aroused by stimulation depends on the particular nerve excited and not directly on the nature of the stimulus. Pressure on the eyeball produces a sight, light on the skin elicits warmth and electricity on any nerve arouses the peculiar quality ("energy") that belongs to the nerve. Later Helmholtz extended this doctrine to differences of quality within a given sense, even seeking in the inner ear a means whereby each one of several thousand distinguishable pitches could be put onto a corresponding nerve fibre. Later research indicated that the specificity of different nerves and fibres lies not in a peculiar nervous energy but in points in the brain to which fibres lead.

Experimental Psychology. — Experimental psychology *(q.v.)* proper began with sense physiology, the study of how sensory experience is dependent on stimulation of the sense organs. which is what Fechner later called psychophysics *(see* PSYCHOPHYSICAL METHODS). Newton's discovery of the laws of colour mixture and Galileo's finding about the dependence of tonal pitch on stimulus frequency were psychophysics. In the 19th century the increased interest in sensory physiology advanced psychophysical investigation greatly.

Research on vision predominated. Thomas Young (1773–1829) published his theory of colour vision in 1801, the theory that Helmholtz later established. The poet, J. W. Goethe. in 1810 published his *Zur Farbenlehre,* an elaborate, dictatorial phenomenology of colour; its immediate influence was great because of the enormous prestige of its author. J. E. Purkinje (1787–1869) also wrote a phenomenology of vision (1819. 1825) which contains the first accounts of several important phenomena; for example, the "Purkinje phenomenon" of the changes of hues as illumination shifts from daylight to night vision. Johannes Müller's first important book (1826) was on visual physiology.

In 1834 E. H. Weber (1795–1878) published his experiments on tactual sensibility, experiments which included his finding that magnitudes of stimuli that are just noticeably different in perceived intensity bear a constant ratio to each other. G. T. Fechner later named this principle Weber's law. It is only approximately true.

The century's two most important experimental psychologists were Fechner and Helmholtz. Fechner (1801–87) was, by way of his *Elemente der Psychophysik* of 1860. the founder and promoter of psychophysics, and some say of experimental psychology, although that distinction is generally reserved for Wundt. Fechner was obsessed by his realization that it is possible to measure sensation as well as the sensory stimulus, and to state in an equation the relationship between the two measures. He described, developed and formalized the three fundamental psychophysical methods of sensory measurement. He named Weber's law and worked out the quantitative relationships which it implies. He established the concepts of the absolute limen (just noticeable sensation) and the differential limen (just noticeable difference between sensations), and the methods of measuring them. In short he put sensory psychology on a quantitative basis.

H. L. F. von Helmholtz (1821–94) made the greatest factual contribution of any one man to experimental psychology. The results of his observations and thought appear in the three volumes of his *Handbuch der physiologischen Optik* (1856–67) and the one volume of his *Lehre von den Tonempfindungen* (1863), which for more than half a century remained respectively the standard reference works on visual and auditory psychophysics.

Fechner's methods and Helmholtz's facts helped Wundt in the founding of experimental psychology. The last quarter of the 19th century saw the founding of many psychological laboratories, first in Germany and then in the United States. Wundt's demonstrational laboratory in 1875 was the first to be created, and his institute at Leipzig in 1879 was the first formal laboratory; William James also had an informal laboratory at Harvard college as early as 1875. Research followed the founding of the laboratories — first on sensation and perception. then on action, then on memory and learning, with the bare beginnings of an experimental psychology of thought and attitude showing before 1900.

Abnormal Psychology. — The history of abnormal psychology *(see* PSYCHOLOGY, ABNORMAL) would consist of a history of witchcraft, animal magnetism, hypnotism. hysteria, psychoanalysis and neurosis. Many of the neurotics of the 17th century were considered to be sorcerers or witches. Late in the 18th century F. A. Mesmer (1754–1815) discovered that he could exercise over other persons a peculiar power which he called animal magnetism and which others came later to call mesmerism. Toward the middle of the 19th century James Braid identified this state with some of its scientific conditions, calling it neurypnology which later became hypnotism (*q.v.*). In the last quarter of this century

J. M. Charcot (1825–93) at the school of the Salpêtrière near Paris undertook the study of hysteria, a neurotic state in which the extreme symptoms resemble the symptoms of hypnosis. Charcot thought that only hysterical persons could be hypnotized, but in that belief he was wrong. Charcot's place as the foremost psychopathologist of France was taken by Pierre Janet (1859–1947), who published the classical text on hysteria in 1892.

Sigmund Freud (1856–1939) was also for a brief time a student of Charcot, but Freud's development of the method and concepts of psychoanalysis were his independent doing.

Psychoanalysis (*q.v.*) may be said to have got under way with Freud's publication of his book on the interpretation of dreams in 1900. Its further development and the emergence and establishment of the dynamic psychology of neurosis, which made use of many psychoanalytic terms and concepts, are largely a history of events in the 20th century.

The history of abnormal psychology is, of course, related to the history of psychiatry (*q.v.*). In Germany Emil Kraepelin (1856–1926), one of Wundt's pupils, contributed notably to psychiatry and to the classification of the abnormal states with which psychiatry deals.

Differential Psychology. — We have seen how Galton became interested in individual differences in mental capacities and formed a scheme of inventorying the British nation in order to assess its psychological resources. He invented a number of simple mental tests and Cattell, in the United States, made up some more and promoted their use. Galton's and Cattell's tests were for the most part simple tests of sensory and motor capacity and did not adequately measure intellectual and scholastic abilities. In France Alfred Binet (1857–1911), assisted by Victor Henri, was developing certain concepts of personality and tests of intelligence for children. Out of that work there emerged in 1903 Binet's intelligence tests. which, because they measured more important intellectual capacities, nere accepted in preference to the sensory and motor tests. The history of intelligence testing, and later of testing for special abilities and aptitudes, belongs, however, to the 20th century.

PSYCHOLOGY IN THE 20TH CENTURY

For the most part the history of the psychology of the first half of the 20th century is given in the special articles on psychology.

(See PSYCHOLOGY and cross references there cited.) The following paragraphs give the general perspective.

Schools. — The century began with introspectionism and functionalism well established in the United States, introspectionism and intentionalism dominating the psychology of Germany, abnormal psychology important in France and evolutionism in England. Gestalt psychology began in Germany about 1912 as a reaction against Wundtian introspectionism, and its leaders came to the United States in the 1930s after Adolf Hitler came to power. Behaviourism began in the United States about 1913 as a protest against both introspectionism and functionalism, but actually hehaviourism was not inconsistent with functionalism, and presently it took over the practical and mechanistic values that had been the occasion for functionalism. The attack on old-fashioned analytical introspectionism was successful, and in the late 1920s Gestalt psychology and behaviourism found themselves practically in possession of the field. With their missions thus more or less accomplished, both these schools tended to die out or at least to lose their aggressiveness during the 1930s. Psychological operationism came in at this time to supplant behaviourism as a more sophisticated mechanistic view of psychology, and the outstanding systematic issue in the early 1940s seemed to be whether the Gestalt psychologists could save consciousness, as observed in direct experience, for psychology, or whether the operationists would succeed in having it reduced to the behavioural terms which define the manner of its observation. In general, the operationists tended to support physiological psychology, whereas the Gestalt psychologists relied more often on the modern substitute for introspection which they call phenomenology. (*See* BEHAVIOURISM; PSYCHOLOGY; *see* also special sections on *Functional Psychology* and *Gestalt Psychology* below.)

Trends. — The first half of the 20th century was marked by the shift of leadership in psychology from Germany to the United States, by a decrease in the importance of schools and an increase in the importance of scientific research, by the diversification of psychology into many special fields, each possessed of its own techniques and special knowledges, and by the growth of applied psychology in its various professional aspects, in England and Germany as well as in the United States.

Experimental psychology, the general scientific psychology of sensation and perception, feeling and emotion, learning and thought, response and action, remained the expanding core of modern psychology, although it could scarcely be said to dominate a subject which now had so many special fields. *Animal psychology,* which began the century as an independent field of research, became amalgamated with experimental psychology, at first under the influence of behaviourism, and later because most of the experiments in general psychology, especially the experiments in the field of learning, could be conducted more efficiently with animal subjects. I. P. Pavlov's researches on the conditioned reflex re-enforced this association. *Physiological psychology* required operative techniques and was likewise fairly independent of experimental psychology at the beginning of the century, but also became fused with it.

By 1940 the distinctions among these three fields had almost disappeared. (*See* PSYCHOLOGY, COMPARATIVE; PSYCHOLOGY, EXPERIMENTAL.)

Differential psychology developed steadily from the beginnings of mental testing with Galton, Binet and Cattell. Up to about 1920 the testing of "intelligence" was the most important activity in this field. About that time psychologists began to realize that social. economic and educational factors can affect ability to do well in an intelligence test, and that biological inheritance is less important than had been supposed. C. E. Spearman in England began in 1904 the development of those statistical correlational methods of the analysis of abilities that later resulted in factor analysis. These improved methods of analysis turned attention away from general intelligence toward the factoring out of the personality those special abilities and aptitudes which function independently in the organism's struggle for success. It is obvious that a great deal of the development of differential psychology has thus been functional and in the interests of applied psychology. (See DIFFERENTIAL PSYCHOLOGY; INTELLIGENCE)

Abnormal psychology was quite distinct from general psychology for fully three decades of the century. Since it dealt with the functional disorders and thus with motivation. it got ahead with the problems of personality much faster than did general psychology. *Psychoanalysis* also constituted an attack on the problems of motivation and personality, and its ideology came largely to be accepted by psychiatrists and psychologists, even when they repudiated its techniques and certain of its tenets. It was this development of abnormal psychology throughout the first three decades of the century that gave rise in the 1930s to a vigorous dynamic psychology. (*See* PSYCHOLOGY, ABNORMAL; PSYCHOANALYSIS.)

Dynamic psychology arose because of the great interest in human motivation. By 1925 it was beginning to concern psychologists more and more. Dynamic psychology provides a general background for many applied psychologies, like *clinical psychology,* and the techniques of counselling and guidance.

Child psychology, although it grew out of evolutionism and the interest in genetic psychology in the late 19th century, has been essentially dynamic psychology, and child guidance has become an important branch of applied psychology. (See CHILD PSYCHOLOGY.)

Educational psychology was also principally a growth of the 20th century. It was stimulated by the development of psychological tests and by the general acceptance of the concept of intelligence as the chief intellectual dimension of maturation in childhood and adolescence. Educational psychology has been, of course, closely associated with child psychology and dynamic psychology.

Social psychology has its roots in the *Volkerpsychologie* of the Germans in the 19th century and in the work of certain French writers, especially Gabriel de Tarde and Gustave le Bon. In 1908 William McDougall's *Social Psychology* based social behaviour on the instincts, of which he furnished a classification. After that time social psychology became dependent for its theoretical structure upon those primitive drives or needs which the dynamic psychology of any given period could provide. In the 1930s social psychology was becoming applied, notably through the development of public-opinion polling and the analysis and control of propaganda. In World War II the techniques of the social psychologists were used broadly for the assessment and control of opinion and attitudes and for the gathering of psychological information about large social groups. In such undertakings social psychology was found to be closely related to social anthropology and to certain modern empirical movements in sociology. *(See* section on *Social Psychology* below.)

Applied psychology was the term used for psychotechnical endeavour prior to 1920. Thereafter the special applied psychologies began to make their appearance. We have already noted the modern concern with educational psychology, with clinical psychology, with counselling and guidance of adults and children (as well as the aged) and with applied social techniques. In addition to these there was some development of *legal psychology* and, after 1920, a great deal of interest in *industrial psychology* which, apparent first in England, was promoted subsequently in the United States and greatly furthered by the successful use of psychology in World War II. Industrial psychology is concerned with the selection and training of personnel, and the establishment of the most efficient conditions for work. Efficiency depends upon the proper design of machines, the reduction of fatigue, the promotion of good health and the maintenance of good morale in the relation between worker and employer. Thus, industrial psychology makes use of many of the principles of perception, sensorimotor co-ordination and learning which general psychology develops. and of dynamic psychology, differential psychology and social psychology.

(See, in addition to the cross references just cited, PSYCHOLOGY, APPLIED.)

BIBLIOGRAPHY.—J. M. Baldwin, *History of Psychology,* 2 vol. (1913); G. S. Brett, *A History of Psychology,* 3 vol. (1912–21); H. C. Warren, *A History of Association Psychology* (1921); G. Murphy, *An Historical Introduction to Modern Psychology,* 2nd ed. (1949); E. G. Boring, *A History of Experimental Psychology,* 2nd ed. (1950) and *Sensation and Perception in the History of Experimental Psychology* (1942); F. Fearing, *Reflex Action: a Study in the History of Physiological Psychology* (1930); J. C. Flugel, *A Hundred Years of Psychology: 1833–1933* (1933); C. E. Spearman *Psychology Down the Ages* (1937); G. Zilboorg and G. W. Henry, *A History of Medical Psychology* (1941). *See* also *The Harvard List of Books in Psychology* (1949).
(E. G. BOR.)

FUNCTIONAL PSYCHOLOGY

Functional psychology is that point of view which emphasizes the biological significance of mental activities, holding that conscious processes, like organic activities, appear and function in response to the needs of the total organism in achieving a more adequate adjustment to its environment. The movement which bears the name functionalism had its roots in the Darwinian evolutionary viewpoint, the biologically oriented psychology of William James, the instrumentalism of John Dewey and the interest in animal psychology. Under the leadership of James R. Angell and Dewey, functionalism, from 1894 on, became the dominant viewpoint of the laboratory of experimental psychology at The University of Chicago. Though its leaders had no intention of developing a unique school, their viewpoint became crystallized through the necessity of defending it against attacks. In stressing the role of conscious processes in everyday living, they seemed to their critics to violate the doctrine, then current, of mind-body parallelism. Their assumption that mental functions develop in response to the organism's adjustmental needs was criticized as teleological; yet, biologists had adopted a similar assumption with impunity. Their attempt to deal with mental functions introspectively met criticism on the ground that functions are meanings, not content, and cannot be objects of introspection. Functional psychology, however, never limited itself to the introspective approach; it investigated activities in terms of what they accomplished, the end product, utilizing both introspection and objective observation. The objection that functionalists use the term function ambiguously, at one time meaning the *process,* at another the *end* served by it, was answered by Harvey A. Carr, who followed Angell as director of the Chicago laboratory. He pointed to a common identity of these two usages in the mathematical term "function," which implies a contingent relation, whether of act to structure, or of means to end. Hence, the distinction made by R. S. Woodworth between primary and secondary functionalism was unnecessary. Carr made mental activity the subject matter of psychology, avoiding any dualistic implications of the term by identifying it with that entire group of psychophysical processes involved in adaptive behaviour; *i.e.,* acquiring, retaining, organizing, evaluating, and subsequently utilizing experiences in the guidance of conduct. By opening the way for the study of behaviour as a legitimate part of psychology and by insisting that mental activity be considered in its practical everyday setting, functionalism paved the way both for the behaviouristic movement and for the phenomenal expansion of the applied branches of psychology in the United States.

BIBLIOGRAPHY.—J. R. Angell, "The Province of Functional Psychology," *Psychol. Rev.,* vol. 14, pp. 61–69 (1907); H. A. Carr, "Functionalism," in C. Murchison (ed.), *Psychologies of 1930,* chap. 3, pp. 59–78 (1930); J. Dewey, "The Reflex Arc Concept in Psychology," *Psychol. Rev.,* vol. 3, pp. 357–370 (1896); E. Heidbreder, *Seven Psychologies,* chap. vi (1933); R. S. Woodworth, *Contemporary Schools of Psychology,* rev. ed., chap. 2 (1948).
(A. G. Bs.)

GESTALT PSYCHOLOGY

Gestalt psychology deals with mental facts which are ignored when merely analytical procedures are used in psychology. That such facts exist was first discovered in perception. For instance, in customary analysis a visual field was regarded as composed of local sensations, each of which corresponded to a local physical stimulus. But in 1890 Christian von Ehrenfels, an Austrian psychologist, remarked that in this description of the field many visual characteristics such as round, angular and slender were omitted. For their occurrence neither single stimuli nor mere sums of such stimuli can be made responsible. This becomes particularly obvious if, in a given case, all individual stimuli are changed in the same proportion. The characteristics in question are not affected by this measure. When presented in a changed colour, in a different place or in another size, an object remains about as round, angular or slender as it was before. Von Ehrenfels added that in the dimension of time, analysis meets with the same difficulty. Thus, in music the major and the minor characteristics of melodies belong to the melodies rather than to individual tones. Since visual shapes (Gestalten) are the most obvious instances of such phenomena, Ehrenfels called the whole class Gestalt qualities.

But analysis in the customary style also ignored the entities which have such attributes. In vision, for example, retinal stimuli represent a mere mosaic. And yet visual Ehrenfels qualities are for the most part attributes of specific objects such as things and figures. What is the nature of these units? Some authors maintain that the units are established by intellectual processes. However, while intellectual activities may interfere with given objects, there is no empirical evidence that such activities form the objects in the first place.

In 1912 M. Wertheimer was led to a much more radical solution of the problem. He denied the existence of sensory elements as parts of perceptual experience. According to him, the nervous system tends to give a unitary answer to the total stimulating situation with which it is confronted at a given time. But far from being uniform, this answer is for the most part quite articulate. In certain areas the unitary character of the response is greatly enhanced, while at the same time these areas are relatively segregated from their environment. Thus, things, figures, etc., originate. In the temporary dimension the same happens: from the unitary course of experience particular events tend to be segregated which are to this extent analogous to objects. Such events and objects again need not be uniform. Just as they are relatively segregated members of the total field so they may have parts of their own. This term parts, however, no has a particular meaning. Genuine parts of a sensory field or of its objects involve, qua parts, inclusion in the larger units in which they lie. They are experienced as referred to these larger entities. They must also be distinguished from the arbitrarily chosen elements into which traditional analysis would split sensory experience. From the new point of view, analysis is justifiable only if it deals with the genuine parts of a field:

In Wertheimer's writings the specific units or entities which appear in a field are called Gestalten. Although this terminology corresponds to common usage in German it greatly disturbed psychologists in England and in America who translated Gestalt as "shape" (which it may also mean in German). In Gestalt psychology, the substantival connotation of the term plays a much more important part than its adjectival meaning, which refers to shapes rather than to the entities which have shapes. In English, the process of articulation is commonly called organization of the field, a term which may also be used for the outcome of the process. According to the dictionaries, the word "structure" has about the same two meanings as Gestalt has in German.

Although the stimuli which impinge upon sensory surfaces constitute a mere mosaic, there are always factors in this mosaic which give the process of articulation a particular direction. These factors are the formal relations which obtain among the stimuli, such as, for instance, their proximity in space and in time, the degree to which they resemble one another, etc. Other conditions being equal, organization tends to form compact and more or less homogeneous structures rather than widely scattered and heterogeneous units. Again, the process is likely to segregate objects with smooth contours rather than irregularly shaped entities.

From the basic conceptions of Gestalt psychology a great many specific investigations and theoretical discussions developed. Particularly interesting are those in which the new point of view was defended against a rival thesis: the thesis that, after all, elementary sensations are the real material of the sensory world, and that only learning about the unitary objects of the physical and practical world makes things out of sensory atoms. This theory cannot explain the fact that the outcome of sensory organization may be at variance with our knowledge of objects in the practical sense. Thus. well-known objects are not seen, and strange things are seen instead, when the principles of organization favour existence of the latter. Experiments have shown that previous experience has a certain influence upon the organization of given fields. But far from proving that learning fabricates things out of sensory elements, these experiments demonstrate only that familiar forms of organization tend to modify subsequent processes of articulation.

Organization ought not to be interpreted as a mere formation of agglomerates. In the first place, the characteristics of things are generally affected by their inclusion in larger organizations. In other words, organization involves interaction. Such interaction seems to explain colour and brightness contrast, most so-called optical illusions and, also, several perceptual constancies. As an example: When the illumination of an object and of its immediate environment changes, stimulation in the area of the object and its background is correspondingly altered. Nevertheless, the colour of the object tends to remain virtually unaffected. According to the Gestalt psychologists, this constancy of object colour is brought about by interaction between the object and its environment. They claim that, under the circumstances given in a case of constancy, this interaction operates against the effects of changed local stimulation, and thus exerts a compensating influence.

In the second place, organization gives its products characteristics of their own, such as the Ehrenfels qualities. It is, however, not only segregated objects as such which exhibit particular characteristics of this kind. The same holds for their parts. Thus, a certain point in an object is a corner only within this larger unit, a line is a boundary only with reference to a segregated area, etc. One particular characteristic of this class has become famous by an investigation of E. Rubin (1921). He called attention to the difference between figure and ground, between the substantial appearance of objects and the looseness of their homogeneous environment. Equally important is A. Michotte's discovery (1941) that, under certain conditions of successive stimulation, causation is directly experienced as a characteristic of organized developments.

Organization in Physics and Physiology. — Since, as a rule. perceptual organization does not originate within experience, it must be processes in the sensory nervous system which are responsible for the formation of perceptual units. for the change of their characteristics by interaction and for the emergence of Ehrenfels qualities. Thus, Gestalt psychology is under obligation to show that organization occurs in the realm of physical facts; that some particular facts of this kind occur in the nervous system; and that physiological organization in this sense actually underlies all instances of organized experience. As to the first point of this program, such eminent physicists as C. Maxwell, M. Planck and A. Eddington have sometimes clearly stated that a purely analytical approach may not be able to do justice to all phases of physical nature. Actually, whole sets of physical processes are never treated in what could properly be called an analytical fashion. The epistemology of physics has merely failed to recognize this fact, although it is implicit in the physicist's own work. It was first made explicit by W. Kohler (*Die physischen Gestalten in Ruhe und im stationären Zustand* [1920]). He showed that all instances in which physical materials or processes distribute themselves under certain limiting conditions fulfil the principal criteria of organization. For instance, if water streams through a system of interconnected pipes, the flow in each pipe depends upon the flow in all other pipes. For, if an obstruction is introduced in one pipe, the flow in the others is immediately affected. Similarly, if an electric current flows in a network of wires, the self-distribution of this flow is maintained in the system as a whole. Any local change of conditions is at once reflected in a redistribution of the current everywhere. In other words, a physical self-distribution is relationally maintained and relationally determined. This is clearly shown in the mathematical expressions which serve to describe such a process. In any formula which refers to local events within the total distribution, these events are related not only to corresponding local conditions but also to the conditions in all other parts. More particularly, the determining conditions appear in the form of their ratios so that physical self-distribulions remain unaffected if all local conditions are varied in the same proportion. Obviously, this agrees with the criterion which Ehrenfels used when he first called attention to Gestalt characteristics.

In connection with psychological problems, it must be emphasized that physical organization is not restricted to self-distributions which occur in conducting networks. On the contrary, this concept applies most readily to instances in which processes distribute themselves within continuous media.

In trying to indicate what particular processes actually underlie organized experience in perception, Gestalt psychologists propose a change in neurological theory. They do not believe that brain function is limited to the propagation of nerve impulses along separate fibres. Kohler developed a theory of vision according to which organized function in the brain is a matter of electric currents. These currents are supposed to distribute themselves in the brain tissue as a continuous volume conductor. The theory is supported by the fact that organized processes in perception have specific aftereffects which can readily be explained on this ground. The general direction in which Gestalt psychologists attempt to develop neurological theory is indicated by the term "isomorphism." The term means that the facts of organized experience and the brain processes which underlie these facts have precisely the same structures. It would, for instance, follow that to any symmetry in perception there corresponds the same symmetry in the functional interrelations of the underlying process, that segregated units in perception are associated with functional units in brain dynamics, etc.

Organization in Higher Mental Processes.—An early extension of Gestalt psychology beyond the field of perception referred to such concepts as memory traces, association and recall. This development was natural because, when experiences are reactivated in memory, they are on the whole organized in the same sense as are the facts of perception. Gestalt psychology assumes that memory traces are direct products of the processes which underlie primary experience; in other words, that human experience writes down its own history in the nervous system. In the course of time, however, the traces are supposed to undergo changes as a consequence of their inherent dynamics. Interaction within the realm of traces seems to be of the same kind as that which is responsible for primary organization. Any condition which makes for particular clearness in perception also favours retention in memory, and any factor by which clear segregation in experience is impaired strongly operates against recall. This thesis has been amply verified. It has also been shown that the concept of association by contiguity must be given a new interpretation. According to classical association theory, the connection between remembered items is quite analogous to the way in which places are connected by roads, or objects, say, by strings; *i.e.*, the connection as such is assumed to be indifferent to the nature of the connected items, and vice versa. Gestalt psychology maintains that associations are aftereffects of the specific interactions which occur in primary organization. From this point of view, associations must depend upon the characteristics of the items in question because all interaction is a function of the nature of the interacting objects. More particularly, the factors which make for strong perceptual organization of items in pairs must at the same time be factors which favour strong association. Experimental tests have corroborated this conclusion.

A similar reasoning has been applied to the concepts of recognition and recall. Facts in present experience reactivate facts of the past in a highly selective way. It seems that recall begins with a process in which a present experience makes contact with the trace of a similar past event. The way in which similarity here operates as a selecting factor is comparable to the fashion in which resemblance makes for specific organization in perception. From this the conclusion is drawn that recall is initiated by a fact of organization in which a new process interacts with a trace of a similar event in the past. Thus, perception, retention, association and recall are given a unitary interpretation.

The most important extensions of Gestalt psychology refer to higher mental processes. Much in contrast with the view which scientists have of their subject matter, the psychological field exhibits many phenomena of experienced nexus. David Hume's statement that "all events seem entirely loose and separate" does not hold in psychology. According to the German philosopher W. Dilthey, all awareness of relations, but particularly of dynamic relations, proves conclusively that connections among experiences may themselves be experienced. Moreover, such connections tend to have the character of being understandable. When two tones of sufficiently different intensity are given in succession, there may be immediate awareness of the fact that the second tone is louder or softer. This relation is experienced not as a third thing by itself but as being necessary in view of the nature of the tones. In a similar way an emotion is felt to be the adequate and understandable answer to its object; a conclusion emerges as following from its premises, etc. As interpreted by Gestalt psychologists, this means that not only in perception, but also in many other psychological situations, causation is directly accessible to observation, and that it then proves to be identical with the fact that the nature of a given situation requires a certain event to happen. Gestalt psychologists can, therefore, say that in experience certain occurrences "make sense" while others fail to do so. With a more subjective expression, they claim that man may have insight into the "ought" of facts. Thus, in Gestalt psychology, the term insight does not refer to a mental power, nor is it necessarily related to new discoveries. Rather, it is a descriptive term which designates a peculiarity of certain forms of experienced nexus.

In this fashion. the Gestalt psychologists relate the concept of value to that of organization. For it is only within organized mental situations that the phenomenon of requiredness is experienced. The school concludes that ethics, aesthetics and logic deal with, and systematize, principles of requiredness which are implicit in experiences of nexus, but are, in common experience, blended with merely factual admixtures.

On such grounds. Gestalt psychologists have begun to investigate learning and thinking as facts which are directly related to organization. Learning, they declare, is often much less an acquisition and retention of given contents than a development of new contents; namely, of new structures in perception and conception. It is not, of course. denied that learning in this sense involves retention of the new structures. But it is stressed that, before the question of retention is raised, the psychologist ought to realize precisely what is being retained. Some theories of learning ignore the organization which given materials tend to undergo when we learn something about a situation. Often, this is the most important achievement in learning, and without it retention would be of little avail.

M. Wertheimer and K. Duncker applied these concepts to the problem of productive thinking. In such thinking a material and a goal are given while the right way from the situation to the goal is not yet available. With sufficient motivation, such a situation tends to reorganize itself so that either the given material changes its structure or the goal is seen in a new light. As a result, relations which played at first no part in the situation may suddenly become entirely obvious. With their appearance the principle of the solution often emerges. To take one of Wertheimer's examples: The task of computing the sum of the terms of an arithmetic series will be greatly facilitated if the even progress of the series in the ascending direction (*i.e.*, the original structure of the material) is replaced by the conception that from the two ends of the series toward the middle the terms increase and decrease at the same rate. Once this is seen, the series readily splits into a known number of quantitatively equivalent pairs of terms, and the result of their sum can be directly found by multiplication. It will be seen that in productive thinking of this kind the reorganization of the field as a whole and the discovery of the main principle of the solution precede the recognition of any particular steps in which the actual solution is eventually realized. Measures of detail are taken only as required by that principle, and in this sense the solution is found "from above" (Wertheimer). In this respect, the Gestalt psychologists' interpretation of thinking differs widely from that given by associationists, who regard both the concept of organization and that of requiredness with suspicion, and interpret the course of thinking "from below"; *i.e.*, as a play of associations which. in conjunction, happen to give the whole solution. From the point of view of Gestalt psychology, it remains to be seen for what reasons problem situations tend to reorganize themselves in more or less adequate directions when the motivation is sufficiently strong.

BIBLIOGRAPHY.—W. Kohler, *Gestalt Psychology* (1947) and ***The** Place of Value in a World of Facts* (1938); K. Koffka, *Principles of Gestalt Psychology* (1935); P. Guillaume, *La psychologie de la forme* (1937); M. Wertheimer, *Productive Thinking* (1945). (W. K.)

SOCIAL PSYCHOLOGY

Social psychology deals with those elements in the ideas, emotions, attitudes and habits of individuals which derive from, and relate to, the fact that man lives in social-cultural relations with his fellows. It studies the behaviour of individuals in so far as their behaviour stimulates others or is itself a response to the behaviour of others. Two main areas of interest emerged in this field: One has to do with the place of social-cultural influences in the rise and functioning of the personality (*q.v.*); the other has to do with the mass or collective aspects of man's thought and conduct.

The Social-Cultural Genesis of Personality.— One basic concept of social psychology, especially as it relates to the development of the personality, is *interaction* or the *social act;* that is, an act which is not completed without the intercession or qualification by the act of another. The earlier systematic psychologists usually took the view that the fundamental habits and thought patterns of the individual are built up, through learning, on the basis of innate neuromuscular potentials, including the drives. and that only later does the individual add social features to his mental and behavioural repertoire. This atomistic viewpoint is rejected by the interactionist school. It agrees with individualistic psychology regarding the importance of biologically inherited drives, of neuromuscular maturation and of learning. But its central theme is that the individual is more or less socially and culturally conditioned at every point from birth on.

This position is defended, first, on the ground that man as a member of the mammalian family is born into a social situation, involving at least the mother and the infant himself. Second, in the early months and years the new member is socially dependent on other members for his food, shelter and bodily protection. Third, within this interactional framework even strictly individualistic, biological reactions such as concern elimination, posture, locomotion and sleep become socialized or conditioned through the tuition of others. In fact, within this social matrix all the basic skills and knowledge develop. The internal organization of stimulus-response patterns (that is, perception, reasoning and concept formation) are all affected by the interplay of the growing child and those who surround him. And in this development communicative as well as overt physical interaction has a part.

Not only is the social impact, as such, basic, but the parents and others bring to the child their culture patterns. These consist of the more or less standardized and expected ideas, attitudes and habits which serve to direct the child's learning and to provide him the content and meaning of his varied experiences. Thus, while the fundamental drives and mechanisms of adjustment are derived from species inheritance, the learning process is social, or cultural, or both, at every step of the way.

The interactionist position derives from the work of J. M. Baldwin, C. H. Cooley and especially George H. Mead and John Dewey. According to Baldwin, the self or personality develops from the give and take of the infant and child with those about him. This he termed the "dialectic of personal growth," operating through imitation, suggestion and accommodation (habit). Cooley's phrase "the looking-glass self" summarized his view that self-feeling, illustrated in pride or mortification, rests upon one's image of himself as he has derived it from others.

It was George H. Mead in *The Journal of Philosophy* (1922) who stated the process of personality formation in interactional terms without positing inherited social instincts. In his words: "The self arises in conduct when the individual becomes a social object in experience to himself. This takes place when the individual assumes the attitude or uses the gesture [or word] which another would use and responds to it himself or tends to so respond. . . ." The growing child introjects into his own stimulus-adjustive-response system the reactions of other individuals with reference to him. He calls out in himself their attitudes and responses as well as his own toward himself. This duplication of the actions of others Mead called role-taking.

At the outset, roles are highly specific. For example, in his play a child may assume the mother's or iather's tones, words and actions toward his toys, dolls and his real or imaginary playmates. In his fantasy he may play many parts. At one moment he is a buyer, at another the clerk making a sale; he may be a gangster for a minute and a policeman arresting himself the next. In taking such roles language has a central place. The child talks to himseli as others have talked to him.

Yet roles do not remain entirely specific. The repetition of the same or similar drives and situations leads particular roles to become generalized. An early general role centres around his age, status and function within the family. The chief general roles of the adult male in our society are those of husband-father-breadwinner, good citizen and solid churchman.

The social seli, however, is not merely a reflection and reorganization of ideas, attitudes and habits which one picks up from others. At all times the drives and action patterns of the individual are present and serve as the dynamic and unique elements in personality. Mead held that these drive-action elements and the specific or general roles together "constitute a personality as is appears in social experience."

Ii one's ideas, attitudes and habits derive irom integrating the roles of others with one's own drive-action systems, it iollows that mind itself must be a social product. The chief medium by which mind is built up is communication through gesture and language.

The thinking function arises as the child rehearses and reorders the interactions—overt and verbal—which have gone on between him and others or which he has observed among those around him. Dewey has aptly pointed out the dramatic (that is, interactional) character of our mental processes. And the investigations of many child psychologists give concrete evidence of the social ioundations of the sense of self and oi the thought processes.

Language as the vehicle of communication sets up expectation or incipient action in the person spoken to, and likewise, in terms of introjection, anticipatory response patterns in the individual speaking. Meaning depends on one's perception and conception of the object of communication as it functions in the other's experience as well as in his own. So, too, the respondent must perceive or conceptualize the idea as it operates in the speaker. As Dewey says in *Experience and Nature* (Open Court Publishing Co., 1925): "To understand is to anticipate together, . . . to make a cross-reference which, when acted upon, brings about a partaking in a common, inclusive, undertaking." In short, meaning always falls within the self-other configuration.

Many social interactionists tended to neglect the place of the content of ideas, attitudes and habits in personal development. But this need was met chiefly from Freudian psychologists in collaboration with cultural anthropologists.

The aim of the culture-personality studies is to compare critically the way in which the basic drives and capacities of the new generation are moulded by culture—chiefly at the hands of family memhers and primary groups; that is, to modify and elaborate them into adult motives, roles and other elements of the self. For example, certain studies show that the masculine-feminine roles as defined in western culture are quite differently organized among other peoples. So, too, co-operative-affectional in contrast to conflictive-aggressive patterns differentially affect personality formation. Among primitives like the Arapesh, Zuni and Hopi, and among certain Christian sects, such as the Amish and Mennonites, the individual is trained irom birth on to be sympathetic and helpful of those around him. Rivalry and personal push are punished. The result is a rather quietistic, mild and nonaggressive person. In contrast, the highly competitive societies like those of the Kwakiutl Indians or the modern United States induct their children into a set of values and habits which stress intense interpersonal struggle, ambition for status and monetary rewards. Or, in militaristic countries like imperial Japan and nazi Germany, the child, especially the male, was brought up in aggressive, conflictive patterns of thought and action.

This does not mean, of course, that aggressive responses are entirely lacking among the Pueblo Indians or among the pietistic sectarians. But they are suppressed and sublimated. Yet among the Zuni vicious gossip provides an outlet for interpersonal antagonism. And some, at least, of the U.S. quietistic sectarians have been known for their sharp competitive business sense.

These comparative analyses show that personal sense of security, presence or absence of inner tensions, the emphasis on introvertive or extrovertive values and activities and other elements of the personality will be greatly influenced by such differentials in training.

A provocative approach in this field was that of A. Kardiner and R. Linton, who examined both primitive and civilized societies in an effort to discover "a group of nuclear constellations in the individual" designated as "the basic personality structure." By applying psychoanalytic concepts to known differences in early child training, especially in the mother-child, father-child and sibling interactions, they traced the integration of ideas, values, attitudes, and habits which form the distinctive modal personality features of all members within any particular society-culture milieu.

The co-operation of workers in psychology and anthropology in tracking down the cultural sources of personality differences marked a step forward toward a science of personality. But there remained many unsolved problems of data, analysis and interpretation. No theory of modal or basic personality for all memhers of a given society can get around the solid facts of individual variation and uniqueness. These differences are based on biological variability as to drive, emotion and intelligence potential, on deviations in acquired skills and knowledge and on variations in interpersonal conditioning at all points. As to the latter, it can be shown that not all social learning is necessarily culturally controlled or directed, unless culture and all interaction are defined as completely synonymous. There is, especially in the early years, a good deal of social learning which occurs outside the framework of the cultural norms and expectancies, and this learning plays a part in the formation of the personality.

Collective Psychology.— Collective psychology deals with group behaviour, in small as well as larger aggregates such as is found in crowds and audiences, in responses to changes in fashion, in public opinion and propaganda and in various manifestations of leadership. However, there is no special psychology oi so-called crowd mind or collective consciousness.

The interactions of individuals in small groups has been studied in order to get at social behaviour which involves, among other things, dominance-submission relationships, degrees of conscious intimacy or hostility among group members, and objects of common or different identification. It is often assumed that generalizations derived from the study of small groups may be applied to similar activities in larger groups. This assumption, however, had not been completely proved at mid-20th century.

Turning to the larger aggregates, a crowd is a relatively temporary congregating of interacting individuals in a limited space. Its typical spatial arrangement resembles the disposition of iron filings around a magnet. There is a centre or focus of attention around which individuals stand or move in varying degrees of verbal, auditory and bodily participation. Unlike the usual face-to-face interactions, the interstimulation of the crowd members is of shoulder-to-shoulder kind.

As to responsiveness, crowds may be further defined as passive or active, the former illustrated by a transitory grouping of pedestrians to watch a dogfight, the latter by the intense emotions and agitated actions of a crowd celebrating the news of a victory, taking part in a lynching or fleeing a fire in panic. Psychologists have given most of their attention to the action crowd.

The principal psychological characteristics of the individual in an action crowd are, first, the expression of strong emotions of love, hate and rage, associated with the basic values of life and security; *e.g.*, bodily survival, sex, property, race, religion, class status and national honour. Second, there is intense ego-expansion in terms of all-or-none, absolutist convictions. Third, a sense of self-righteousness overrides one's habitual sense of guilt and shame. Also, the crowd-man quickly identifies himself with some in-group which stands opposed to some out-group.

Men under these conditions release hidden and suppressed motives. In so doing imitation (*q.v.*) and suggestion (*q.v.*) play a large part, especially in adding a crowd-stimulus or social facilitation to that of the deep-seated drives. Suggestibility and imitative training in copying and conforming to others lead to the inhibition of critical attitudes in favour of doing unwittingly what those around one are doing. There also develops a strong sense of safety in numbers. The prestige and power of numbers fosters anonymity and the "impression of universality." Finally, long training in deference and obedience to leaders and symbols of authority makes for adherence to the emotion and action stimulated by the leader of the crowd. Such interactions as rhythm of bodily movements, whispering, shouting and pushing all add to social facilitation. In short, there is a summation of primary and crowd stimuli which impels the mass along its particular course of action.

It is often said that the crowd-man loses all morality and decency. By traditional standards this is correct; but the self-righteousness of mobs is well known. There arises a primitive morality of survival and group solidarity which temporarily replaces customary conscience. This rudimentary morality even persists, when the violence is over, in the rationalizations which people give for their participation in a mob or panic.

However, a crowd does not act entirely outside the framework of culture. Clearly all kinds of mobbish behaviour have their roots in the faiths and values of the participants. On the American frontier the lynching of cattle thieves was an accepted form of social control. So, too, the lynching of Negroes in the south. Even the periodic mass violence of race and religious riots in the Cnited States, the near east and in India have their original motivations in the values of race, class and religious differences.

An *audience* is an institutionalized crowd which meets for a more or less specific purpose at a predetermined time and place. The polarization and interactional forms vary with the kind of audience. Most audiences may be classified as information-seeking, recreation-seeking and conversional. The first is characterized by a rational aim and function; the other two are loaded on the side of emotion and action.

The psychology of the audience is revealed, first, in the preliminary tuning or prior stimulation, as through advertising and conversation designed to draw out the participants. Second, there are some initial interactions at the time the group forgathers but before the central function begins. Third, the speaker or performers must gain rapport or attention to bring about close identification with the activity. In the informational audience this tends to be by means of logical imagery and abstract ideas. In the other two it is usually a mixture of the rational and the irrational.

Fashion is a prevailing usage, mode, style or manner of expression or presentation of certain cultural elements which are open to, or subject to, relatively rapid change. Fashion ope ates chiefly with respect to clothes, architecture, furniture and modes of transport and communication. *Fad* refers to more superficial, more fleeting and more bizarre forms of such things as decorations or slang. The word *craze* is usually applied to highly transitory, though often widespread, forms of bodily activity, such as certain dances, miniature golf or unconventional gestures or postures.

For the individual, being in fashion provides a curious but pleasing mixture of personal distinction and group conformity. It at once sets one apart from the masses but gives evidence of adherence to one's class by virtue of others also following the fashion parade.

To understand public opinion the meaning of both "public" and "opinion" must be clear. As an adjective, "puhlic" means that which is known, actually or potentially, to all members of a community. As a noun it refers to a relatively large aggregation of persons, not necessarily contiguous, loosely associated together by some common interest. There is not just one public, the political, but actually various publics concerned with any focus of wide community interest. "Opinion" is a judgment or belief based admittedly on ground short of full proof or certainty. Public opinion, then, consists of judgments about some topic of interest in a given public at some particular time and place. It is usually expressed in words and is often related to deeper and more permanent attitudes and values.

The crucial matter of public opinion is its formation and change. While there are some situational variations, the formation of public opinion follows certain stages through time. The first is the rise of an issue or problem confronting a given public. The second is the conversation and discussions by members and leaders who try to define the issue more sharply and perhaps offer some tentative solutions. The third stage appears with the taking of definite positions as to the nature of the solution and the means of attaining it. The final stage is the arrival at consensus. This may mean a compromise of opposing views or it may mean the acceptance by the majority of the views of one side. Consensus may be expressed by written memorials to legislative bodies or executives, by public opinion polls and by legal voting. The overt execution of any decision belongs to action programs and lies outside the strict process of opinion formation.

In democratic societies the formation of public opinion follows this general pattern. Under totalitarianism, opinion formation tends to be restricted to the élite of the dominant party or to party members only. It is not a function of members of the wider community or society. However, this does not mean that amorphous and less vocal publics may not influence opinion formation at any step. Dictatorial governments usually "have their ears to the ground" though they may, by propaganda, attempt to determine the nature and direction of any popular ground swell.

In contrast to conditions in simpler, rural societies, public opinion in highly industrialized, urban societies raises many questions of manipulation and control by political and special interest pressures.

Under such modern conditions propaganda and censorship have especially important bearings on the formation of public opinion.

Propaganda is the deliberate use of symbols, chiefly through suggestion and persuasion, with a view, first, to changing and controlling opinion, attitudes and values, and ultimately to altering overt action along predetermined lines. Also propaganda may be open and obvious to the recipient as in advertising or a public health campaign, or thoroughly hidden and disguised as in the promotion of a revolution or a war.

The essential mechanism of propaganda is suggestion, the aim being acceptance, not logical reflection. Yet in analyzing propaganda it is necessary to know the motive and purpose of the operator, the symbol content he uses and the responses of his would-be recipients in order to find out to what extent their opinions, attitudes and habits have been altered.

Successful propaganda must be related to motivation and culturalized attitudes and habits. While the particular situations vary, among the more common facts which the propagandist must bear in mind are these: (1) It must be linked to basic motives of those to whom it is addressed; (2) the primary appeals should be emotionalized symbols of promise and satisfaction; rarely, and for selected audiences, may rational appeals be used; (3) both the issues and the proposed solutions must be simplified; the promotional artist deals in whites and blacks, in good and evil, not in the intellectual elaboration of a topic; (4) systematic and rhythmic repetition of these few and simple elements is usually effective; (5) innuendo, indirection and implication are frequently preferable to direct statement, especially in the early phases; (6) once the desired motive and bias are established, blunt, declarative and unsupported statements may be used as well as exaggeration, startling accusations and outright falsehood; (7) finally, short-run propaganda may be directed to all age groups, but that designed for more complete and lasting indoctrination should be directed to children and youth. They are the most suggestible since their basic values and attitudes are less deeply rooted.

The tactics just cited deal with the intent and stimuli of propaganda. Accurate knowledge about the effects on those to whom it is directed is more difficult to secure. However, we have some information on the influence of deliberate planting of content in newspapers and of exposure of young people to selected propaganda through the films or radio. The results show that within the limits of previous socia:-cultural learning changes in opinions and attitudes can be effected. There is little if any valid data on the influence of such experimental propaganda on later overt conduct.

Yet, it would be a mistake to hold that propaganda is ineffective. Campaigns to repeal the Corn laws in Britain, the abolitionist, prohibition and populist movements in the United States, Communist and fascist agitation and its use in war—all exemplify its importance.

Leadership is a universal feature of social interaction. It means the determination of certain responses of another or others in line with the leader's wishes.

Attempts to classify dominant individuals are common but difficult to support objectively. Srme writers take their cue from differences in leadership role and status under varying situations. There is the dual classification of leaders into executives, or men oi action, and thinkers, or men of thought. Some writers require more than two categories, as in the division into executive, dominant, persuasive and expert leaders, or into headship, voluntary leadership and status iorms of dominance.

Classifications which attempt to get at psychological characteristics also face difficulties. Followers of Carl Jung's typology often divide leaders into introverts or extroverts; ochers use Ernst Kretschmer's schizothymes or cyciothymes. But most attempts to use these types empirically lead to further assumptions of mixed types as well.

So, too, psychologists who approach personality from the angle of specific traits and attitudes have trouble in deriving any common clusters of these elements which might characterize all leaders, or, for that matter, even those within such social categories as those noted above. One writer tabulated the 79 distinct traits cited in 20 separate studies of leadership. Of the total list, two-thirds of the traits were named but once, and only 5% had as many as four traits in common. The most common trait cited (in ten studies) was intelligence. Initiative was noted by six; extroversion and sense of humour, each by five; and enthusiasm, fairness, sympathy and self-confidence, each by four. Much careiul research needs to be done before any satisiactory generalizations can be made about the psychological traits or types which characterize the dominant individual.

Regarding the relation of psychological characteristics to occupational or other social roles, there is some evidence that men of introspective, introvertive make-up tend to be more successful in science and the arts and that out-going, extrovertive persons are more successful in administrative roles. But cultural expectancies and differential circumstances may serve so to disguise the deeper motives, attitudes and values that any one-to-one correspondence of psychological make-up and social role is difficult to find. Men of the introrertive order are found in executive positions. Furthermore, since mixed types are probably more common than so-called pure types, most individuals may adapt themselves to one role or another without undue inner tension.

The qualities of leadership are definitely affected by the ideas and reactions of followers. The latter invariably attribute certain ideal qualities and powers to the leaders. This sets up expectations as to conduct on the part of leaders which they must follow, or seem to follow, if they would retain their dominance. This projection of ideal qualities is doubtless the reason why the traits of leadership are nearly always put in laudatory, admiring terms. Negative and derogatory traits seldom appear in listing the characteristics of leaders.

Methodology. — Though by no means well-ordered as a logical system, social psychology has developed points of view, hypotheses and methods of empirical research which, in time, should produce a body of systematic knowledge adequate to provide predictions and control of human conduct.

The principal scientific approaches to social psychology are the case- or life-history method and the use oi statistical techniques. An attack on the problems in this field by strictly experimental methods has only recently begun.

The aim of the life history is to discover and analyze the social-psychological processes, operating through time, which cause the emergence or modification of roles, statuses! traits, opinions, attitudes, values and other elements of the personality. In some studies there is an attempt to reconstruct the whole course of personality growth on the assumption that this will permit a fuller understanding of adult behaviour.

The data for the case study are protocols of oral interviews or formal and iniormal writings of the informant. Interviews may be prolonged in time and demand special skills, as in psychoanalysis, or may be relatively short. Free-association techniques or direct questioning may be used in either to elicit forgotten and unconscious memories necessary to reconstruct the genesis and meaning of the factors in personality growth. Formal written reports may be secured by questionnaires or outlines likewise designed to bring out memories of past events. Informal written documents consist of free-flowing autobiographies, letters and diaries or the protocols from projective tests.

The life history is open to question, first. in terms of the assumptions that this device will lay bare the genetic and functioning processes; second, as to the validity of memories on which the data depend; and. third, as to the standardization of procedures, since the difficulties of communication of meaning unwittingly qualify the responses of both informant and observer. Fourth, generalizations are often made on too few cases and with complete neglect of sound sampling.

Yet the case study provides an understanding of motivation and meaning which is often not obtainable through so-called more exact techniques. 4 combination of statistical and case methods, as in some of the projective techniques (*see* PERSONALITY), should, in time, contribute valuable data to a science of social psychology.

The quantitative study of personality derives from the measurement of intelligence. Taking their cue irom mental testing, psychologists and sociologists developed a large number of questionnaires and scales in an effort to measure the manifestations oi personality by tapping a wide variety of traits, attitudes and opinions. Usually there are a series of statements arranged in such form that the respondent may mark his agreement or disagreement and perhaps the intensity of his attitude toward each item. An index is then determined by summation o~ the separate responses or by using such measures as the standard deviation of the distribution. However, the problems of developing equal and interchangeable units on the scale and of composing the scale so as to measure one dimension or cluster of traits, attitudcs or opinions at a time have not yet been satisfactorily solved.

While the more adequate scales are statistically iairly reliable; validity is frequently neglected. The basic test of validity is a high positive correlation oi measured trait, attitude opinion or value with overt behaviour. All too often it is not clear just what outside criteria, if any, were used to validate a questionnaire or scale.

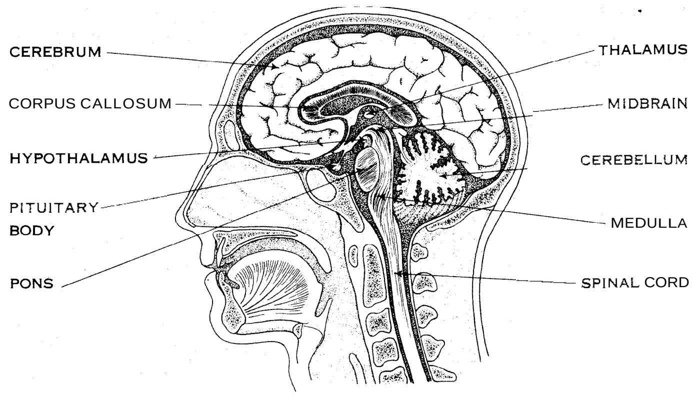
Although public opinion polls and market analyses usually handle the matter of sampling reasonably well, most studies oi traits and attitudes do not. Almost all of them use high school and college student populations, not adults outside. Even so, there is seldom any concern with the representativeness of the sample of this particular universe.

Both from the standpoint of contributing to a scientific knowledge of total personality and of periecting instruments ior predicting specific behaviour, the tests of motives, attitudes, opinions and values have much ground to cover. Yet, with more careful attention to matters of units, reliability, validity and sampling, we may expect,, in time, a body of substantive objective generalizations in social psychology.

BIBLIOGRAPHY.—W. Albig, *Public Opinion* (1939); F. H. Allport, *Social Psychology* (1924); G. W. Allport, *Personality: A Psychological Interpretation* (1937), *The Use oj Personal Documents in Psychological Science,* Social Science Research Council Bulletin no. 49 (1942); J. M. Baldwin, *Social atzd Ethical Interpretations of Mental Development,* rev. ed. (1897); R. Benedict, *Patterns of Culture* (1934); C. Bird, *Social Psychology* (1910); E. S. Bogardus, *Leaders and Leadership* (1934); H. Cantril, *et al., Gauging Public Opinion* (1914); C. H. Cooley, *Human Nature and the Social Order* (1902); L. S. Cottrell and R. Gallagher, "Developments in Social Psychology, 1930–1940," *Sociometry Monographs,* no. 1 (1941); J. Dewey, *Experience and Nature* (1925); J. Dollard, *Criteria for the Life History* (1935); J. Dollard, *et al., Frustration and Aggression* (1939); E. Faris, *The Nature of Human Nature* (1937); S. Freud, *Group Psychology and the Analysis of the Ego* (London, 1922); A. I. Hallowell, "Fear and Anxiety as Cultural and Individual Variables in a Primitive Society," *Journal of Social Psychology,* vol. 9, pp. 25–17 (1938); K. Horney, *The Neurotic Personality of Our Time* (1937); A. Kardiner, *The Individual and His Society* (1939); A. Kardiner, *et al., The Psychological Frontiers of Society* (1945); O. Klineberg, *Social Psychology* (1940); R. T. LaPiere and P. R. Farnsworth, *Social Psychology,* 3rd ed. (1949); R. Linton, *The Cultural Background of Personality* (1915); W. Lippmann, *Public Opinion* (1922); W. McDougall, *An Introduction to Social Psychology* (1908); Q. McNemar, "Opinion-Attitude Methodology," *Psychological Bulletin,* vol. 43, pp. 289–374 (1946); G. H. Mead, "A Behavioristic .Account of the Significant Symbol," *Journal oj Philosophy,* vol. 19, pp. 157–163 (1922), *Mind, Self, and Society* (1934); M. Mead, *Sex and Temperament in Three Primitive Societies* (1935); M. Mead (ed.), *Cooperation and Competition among Primitive Peoples* (1937); G. Murphy, L. B. Murphy and T. M. Newcomb, *Experimental Social Psychology,* rev. ed. (1937): J. J. Piaget, *The Language and Thought oj the Child* (1926), *The Child's Conception of the World* (1929): L. F. Shaffer. *The Psychology of Adjustment* (1936); R. Stagner. *Psychology of Personality,* 2nd ed. (1938); O. L. Schwarz, *General Types of Superior Men* (1916); K. Young, *Personality and Problems of Adjustment* (1940), *Social Psychology,* 2nd ed. (1914); C. Kluckhohn and H. A. Murray (eds.), *Personality in Nature, Society, and Culture* (1948); K. Lewin, *A Dynamic Theory of Personality* (1935); D. Krech and R. S. Crutchfield, *Theory and Problems of Social Psychology* (1948); N. E. Miller and J. Dollard, *Social Learning and Imitation* (1941); G. Murphy, *Personality: A Biosocial Approach to Origins and Structure* (1947); H. A. Murray, *et al., Explorations in Personality* (1938); Society for the Psychological Study of Social Issues, *Readings in Social Psychology* (1947); T. M. Nemcomb, *Social Psychology* (1950). *(K. Y.)*

PSYCHOLOGY, PHYSIOLOGICAL, is the study of the biological machinery of behaviour. Primarily it is concerned with how the brain and the rest of the nervous system function to produce the behaviour recognized as characteristic of man and the other animals. Because the nervous system critically depends upon other organs of the body for its normal function, physiological psychology also is concerned with the mechanisms of metabolism, the elaboration of hormones by the endocrine glands, and other regulations of the internal environment. Furthermore, the structural and functional characteristics of the nervous system, as well as of other organs, are determined by the mechanisms of heredity and are affected by diet, drugs and disease. Thus, behaviour may be influenced by all of these things, for the nervous system is the final agent of behaviour.

Although the early philosophers did not understand the nervous system very well, they knew that behaviour and mind were in some way related to the body and its functions. Thus the historic roots



FROM N. L. MUNN, "PSYCHOLOGY" (1951); REPRODUCED BY PERMISSION OF HOUGHTON MIFFLIN CO

FIG. 1.—INTERNAL STRUCTURE AND ORGANIZATION OF BRAIN

of physiological psychology lie in the classical mind-body problem of philosophy (see BODY AND MIND). Aristotle's view of this problem, known as the double-aspect theory, was that mind and body were different aspects of the same thing, that body nas the form or structure and mind the function. This surprisingly modern view did not entirely satisfy Aristotle's folloners, however. Descartes. for example, was impelled to reserve a special realm for the mind of man. He denied mind in animals and viewed their behaviour completely mechanistically, ascribing it entirely to the functioning of the brain and its nerves. For man, however, he argued that while basic reflexes were mechanistically determined, mind was relatively free of the body's influence. For those special occasions when mind and body could influence each other he proposed an interaction theory, holding that the site of the interaction between mind and body was the pineal body.

Even more independence of mind from body was envisaged by Leibniz in his theory of psychophysical parallelism. Leibniz maintained that mental events and bodily events occurred in two separate realms, entirely independent but nevertheless paralleling each other perfectly, as though in accordance with a predetermined plan.

In modern history, the behaviourists under J. B. Watson tried to carry the solution of the problem one step beyond Descartes by denying the existence of mind in man as well as in animals and by embracing a monistic, deterministic philosophy. They tried to strike all mentalistic terms—mind, consciousness and feelings—from scientific use and spoke only of observable behaviour. which they believed was the biological outcome of the activity of the nervous system (see BEHAVIOURISM).

Although mind is still more difficult than overt behaviour to define and specify scientifically, there is actually no need to exclude it from the realm of scientific inquiry, for the term mind is useful to designate certain realy if ill-understood, aspects of man and his experience. Mind is a complex and subtle aspect of behaviour, and ways should be found to investigate it rather than to ignore it. Scientifically, ho ever, mind cannot be regarded as a nonmaterial entity, despite the great emphasis that our philosophical and cultural heritage has placed upon the spiritual. Physiological psychology must begin, then, with the basic concept that mind and behaviour are the result of the structural and functional characteristics of the nervous system. The question is: how?

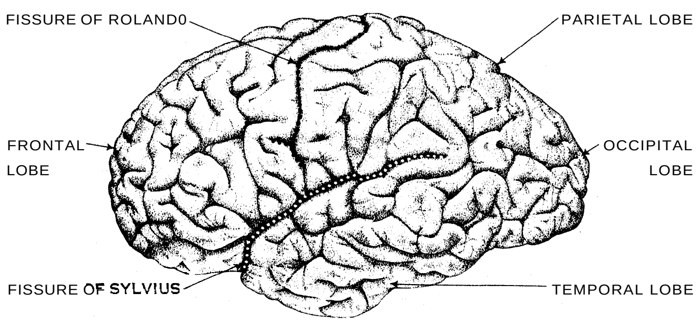
Basic Properties of the Nervous System.—The anatomy and physiology of the nervous system are discussed fully in the articles BRAIN; SPINAL CORD; NERVE; NERVE CONDUCTION; and NERVOUS SYSTEM. Only a brief review will be given here.

Grossly, the nervous system consists of the brain and spinal cord and their nerves. Coming into the posterior part of the spinal cord are the sensory nerves. These connect with other nerves within the cord which, in turn, connect with motor nerves leaving the anterior region of the cord to go out to the muscles and glands. This simple circuit provides the basis for reflexes such as the automatic withdrawal of a leg from a painful stimulus (see REFLEX). In addition, the incoming sensory nerves send branches up to the brain, and the brain in turn sends motor nerves down to the various segments of the spinal cord. At various levels in the brain, the incoming sensory nerves connect by multitudinous linking nerves to the outgoing motor nerves: making up an infinitely complex mechanism for the integration of behavioural functions, similar in principle to the reflex mechanism.

To understand the complexities of these brain connections and their importance in behaviour? it is necessary to appreciate the gross morphology of the brain and its gross function (see fig. 1 and 2). The continuation of the spinal cord into the brain is called the medulla; it contains, in addition to the major sensory and motor pathways and integrating mechanisms, many groupings of nerve cells that make up the mechanisms controlling the vegetative functions of the body such as respiration and circulation of blood. Above the medulla is the midbrain, serving in many simple visual and auditory reflexes. Behind'the medulla and midbrain lies the cerebellum, a large organ concerned primarily with coordination of posture and locomotion. The thalamus, situated above the midbrain, contains major mechanisms for the integration of incoming sensory nerve impulses and also serves to relay sensory impulses forward in the brain. Belon the thalamus is the hypothalamus, concerned aith control of the pituitary gland and with general vegetative functions, including such complex functions as water balance and thirst, sleep, food ingestion and reproduction. Finally, above the thalamus are the great cerebral hemispheres so prominent in man. The main mass of these hemispheres consists of white nerves entering and leaving the outer mantle of gray nerve cells, known as the cerebral cortex. Actually there are two kinds of cortex: (1) the old cortex, seen in many lower animals as well as in man, which seems primarily concerned with vegetative functions and the emotions; and (2) the new cortex subserving sensory, motor and associative functions. The new cortex may be subdivided into an occipital lobe in the back of the head, concerned with visual function; a temporal lobe on the lower side of the brain, concerned with auditory and language functions; a parietal lobe on the upper side of the brain, integrating sensory information coming from the skin and muscles: and a frontal lobe, including the motor areas controlling discrete movements and postural adjustments; and ahead of them, the frontal poles presumed to serve in complex associative functions.

In this greatly simplified picture of the nervous system, sensory stimulation typically results in activation of integrative mechanisms at all levels, from the spinal cord to the cortex. The major sensory pathways described so far are quite discrete as to the sensory modality aroused and the part of the body or sensory surface stimulated; this gives the nervous system great discriminative powers. In addition, however, all the sensory pathways contribute branches to a feltwork of nerves lying in the centre of the hindbrain or brain stem (medulla and midbrain), known as the reticular formation. The reticular formation relays nerve impulses to all parts of the brain and serves the important function of activating or arousing the brain generally. It is believed that this arousal function is part of the mechanism of wakefulness. attention and emotion, and thus it may be thought of as an important mechanism in the preparation of the brain for the reception of discriminative stimuli.

The great mass of the nervous system just described consists



FROM E. GARDNER. "NEUROLOGY," 1ST ED. (1947), W. B. SAUNDERS COMPANY, PHILADELPHIA

FIG. 2.— SIDE VIEW OF HUMAN BRAIN. SHOWING MAJOR LOBES AND EXTERNAL SURFACE OF CORTEX

of billions of individual nerve cells, some of which send their tiny filaments all the way from the foot to the head and some of which are not much longer than they are wide. These individual cells of the nervous system connect with each other across tiny gaps between them, known as synapses. Connections may be such that the activity in one cell will arouse activity in a host of connecting cells; or, conversely, activity in many cells may converge on a small number of cells: or there may be reverberatory loops such that a series of cells is activated in turn until the first cell is aroused again and again by the activity it initiated.

The activity of the nerve cells is known as the nerve impulse, a disturbance which may be propagated down a nerve filament at a rate as rapid as 120 metres per second. These disturbances can be accurately recorded electronically with suitable amplification devices, and such recording shows that if a nerve cell is to be activated at all, it must be stimulated by a certain minimal energy, threshold energy; once a nerve cell is activated, it discharges fully in its characteristic pattern of response. From such recording work! it has been learned that the nerve impulse is the mode of communication by which effects are conducted in and out of the brain and spinal cord and from one part of the nervous system to another. Furthermore, it is the combined effects of nerve cells on each other at synapses that provide the mechanism for integration in the nervous system.

Classically, two major integrative mechanisms have been described in the nervous system. One is excitation, the arousal of a nerve to activity; the other is inhibition. the effect of stopping activity in a group of cells. Excitation and inhibition can be illustrated in spinal reflexes where the flection of a limb, initiated by painful stimulation, requires the excitation of the nerves leading to flexor muscles that pull the limb toward the body and the simultaneous inhibition of the nerves leading to extensor muscles.

Given these basic properties of the nervous system, we may now ask how the complexities of behaviour may be mediated. Psychological analysis classically divides behaviour into a number of broad basic categories which will be taken up in turn: (1) sensation and perception; (2) motivation and emotion; (3) learning and intelligence; (4) personality and its disorders.

Sensation and Perception. — One of the oldest questions in physiological psychology is how information is received from the world outside the body and from within the body as well. For man, this is the problem of the anatomical and physiological basis of sensation (*q.v.*) and its attributes: the quality, intensity, spatial and temporal characteristics of sensation following the isolated stimulation of one sensory system. In animals, of course, it is possible to deal only with the capacity to discriminate behaviourally among these attributes of stimulation. Perception (*q.v.*) differs from sensation only in the matter of degree. It is a complex response to stimulation that may involve more than one of the sensory avenues or modalities and that may call into play past experiences that then help to determine the nature of the response or the experience.

The oldest scientific conceptualization of the basis of sensation and perception is the "doctrine of specific nerve energies," first put forward by Johannes Miiller in 1826. While the anatomical and physiological details of this early conception are incorrect, the theory itself has much validity today. What it says, in essence, is simply that sensations or responses to stimulation are determined by the events occurring in the nervous system and not necessarily in the physical world. Thus we see light when pressure is put on the eye with the finger because this pressure mechanically activates the receptors and nerves concerned with vision. So Miiller argued we would see thunder and hear lightning if the nerves from the eye and the ear could be interchanged. Many phenomena support Miiller's doctrine, but its general validity can be seen most easily in the fact that an electrical stimulus, which can activate all the sense organs and nervous tissue. will produce sensations appropriate to the sensory system stimulated, whether it be the eye. the skin, the tongue or some point within the brain to which nerves from these structures go. Thus the sensation experienced or the discriminative response made to stimulation is determined rather specifically by the part of the nervous system that is activated.

To illustrate the point more fully, the case of hearing (*q.v.*) may be considered. The sensation of pitch is determined largely by the frequency of the tone heard. so that the higher the frequency. the higher the pitch. Each tonal frequency vibrates the air at that frequency which in turn vibrates the eardrum. The eardrum passes this vibration through tiny bones in the middle ear to vibrate the membrane of the oval window of the cochlea. As the window moves in and out of the cochlea, it vibrates a fluid in it which, in turn, sets up a standing wave in the basilar membrane, which extends throughout the coiled length of the cochlea. The critical point here is that the standing wave has its maximum effect on the basilar membrane at different places depending upon the frequency of vibration introduced. Low frequencies affect the basilar membrane near the apex of the cochlea. while higher frequencies have their effect near the base. The basilar membrane is lined with the hair cells of the organ of Corti, and as the membrane is moved, the shape of these hairs is distorted. Like crystals that are distorted mechanically, these hairs give off tiny electrical currents, which are believed to stimulate the fibres of the auditory nerve that arise from the vicinity of the hairs. In this way, different fibres of the auditory nerve are activated by the different vibrations produced by tones of different frequencies.

More than that, the different auditory nerve fibres are kept distinct from each other in their course into the brain, at each of the relay stations and at the auditory region of the temporal lobe of the cerebral cortex. Hence it is possible to record electrical activity along different parts of the auditory cortex, representing the different tonal frequencies that stimulate different parts of the basilar membrane. It is even possible in an animal experiment to stimulate different parts of the basilar membrane directly with electrical current and find the same array of different places activated in the cerebral cortex. So the sensation of pitch seems to depend upon the place in the auditory nervous system that is activated by the stimulus.

The other attributes of sound are mediated by somewhat different mechanisms. The loudness of a tone depends upon the energy in it or its intensity, and it is believed that the sensation of loudness is a function of the density of nerve impulses conducted over the nerve fibres serving the frequencies used to stimulate. Density can be increased both by firing individual fibres more rapidly and by the activation of additional fibres of high threshold; *i.e.*, fibres that require a great deal of energy before they will fire.

The temporal pattern of pitches and loudnesses of sounds presumably is given by the temporal pattern of arousal of nerve fibres activated by a frequency- or intensity-patterned stimulus. Finally, the localization of sounds in space depends mainly upon the differences in time of arrival and intensity of a sound from a single source reaching the two ears. These differences are preserved in the brain, for they show up in electrical recordings from the auditory cortex as appropriate differences in time of arrival and amplitude of nerve impulses on the two sides of the brain.

The same general principles apply to the other senses. Thus there are separate fibres and pathways in the spinal cord bearing nerve impulses produced by stimuli that give rise to sensations of pain, touch, heat or cold in the skin. Different patterns of fibres from somewhat different parts of the tongue are activated by sweet, sour, bitter and salty stimuli, and as the tongue is stimulated with stronger and stronger taste substances, the density of the patterns of impulses increases proportionally. In vision, different parts of the receptor surface of the eye, the retina, are sensitive to the wave lengths of light that produce the different colours. Furthermore: there appear to be different combinations of receptor cells in the retina that are maximally sensitive to these different wave lengths that colours emit.

Physiological approaches to the more complex problems of perception can best be illustrated with some of the phenomena of vision such as the perception of real and apparent movement, the perception of depth and visual localization. The visual localization of objects in space, for example, depends upon the part of the retina stimulated and the manner in which that localization or "local sign" is preserved in the brain. Philosophical interest in this problem arose when it was learned that the lens of the eye inverts the image of objects on the retina. The question then became: why do we not see the world upside down? Although this question makes no physiological sense, it nevertheless inspired investigations into the role of early learning that might account for upright localization, and it led to a series of interesting experiments on the inversion of the visual field.

If the eye of the salamander is rotated 180°, the animal will localize 180" out of phase and will snap upward at a lure held below it and to the left at a lure held to its right. Even if the salamander's optic nerve is cut and allowed to grow back, the animal will not reorganize its vision in accordance with its experience! and it will still be 180° out of phase upon recovery. The visual field of man also can be rotated experimentally by placing reversing lenses over the eye. Everything is backward and upside down and never changes from this through long experience with the inverted field, even though man can learn to cope with his reversed visual field and make excellent adjustments to the world around him. Thus it appears that visual localization is a function of the central connections of the retina and is not basically modified by experience.

The role of the brain in perception has been studied in many animal experiments but is shown perhaps most clearly by the complex effects of brain injury on visual processes in man. In such cases, a man with damage to the area around the visual cortex may fail to recognize familiar objects for what they are (visual agnosia), although he may clearly be able to see them and describe their physical attributes. In other cases, such a brain-injured man may totally ignore all visual events occurring in some part of his visual field, although it can be shown by careful tests that he can actually see in that field; or in certain cases he may be subject to gross distortions in that visual field. Thus the brain, and particularly the cerebral cortex, is concerned with the interpretation of sensory impressions.

Motivated Behaviour and the Emotions.—A second problem of historic interest to physiological psychology concerns the basis of feelings, urges and emotions. This is a most difficult area of scientific inquiry, for the very concepts derived classically from the subjective experience of man, and the first attempts to approach the problem in animals came in the study of instincts at a time when instinct implied mysterious forces impelling and guiding the organism. With the advent of objective behaviourism, however, emphasis was placed on the bodily expression of emotion, an approach that applied to animal as well as man and that furthermore provided a basis for scientific measurement. In addition, as efforts were made to uncover the physiological mechanism of emotion, instinct and motivated behaviour, it became apparent that these behavioural expressions had much in common biologically as well as behaviourally.

Behaviouristic analysis divides these complex behaviours into three components: (1) drive, (2) goal-directed behaviour and (3) satiation. Drive ("instinct") is the arousal of the organism to intense activity, measured as an increase in general activity or the appearance of a highly specific activity. Thus the hungry animal becomes restless and hyperactive. Typically. however, the behaviour is goal directed and the drive has a highly specific goal, such as food or a mate; or it might be a bodily expression as in the case of sleep or flight or rage. Upon execution of the goal-directed behaviour, the organism reaches a point of satiation; drive is reduced, hyperactivity ceases and behaviour is no longer directed strongly toward the specific goal. The clinical case of a three-year-old boy with a history of abnormal craving for salt illustrates the points of this analysis. This boy's history showed that his general appetite was poor and that he was restless and upset in his first years, when fed a normal diet. He strongly preferred salty foods such as bacon and crackers, and these seemed to appease him a great deal, but his great craving did not become apparent until he discovered the salt shaker at the age of 18 months and ate salt by the spoonful. Unfortunately, the pathology in this case was not understood at the time, and the child was taken to a hospital for observation and placed on a standard diet; within seven days he died. Autopsy revealed extensive damage to his adrenal glands. It is now known that adrenal damage means that the body cannot retain salt normally. Thus the boy had developed a salt deficiency which produced his strong drive, directed toward the specific goal of salt, when salt was ingested in sufficient amounts, the drive was reduced, and it was thus, in repeated cycles of drive and satiation, that the boy managed to keep himself alive.

This example also serves to make the physiological problem clear. There must be a mechanism in the brain, sensitive to the internal state and to the effects of sensory stimuli as well, which controls the arousal of drive and its specific expression; and there must be a neurological mechanism of satiation. Theoretically, these might be one and the same mechanism, but experimental findings show that there actually may be two interrelated mechanisms, centring in the hypothalamus (*q.v.*): an excitatory mechanism for the arousal of drive and an inhibitory mechanism for its reduction or for satiation. For example. bilateral destruction of small areas in the ventromedial hypothalamus of the rat, cat, monkey and possibly also man results in a doubling or tripling of food intake, leading to great obesity; on the other hand, similar destruction of nearby regions of the lateral hypothalamus, on either side of these first areas, results in refusal to eat and starvation in the presence of customary food supplies. That the first areas in the ventromedial hypothalamus are inhibitory is shown by another experiment in which electrodes, insulated except for their tips, are chronically implanted into this part of the brain. Electrical stimulation through these electrodes in the waking. hungry animal results in inhibition or depression of feeding. Conversely. the excitatory nature of the lateral areas is shown by the fact that electrical stimulation of these regions produces increased feeding.

Similar control mechanisms can be found in the hypothalamus in the cases of thirst, sexual behaviour and sleep. In sexual behaviour it is clear that the hypothalamus also is directly influenced by sex hormones, for it is possible to arouse mating behaviour by introducing minute quantities of hormones directly into the brain through chronically implanted pipettes. The cerebral cortex also makes a contribution to the arousal of sexual behaviour, particularly in the male animal; extensive damage to the cortex may eliminate the possibility of sexual arousal. That the animal is still capable of mating, however, is quite clearly shown by the fact that a massive systemic dose of sex hormones can restore the mating response lost through decortication. Of further interest is the fact that sexual behaviour is independent of any particular sensory modality, including those arising from the genitals, for cutting the nerves from the genital area or surgical elimination of any one other sensory modality does not by itself affect sexual behaviour. In the naive animal, it takes elimination of no more than two sensory avenues at once to preclude sexual arousal; in the experienced rat, however, sexual behaviour may survive the elimination of three modalities, illustrating the role of learning and experience in the physiological control of sexual behaviour. It is important to point out that the mechanism of sexual behaviour must have gone through marked changes in evolution. Comparing animals from rat to man. it is clear that there is a decreasing dependence on sex hormones and an increasing dependence on sensory stimuli, learning and the cerebral cortex.

Much the same physiological mechanism operates in the case of the emotions. Cats deprived of the cerebral cortex are greatly changed in their rage responses. These animals are easily aroused to rage by almost any mild stimulus, but their emotion is short-lived and poorly directed. If only the new cortex is removed, cats become placid; if the old cortex is removed alone, they become fierce. hlonkeys, on the other hand, become strangely placid in the absence of certain portions of the old cortex, particularly the hippocampus and amygdala. These animals show, in addition to placidity, exaggerated sexuality and markedly increased and indiscriminate oral activity, even to the point of putting a snake or a lighted match into the mouth.

That the hypothalamus is also central in the control of emotions is shown by the fact that damage to different parts of it can lead to great increases and decreases in the expression of emotion. Furthermore, electrical stimulation of the waking animal through chronically implanted electrodes will lead to emotional responses such as rage and flight.

Electrical stimulation of the hypothalamus and related structures under somewhat different circumstances illustrates further the physiological mechanisms of motivation and emotion. In this case, the animal is allowed to press a lever which electrically stimulates its brain through chronically implanted electrodes. Such an animal will operate the lever as many as 5,000 times in one hour; under some conditions, pressing the lever is preferred to food, and it has been shown that animals will readily walk through a strongly electrified grid on repeated occasions to depress the lever that produces stimulation of their own brains. Such experiments demonstrate the rewarding nature of this kind of brain stimulation and point to mechanisms that may well be at the physiological basis of all positive emotion and motivation and, indeed, of pleasure itself.

It may be concluded, in general, that the organism is aroused to strong motivated behaviour and emotion as a result of physiological activity in an excitatory neurological mechanism centring in the hypothalamus of the brain. Contributing to this physiological and behavioural arousal are two major influences: (1) sensory stimuli, both learned and unlearned; and (2) internal factors such as hormones, blood temperature. osmotic pressure, salt levels, etc. As the goal-directed behaviour is executed, similar influences arouse the inhibitory mechanism, which then results in satiation or the satisfaction of biological drives. (See also EMOTION; INSTINCT; MOTIVATION.)

Learning and Intelligence. — While many remarkable adaptations to the environment are accomplished through the mechanisms of instinct and motivated behaviour, it is obvious that the greatest factor in the adaptation of the mammal, and especially of man, is the capacity to profit from experience, or to learn. While the mechanism of learning (*q.v.*) is still much of a mystery, it is an article of faith among students of the nervous system that learning and memory (*q.v.*) must depend upon some enduring change in the nervous system. Classically, two scientific questions have been asked in this connection: (1) where does learning take place in the nervous system? and (2) what is the nature of the change?

There are many kinds of learning. but in all of them the organism makes a new response to some specific stimulus or to a general situation. Thus I. P. Pavlov's dog learned to salivate consistently in response to a bell, E. L. Thorndike's cats learned to press a pedal that opened a door when they were locked in a cage and, as is known from common experience, the student of Latin-English vocabulary learns to say "table" when presented with *mensa*. Governing the process of learning and the resultant memory are the "laws of association" (see ASSOCIATION, MENTAL), first formulated by the English association philosophers and expanded through subsequent experimental work: (1) contiguity in time and place; (2) repetition; (3) effect or reinforcement; and (4) interference, leading to forgetting or extinction.

Pavlov, for example, found it necessary to present the bell together in close temporal relationship with meat which naturally elicited salivation; this pairing had to be repeated many times before the bell alone would elicit salivation. The meat functioned as a reinforcement of learning in the sense that the response of salivation to the bell grew weaker and weaker each time it was presented without the meat and gained in strength each time the meat was included. The waning of the strength of salivation to the bell alone is called extinction and is similar to forgetting. Both extinction and forgetting appear to be the result of responses that interfere with the one that was learned, and these interfering responses are favoured when the reinforcement is omitted. Contrary to what one might think on the basis of common experience. there is reason to believe that most learning is permanent; that it is merely covered over or masked by interfering or competitive learning and is not really completely lost.

Many experiments have been directed toward answering the question of where learning takes place in the nervous system. Pavlov believed that even simple learning such as conditioning depended upon the cerebral cortex, but it has been amply shown that animals may be conditioned after the cortex has been removed by experimental surgery. K. S. Lashley demonstrated, in a more complex learning situation, that rats surgically deprived of the visual cortex could learn to discriminate between a white square and a black square. But if an animal had learned this discrimination with the visual cortex intact, subsequent lesion of the visual cortex destroyed the discrimination; as would be expected, the discrimination could be relearned without the visual cortex about as rapidly as it was learned originally. This suggested that the memory for the discrimination was lost as a result of surgery but could be relearned with other parts of the brain. On the other hand, it might be that the memory was not lost, but rather that the animal was incapable of responding to the visual details of the black and white cards after operation and had to learn the problem without the benefit of detail vision; *i.e.,* on the basis of ill-defined light and dark areas. That this may be so is suggested by the fact that the rat without its visual cortex cannot learn to discriminate a triangle from a circle where the difference in detail is the only basis for the discrimination. Conversely, if the animal is required to respond only to brightness change in a large area without any dependence on detail, it can retain a brightness discrimination without impairment after brain surgery.

Lashley also studied the role of the rat's cortex in maze learning and found that the larger the area of the cortex destroyed the poorer the learning and the poorer the retention of the maze learned before operation. It did not matter which parts of the cortex were destroyed and which remained intact, the result was the same: the larger the lesion, the greater the impairment. These findings led to the principles of "mass action" and "equipotentiality," according to which maze learning is a function of the amount of cortex available and the various parts of the cortex are equally potential in subserving learning. Again it seems likely that these results can be understood in terms of impairment of sensory capacities of the animal. It is known from other studies that the more sense organs that are experimentally eliminated in the rat, the poorer the maze learning and retention; furthermore, no one sensory avenue is critical for such learning. Since the rat's cortex is mainly sensory in function, larger and larger cortical lesions would eliminate more and more sensory avenues centrally. and it may be for this reason that larger lesions impair learning and retention more than do smaller ones.

At one time it was thought that the frontal lobes of the brain were critical in the memory processes demanded in the solution of difficult problems. Monkeys without their frontal lobes fail in the delayed reaction test, for example. where they are shown food placed under one of two identical cups and then made to wait for 10–60 seconds before being allowed to uncover the correct cup. Something other than memory is involved in this defect, however, for monkeys without frontal lobes turn out to be quite distractible. If their attention is fixed firmly on the baited cup before the delay, the lobectomized monkeys succeed; if the monkeys are made to keep very still by putting them into darkness during the delay period or by giving them sedatives, they also perform successfully.

The cortex therefore is important in the performance of a learned task, but probably more because of its importance in perception and attention than in learning per se. On the other hand, some of the difficulty in defining cortical function here may be due to the fact that these studies are based only on the method of experimentally damaging cortical tissue. When W. Penfield studied the temporal lobes of epileptic patients whose brains were exposed for surgery under local anesthesia, he found that electrical stimulation could evoke dreamlike sequences that contained familiar episodes from past life. Furthermore, n-hen the temporal lobes are damaged in man, some curious memory defects do show up. While these patients are able to recall events from past life very well, they typically are unable to remember things they learned or experienced a few hours earlier. Closer examination shows that they actually do remember things they learn quite well if they are tested for memory within about 15 minutes, but beyond that the memory fades and is lost. It is as though there were two memory processes separated by the temporal lobe damage: (1) a temporary memory process capable of very short retention that is spared by the lesion; and (2) a more permanent memory process that is impaired by the lesion.

Support for this notion comes from several rather different experiments. In one performed on the octopus the animal was first presented with a crab, dangled in the far end of its tank, every two hours, six times a day. It quickly learned to venture out and eat the crab. Then, on half the tests, a white card was lowered with the crab, and with this cue the octopus learned not to venture out under penalty of electric shock. Thus a simple discrimination was learned. After removal of the vertical lobe of the brain, the octopus could no longer respond differentially in these tests; it kept emerging when the ahite card was presented. Even repeated trials every two hours with the white card and electric shock proved ineffective. But if the trials were run closer together, the octopus was able to perform much better; thus if a test came within 15 minutes to an hour after the octopus was shocked upon approaching the white card. it did not venture out toward the crab and white card. Again it appears as though the capacity to carry a memory over a long period of time was impaired while very short-term memory was left intact.

In studies in which rats were given electroconvulsive shocks at some interval after each daily learning trial, additional evidence for a two-process memory was found. Here there was very little learning if the convulsive shocks were given within an hour after learning. but if the shocks came beyond an hour after each trial, learning was normal. Thus it seems to take some time for the effects of a learning trial to consolidate in the brain to a point of stability. For an hour after a learning experience, memory can be disrupted by convulsive shock, but after that it is not easily disturbed.

The conclusion from all these studies seems to be that the effects of learning are retained in the brain first by some reversible process. but that after some time (nithin an hour) some more permanent change takes place within the brain. It is suspected, therefore. that learning is mediated neurologically by at least two types of processes, and the time course of these processes is partly understood. It is still, however, possible only to speculate as to the nature of the change itself. It has been suggested that the first, temporary and reversible process is a physiological process such as an electrical or chemical change at the synapse or perhaps at a group of synapses, so that a reverberatory loop is activated for some period of time, keeping the memory trace alive. The second, more permanent process has been envisaged by some as an anatomical process consisting of the swelling of nerve terminals or the outgronth of new terminals over short distances so that synapses are enriched in the number of anatomical contacts they have or that new synapses actually are formed. Another possibility, even more speculative, is that in learning there are changes in the chemical structure of nerves, possibly in the structure of complex protein molecules.

As to the locus of the change that takes place in learning, there is still no certainty. Many studies show that the cerebral cortex is not essential for many kinds of learning, but they do not offer a positive clue as to nhere learning might take place outside the cortex. On the other hand, electrical recording studies report that electrical changes take place at many loci in the brain at once during learning. Whether some loci are more important than others, however, still is not known. (For a more detailed discussion of the processes of learning, *see* LEARNING; *see* also MEMORY.)

Related to the problem of learning are the even more complex problems of reasoning, problem solution, intelligence and language. These have been studied primarily in cases of brain damage, particularly in man but to some extent also in animals. First, it should be pointed out that in both man and animal, large amounts of brain tissue may be destroyed without measurable impairment of these complex processes. For example, while removal of one entire cerebral hemisphere results in specific sensory and motor defects, intelligence within the sensory and motor capabilities of the person may be virtually unimpaired. On the other hand, lesions in certain restricted regions of the brain, particularly the cortex. may have devastating effects. Thus following damage in the lateral surfaces of both frontal poles of the brain severe intellectual impairment. as measured by intelligence tests in man and tests such as delayed reaction in monkeys, may result. In man, there are also fairly specific speech areas in the lower parts of the sensory-motor area of the cortex in the dominant hemisphere. Damage here results in aphasia, in which there is an inability to name objects properly or to point to objects named by the examiner, even though in both cases the patient can see the object and say what it is used for. If the lesion is in the temporal, parietal or occinital lobe, there may be difficulty in formulating language, in writing meaningfully (agraphia) or in comprehending written material (alexia).

As mentioned above, lesions in the visual association areas of the occipital lobe produce a visual agnosia in which familiar objects are not recognized even though elementary sensory processes are substantially normal. With parietal lobe lesions, there may be difficulty in recognition of parts of the environmental space, including one's own body, in which case we speak of distortions of the body image. Often in such cases skilled acts such as putting on clothes cannot be carried out even though individual movements can be made normally, a disorder called apraxia. In some cases of frontal-lobe damage there may be a loss in abstract ability. In such an instance, a patient may not be able to go through the motions of drinking from an empty glass, although he can easily drink from a glass with water in it when he is asked to do so. Disorders such as these are not well understood, and there are still many difficulties in making good scientific measurements of such complex behaviour, but it is clear that in many instances relatively small lesions of the brain can lead to major intellectual impairment.

Personality and Its Disorders. — Perhaps the most difficult and perplexing area of human behaviour to study is personality (*q.v.*), and particularly its disorders. For a long time the dominant thought has been that normal personality, neurosis and psychosis are purely psychological matters, the products of life experiences and life stress. But even from the beginning the view also has been held by some that personality is partly a matter of underlying physiological processes, some of which may be determined by heredity. Hippocrates, for example, believed that human temperament was largely determined by humours of the body, and while this view is chemically, biologically and psychologically incorrect, we can see nevertheless many examples in everyday life of the potent role of body chemistry in the expression of personality; consider, for example, the effects of alcohol, mescaline, opium and nitrous oxide on human behaviour.

These drugs affect the functioning of the nervous system, and so also do many naturally occurring chemicals such as vitamins, hormones and enzymes. Furthermore, the morphology of the nervous system and the enzymes directing its metabolism, and therefore its function, are determined by the mechanisms of heredity. For example, the striking case of feeble-mindedness known as phenylpyruvic oligophrenia is caused by a defective gene which produces a defective enzyme. leading to the inability to metabolize phenylpyruvic acid, which in some way impairs brain function. F. J. Kallmann's studies of the major psychoses (*q.v.*) show that heredity is an important factor. When these diseases are found in one identical twin, they are almost certain to occur in the other, even if the two have been reared apart; fraternal twins, having no more similar heredity than siblings, show the same concordance of these diseases as nontwin members of the same family, typically under 16%. Quite clearly the genetic factor predisposes the individual to psychosis; life experience, stress, disease or other factors may, of course, contribute to its precipitation. It is believed that the genetic predisposition is a biochemical defect affecting the nervous system, and the hope in the pharmacological treatment of mental disease with tranquilizers and other inhibitors and exciters of brain chemistry is that the defect may be corrected or counteracted to some degree by drugs (see NEUROPHARMACOLOGY AND PSYCHOPHARMACOLOGY).

Neuroses (*q.v.*) are much harder to understand than psychoses in physiological terms. Here no genetic factor has been demonstrated, and the defect is not so severe and incapacitating as in the psychoses. The work of H. Selye and others. however, indicates that life stress and anxiety can have widespread effects on the physiology of the organism, and it may be possible to understand neurosis as partly a matter of an altered physiological state. Experiments have shown that both physical and psychological stress activate the pituitary gland, in part through the neurosecretory activity of the hypothalamus. The pituitary, in turn, releases hormones that activate other endocrine glands of the body, particularly the adrenal cortex. Once stressed, this system may become more sensitive to additional stresses, and two kinds of disorders may occur: an early one due to oversecretion of the adrenal gland and possibly contributing to such psychosomatic symptoms as hypertension; and a second one, due to adrenal exhaustion and perhaps contributing to symptoms of rheumatism and arthritis, also believed to be partly of psychosomatic origin. Many of these notions are still frankly speculative, and the examples given here do not include many of the important symptoms of neurosis that are not psychosomatic. But the important thing is the physiological principle that seems to be at work which suggests ways in which prolonged emotional stress may affect the physiology of the organism and sensitize it to further emotional disturbances.

See also PSYCHOLOGY, EXPERIMENTAL.

BIBLIOGRAPHY.—E. G. Boring, *A History of Experimental Psychology* (1929), *Sensation and Perception in the History of Experimental Psychology* (1942); J. B. Watson, *Psychology From the Standpoint of a Behaviorist* (1919); C. T. Morgan and E. Stellar, *Physiological Psychology,* 2nd ed. (1950); E. D. Adrian, *The Physical Background of Perception* (1947); S. S. Stevens (ed.), *Handbook of Experimental Psychology* (1951); N. E. Miller. "Experiments in Motivation." *Science,* 126:1271–78 (1957); C. T. Morgan, *Introduction to Psychology* (1956); E. Stellar, "The Physiology of Motivation," *Psychol. Rev.,* 61:5–22 (1954), "Physiological Psychology," *Annu. Rev. Psychol.,* 8:415–436 (1957); J. E. Deese, *The Psychology of Learning* (1952); D. O. Hebb, *The Organization of Behavior* (1949); F. J. Kallmann, *The Genetics of Schizophrenia* (1938); H. Selye, *The Physiology and Pathology of Exposure to Stress* (1950). (EL. S.)

PSYCHOPHARMACOLOGY: see NEUROPHARMACOLOGY AND PSYCHOPHARMACOLOGY; TRANQUILIZING DRUGS.

PSYCHOPHYSICAL METHODS. Psychophysics is the science concerned with quantitative relations between psychological events and physical events or, more specifically, with quantitative relations between sensations and the stimuli that produce them. Psychophysical methods are those methods developed for the purpose of specifying and testing such quantitative relations.

Physical science enables us, at least for some of the senses, to measure with accuracy on a physical scale the magnitude of a stimulus. By determining that stimulus magnitude just sufficient to produce a sensation (or a response), it is possible to specify the minimum sensible stimulus or the absolute stimulus threshold (stimulus limen) for the various senses. It is also possible. although practically more difficult, to determine the lowest stimulus magnitude that produces maximal sensation, the terminal threshold; *i.e.,* that point on the physical scale beyond which no increase in stimulus produces any appreciable increase in sensation. Thus are determined limiting stimulus values, between which changes in stimulus intensity are accompanied by changes in sensation. The central inquiry of psychophysics pertains to the search for a lawful quantitative relation between stimulus and sensation for the range of stimuli between these limits.

Psychophysics was established by Gustav Theodor Fechner (*q.v.*), who coined the word, invented the three fundamental methods, conducted elaborate psychophysical experiments and began a line of investigation that still persists in experimental psychology. Fechner's classic book, Die Elemente der *Psychophysik* (1860), may be looked upon as the beginning not only of psychophysics but also of experimental psychology (see PSYCHOLOGY, EXPERIMENTAL). Fechner, trained in physics, became interested in his later life in metaphysics and cast about for a way of relating the spiritual to the material world. He hit upon the notion of measuring sensation in relation to its stimulus. The physiologist Ernst Heinrich Weber (*q.v.*) had discovered that the amount of change in magnitude of a given stimulus necessary to produce a "just noticeable" change in sensation always bore an approximately constant ratio to the total stimulus magnitude. This fact, properly speaking, is Weber's law: if two weights differ by a just noticeable amount when separated by a given increment, then, when the weights are increased, the increment must be proportionally increased for the difference to remain just noticeable. Fechner chanced upon Weber's law and undertook to use it for the measurement of sensation. If R be the stimulus (*Reiz*), and S be the resultant sensation, and Δ signify an increment of either, then Weber's law becomes $\Delta R/R =$ a constant, for the just noticeable difference. Fechner went further and assumed that all equal increments of sensation must be proportional to the same ratio, $\Delta R/R$, that is to say, $\Delta S = c\Delta R/R$, where c is a constant of proportionality. If this equation is integrated, if R be assigned a value of zero corresponding to the absolute stimulus threshold and if the constant be changed to k for common logarithms, the result is $S =$ k log R.

This particular formula Fechner named Weber's law, although it is really Fechner's law and is thus often called the Fechner-Weber law. It expresses the simple relation that the magnitude of a stimulus must be increased geometrically if the magnitude of sensation is to increase arithmetically. For Fechner it meant that the relation between the spiritual and material worlds is statable and that there is therefore only one world, the spiritual; but for physiologists and for many philosophers it meant the measuring of sensation in relation to a measured stimulus and thus the possibility of a scientific quantitative psychology. Fechner got his conception of psychological measurement from J. F. Herbart (*q.v.*), but he was really refuting Herbart in demonstrating that psychology can be experimental.

Fechner's original work stimulated much research and much controversy. It was argued against him that it is introspectively obvious that sensations do not have magnitude (the quantity objection), that "a scarlet is not just so many pinks." This difficulty was met by the Belgian J. R. L. Delboeuf (1831–96), who developed the concept of the sense-distance, holding that sensations, although not complex magnitudes. are separated by variable distances that can be compared as '(greater," "equal" or "less," the three categories of judgment that the psychophysical methods require. In Germany Georg Elias Müller (1850–1934) undertook an elaborate criticism of Fechner and an extension of his work. In the United States E. B. Titchener (*q.v.*) made a historical and practical exposition of psychophysics in the second volume of his Experimental Psychology (1905). F. M. Urban, then also in the U.S., improved one of the methods and developed the concept of the psychometric curve or psychometric function. In England William Brown (1881–) and Sir Godfrey Thomson (1881–1955) were prominent psychophysicists.

Three Classical Psychophysical Methods.—Among the lasting contributions of Fechner are the three fundamental psychophysical methods he invented. Each method is designed to investigate the nature of relationship between the psychological scale and the physical stimulus scale.

Method of Minimal Changes.—This, also called the method of limits or of just noticeable differences, consists of successively adding small constant increments of intensity to a stimulus until a change is noticed. For example, to determine the absolute stimulus threshold of intensity, imperceptible intensities are presented in increasing order until the stimulus is first sensed; then a descending series from perceptible to imperceptible is observed. The results of many such series are averaged to determine a single best estimate of threshold value. To find the difference limen or difference threshold, that difference between two stimuli that marks the boundary between sensed difference and sensed equality, two stimuli always are presented. One, the standard stimulus, is kept constant while the other, the variable, is successively altered by small amounts until a difference between the variable and the standard appears or disappears, according to the direction of change. The difference threshold is the distance from the standard to the average point of change, and there are always both an upper and a lower difference threshold. since change can be noticed on either side of the standard. The method of minimal changes has been used primarily to find intensity thresholds for sounds. odours, tastes. colours. temperature, pain, brightness and tactual stimuli, to name a few.

Method of Average *Error*.—The method of average error, or method of reproduction, also makes use of tno stimuli, a variable and a standard, but in this case the variable is capable of continuous change (in intensity. say) by the turn of a dial The task of the experimental subject is to adjust the variable stimulus until it is subjectively equal to the standard stimulus. Since subjective equality is not physical equality, the results yield an average error (from physical equality), constant for the subject, and also a variable error about his average. The method of average error has been applied most frequently to the study of visual distance, particularly to determine extent of visual illusions.

Constant *Method*.—In the constant method the subject is presented, in random order, a predetermined set of stimuli. for each of which he judges presence or absence of a sensation. In the typical application of the method, each selected stimulus is presented a large number of times. As an example from the cutaneous field, consider determination of the tno-point tactual threshold. With a "touch compass" two points at graduated distances are simultaneously applied to the skin The subject's task is to distinguish between two points and one. Depending upon the part of the body stimulated, the two-point threshold may vary from approximately 1 mm. (tip of the tongue) to about 70 mm. (parts of the back, thigh and upper arm). On the basis of preliminary trials, six or seven distinct distances (stimuli) might be selected so as to include the threshold for a particular subject and a given part of the body. By presenting each stimulus 100 times, a stable estimate for two-point threshold could be obtained. (Due to variability in the conditions of excitation. repeated application of the same stimulus distance is not expected always to yield the same judgment from the subject. However, as the two-point distance increases, the frequency with which the difference is reported increases. The value of that stimulus distance resulting in an equal number of judgments "one point" and "two points" can be taken as the threshold.)

In a somewhat different application of the constant method, two distinct stimuli are presented, either simultaneously or successively, and the subject is instructed to judge whether stimulus B is greater than, equal to or less than stimulus A. Stimulus A might be a standard stimulus, presented on each trial; the second stimulus might have any one of six or seven preselected values.

A classic example is that of lifted weights: on each trial a standard meight is compared with a variable meight, and the subject responds nith one of three possible judgments. Values for the variable stimulus are selected, some to be heavier and some to be lighter than the standard. Each value of the variable stimulus might be presented with the standard 100 or more times, with order of presentation randomized. Relative frequencies of judgments may be plotted as shown in the figure. It may be seen that as the variable stimulus becomes heavier the frequency nith which the variable is judged "less" than the standard decreases. the frequency of "greater" judgments increases. while the judgments of equality become first more. then less frequent. with a maximum near the centre. The loner threshold or limen value of the stimulus is taken as that value where the judgment "less" is as likely as it is not; i e., that point on the stimulus scale corresponding to 50% judgment of "less" The upper liminal stimulus value is similarly defined nith reference to the distribution of "greater" judgments (sometimes called the psychometric function for "greater" judgments). The difference limens are the distances of these liminal values from the standard stimulus (the distances L_l to S and L_u to S). Subjective equality of variable to standard stimulus is usually taken as the point where judgments "less" and "greater" are equally likely; *i.e.*, where the two psychometric functions intersect. Empirically it has been found for a wide range of situations that the observed relative frequencies for "less than" and "greater than" judgments can be fitted reasonably well by the ogives of the normal probability integral, in early psychophysical literature sometimes referred to as the phi function of gamma or the phi-gamma function.

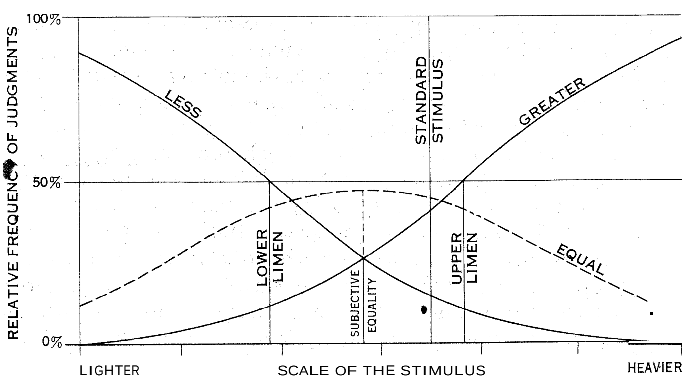


DIAGRAM OF THE CONSTANT METHOD, USING TWO DISTINCT STIMULI

The constant method is regarded as the most accurate and general of the psychophysical methods. While its use has been illustrated here primarily for the estimation of threshold values, it is widely used for other problems of sensory psychology. The method has been found particularly useful for industrial research in the quality control of food and beverage products, where sensory characteristics of the product play a large role in consumer acceptance.

Direct Psychological **Scaling.**—*Method* of Paired *Comparisons.*—Related to but distinct frdm the constant method is the method of paired comparisons, developed in 1927 by the U.S. psychologist L. L. Thurstone (*q.v*). Taken together nith Thurstone's lam of comparative judgment. the method of paired comparisons provides a model by which sensations may be scaled directly, without reference to corresponding physical measurements of stimuli. In the formulation of Weber ($\Delta R/R = c$), the concern is only with the physical measures of the stimulus R Fechner's proposal ($S = k \log R$) explicitly introduced a continuum of sensation, and allowed indirect "measurement" of sensation by using a functional relation between sensation and physical measurement. Thurstone's model allows direct measurement of psychological events without having first established an intervening quantitative relation between psychological and physical events. One striking feature of the method, thus, is its applicability to the scaling of human attitudes, consumer preferences, aesthetic values and other psychological variables associated directly with no apparent physical counterparts.

In the method of paired comparisons, each one of a set of stimuli is presented together with every other stimulus in the set. The subject is asked to make one of two possible judgments to each stimulus pair, either that stimulus A is "*x*'er" than stimulus B or that stimulus B is "x'er" than stimulus A. The quality x is defined by the purpose of the study, so that. judgments might be "heavier," "brighter" or "louder," or could be "more valuable," "friendlier" or the like. Paired stimuli could be presented on many occasions to a single subject or many similar subjects may judge each stimulus pair just once. In either case the result is a matrix of relative frequency showing the proportion of times each stimulus was judged higher on the scale than every other stimulus.

From these basic data, scaling proceeds by the law of comparative judgment. Assuming that a subject's response reflects the momentary subjective value associated with the stimulus, and assuming further that the probability distribution of these momentary values is Gaussian (normal), either over numerous occasions for one subject or over a population of homogeneous subjects, then, applying the simplest case of the law, $\mu_i - \mu_j = z_{ij}$, nhere μ_i and μ_j are the mean psychological values associated with a pair of stimuli. i and j, and z_{ij} is the unit normal deviate associated with p_{ij}—the proportion of judgments that stimulus i is greater than stimulus j (z_{ij} is uniquely determined from p_{ij} and may be read as an entry in the table of the normal distribution function). If the numbers z_{ij} are arranged in matrix (tabular) form, the mean values for the columns provide estimates for the n values, μ_i. For the case where $n = 4$, the table takes the following form (noting that for z_{ij} may be substituted the quantity $\mu_i - \mu_j$):

	$\mu_1 - 1$	$\mu_2 - \mu_1$	$\mu_3 - \mu_1$	$\mu_4 - \mu_1$
	$\mu_1 - \mu_2$	$\mu_2 - \mu_2$	$\mu_3 - \mu_2$	$\mu_4 - \mu_2$
	$\mu_1 - \mu_3$	$\mu_2 - \mu_3$	$\mu_3 - \mu_3$	$\mu_4 - \mu_3$
	$\mu_1 - \mu_4$	$\mu_2 - \mu_4$	$\mu_3 -$ p 4	$\mu_4 - \mu_4$
Sum:	$4\mu_1 - \Sigma\mu_i$	$4\mu_2 - \Sigma\mu_i$	$4\mu_3 - \Sigma\mu_i$	$4\mu_4 - \Sigma\mu_i$
Letting $\Sigma\mu_i = 0$				
Mean:	μ_1	μ_2	μ_3	μ_4

Since the zero point to this scale is arbitrary, $\Sigma\mu_i = 0$ may be defined as above, and this yields the desired solution.

Psychological scaling methods typically allow measurement on a scale characterized by equality of intervals, but one with only a n arbitrary origin or zero point. As upon the centigrade or Fahrenheit scales of temperature, nominal magnitude of zero does not correspond with absolute absence of that which is measured. On such scales ratio comparisons of measures are not valid. (A substance registering a temperature of 40° C., for example. is not twice as hot as a body with measured temperature of 20" C.)

However, the method of paired comparisons has been extended so as to provide a rational zero point. and thus to allow for meaningful ratio comparisons of psychological magnitudes. On a scale of consumer preference, the psychological zero point is that psychological value which, if assigned to a consumer item, would result in consumer indifference toward that item. An absolute scale is established by first assuming the additivity of psychological magnitudes — that (under specified conditions of independence of stimuli) the subjective value for a combination of two stimuli is equal to the sum of the two values associated with the individual stimulus items. The assumption may be stated $\mu_{ij} = \mu_i + \mu_j$, where μ_{ij} is the mean psychological value associated with a composite stimulus and μ_i and μ_j are the mean values associated with the two component stimuli. There is one such equation for every composite stimulus included in a particular study, and it becomes a matter for empirical test to determine whether the several equations are consistent with subjects' judgments scaled by the method of paired comparisons.

Method oj Successive Categories. — Derived from assumptions similar to those for the method of paired comparisons is the method of successive categories. Subjects are instructed to rate each of a set of stimuli by assigning it to one of a group of ordered categories of judgment (usually between five and ten categoriesj. Ratings are to reflect the subjects' judgments concerning the stimulus and are taken as gross indicants of the underlying psychological values associated with the stimulus. Under the assumption that the ratings represent random variables from a normally distributed population of underlying scale values, it becomes possible to estimate the mean and standard deviation of the underlying distribution of subjective values for each stimulus. The method of successive categories has the advantage of requiring just one rating from each subject for every stimulus, in contrast to the method of paired comparisons which requires $n(n-1)/2$ judgments for each of n stimuli.

Results from the two methods generally have been found to be nearly identical.

An Alternative to the Fechner-Weber Law: the Power Function. — One of the earliest criticisms of Fechner's psychophysical approach was that of the Belgian physicist J. A. F. Plateau (1801–83). Plateau reasoned that, since the apparent relations among different shades of gray remain *sensiblement le même* when the general illumination is changed, the ratios among the sensations produced by the grays must remain fixed. This, he argued, is more rational than Fechner's view that it is the differences that remain fixed. While Fechner's formulation entaiis a logarithmic relation between sensation and stimulus, Plateau's assumption entails a power function of the form $S = aR^n$, where sensation (S) is proportional to a constant power (n) of stimulus magnitude (R).

Since the time of Plateau, the power Eunction alternative to the Fechner-Weber law has been revived on several occasions, but never before with such force as that brought to bear by the U.S. psychologist S. S. Stevens. Stevens vigorously attacked the Fechnerian assumption that the just perceptible stimulus difference may serve as a unit of measurement for sensation. As a result of extensive laboratory investigation, a power function has been found to relate psychological magnitude to stimulus magnitude ($S = aR^n$) for more than a dozen distinct psychological continua. Empirical determination of the exponent n has shown it to vary from about 0.3 (for loudness) through unity (for taste, visual length, visual area) and 1.5 (heaviness) to approximately 2.0 (visual flash rate).

The methods utilized in these studies differ sharply from Fechner's psychophysical methods. In the work of Stevens and his students, subjects are required to make direct quantitative estimates of subjective events. The most prominently used of these methods is that called fractionation. The subject is required to adjust one stimulus so as to produce a sensation half (or some other fractional amount) as great as a given standard stimulus.

It seems highly probable that the distinct psychophysical laws, logarithmic and power function, result from application of different measurement methods. By this view! the power function formulation is not necessarily inconsistent with the Fechner-Weber law. Rather, each is valid, but pertains to a unique definition of psychological magnitude, a definition specified by the psychophysical method employed.

For application of the psychophysical methods, *see* PSYCHOLOGICAL TESTS AND MEASUREMENTS.

BIBLIOGRAPHY.—G. T. Fechner, *Die Elenzente der Psychophysik* (1860). For a detailed summary of 19th-century psychophysics, *see* E. B. Titchener, *Experimental Psychology*, vol. ii, parts i and ii (1905). Urban's contributions appear in F. M. Urban, *Application of Statistical Methods to the Problems of Psychophysics* (1908); the work of Brown and Thomson appears as W. Brown and G. H. Thomson, *Essentials of Mental Measurement* (1921). The method of paired comparisons is presented in L. L. Thurstone, "A Law of Comparative Judgment," *Psychol. Rev.*, 34:273–286 (1927). For application of this method to solve for the subjective zero point, *see* L. L. Thurstone and L. V. Jones, "The Rational Origin for Measuring Subjective Values," *J. Amer. Statist. Ass.*, 52:458–471 (1957). Evidence ior the power iunction form of a psychophysical law is summarized in S. S. Stevens, "On the Psychophysical Law," *Psyckol. Rev.*, 64:153–181 (1957). A general summary of psychophysical methods is to be found in J. P. Guiliord, *Psychometric Methods*, 2nd ed. (1954). (L. V. Jo.)

PSYCHOSES. A psychosis is a mental illness in which the patient fails to discriminate between stimuli arising within himself and stimuli received from the external world. The healthy personality accurately perceives and evaluates the environment. When the stress of conflict between the self and the environment becomes too great, however, the perceptive and evaluative (ego; *q.v.*) functions of the personality may break down. In such situations the person appears to distort his concept of the environment into a form which is more satisfactory for him; he organizes it into a less confusing place in order to protect himself. In the process he loses contact with reality and becomes psychotic.

Psychoses are rare until adolescence, but thereafter continue to increase in incidence with the advance of age. There is an especially sharp rise at the older age levels. The problems and conflicts of phases of development and stress, such as adolescence, marriage, pregnancy, parenthood, the involutional period and senility, tend to disturb psychological integration and may precipitate a psychotic disturbance in vulnerable persons.

Psychoses present symptoms that have multiple causations and multiple meanings. These are indicative of underlying conflict and represent ways of trying to deal with the conflict. Symptoms may represent attempts to adapt through protective and safety devices. or else they may appear when defenses collapse and disintegrate. Psychotic symptomatology is a manifestation of both regressive and restitutional phenomena. Initial symptoms, such as world-destruction fantasies, hypochondriasis and depersonalization, often represent regression to earlier behaviour patterns or renunciation of the objective world. Later symptoms, such as world-saving fantasies: hallucinations and delusions, may be evidence of a swing toward restitution or toward reintegration of the psychotic ego. The psychotic appears to oscillate between an almost complete loss of object relationships and a striving to re-embrace them.

Symptoms of Psychosis.—Psychotic symptoms may be considered under the following headings:

1. Disorders of perception. A hallucination (*q.v.*) is a misperception (either auditory, visual, olfactory or, less frequently, gustatory). Something is perceived which has no objective reality; for example, voices may be heard when no sound exists. An illusion is a misinterpreted perception in which a sensory impression is received correctly but then misconstrued so that it takes on an erroneous meaning. For example, the rustling of leaves may be interpreted as whispering reproaches; although the rustling is heard, it is given a specific psychological meaning.

2. Disorders of thinking. In autistic or dereistic thinking the mind appears to operate without regard to reality, building up an unrealistic fantasy life and becoming preoccupied with the fantasy to the exclusion of reality. A ('flight of ideas" is characterized by a rapid digression from one thought to another, often expressed as words or clauses run quickly together without an apparent logical connection. Perseverations are repetitive expressions of an idea and include verbigerations, or repetitions of apparently meaningless words or sentences. A delusion is a false belief which is not susceptible to correction by reason or logic. Thus many patients suffering from delusions of persecution may believe there is an international plot directed specifically against them, and they cannot be shaken from this belief. Patients with delusions of grandeur are convinced they are such exalted figures as Napoleon or Jesus Christ.

3. Disturbances of consciousness. A confusional state usually includes bewilderment. perplexity, uncertainty, disorientation and difficulty in grasping the simplest concepts. Stupor is a state of mind manifested by varying degrees of consciousness but always including diminished responsiveness, either through suspension of thought processes or through intense preoccupation with internal concerns, withdrawal and loss of reality sense. Delirium (*q.v.*) is characterized by combinations of the above plus illusions, hallucinations and intense fear.

4. Disturbances of affectivity and mood. Affectivity or feeling tone are terms signifying the minute-to-minute variations in the subjective feelings of a person. Mood is a sustained feeling tone over a longer period of time. These emotional states range along a continuum from extreme depression through normal affect to extreme elation. In the most extreme elation reality is completely denied, and attitudes of grandeur and peaceful rapture, detachment and power are assumed. Another dimension of affect includes panic, consisting of marked fear and a tendency toward disorganization of the personality. Characteristic of all these affect states (elation, depression, panic) is their inappropriateness; that is, the feeling tone is not appropriate to the patient's life situation.

5. Disturbances of activity. Marked increases or decreases in the rate of mental and physical activity are common. Hyperactivity includes excessive restlessness, pacing, agitation and excitement. The extreme of diminished activity is called waxy flexibility, in which the limbs are maintained in fixed poses for long periods of time.

Defense Mechanisms.—Although the ego defends itself against overwhelming anxiety with defense mechanisms, the mechanisms themselves may become of pathological degree.

1. Rationalization is a form of self-deception by which a person acclaims in a manner acceptable to himself an act, thought or feeling that in actuality has a different and more unacceptable motive. The real reason thus remains obscure. Although rationalization is commonly used by all people, such self-deception may become a full-fledged delusion if carried to an extreme.

2. Projection is a mental technique whereby a person unconsciously externalizes some of his own thoughts or feelings or inadequacies. He thus defends himself from his unacceptable impulse by attributing it not to himself but to another. Thus a person who cannot face his own hostility may attribute it to another and accuse the other of hostile designs against him. This mechanism characterizes the formation of paranoid reactions (see below).

3. Autism, withdrawal into fantasy and regression (a moving back to ard less mature but more comfortable levels of personality development) are protective devices but may lead to psychosis formation.

4. The process of internalization or introjection involves a turning inward upon the self of certain feelings and attitudes which thereby may produce depression. (See also DEFENSE MECHANISMS.)

Causes of Psychosis.—The causes of psychoses appear to be multiple. They include somatic (physical), biological, psychological (intra- and interpersonal) and sociological factors, all of which affect attitudes, feelings and behaviours. Studies of psychological causes stress the importance of the mother-infant relationship, inability and/or lack of opportunity for the child to obtain gratification of his basic needs, and defective development of a sense of reality. Extreme maternal deprivation during the first few months of life, caused either by lack of a mothering figure through loss or by an unusually barren mother-infant relationship, generates unbearable tensions. Since deprived children have had no one with whom to relate when relationship was most important, the warmth and security derived from relating to another human being are lacking. Genetic studies indicate that a specific potential for reacting to personality stresses in a specific way can be inherited; that is, it is possible to inherit a constitutional predisposition to psychosis which is then stimulated or extinguished by other etiological factors.

In addition to the basic determinants, there are a variety of factors that may precipitate a psychosis. These may be obvious reproductions or re-enactments of earlier stresses, or they may be less apparent and seemingly irrelevant events whose relationship to previous stress is obscure. Frequently precipitating factors are organic, such as alcohol and other drugs, infectious processes, endocrine and vitamin deficiencies, physical defects and brain injuries. Other precipitating factors appear to be manifestations of stressful times and events of life, as marriage or pregnancy. Overwork has frequently been implicated, but it is a symptom rather than a cause.

Organic Psychoses.—The psychoses are divided into two main categories, organic and psychogenic (for which see below). according to the presence or absence of discernible organic factors. Organic psychoses result primarily from pathological changes in the central nervous system. They are divided into acute and chronic types. The acute group includes those reactions which come on suddenly, last for a limited time and then disappear. The chronic diseases are slower in onset and tend to produce more lasting effects, which do not appear to be reversible but become stationary or gradually progressive.

The brain is particularly susceptible to physiochemical changes. It is dependent on a large flow of well-oxygenated blood, and since its metabolic activity is high, its oxygen consumption is also high. The brain has a small oxygen reserve and cannot withstand oxygen deprivation very long. It can expand little. yet is suspended and quite movable, subject to injury and sensitive to any noxious stimuli. Thus a state of reduced cerebral competence from whatever cause predisposes the individual to the development of an organic psychosis: (1) personality change, defects in judgment and moral code, tendency toward egocentricity; (2) disturbances in memory, especially for recent events, disorientation for time, place and person; (3) emotional instability, irritability and frequent shifts in mood; (4) exaggeration of previous personality problems (persons who have been aggressive tend to become overwhelmingly hyperactive, whereas persons who have been quiet and reserved tend to withdraw even more); (5) diminished tolerance to medications (more severe reactions to sedatives, other drugs).

In addition to acting as a specific cause or precipitating stress for the development of a psychosis, organic brain disease may interfere with and impinge upon the healthy integration of the personality. The result is impaired ego function, and the symptoms are a manifestation of ego disintegration. A less competent ego then permits the release of previously warded-off impulses which overwhelm the ego and lead to a psychosis.

The following are significant clinical entities:

1. Infectious processes. A meningitis (*q.v.*) may be either intracranial or systemic. Although commonly an acute reaction, some types of meningitis are long-standing. slowly developing diseases. Syphilitic meningoencephalitis (formerly called general paresis; *q.v.*), an infection not only of the meninges but also of the brain itself. may require years to develop.

2. Intoxications. A variety of drugs or poisons produce acute and chronic symptomatoiogy. Bromides, barbiturates, lead and alcohol taken over a prolonged period of time may lead to psychoses. Profuse and frequent imbibition of alcohol followed by sudden withdrawal and accompanied by a nutritional deficiency leads to a condition known as delirium tremens. Korsakoff's psychosis, associated with alcoholism, is in reality due to a severe vitamin B deficiency and is characterized by amnesia, disorientation for time and place and falsification of memory (*see* ALCOHOLISM).

3. Injuries. Severe head injury may produce an acute syndrome known as traumatic delirium or a chronic personality disturbance such as seen in the prize fighter who is "punch drunk."

4. Metabolic disorders such as hypoglycemia (a deficiency of sugar in the blood) and certain swellings or growths (brain tumours and cysts) may bring about a psychosis.

5. Degenerative diseases. Advanced age may be associated with a degenerative disease of the brain which leads to dementia. a psychotic disturbance characterized by progressive impairment of basic mental capacities. In these cases the brain cells literally "wash away" and disappear (see DEMENTIA!.

6. Circulatory disturbances. One of the commonest disease processes expressing itself in both acute and chronic psychotic forms is cerebral arteriosclerosis. In this condition there is gradual or fairly rapid hardening of the blood vessels of the brain, and deposits of fat in the deteriorating vessel wall tend to narrow or almost obliterate the vessel: thereby obstructing the flow of blood. When less blood is carried to the brain its nutritional status is affected and psychosis appears. There is often a fluctuation in the course of cerebral arteriosclerosis, and the patient often recognizes his decline. in contradistinction to other organic maladies where there is no insight.

The treatment of an organic psychosis depends on its cause, and each is handled individually. Both physiological and psychological therapies are employed, ranging from vitamins, medications and surgical procedures to the establishment of emotional security and an increasing sense of self-esteem.

Psychogenic Psychoses.—Disorders of psychogenic origin appear to be free of structural, anatomical or physiological changes and are the result of disturbed psychological experience. The six major psychoses of psychogenic origin are divided into two distinct but by no means mutually exclusive types, the affective reactions and the thought disorders. In the former, mood disturbances are dominant; in the latter, there is a predominant disturbance in the capacity to think and judge and the power to reason. The three affective reactions are involutional depression, manic-depressive psychosis and psychotic depressive reaction. The three thought disorders are schizophrenia, paranoia and paranoid state.

Affective Reactions.—An involutional depression is a depression coming on in the so-called involutional period of life (*i.e.*, approximately 40–60 years of age in women, 45–65 in men). It is often accompanied by agitation, usually represents the person's first "breakdown" and occurs in people whose premorbid personalities are characterized as energetic but inhibited, compulsive and overconscientious, chronically worried, inflexible and sensitive.

A manic-depressive psychosis, as the name suggests, may be made up of both manic (hyperactive, elated) phases and depressive states, alternating with one another or occurring haphazardly without any particular order. Instead of alternating, all episodes may be manic, or all may be depressed. These episodes are usually cyclic in nature and may come on every few months or every few years with reasonable regularity. The disease occurs in young people (early 20s) and may continue intermittently for many years. each attack lasting a few weeks or a few months. The manic phase may represent a defense against a basic depression; certainly the swings from one phase to another give credence to the homogeneity of the two elements. The symptomatology of the manic is characterized by exaltation and excitement. loquaciousness and rapid association of ideas. Psychomotor activity is described as overactive. The depressed phase. on the other hand, is usually characterized by psychomotor retardation; *i.e.*, movement and mental activity are slow and there is an inhibition of the stream of thought.

The prepsychotic personality of the manic-depressive is distinguished by its lability, mood swings and unpredictable oscillations of emotion.

The term psychotic depressive reaction describes a depression of psychotic proportions, arising as a direct result of one or several specific precipitating stresses. It may come at any age, and is often an isolated. single episode in a person's life.

Thought Disorders.—Schizophrenia is a term coined by E. Bleuler in 1911. from two Greek words meaning "splitting of the mind." As with the others, this disorder represents an expression of the total reaction of the person to internal and external stress. There is a breakup in the normal synthesis of thought. and part of the split takes place between the thought process and the affect connected with it. In its most definitive form the schizophrenic syndrome is made up of: (1) a disorder of association—the train of thought does not seem to follow a usual rational pattern: (2) a disorder of affect—the feeling state is inappropriate to the situation, to the particular thought or idea expressed; (3) autistic thinking—withdrawal into self and a fantasy world; and (4) ambivalence—indecision or complete blocking because of two conflicting feelings or two opposing impulses.

Emerging from these manifestations are a host of varied symptoms and signs including poverty and disharmony of feeling tone. inability to relate to another person and delusional or hallucinatory mental content or both. A schizophrenic person may appear dull and apathetic. He may be catatonic and stay in one position over a long period of time. He may exhibit mutism. impulsive or stereotyped behaviour and occasional phases of stupor or excitement; or he may be preoccupied with delusional thoughts with behaviour corresponding to these thoughts. In general there may be mixtures and combinations of symptoms. attitudes. expressions and patterns, so that it is difficult to classify schizophrenics into subtypes or to place them in various subdivisions (see SCHIZOPHRENIA).

The paranoid psychoses are characterized by delusions of a persecutory or grandiose nature. with varying degrees of ego disintegration. In true paranoia there is usually one basic, well-systematized delusion, while the rest of the ego remains reasonably intact. The true paranoiacs are rarely identified. as they usually manage to conceal their delusions and to function adequately. Paranoid states involve a more elaborate delusional system in which the delusions are less believable and more loosely organized and lead to a more disintegrated ego structure. During the paranoid episode the patient may be obstreperous and hostile (see PARANOID REACTIONS).

The bridge between the paranoid psychosis and the schizophrenic psychosis is an entity known as paranoid schizophrenia. In the most serious forms the delusions are poorly organized. bizarre and contradictory. and ego disintegration proceeds at a rapid pace. Paranoid schizophrenics range along a continuum from relatively harmonious ego co-ordination to almost complete ego decomposition and loss of control. The paranoid schizophrenic is potentially dangerous to himself or others because of his feeling that others are against him and because of his bizarre reactions to this thought.

Treatment of the psychogenic psychoses is varied and variable. Several therapies usually are combined in managing a particular syndrome with one or more therapeutic procedures utilized at specific times for specific reasons.

Many patients with psychosis require hospitalization; some do not. Outside a hospital, psychotherapy, environmental manipulation and the administration of drugs are valuable. In a hospital, concomitant with the above, a program that includes individually prescribed activities for the patient and certain helpful attitudes on the part of the ward staff, plus somatic therapies such as insulin, electroshock and lobotomy (surgery on the brain) are employed when necessary. The affective psychoses, particularly the involutional depressions, respond more favourable to electroshock than do the thought disorders. In the paranoid conditions sometimes insulin and occasionally lobotomy have been used, and favourable results with drug therapy have been reported. However, psychotherapy and the provision of a therapeutic milieu are the basic treatment in all the psychoses.

Childhood Psychosis.—Childhood psychosis is an uncommon but severe form of ego disturbance which becomes apparent in the early years of life (before puberty). Onset may be sudden or insidious. Symptoms include withdrawal, negativism (refusal to do whatever is asked, or doing the oppositk of what is expected or desired), anxiety, stereotyped behaviour and a tendency toward an abandonment of reality. In infancy the baby may be apathetic and fail to react emotionally to being approached or when picked up.

Etiologically the lack of an affectional tie between infant and mother appears to be important. Often the mother (or both parents) as nell as the child require treatment. Institutional care for the child is sometimes indicated.

For other types of mental disorders, see NEUROSES. For treatment, see PSYCHIATRY; PSYCHOANALYSIS; PSYCHOTHERAPY; NEUROPHARMACOLOGY AND PSYCHOPHARMACOLOGY. See also PSYCHOLOGY. ABNORMAL, and Index references under "Psychoses" in the Index volume.

BIBLIOGRAPHY.—0 Fenichel, *The Psychoanalytic Theory of Neurosis* (1945); H. S. Lippman, *Treatment of the Child in Emotional Conflict* (1956); A. P. Noyes and L. C. Kolb, *Modern Clinical Psychiatry*, 5th ed. (1958); G Zilboorg and G. W. Henry, *A History of Medical Psychology* (1911) (P. M MA)

PSYCHOTHERAPY in its broadest sense is the systematic effort of a person or group to relieve distress or disability by influencing the sufferer's mental state, attitudes and behaviour. Drugs may be used as adjuncts, but the healing influence is exerted primarily by words and actions that are believed by sufferer, therapist and the group to which they both belong to have healing powers and that create an emotionally charged relationship between them. Psychotherapeutic methods are used to treat all forms of suffering in which emotional factors play a part. These include behaviour disorders of children and adults; emotional reactions to the ordinary hardships or crises of life; psychoses, characterized by derangements of thinking and behaviour usually so severe as to require hospitalization; psychoneuroses, which are chronic disorders of personal functioning often accompanied by bodily symptoms of emotional strain; addictions; and psychosomatic illness, such as gastric or duodenal ulcer and certain skin diseases, in which tissue damage is caused or aggravated by emotional components. Since loss of morale contributes significantly to the degree of disablement of all chronically ill or handicapped persons, psychotherapeutic principles are emphasized in rehabilitation programs.

Historical Survey.—Early psychotherapeutic theories and methods were based on either the religio-magical or the naturalistic view of mental illness. The former, originating before recorded history, regarded certain forms of personal suffering. or of alienation from one's fellows, as caused by an evil spirit that gained entrance into the sufferer because he had sinned or through an enemy's curse. The curse could be lifted or the transgression atoned for, leading to expulsion of the evil spirit, by the participation of the victim and his group in suitable rites, under the leadership of a priest-physician, the medicine man or shaman. Thereupon the victim's health was restored and he was once more accepted by his group. The tradition of supernatural healing remained strong and finds its modern expression in, for example, healing shrines and numberless cults led by healers whose claims are accepted only by their devotees.

The naturalistic tradition viewed mental illness as a phenomenon that could be scientifically studied and treated, like other forms of illness. Treatment consisted in measures to promote bodily well-being and mental tranquility. The earliest surviving expression of this concept is in the writings attributed to Hippocrates in the 5th century B.C. Though largely eclipsed in the middle ages, at the turn of the 19th century it again began to cotne to the fore under the leadership of the great French physician Philippe Pinel. For him, many forms of insanity were the results of excessive exposure to social and psychological stresses, and he tried to help the insane regain their reason through "moral treatment," which included close. friendly contact, intimate discussion of personal difficulties and a planned program of purposeful activities. The popularity of moral treatment depended upon the belief that insanity was curable by psychological influences. As the theory gained ascendance that mental illness was caused primarily by organic disease of the nervous system rather than by the stresses of life, faith in its curability by psychological means declined and, starting in the middle of the 19th century, mental hospitals tended to degenerate into custodial institutions, which most of them continued to be until the mid-20th century.

Psychotherapy of nonhospitalized patients in the naturalistic tradition was not distinguishable from ordinary medical practice until the latter half of the 19th century. The emergence of psychotherapy as a specialized treatment probably is traceable to the dramatic demonstration by Franz Anton Mesmer (*q.v.*) in the late 18th century that many symptoms could be made to disappear by putting a patient into a trance. Although his theories and methods mere soon discredited, mesmerism was the precursor of hypnotism, which became a widely used psychotherapeutic method. Through it Josef Breuer and Sigmund Freud (*q.v.*) made the epochal observations on the relationship to later mental illness of emotionally charged damaging experiences in childhood. From these discoveries grew the theory and practice of psychoanalysis, which, uith its many modifications, immensely influenced the subsequent development of psychotherapy.

Despite the widespread recognition that the groups to which a person belongs powerfully affect his attitudes and behaviour, the traditional medical emphasis on the privacy of the doctor-patient relationship slowed general acceptance of group psychotherapy. Though foreshadowed as early as 1905 by Joseph J. Pratt's group treatment of tuberculosis patients. only a few physicians practised group therapy before World War II. The large numbers of soldiers requiring psychotherapy compelled psychiatrists to try to treat them in groups, and the use of group methods proved so effective that they developed rapidly in the postwar years. During this period, two societies and two journals devoted exclusively to group therapy appeared in the United States alone. The professional acceptance of the importance of group influences led to the development of social or milieu treatment for hospitalized patients, based on the recognition that all aspects of institutional life had therapeutic potentialities. This gradually began to transform mental hospitals from custodial institutions into therapeutic communities.

The rapid growth of group therapy was one manifestation of a striking upsurge of public interest in mental health, especially in the United States following World War II, leading to a demand for psychotherapy that went far beyond the capacity of the medical profession to meet it. As a result, members of related disciplines, particularly clinical psychology and psychiatric social work, received increasing recognition as competent to treat certain types of sufferers.

Psychiatrists continued to have responsibility for treatment of the hospitalized insane and patients in psychiatric clinics. They also enjoyed the highest prestige as private practitioners of psychotherapy. Other physicians continued to practise effective psychotherapy of an informal sort on the large proportion of their patients whose bodily complaints were associated with emotional stress. Clinical psychologists and psychiatric social workers treated patients or their families under psychiatric supervision in mental hospitals and psychiatric clinics for adults and children. In addition. members of each profession used methods analogous to, if not indistinguishable from, psychotherapy in certain institutional settings without medical supervision. The type of person or problem with which psychologists and social workers dealt depended largely on the settings in which they worked. Psychologists in educational institutions counseled children, adolescents and young adults; social workers did casework with clients of social agencies. whose personal difficulties tended to be bound up with environmental stresses. The exact limits of the various fields of competence of these disciplines remained vague and the jurisdictional problem became more acute as psychologists and social workers in the larger cities entered independent private practice in direct competition with psychiatrists.

A significant development during this period was the growing rapprochement between naturalistic psychotherapy and religiously oriented psychotherapy in the form of pastoral counseling. As psychotherapy became more popular, certain persons came to seek it as a means of achieving a fuller life and finding personal solutions to the general problems of human existence. Psychotherapists thus were faced with questions that traditionally lay in the province of philosophy and religion. At the same time, parishioners put increasing demands on their ministers for help with personal problems, leading the latter to turn for help to the newer insights of psychotherapy. Both groups saw resemblances between the moral and spiritual conflicts or emotional responses to the crises of life, which were the primary concern of the pastoral counselor. and the issues raised by patients in psychotherapy.

The variety of therapeutic practitioners was paralleled by a wide diversity of theories of mental illness and methods of treatment. The preferred form of psychotherapy in different cultures seemed to accord with the characteristic pattern of social interaction. Psychotherapy in Germany and the U.S.S.R. tended to be directive, while in the United States permissive, democratic methods had a higher prestige. Within a given culture, furthermore. patients of different socioeconomic levels tended to receive the type of psychotherapy that accorded best with their typical views of treatment. One study of patients in psychiatric treatment in New Haven, Conn., in 1951. for example, found that about half the upper- and middle-class neurotics received insight therapy (see below) as compared with only 5% of the lower-class neurotics. This seemed related to characteristic differences in the conceptions of these classes as to what constituted treatment.

The existence of so many theories and techniques was an indication of the need for research. which received extensive and increasing public and private support in the decade following World War II.

Features Common to **All** Forms of Psychotherapy. — There is no convincing evidence that the results of one form of treatment are better than any other, lending plausibility to the supposition that their underlying similarities might be more significant than their apparent differences. Despite differences in emphasis, most schools of psychotherapy agree that mental illnesses are, at least in part, expressions of chronic states of anxiety and frustration, related to unsolvkd inner conflicts and unsuccessful ways of dealing with other persons Though genetically or physiologically caused vulnerabilities might contribute to the difficulties of these patients, unfortunate early experiences aith family members and other emotionally significant persons are believed to play a major role.

Chances of successful treatment are generally held to be related to the degree of the patient's emotional involvement in the treatment process. This is influenced by the intensity of his suffering and by his faith in the therapist and the treatment method. The patient's expectancy of help is enhdnced by the therapist's ability to convince the patient that he understands him intimately and is dedicated to his welfare. Personal qualities of the therapist and his emotiondl reactions to the patient seem important in the development of a successful therapeutic relationship.

The close, confiding relationship between patient and therapist, including the shared expectancy that the patient will be helped that is common to all forms of psychotherapy, is probably healing in itself. It tends to allay the patient's anxieties and bolster his morale, resulting in direct relief of bodily symptoms due to emotional tension In addition it helps him mobilize the courage necessary to give up habitual but unsatisfactory nays of feeling and behaviour and search for better ones. The search is aided by the fact that the therapist or therapeutic group represent certain values and principles of conduct with which the patient can compare his own and adopt what is helpful to him. This usually occurs not through deliberate choice but more or less unconsciously. just as children take over behaviours and attitudes of their parents, which then become integral parts of their own personalities. Psychotherapy thus is essentially a process of reeducation, both emotional and intellectual. through which the patient develops better patterns of adjustment to life.

Major Forms of Psychotherapy. — Psychotherapies differ primarily in the nature of the activity that mediates the therapeutic relationship. The variety of these activities is bewildering, but they may be classed as individual or group, depending on whether or not the therapist treats more than one patient at a time. Both forms can be divided roughly into methods that seek to alleviate the patient's distress or teach him more satisfactory behaviour through direct interventions, and those that try to facilitate his over-all emotional growth and capacity for responsible behaviour. Many psychotherapeutic methods contain an admixture of both, and most psychotherapists emphasize one or the other with different patients, depending on the nature of their difficulties.

Individual Psychotherapies. — Individual psychotherapeutic methods for influencing patients directly include advice giving, persuasion. suggestion and training in specific curative activities. These include relaxation exercises to combat emotional tension and efforts to inculcate behaviour that is incompatible with that presumably causing the patient's distress. thereby overcoming it. Many of these methods are based on the conditioned reflex theories of I. P. Pavlov (see CONDITIONING; REFLEX). They frequently use hypnosis (*q.v.*) to heighten the therapist's power over the patient, and often include efforts to change his social environment so as to reduce the stresses it places upon him.

Individual therapies that seek to foster the patient's general personality growth emphasize heiping him to gain insight into his feelings and behaviour. They hold that, since symptoms of emotional illness are expressions of flaws in the patient's over-all approach to life, permanent relief requires major personality change. To facilitate this they try to create a therapeutic situation that will enable the patient to express himself with complete freedom, while the therapist maintains a consistent, warm, nonjudgmental interest. Feeling himself understood and accepted by someone whom he admires and to whom he feels close. the patient will progressively dare to reveal those shameful or frightening aspects of himself that he has pushed out of awareness. As his self-understanding increases, his self-esteem will grow and he will become more spontaneous, enabling him to relate more flexibly and appropriately to persons important to him. Thus he will derive increasing satisfaction and security and his distress will diminish, leading to further gain in his sense of self-worth. In this way a beneficial circle is set in motion, resulting in increasingly deep and permanent improvement.

The influential U.S psychotherapeutic school of Carl R. Rogers holds that the consistent, warm "unconditional positive regard" of the therapist for the patient is sufficient to produce these changes. Therapies in the psychoanalytic tradition, while also emphasizing the importance of the therapeutic relationship, try to help the patient understand and master his feelings by labeling and analyzing them. They differ in their concepts and in the relative emphasis placed on different types of rnaterial produced by the patient. Traditional psychoanalysis emphasizes the use of dreams as short cuts to the patient's deeper feelings. It also puts great stress on helping the patient to rediscover, re-experience and "work through" the traumatic emotional experiences of early life in which his current difficulties are believed to originate. Hypnosis may be used to facilitate this, although Freud believed free association (see ASSOCIATION, MENTAL) to be more effective. Later modifications of psychoanalysis put more emphasis on analysis of the patient's current problems. and some emphasize helping the patient to gain a better philosophy of life. Ali agree that in an intimate, prolonged relation with the therapist, the patient will eventually experience toward him the feelings that trouble his relationships with persons emotionally close to him in his past and present life. Since both therapist and patient can observe these "transference reactions," as Freud termed them, exploring their inappropriateness is deemed a powerful means of resolving them.

Group *and Social* Therapies.—Group therapeutic techniques are as varied as those of individual therapy, and similarly tend to stress either alleviation of members' distress by direct measures or creation of a group atmosphere conducive to increased self-understanding and personal maturation. Groups of the first type may have any number of members, up to 50 or more. Some are primarily inspirational in that their chief aim is to raise members' morale and combat feelings of isolation by cultivating a sense of group belongingness through slogans, rituals, testimonials and public recognition of members' progress. Certain of these groups have developed into autonomous movements conducted solely by their members. An outstanding example is Alcoholics Anonymous, organized by chronic alcoholics to help themselves. Two other popular directive methods are didactic group therapy, which seeks. through organized discussions of assigned topics, to stimulate group members intellectually so that they will function more successfully; and therapeutic social clubs, which stress development of social skills through participation in self-organized social activities.

The other class of group methods strives to foster free discussion and uninhibited self-revelation. Most use small face-to-face groups, typically composed of five to eight members. Members are heiped to self-.understanding and more successful behaviour through mutual examination of their reactions to persons in their daily lives, to each other and to the group leader in an emotionally supportive atmosphere. An influential variety of this approach that utilizes larger groups is the "psychodrama" of J. L. Moreno. In this method patients more or less spontaneously dramatize their personal problems beiore an audience of fellow patients and therapists, some of whom also participate in the dramatic production itself. The dramatization is followed by discussion between players and audience.

Social therapy for institutionalized patients represents at once an extension of group therapeutic principles and a revival of the moral treatment of Pinel. Its aim is to make the mental hospital a therapeutic community, all aspects of which will help to restore the patients' mental health. This involves the creation of a cheerful, homelike atmosphere and a full program of occupational, recreational and social activities. It also involves the development of a flexible, democratic social structure in which all members of the treatment staff work as a co-ordinated team and the patients participate responsibly, to the limits imposed by their disabilities. in all phases of hospital life. Through patient government they help make policy decisions, plan and carry out activities and may even have a voice in the handling of deviant or disturbed hehaviour of individual patients.

By heightening the patients' sense of personal worth and instituting social controls of behaviour, social therapy in conjunction with drug therapies may lead to a striking decline in violent or disorganized conduct. This makes possible the reduction or even elimination of physical restraints or locked wards. Social therapy programs lead to a more flexible use of hospital facilities, in that some patients can come to the hospital only during daylight hours. others only to spend the evening and night. In many ways social therapy thus lowers the barrier between mental hospital and community, which improves the morale of hospitalized patients by combating their sense of alienation from the outside world, thereby aiding the recovery process.

Integrated treatment programs finally succeeded in bringing about a progressive decrease in state hospital populations. Though admissions continued to rise, discharges rose even more rapidly. This heartening development enhanced hopes for the increasingly successful treatment of the hospitalized insane.

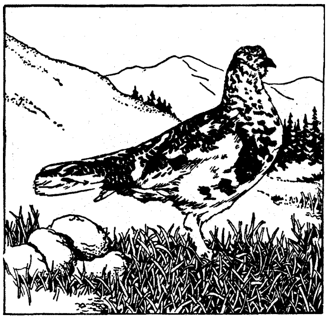
See also PSYCHIATRY; PSYCHOANALYSIS; PSYCHOLOGY, APPLIED: *Psychology in* Treatment.

BIBLIOGRAPHY.—Lewis R. Wolberg, *The Technique of Psychotherapy* (1954), is *a* review of all forms of psychotherapy, with a full bibliography. *See* also Carl R. Rogers, *Client-Centered Therapy: Its Current Practice, Implications and Theory (1951)*; Milton Greenblatt, Richard H. York and Esther Lucile Brown, *From Custodial to Therapeutic Patient Care in Mental Hospitals* (1955); S R. Slavson (ed), *The Fields of Group Psychotherapy* (1956); August B. Hollingshead and Frederick C. Redlich, *Social Class and Mental Illness: a Community Study* (1938); Joseph Wolpe, *Psychotherapy by Reciprocal Inhibition* (1958). (JE. D F.)

P.T.A.: *see* PARENTS AND TEACHERS, NATIONAL CONGRESS OF.

PTAH, Egyptian god. was originally the local deity of. the town of Memphis (*q.v.*), capital of Egypt in the 3rd millennium B.C.; to its political importance was due the expansion of Ptah's cult over the whole of Egypt. The Asiatic origin of Ptah suggested by some scholars is extremely doubtful and the Semitic words from which it has been allegedly derived appear in Egyptian not earlier than the 3rd century B.C. In Egyptian belief, Ptah was the creator of the universe and maker of things, therefore also a patron of craftsmen. especially sculptors; the title of his high priest was "supreme leader of craftsmen." Consequently, the Greeks identified him with their Hephaestus, the divine blacksmith. Ptah was always represented in purely human form. The connection between him and the sacred bull Apis was artificial, but Apis had his stall in the great temple of Ptah at Memphis and was called "intermediary of Ptah," that is, intermediary between men and the god.

See M. Sandman Holmberg, *The God Ptah* (1946). (J. CY.)



BY COURTESY OF THE AMERICAN MUSEUM OF NATURAL HISTORY

WHITE-TAILED PTARMIGAN, OR MOUNTAIN GROUSE (LAGOPUS LEUCURUS), SHOWING SUMMER PLUMAGE

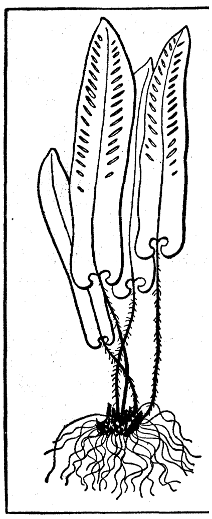
PTARMIGAN (*Lagopus*). A gallinaceous bird of several species inhabiting arctic and sub-arctic regions. In its northern range the plumage becomes pure white; in the southern part the summer plumage of reddish brown barred with black is assumed. The feet are covered with hairlike feathers which aid in walking over snow. From 6 to 12 eggs of various shades of buff marked with brown are laid in a depression in the ground. (K. P.)

PTERIA, the ancient capital of the "White Syrians" of northern Cappadocia, which Croesus (*q.v.*) of Lydia is stated by Herodotus to have taken, enslaved and ruined: after he had declared war on Persia and crossed the Halys (Kizil Irmak). Pteria is mentioned only by Herodotus among the ancients. The identification of Pteria with the modern Bogazkoy, once taken for granted, is quite uncertain. Pteria is probably to be sought in a district nearer to the Black sea.

PTERIDOPHYTA, one of the groups comprising the ferns and their allies. of the second great division of plants. the Archegoniatae, the other being the Bryophyta (*q.v.*). The Pteridophyta thus share with the Bryophyta a middle position between the essentially aquatic Thallophytes and the essentially terrestrial Spermatophytes. Much of their special interest centres round that fact. They include plants well represented at the present day; but many already existed in the early land vegetation of the Devonian period, now known only as fossils; they appeared in greater profusion as fossils of the coal, and many of these early types continued on into the Mesozoic age while their correlatives are included in the flora of the present day. Thus their geological history supports the conclusion that they take a middle position in the evolutionary progression of plant life. in which a transition from life in water to life on land was a striking incident.

Hofmeister first showed that there is essential similarity underlying the life histories of mosses and ferns, and that the same scheme, in modified form, extends to the seed plants also. Since this is so, an account of the Pteridophyta may fitly be introduced by a brief record of the life history of a fern, as an example of the Archegoniatae generally! and of the Pteridophyta in particular. There are two periods in each normally completed life cycle of these plants when the individual is represented by a single cell; and these punctuate the limits between two distinct bodily phases, or generations as they are called. One of these is the leafy *fern plant* which every one knows; the other is a small green scale-like body, delicate in texture, called the *prothallus,* which escapes the observation of most people, though actually common enough. The former is sexless, but bears *spores* in large numbers; it is the *sporophyte* generation. The latter is the sexual generation, and, since it produces *gametes,* it is called the *gametophyte.*

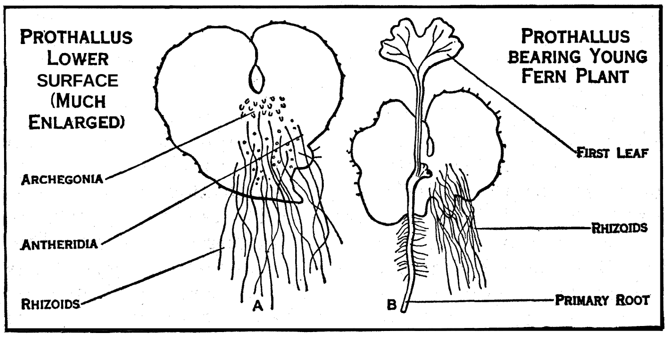
Life-history of a Fern. — The fern plant varies in size from a minute herb to a tree-like body, 60 or even 80ft. in height. It consists of a stem bearing characteristic leaves, usually of large size and delicate outline; the shoot thus constituted is attached by roots to the soil, the whole being traversed by conducting tracts. Since the green leaves serve a nutritional function, the plant is able to subsist as a perennial land-plant (fig. 1). On the leaves the *sori* are borne, of various form and position. In the hart's tongue or the common shield fern they appear as dense groups of brown *sporangia* seated on the lower surface, and covered while young by a membranous indusium. Each sporangium is a stalked capsule containing numerous minute, dry and dusty spores, which are violently ejected when ripe, and each is then liable to be carried away individually by the breeze. The spores are unicellular propagative organs.



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 1.—HART'S TONGUE (PHYLLITIS SCOLOPENDRIUM)

Each spore germinating on moist soil may grow into a prothallus or gametophyte (fig. 2), which never grows large, though being green it is physiologically independent. It bears the *sexual organs* or *gametangia,* usually on its lower surface (fig. 2, A). Near its base are the male gametangia or *antheridia,* which when ripe consist each of a protective wall of cells surrounding numerous spermatocytes. When bathed by external water (rain or dew) the wall ruptures, and each spermatocyte emits a single spiral *spermatozoid,* which moves in the water by lashing cilia (fig. 3). Near the indented apex of the prothallus the female gametangia or *archegonia* are formed (fig. 2). They are flask-shaped organs, also protected by an external wall; each contains a row of three

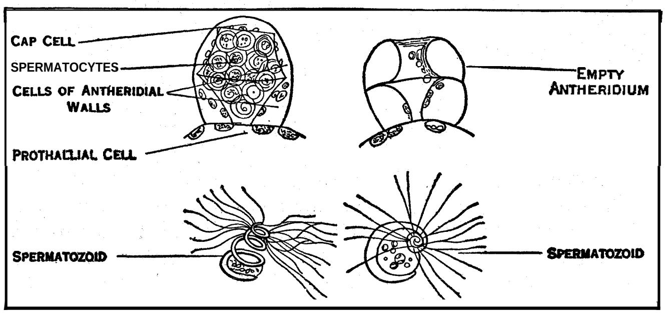


FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 2.— PROTHALLUS OF SHIELD FERN (DRYOPTERIS FILIX-MAS)

cells, of which the lowest and largest is the ovum or egg, sunk in the tissue of the parent (fig. 4). When ripe the archegonium also ruptures on access to external water, the distal cells of the wall parting so that an open channel filled with mucilage leads down to the rounded egg. *Fertilization (syngamy)* consists in the fusion of the spermatozoid with the egg to which it is attracted by soluble substance diffusing from it into the water that bathes the open archegonium. The result of that fusion is the *zygote,* which is the starting point for the development of a new fern plant. This new individual appears first as a spherical mass of delicate cells, nursed in the cavity of the archegonium; but it soon bursts out with its first leaf and root, and its apical bud ready to grow into a new fern, while the prothallus rots away (fig. 2, B).

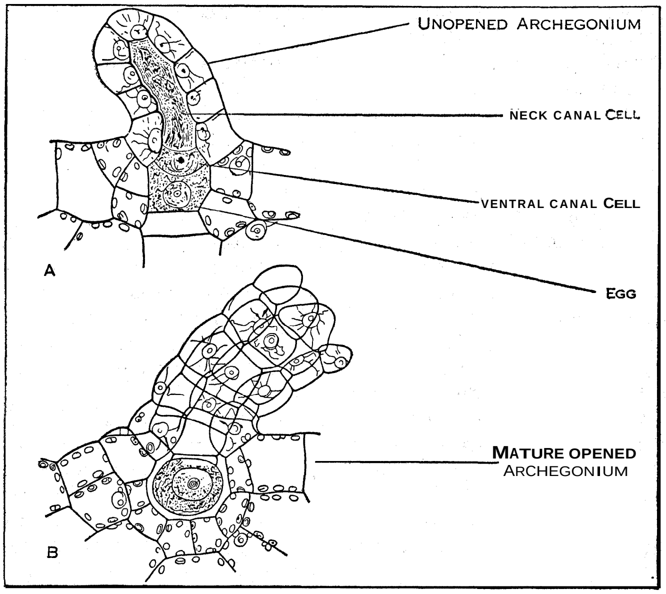
The central feature in syngamy is the *coalescence of the male and female nuclei;* the resulting fusion-nucleus is then *diploid,* with the $2n$ number of chromosomes *(see* CYTOLOGY*).* That character is then maintained throughout the tissues of the sporophyte. On the other hand, when the fern-plant comes to maturity and forms sporangia, the cells that are to form the spores undergo



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 3.— ANTHERIDIUM OF POLYPODY (POLYPODIUM VULGARE)

a nuclear change, called *reduction* or *meiosis,* by which they resume that simpler constitution possessed by the nuclei of the prothallus, and described as *haploid (n).* These events normally alternate in regular succession, and they constitute that *nuclear cycle* which underlies all normal life-histories of the Archegoniatae. They stamp structurally the distinction of the two alternating generations. Such alternation, in one form or another, appears in all plants that show sexuality. The Pteridophyta illustrate the cytological cycle with unusual clearness, since the two somatic phases (viz., the haploid prothallus and the diploid fern plant) are so unlike, and so markedly independent the one of the other during their adult existence. It seems probable that in the course of evolution some simple form of alternation present in an algal



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

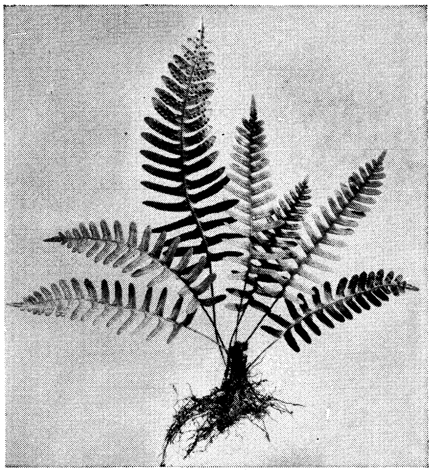
FIG. 4—ARCHEGONIUM OF POLYPODY (POLYPODIUM VULGARE)

ancestry has been regularized and standardized in the Archegoniatae in accordance with a passage from the relative uniformity of aquatic life to the more varied vicissitudes of life on land. In the Bryophyta the gametophyte was more adaptive, and became the dominant generation; on the other hand, in the Pteridophytes, as also in all the higher land-plants, the sporophyte became specialized as the dominant land-living organism. But the Archegoniatae themselves were never wholly emancipated from dependence on external liquid water. They show their amphibious character by their zoidiogamic fertilization; and this confirms their position as primitive land-plants.

For the most part the Pteridophyta are like the Bryophyta in

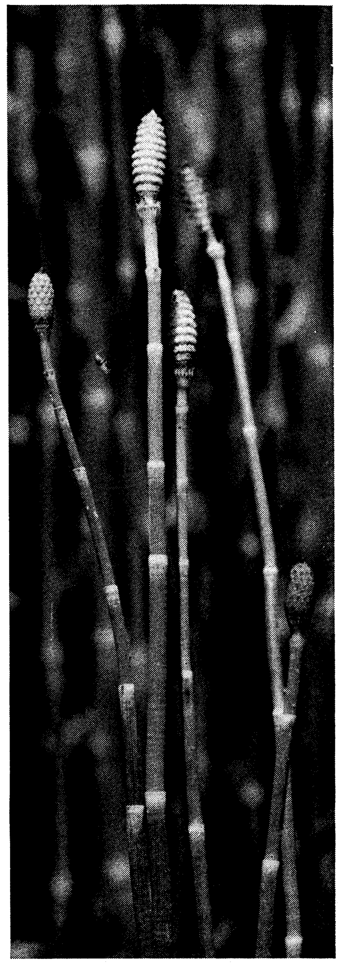
PTERIDOPHYTA

PLATE I

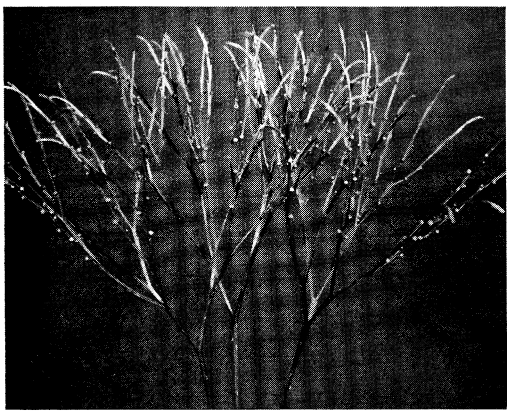


Plant and roots of the common **polypody** (*Polypodium vulgare*), a fern widely distributed in the U.S., Great Britain and Europe

Grape fern (*Botrychium virginianum*), one of the **Ophioglossales** or sucoulent ferns, primitive types limited to four **living** genera



Reproductive stems of rough horsetail (*Equisetum* hyemale), a member of the most primitive of living plant **families** allied to ferns. The plant grows to heights of 5 ft. or more



Psilotum triquetrum, showing spore cases. This plant is of the class **Psilophytinae**, fern allies which do not have true leaves

Detail of the fiddlehead, or crozier, of the **Christmas** fern (*Polystichum* acrostichoides)

Tree ferns, about 20 ft. high, growing on the island of Fernando Po, Spanish Guinea. These are true ferns of the family Cyatheaceae

Leaf of a broad beech fern (*Thelypteris hexagonoptera*)

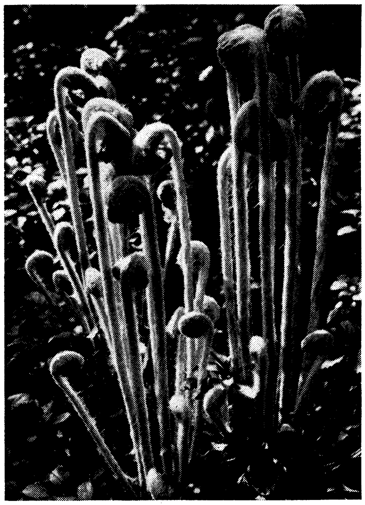
FERNS AND FERN ALLIES

PHOTOGRAPHS. (TOP LEFT) J. HORACE MCFARLAND CO., (TOP CENTRE, TOP RIGHT, CENTRE LEFT, CENTRE. BOTTOM RIGHT) JOHN H. GERARD. (BOTTOM LEFT) R. J. HARRISON-CHURCH

P'I'ERIDOPHYTA

Bulblet fern (Cystopteris bulbifera) usually found on rocky limestone slopes

Bird's-nest fern (*Asplenium nidus*), native to the oriental tropics, is frequently cultivated. This plant was photographed in Polynesia



Croziers of the cinnamon fern (*Osmunda* cinnamomea). Each head unfolds into a leaf

Crested table fern (Pteris *cretica*), a coarse fern of the oriental tropics

Ebony spleenwort (Asplenium platyneuron), a tall fern widely distributed in the U.S.

Maidenhair fern (*Adiantum* pedatum), another fern common to much of the U.S. from the Gulf states to Alaska

Walking fern (Camptosorus *rhizophyllus*), so named because the tips of its leaves often take root and sprout new plants. Note irregular pattern of fruit dots on the underside of leaf at centre

FILICALES: TRUE FERNS

PHOTOGRAPHS, (TOP LEFT, CENTRE, CENTRE RIGHT, BOTTOM LEFT. BOTTOM RIGHT) JOHN H. GERARD, (TOP RIGHT) E AURERT DE LA RUE. (CENTRE LEFT) J. HORACE MCFARLAND CO possessing only one type of spore (*homosporous*); but they produce these in enormous numbers. A common shield fern may ripen over 50,000,000 of them in a season. This is a primitive mode of propagation characteristic of early vegetation.

On the other hand, some few Pteridophyte-types such as *Selaginella* and *Isoetes,* and those curious little fern-derivatives styled collectively the Hydropterideae, possess sexually-differentiated spores, and are described as *heterosporous;* numerous smaller spores (microspores) bear each a rudimentary male prothallus, while a few larger spores (*megaspores*), or only a single one, produce each a massive female prothallus. Ir. this they show a state of specialized advance along lines that have led to the final success of the flowering plants. The Pteridophytes as a whole present the paradox of a great division of the vegetable kingdom that has achieved success by force of numbers, rather than by the more refined methods of physiological adjustment and of propagation even in the higher plants. These paragraphs, of necessity rather technical, will suffice to introduce the Pteridophyta, Vascular Cryptogams, or fern-allies as they are sometimes called. They are represented by six natural groups or classes of organisms, of which four include forms both living and fossil, but two are known only as extinct and very early fossils. Such facts at once confirm their position as representing a primitive vegetation. They may be arranged in rough sequence according to their complexity of form and structure; but this must not be understood as conveying any definite view as to affinity.

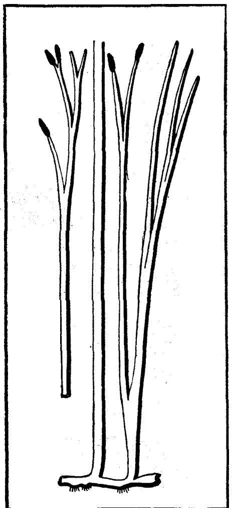
CLASSIFICATION

I. PSILOPHYTALES, comprising only fossil types of simple conformation, from early Devonian rocks.

II. PSILOTALES, represented by two genera of living plants, Psiloturn which is intertropical, and *Tmesipteris* which is confined to Australia.

III. SPHENOPHYLLALES, containing extinct Palaeozoic fossils of small size, which hardly extended into the Mesozoic period.

IV. EQUISETALES, including only the single living genus of the horsetails (Equisetum), but largely represented also by Palaeozoic fossils often of dendroid form (Calamariaceae).



FROM KIDSTON & LANG IN BOWER, "FERNS" (CAMBRIDGE UNIVERSITY PRESS)

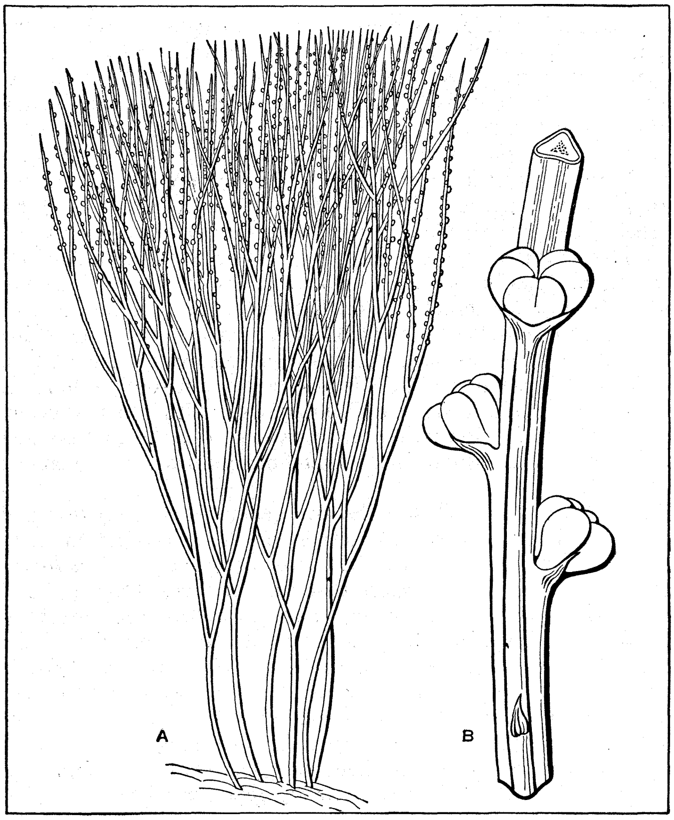
FIG. 5.—HORNEA LIGNIERI

V. LYCOPODIALES, or so-called club-mosses, well represented at the present day by the large genera, *Lycopodium* and *Selaginella;* also by *Phylloglossum* and *Isoetes*. But in the Palaeozoic period there existed the giant Lepidodendroid trees, as well as allied plants of humbler dimensions.

VI. FILICALES, or ierns; these comprise not only the living ferns, with about 150 genera and over 6,000 species, but also a rich sequence of fossils, from the Palaeozoic Coenopteridaceae to the most recent strata.

A newer scheme of classification treats the higher cacegoriee in a somewhat different manner. The phyla Pteridophyta and Spermatophyta (Seed,Plants) are united into one group, the Vascular Plants or TRACNEOPHYTA. This includes four subdivisions: (1) the PSILOPSIDA, including the Psilcphytales and Psilotales, (2) the LYCOPSIDA, including the Lycopodiales, (3) the SPHENOPSIDA, including the Equisetales and Sphenophyllales and (4) the PTEROPSIDA, including the Filiciniae, the Filicales of the above treatment, and also the Gymnospermae and Angiospermae, the two large groups of seed plants.

I. **Psilophytales.**—This new class of plants was constituted by Kidston and Lang to receive certain fossils of early Devonian time, discovered by Dr. Mackie at Rhynie in Aberdeenshire. Its name is taken from the old genus *Psilophyton* of Dawson, and the class now comprises a number of other genera of like age, more recently discovered, forming together a very distinctive flora: But of these only the sporophyte is known (fig. S). The vegetative system consists of upward-growing, forked. aerial shoots that spring from a rhizome sometimes creeping, sometimes tuberous and mycorhizic; sometimes the underground branchlets are rootlike, forking in the substratum (Asteroxylon). The erect shoots are cylindrical, and were evidently green, covered by an epidermis, with stomata, and they are traversed by conducting strands of simple structure. Various superficial growths, often with the appearance of thorns or prickles, are borne upon the larger branches, as in *Psilophyton* and Asteroxylon. The plants



FROM ENGLER & PRANTL, "DIE NATURLICHEN PFLANZENFAMILIEN" (WILHELM ENGELMANN)

FIG. 6.— PSILOTUM TRIQUETRUM. (A) HABIT OF PLANT, SHOWING DICHOTOMOUS BRANCHING (B) PART OF A SHOOT

were of low stature, and growing gregariously they must have looked rather like grass. The genera Hornea, Rhynia and *Asteroxylon,* described by Kidston and Lang were so well preserved that their structure is as well known as though they were modern plants. The class stands conspicuously apart as leafless and rootless vascular plants.

The most distinctive feature of the class for diagnosis is that the large sporangia, protected by a wall of many layers and con: taining numerous homosporous spores, are terminal on the vegetative twigs. The early existence thus demonstrated of leafless, and rootless and homosporous vascular plants, with distal sporangia of primitive construction is a fact of the first comparative importance. It is true it does not demonstrate any nearer connection with the Algae, but as regards other relations the new facts are highly suggestive. Long ago it was remarked that the widest gap in the sequence of plants was that between the Bryophytes and Pteridophytes. It is within this gap that the newly discovered fossils take their natural place, acting as synthetic links for the whole sequence of land-living, sporangium-bearing plants.

II. **Psilotales.**—The Psilotales are represented by two living genera, Psiloturn and *Tmesipteris,* of which both generations are now known. They form a natural family of the Psilotaceae. By their features they appear remarkably isolated among living plants, and their nearest affinity is to be sought among the Psilophytales and Sphenophyllales, both being classes of plants long extinct. These two genera appear in fact as living fossils.

They live epiphytically, or in soil rich in humus, and are rootless. The green, more or less shrubby shoot is fixed in the substratum by much branched leafless rhizomes, which are infected by a mycorhizic fungus. The saprophytic nutrition by these is supplemented by photosynthesis in the green leafy shoots. In Psilotum the aerial stems bifurcate, bearing small and simple scaly leaves, which however pass upwards into bifid "sporophylls," and between the two teeth is seated a large trilocular synangium, containing numerous homosporous spores (fig. 6). *Tmesipteris* resembles it in general character, but branching is infrequent, the leaves and "sporophylls" are larger, and the synagium has only two large loculi. The anatomy of the green stem of *Psilotum,* with its epidermis and stomata, its photosynthetic cortex and conducting protostele, is on the same general plan as that of *Rhynia* or *Asteroxylon;* the bifurcation and presence of minute leaves, and the rootless mycorhizic base all support the comparison with the Devonian types of Rhynie.

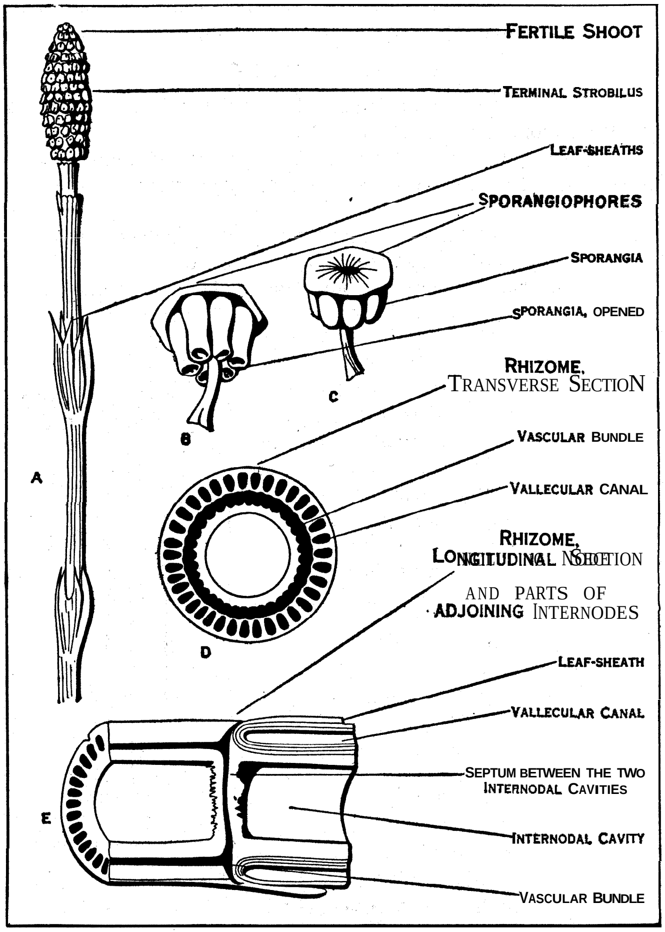
The prothalli of both genera have been discovered since 1914. They are colourless, nourishing themselves saprophytically through fungal agency. In fact these primitive plants conform in their life-cycle to what is seen in many primitive ferns and Lycopods. Moreover, the embryology has been traced in *Tmesipteris;* there is neither suspensor, nor root, nor cotyledon. The embryo with its apex directed, like that of the Bryophytes towards the neck of the archegonium, soon bursts its way out, proceeding to branch distally and form a leafless rhizomic system from which aerial shoots arise later. Such details of the gametophyte link the Psilotales, and indirectly the Psilophytales, with other Pteridophytes as regards alternation on the whole; but the rootless and leafless embryo presents a state that finds its nearest comparison with the Bryophyta.

III. **Sphenophyllales.**—The two genera *Sphenophyllum* and *Cheirostrobus* are the representatives of this class, but in more or less loose association with them are such types as *Pseudobornia* and Hyenia; these suggest that the articulate type of land-plants, which they all illustrate, in common with the horsetails, was well represented in the primary rocks. The existence of the Sphenophyllales extended from the Upper Devonian to Triassic time. (For details of Sphenophyllales see PALAEOBOTANY.)

IV. **Equisetales.**—Those Pteridophyta which have their appendages disposed in successive whorls, with long internodes intervening between them, have been designated the Articulatae. In the distant past this type was strongly represented by the Sphenophyllales, and by the Calamariaceae and others. But it is familiar to us to-day as it is seen in the horsetails, included in the cosmopolitan genus Equisetum, the only species of Equisetaceae, and the only living representatives of the Equisetales. These are semi-aquatic plants; they vary in height from a few inches to 30ft. or more, and are rhizomatous, with erect shoots arising from richly branched, subterranean stems, which are themselves rooted in the soil. The habit of the plants depends upon the method of branching of the shoot rather than upon the foliage, for the leaves are minute (microphyllous), and closely appressed to the stem that bears them. Each whorl of them forms a sheath closely investing the base of the next higher internode, while the teeth projecting upwards from it are all that represent the individual leaves. Their position alternates in successive nodes (fig. 7). The internodes are fluted, the ridges being continuous downwards from the next higher leaves; consequently those of successive internodes alternate. The number of the leaves in a whorl may vary according to the size of the stem, from three to 20 or 30. This is the scheme of the shoot in all species of Equisetum, and the shoot is constantly of radial construction. In some species the branching is sparse (E. *limosum*); in others it is profuse (E. *sylvaticum* and maximum), and the branches may themselves branch again repeatedly. Their number and the degree of secondary branching defines the habit, and justifies for the more bushy types the familiar name of horsetails. The branches arise in the axils of the leaf-sheaths, but they alternate with the leaves themselves. Many of those initiated remain dormant. A root is found at the base of each bud, but it also is frequently dormant, especially in aerial shoots. The structure of the underground rhizome is on the same plan as that of the aerial branches that it bears. Thus the whole plant consists of a succession of shoots, each with a dominant axis, whorls of subordinate leaves, and accessory roots.

In the transverse section of an aerial internode the sinuous outline shows the projecting ridges and depressed furrows of its fluted form, though this is less evident in the rhizomes (fig. 7, D). The centre of the section is occupied by a large air-cavity, surrounded by the remains of the pith. A circle of isolated vascular strands, corresponding in number to the leaves in the next whorl above, is in most species enclosed by a sinuous endodermis, which thus delimits the stele (E. arvense, etc.). Outside this lies the cortex, marked by an equal number of large air-cavities, which alternate with the vascular strands, and correspond to the furrows of the fluting. The vascular strands themselves are opposite the projecting ridges, and are extended upwards into the several leaf-teeth. Between the ridges are regions of green chlorophyll-parenchyma, while the whole is invested by a well-marked epidermis, with curiously elaborate stomata: these are ranged along the furrows, and so are opposite the photosynthetic tissue. The anatomy is clearly that of a semi-aquatic plant with its reduced vascular tissue and large air-spaces.

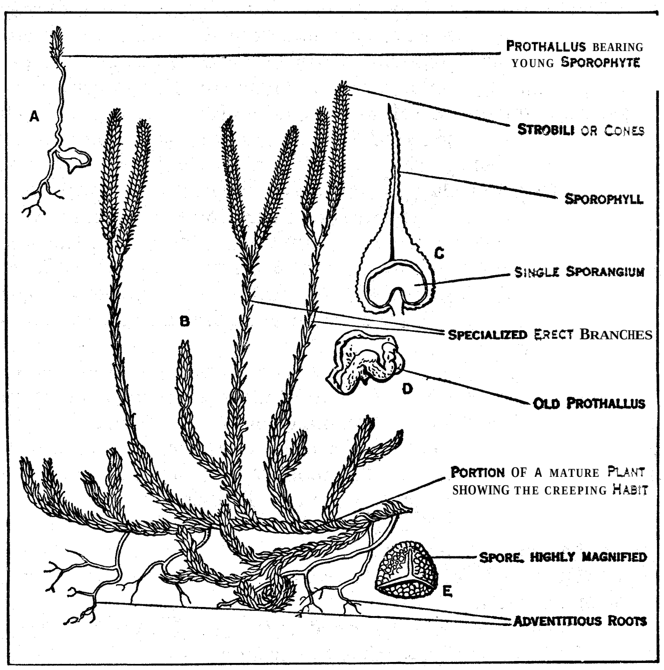
The sporangia of Equisetum are borne upon lateral appendages of the axis, sporangiophores, which are disposed in whorls, and are associated in definite strobili or cones, borne distally (fig. 7, A). Each sporangiophore consists of a stalk that expands into a peltate disc, from the inner surface of which some



FROM (A, B, C) STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 7.—LARGER HORSETAIL (EQUISETUM TELEMATEIA)

six to nine large sporangia hang parallel with the stalk (fig. 7, B, C). A single vascular strand passing through the stalk supplies a branchlet to each sporangium. These arise as massive growths from the first, and each produces a large output of homosporous spores (eu-sporangiate). The spores themselves are large; in ripening the outermost layer of the wall of each splits along spiral lines, giving rise to four elaters that straighten out when dry, and close round the spore in damp air. They are effective in forcing open the sporangium, which dehisces by a longitudinal slit: and those of different spores hooking together, the spores are grouped in germination, a matter of importance since the sexes are usually borne on separate prothalli. The spores germinate at once, producing each a green prothallus, which may be filamentous, flattened, or irregularly lobed. The smaller bear sunken antheridia, each with numerous spermatocytes, from which spermatozoids are liberated on access of water. The larger bear archegonia. The conditions of syngamy and formation of the embryo are essentially as in ferns; but here the embryo has its apex directed to the archegonial neck (exoscopic), and it grows out directly into the apex of the young plant, successive whorls of leaves arising laterally upon it; a root derived from the basal region fixes the young plant in the soil. Notwithstanding the differences of detail, the life-cycle of a horsetail is comparable as **a** whole with that of a fern.



FROM STRASEURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 8.—A CLUB-MOSS (LYCOPODIUM CLAVATUM)

A greatly added interest in Equisetum arises from comparison with allied fossils; for not only were these numerous and of early occurrence, but they attained dendroid proportions, while some were heterosporous. They are grouped as the Calamariaceae, which will be specially treated elsewhere (see PALAEOBOTANY).

The Equisetales, thus comprising the Equisetaceae and the Calamariaceae, form a natural and closely reiated class, of which the nearest affinity was with the Sphenophyllales, but with some degree of relation also with the Psilotales; all of these being sporangiophoric Pteridophytes.

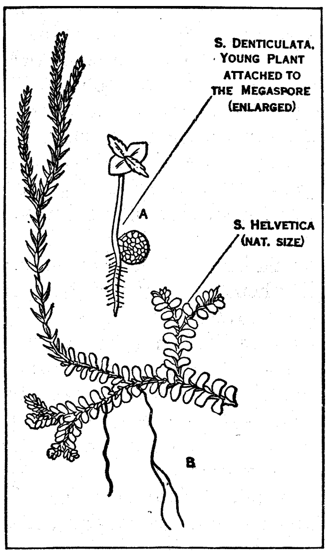
V. **Lycopodiales.**—This class comprises a considerable number of species now living widely distributed upon the earth, and known as club-mosses; though they are in fact vascular plants, and quite distinct from the true mosses. They are all relatively small, and indeed insignificant as features in the present flora, compared with the fossil types which, though they may have included a number of relatively small species, comprised also some of the largest plants of the forests of the coal period. It may be that among the lycopods no actual diminution in size took place as time went on, but rather that the types which were always small survived, while the giant members of the group became extinct.

The features which all club mosses have in common are that the leaves are relatively small and simple in form (*microphyllous*), while the sporangia are seated singly, one in the axil of each leaf of the fertile region, or spreading outwards on its base. This marks off the Lycopodiales clearly from the sporangiophoric Pteridophytes on the one hand, and from the Filicales on the other. As in the former, however, the axis is dominant in the adult shoot, and forks equally or unequally. According to the position assumed by the stem the habit of living club mosses is upright or pendent; but frequently, as in the stag's horn moss common on Scottish hills, with its creeping stem rooted in the soil, and bearing upright fruiting branches (fig. 8, B).

The class is divided systematically according to the presence or absence of a ligule, which is a small scale-like body borne on the upper surface of each leaf, near its base. Those in which no ligule is present, the ELIGULATAE, include Lycopodium and *Phylloglossum*, together with certain early fossils designated *Lycopodites;* those which possess a ligule, the LIGULATAE, include *Selaginella* and Zsoetes, and with these are associated the fossil Lepidodendraceae and Sigillariaceae. The distinction is accentuated by the fact that the former are all homosporous, the latter heterosporous.

A. Lycopodiales Eligulatae. Lycopodium comprises about 100 species of small plants of varied habit, creeping, shrubby or epiphytic. The construction of the shoot is uniformly microphyllous, the bifurcating stem dominating the conformation of the whole plant. The leaves are simple and small, and in some species uniform throughout the plant. In others the sterile leaves are larger than the membranous sporophylls, the latter being associated in definite strobili, or cones (fig. 8, B). The former probably represent the more primitive type. Each of the isolated sporangia is seated at the base of its sporophyll; it is large, and kidney-shaped, with a short massive stalk, and it dehisces like an oyster-shell, in a piane parallel to that of the leaf. The arrangement of the leaves is sometimes in regular whorls, but frequently it is according to some more or less interrupted spiral scheme. The plant is fixed at its base by roots which spring endogenously from the stem, and show bifurcation.

The stem of Lycopodium is seen in transverse section to be surrounded by a bulky and often indurated cortex, and traversed by a stele continued to the apical cone itself, while from each leaf a minute vascular strand passes to its periphery. In the young stem there is a solid woody core, surrounded by phloem and ill-defined sheaths. But in fully-grown stems the core may be invaded by tracts of phloem, moulding it into a cruciform or stellate transverse section, or even separating it into distinct radiating plates, or permeating it to form a sort of woody sponge.



FROM STRASBURGER, "LEHRBUCH DER BOTANIK" (GUSTAV FISCHER)

FIG. 9.—A CLUB-MOSS (SELAGINELLA)

The sporangia are massive from the first, and vary slightly in spread along the leaf-surface, a point of interest for comparison with the ligulate types. Each produces after the usual tetrad-division a large number of homosporous spores, which germinate slowly. The prothalli produced from them, and the embryology that follows, vary more than is usual in a single genus. The prothallus sometimes grows at soil-level and is green (L. cernuum); but often it is underground and wholly saprophytic (L. clavatum, fig. 8, D, A). Whatever its form, the sex-organs are massive and deeply sunk, and both are present on the same prothallus. The antheridia produce numerous biciliate spermatozoids; the archegonia vary in length of neck, and sometimes have numerous canal-cells. But the egg is deeply seated, and produces an embryo with a suspensor. This thrusts the embryo deep into the prothalius, where it often develops juvenile characters of importance for comparison. The most striking of these is the swollen "protocorm," a tuberous growth seen in Hornea, and present also in Phylloglossum. Bursting out from the prothallus the embryo develops shoot and root, the former in the underground types finding its way upwards to the soil-level (fig. 8, **A).**

B. Lycopodiales Ligulatae. Selaginella comprises about 500 species, widely spread through the tropics, some native on temperate hill stations. The latter, chiefly of exposed habit, have radial symmetry, but most *Selaginellas* are dorsiventral and live under shade. The genus shares the leading features of *Lycopodium*, but it differs in the presence of a ligule and in the fact that all the species are heterosporous.

Various *Selaginellas* are favourite greenhouse plants, and the fanlike spread of the delicate branches with their dimorphic leaves is well known (fig. 9, B); also the strange rhizophores springing from points of branching of the shoot, which turning downward give rise to the true roots, being themselves organs of indeterminate morphological nature. It is unnecessary to describe the vegetative organs or their anatomy in detail; the chief comparative interest lies in the propagative process.

The sporangia are borne on radially constructed distal cones. A single sporangium, similar to that of *Lycopodium*, is borne just above the insertion of each sporophyll, with the ligule protecting it from without. The microsporangia are brownish when ripe and the megasporangia pale in colour, and both may be borne on a single cone. They appear all alike up to the stage when the numerous spore-mother-cells are formed. If all the spore-mother-cells undergo tetrad division, numerous microspores resembling those of *Lycopodium* result. But in a megasporangium only one, or at most a few of them, form tetrads, and the resulting spores are large with a rugged wall; the number matured in a single sporangium may vary from one to four, or some multiple of four. On germination each microspore produces a small number of spermatozoids from a very reduced prothallus; but the large megaspore forms a more bulky prothallus, which, projecting from the disrupted wall, bears archegonia. One of these on fertilization develops an embryo with a suspensor. The essentials of the process are as in *Lycopodzum*, though the details are different. As-the sporeling develops its leafy shoot grows upward and its root downward; with the megaspore attached laterally the whole has the appearance of a seedling of some flowering plant (fig. g, A). This is clearly an advance upon *Lycopodium*.

The other genus, *Isoetes*, is peculiar in habit and in habitat, yet shares many of the characteristics of *Selaginella*. It contains about 50 species of tufted herbs, mostly living at the bottom of freshwater lakes, though a few are amphibious or terrestrial. The plant consists of a short, massive, lobed stock, bearing crowded awl-shaped leaves of considerable length. Each bears a ligule on its upper surface, and when fertile, as any one of them may be, a large cakelike sporangium lies between this and the axis. Roots with dichotomous branching arise from furrows between its lobes. The sporangia are heterosporous, and propagation is essentially similar to that in *Selaginella;* but there is no suspensor, and the spermatozoids are multiciliate.

A chief interest in these Ligulate types lies in their comparison with the Lepidodendraceae and Sigillariaceae, for these are also ligulate and heterosporous (*see* PALAEOBOTANY). These fossils attained dendroid dimensions, and, though the primary vascular system was not unlike that of the modern Lycopods, they often differed in having secondary growth with an active cambium. In *Isoetes* there is a sluggish secondary growth in the short stock, which itself shows certain analogies with the Stigmarian trunks of the gigantic fossils. Since any of the leaves of *Isoetes* may be fertile the whole plant appears as a strobilus of the same nature as *Lepidostrobus*, seated upon a Stigmarian base. In fact *Isoetes* is like a telescoped, but still living, fossil.

VI. **Filicales.**—The Filicales may be held as comprising all the living Megaphyllous Pteridophytes, together with such fossils as show essentially similar characters. But the mere fact that their leaves are relatively large in proportion to the stem that bears them is not a sufficient diagnosis. Some Lycopods (*Isoetes, Sigillaria*) share this character, and megaphylly is possible in any of Pteridophytes. But as a matter of fact, excepting *Isoetes*, none such are now living other than the Filicales. The most distinctive feature of ferns, however, is that *on the relatively large leaves many sporangia are borne, either singly or in groups (sori).*

Ferns are represented at the present day by about 150 genera and 6,000 species. Some are minute, others attain considerable size as tree ferns; but none can be reckoned among the largest of living plants, nor is there fossil evidence that ferns ever attained extreme dimensions. Their geographical spread is general; a few are arctic, but ferns increase in numbers both of species and of individuals toward the equator. Most are mesothermal hygrophytes (*i.e.*, they flourish under moist conditions with a moderate temperature), and the majority are shade-loving. Hence their headquarters are in the mountains of the tropics, where they form a considerable part of the undergrowth below the forest canopy. But their habitat is variable; some specialized types are actually aquatic, while others are able to withstand conditions of moderate, some even of extreme, drought. Ferns are much richer in genera, species and individuals than any other living Pteridophytes. They present the climax of successful development in homosporous vascular plants. They show also a high degree of variety both in their vegetative and their propagative characters; these provide good diagnostic features for their classification. They have a full and long palaeontological history that stretches back to Palaeozoic times. The geological record can therefore he used as a valid check upon the conclusions drawn from the comparison of living types.

It has been said that the Palaeozoic period was the age of ferns, and it is true that "fernlike" leaves were then common. But it has now been shown that many of these belonged to seed plants ranked as Pteridosperms, a class long since extinct, which also had fernlike leaves (*see* PALAEOBOTANY). It is not improbable that they represent a stock more distinct from ferns than the similarity of their foliage would suggest, for they had advanced early to seed formation. It may be left as an open question whether or not both may have had far back in their evolution some common origin.

The life history already described at the opening of this article holds for ferns generally, so that the grouping and natural classification of the class must depend upon differences of detail other than the life history itself. A general comparison of them led long ago to the recognition of eight main families, which may here be placed in the reverse order to that first given by Mettenius (1856):

I. Ophioglossaceae.	V. Gleicheniaceae.
II. Marattiaceae.	VI. Hymenophyllaceae.
III. Osmundaceae.	VII. Cyatheaceae.
IV. Schizaeaceae.	VIII. Polypodiaceae.

This grouping in linear sequence places the more robust types first and the more delicate last, while the rest take middle positions. The former were styled by Karl von Goebel the *Eusporangiate ferns*, in which the sporangium is from the first a massive body, in the formation of which many cells co-operate; in the latter each sporangium arises from a single cell, and those ferns in which this is so were styled *Leptosporangiate*. Intermediate states exist, and these suggest that the whole series constitutes an evolutionary progression. If this is true the question arises which is the more primitive and which the more advanced state? The importance of this question is enhanced by the fact that the sporangium is a mere index of a general difference of organization of the two contrasted types. In point of fact *the Eusporangiate ferns are relatively robust in their general constitution, while the Leptosporangiate are relatively delicate.* Thus the question is whether there has been in the course of evolution a progression from a robust to a delicate state, or the reverse. Since the Eusporangiate ferns find their correlatives in the fossils of Palaeozoic time and are relatively few today, while the specialized Leptosporangiate ferns are absent from the Palaeozoic rocks and comprise the bulk of living ferns, it is concluded that the general progression has been from a more robust ancestry toward a more delicate and precise constitution.

Having perceived this general scheme of progressive refinement, it cannot be assumed that the 150 genera and 6,000 species have formed a simple sequence. In testing the question of their relationships it will become necessary to revise the methods in use by systematists, whose aims were primarily classification. They worked as a rule upon few criteria of comparison, drawn almost exclusively from the sporophyte generation. A more exact comparison will be necessary not only as regards external form, but also of internal structure and development, both of the vegetative and the propagative organs, and it must be extended to both generations. The larger the number of the criteria used in comparison the more trustworthy will be the conclusions drawn from them. The criteria currently used in the comparison of ferns are these:

1. The external morphology of the shoot.
2. The initial constitution of the plant-body as indicated by segmentation.
3. The architecture and venation of the leaf.
4. The vascular system of the shoot.
5. The dermal appendages.
6. The position and structure of the sorus.
7. The indusial protections.
8. The characters of the sporangium, and the form and markings of the spores.
9. The spore-output.
10. The morphology of the prothallus.
11. The position and structure of the sexual organs.
12. The embryology of the sporophyte.

By the combined use of these criteria it has been possible to revise the natural groupings of ferns, sometimes amending but more often upholding the decisions of the earlier systematists. The main conclusions may be stated as follows: The *Eusporangiatae* include the living Ophioglossaceae, Marattiaceae and Osmundaceae, together with the fossil Coenopteridaceae *(see* PALAEOBOTANY). All these are Palaeozoic types, though they overlapped into the Mesozoic, and some representatives have even survived to the present day. With them are to be associated also the Schizaeaceae, Gleicheniaceae and Matoniaceae, all of which figured prominently in the Mesozoic, and are well represented among living ferns. In addition to many archaic features of the vegetative system they all possess relatively massive sporangia, which originate simultaneously, being produced either singly or in small numbers in the sori. They are collectively styled *Simplices.* Each sporangium has a relatively large spore-output.

The Ophioglossaceae and Marattiaceae appear to have ended blindly and left no further derivatives. But derivative phyla may be traced by comparison from each of the Schizaeaceae, Osmundaceae, and Gleicheniaceae, while to the Matoniaceae so closely allied to the Dipterids, another phylum may be ascribed. The Schizaeaceae with their solitary marginal sporangia lead to the marginal Dicksoniaceae. The Osmundaceae have many features in common with *Plagiogyria,* while the superficial Gleicheniaceae link on to the Cyatheaceae, these being distinguished by their superficial sori from the marginal Dicksoniaceae. In both of these last-named families the sorus has become *"gradate," i.e.,* after the distal sporangia have been formed on the receptacle, a sequence of further sporangia follows *in basipetal sequence,* the effect of which is that the drain of nutrition is spread over a longer period of time. This may well have been a real factor in the success of these families.

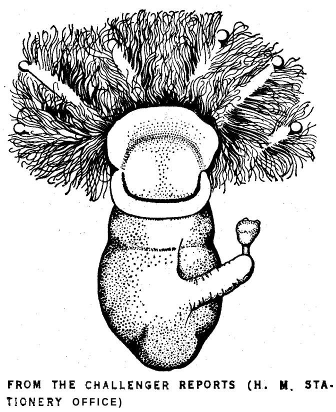
A third state of the sorus, which has a like effect to the last, and may either be initiated independently or by transition from the gradate, is the *"mixed"* state. where sporangia of different ages are irregularly *interpolated between those already present.* This is the final condition seen in the evolution of the Leptosporangiate ferns, and is found in all the more advanced types.

From such intermediate stocks as those mentioned some *six derivatzve phyla of advanced Leptosporangzate ferns* may be distinguished, each centring round some well-known genus. Two of these comparison shows to have been derived from the Dicksoniaceae, viz., the Davallioid ferns centred round *Davallia,* and the Pteroids round *Pteris.* The Gymnogrammoid ferns are naturally grouped round *Gymnogramme,* and may probably be traced from the Osmundaceae, with *Plagiogyria* as a suggestive link. The Cyatheaceae prooably gave rise on the other hand to the Blechnoid ferns, with *Blechnum* as a central type; and the Dryopteroids round *Dryopteris.* Lastly, a quite considerable number of genera may be traced as Dipteroid derivatives, from an ancestry suggested by *Matonia* and *Dipteris.* Thus at least six main evolutionary sequences of advanced Leptosporangiate ferns, with more or less pronouncedly "mixed" condition of their sori, may be referred in origin to types already distinct in Palaeozoic, or certainly in Mesozoic time. Each of these will have pursued its own phyletic advance independently of the others. Comparison reveals that most of them, or in some respects all, show parallel features of advance in form, vascular structure, soral characters, and sporangia, and particularly in the reduced spore-output from each sporangium. There is thus wide evidence of independent *homoplastic, and even convergent evolution* in the several phyla. In no respect is this clearer than in the distinctive feature of heterospory: for the Marsileaceae are referable in origin to a Schizaeoid source, while the Salviniaceae, whatever their actual relation, were of distinct origin from the Marsileaceae.

This brief abstract of the present position of the phyletic study of the Filicales can do no more than suggest how the matter stands to-day. Of all the Pteridophyta the ferns yield the most consecutive results. The living representatives of all the rest appear as isolated survivals, illuminated by fossil evidence, often as fragmentary and isolated as theirs. They raise as many evolutionary questions as they solve. It is only in the Filicales that it is possible, by placing together the evidence from palaeontology and that derived from the living flora, to reconstruct a story which, however incomplete, is sufficiently consecutive to serve as a basis for evolutionary opinion. The sum of it is for the ferns, as also for other Pteridophyta, that they have held their own to the present day as a class which has made the best of their amphibious existence by help of profuse production of homosporous spores. But from the point of view of descent, they have led on directly to no further type of land vegetation. The sources of this must be sought elsewhere.

BIBLIOGRAPHY.—J. Hooker and J. G. Baker, *Synopsis Filicum* (London, 1874), purely systematic; J. G. Baker, *Fern Allies* (London, 1887), purely systematic; Luerssen L. Rabenhorst, *Kryptogamen Flora,* vol. iii.; *Farnpflanzen* (Leipzig, 1889), a general treatise on European Pteridophytes; A. C. Seward, *Fossil Botany,* vol. i. (Cambridge, 1898); A. Engler and K. Prantl, *Natürl: Pflanzenfamilien* (Leipzig, 1892–1902), a general treatise, with copious references; F. O. Bower, *Origin of a Land Flora* (London, 1908), a general treatise; D. H. Campbell, *Mosses and Ferns* (1918), contains copious references; D. H. Scott, *Studies in Fossil Botany,* vol. i. (London, 1920); R. Kidston and W. H. Lang, "Old Red Sandstone Plants from the Rhynie Chert," *Trans. Roy. Soc. Edin.* (1917–1921); F. O. Bower, *Ferns,* vols. i.–iii. (Cambridge, 1923–28); D. H. Scott. *Extinct Plants and Problems of Evolution* (London, 1924); C. E. Von Goebel, *Organographie, Zweite Aufl.* (1913–24); A. J. Eames, *Morphology of Vascular Plants, Lower Groups* (New York, 1936) (F. O. B.; X.)

PTEROBRANCHIA, a very peculiar group of small marine animals, mainly found in the deeper parts of the ocean. They live as colonies, as individuals within a common mass or branching systems, in which they reproduce by budding as well as by sexual reproduction involving eggs and sperm. Their special interest lies in their structure, which seems to relate them to hemichordates such as *Balanoglossus* (*q.v.*) and so possibly to the vertebrate kingdom on the one hand, and, on the other, to the ancient group of fossils known as graptolites. In all likelihood the pterobranchs are the surviving members of an important class of Pre-Cambrian antiquity.



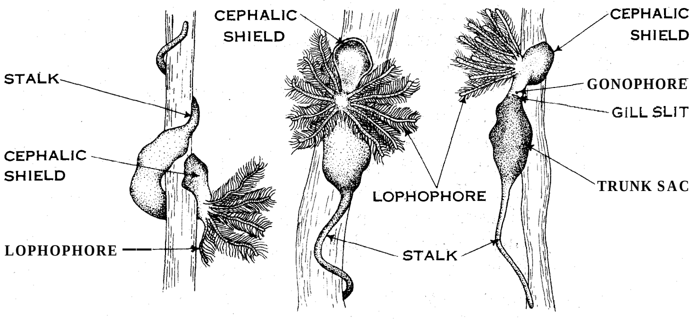
FROM THE CHALLENGER REPORTS (H. M. STATIONERY OFFICE)

FIG. 1.—CEPHALODISCUS DODECALOPHUS AS SEEN FROM IN FRONT; (AFTER MCINTOSH)

The two types are *Cephalodiscus* and *Rhabdobleura.* the former having been discovered by the "Challenger" expedition when dredging in the Straits of Magellan, and by later expeditions all through the southern oceans. *Rhabdopleura,* however, is truly cosmopolitan, ranging from the subarctic to the subantarctic.

A colony of *Cephalodiscus* is generally an orange-coloured gelatinous mass ½ in. to 1 ft, long and composed of numerous branches and layers within which the individual animals, all descended from a single egg, occur in large numbers and wander freely about. Each individual, which may be from one to seven millimetres long, depending on the species, consists of three regions, namely, a broad shield in front, which is used for crawling; a collar immediately behind, which bears featherlike tentacles or gills (hence the name Pterobranchia); and a body with its hind end prolonged as a slender stalk.

Each individual also has its own tube within the colony, and



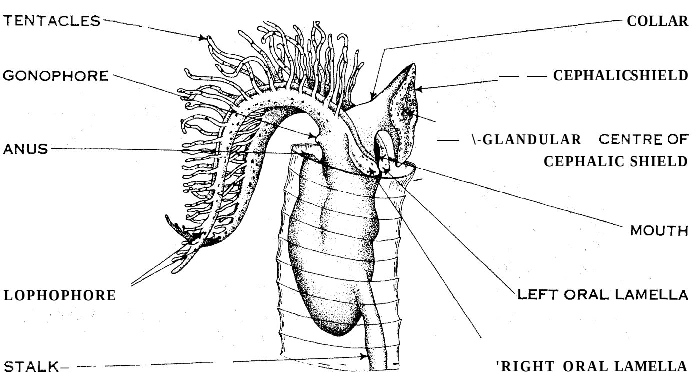
FROM P. GRASSÉ, "TRAITÉ DE ZOOLOGIE," VOL. 11 (1948)

FIG. 2.— ASPECTS OF CEPHALODISCUS HODGSONI ON INDIVIDUAL TUBE HABITATS THAT ARE ASSOCIATED IN LOOSE COLONIES

when wandering about on the surface it keeps the lower end of its stalk attached to the tube to facilitate quick retraction when necessary.

The tentacles. taken together, comprise a broad fan-shaped structure called the lophophore. It serves partly as a gill for respiration but primarily as the feeding organ, for the action of minute cilia on its surface causes a current of water to converge toward the mouth, bringing with it microscopic organisms suitable as food. Such water enters the mouth and is filtered out again through a single gill slit leading from the throat to the exterior on each side. It is the presence of this pair of gill slits that suggests that these primitive simple animals are in some way related to the vertebrates and their more obvious relatives such as Amphioxus and the Tunicata (*q.v.*), for gill slits are a distinctive feature of the group. Within the body, however, the digestive tube is U-shaped, so that bcth mouth and anus are near the front end and the bend of the tube is at the other, a condition characteristic of many other kinds of stalked animals. Even the pair of ovaries or testes open forward, near the base of the lophophore.

The position of the nerve centre dorsal to the mouth is also distinctive, and so are the openings or pores that connect the



FROM P. GRASSÉ, "TRAITÉ DE ZOOLOGIE," VOL 11 (1948)

FIG. 3.— PROFILE VIEW OF RHABDOPLEURA

body cavities of the shield and of the collar region with the exterior. and especially the location of the heart in the shield (proboscis) cavity.

These are all features that place pterobranchs with Balanoglossus and, apart from gill slits and the position of the nerve centre. set them aside as a type uniquely different from all other kinds of animals.

Individuals of *Rhabdopleura* species are very small even when compared with those of *Cephalodiscus*, and probably because of this their structure is somewhat simplified; instead of three to nine pairs of plumelike tentacles constituting the lophophore, only one pair is present, and gill slits are absent altogether.

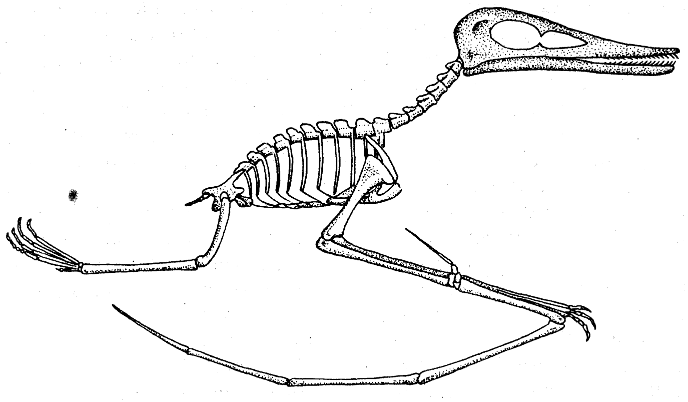
Otherwise the individuals of the two genera are organized in essentially the same way, except that in *Rhabdoplezira* the individuals produced by budding do not become free but remain attached to one another by a connecting cord. They live in a branching system of minute ringed tubes which are about one-tenth of an inch long.

Bibliography. — K. A. Anderson, *Schwedische Sudpolar Expedition,* V (1907); C. Dawydoff, *Traité de Zoologie,* xi, Grassé (1948); S. F. Harmer, *Siboga Expedition,* xxvi (1905); A. Schepotieff, *Zool. Jahrb. Abt. Anat.,* xxiii, xxiv (1906–07). (N. J. B.)

PTEROCLIDAE, a small family of birds of the order Columbiformes.

See Sand Grouse.

PTEROSAUR (Pterodactyl), terms applied to members of a group of flying reptiles that flourished in the Jurassic and Cretaceous periods. between (approximately) 150,000,000 and 70,000,000 years ago. The order Pterosauria is one component of the major reptile group of the Archosauria or "ruling reptiles," to which dinosaurs and crocodilians (*qq.v.*) also pertain and from which birds are descended. Triassic archosaurs tended toward a bipedal gait, thus freeing the "arms" for use in some other fashion, both birds and pterosaurs converted them into wings. In contrast with birds, and as in bats, pterosaurs formed a wing



FROM S. W. WILLISTON'S "THE OSTEOLOGY OF THE REPTILES' (HARVARD UNIVERSITY PRESS)

FIG. I.— SKELETAL RESTORATION OF PTERODACTYLUS

surface by means of a membrane of skin. In bats all the fingers except the thumb support the membrane. In pterosaurs, however, the membrane was attached solely to one elongated finger—the fourth — and extended thence back along the flank to the knee; an accessory membrane lay between the neck and the "arm." The first three fingers were slender, clawed. clutching structures. The pterosaur membrane appears to have been well adapted to soaring and gliding, but lacking in contrast with bat or bird wings, in maneuverability; disadvantageous, too, is the fact that, in contrast with bats. damage to the membrane at any point would affect the entire wing

The body was compact; the hind legs were long but slender and their structure suggests that, unlike birds, pterosaurs were little adapted to upright locomotion or perching but rather like bats hung suspended by the hind limbs when at rest.

The neck appears to have been held upright in flight. with the head attached to it at right angles and pointing foruard The skull was lightly but strongly built with fusion of most of the component bones; there was a long slender beak. The eyes were large, and the eyeball, as in many birds, was reinforced by a series of bony plates (sclerotic ring) lying in its walls.

Casts of the interior of the braincase show that the brain was large and apparently comparable to that of birds in pattern; as in that group, sight rather than smell appears to have been the dominant sense. Most remains of pterosaurs are found in marine sediments; it is probable that they made their livelihood by diving for fish. like terns and gulls, and it is difficult to understand how they could have risen from land or water after alighting.

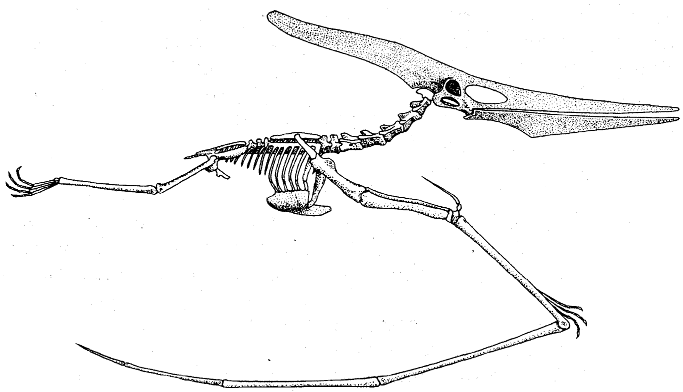
Two major groups of pterosaurs are known. *Rhamphorhynchus* of the late Jurassic Solenhofen slates is typical of the more primitive division, although earlier forms are present in the Early Jurassic (Lias).

Characteristics of this group include the presence of a battery of powerful, sharply pointed teeth in the jaws, relative shortness of the bones supporting the fingers (the metacarpals), and the retention of a long tail, which in *Rhamphorhynchus* is knonn to have had a diamond-shaped rudder at its tip.

Rhamphorhynchus had a wing spread of about two feet, and members of this group, confined to the Jurassic, were generally of similar size.

A second group of pterosaurs appeared in the late Jurassic and continued on into the Cretaceous. The typical Jurassic form is *Pterodactylus,* of which numerous examples are known from Solenhofen. This was a small reptile, some specimens being no larger than a sparrow.

Diagnostic features include the reduction of the dentition to a relatively few small teeth, elongation of the metacarpal bones, and the shortening of the tail to a mere nubbin. Descendants of the pterodactyl type continued on into the Cretaceous, and were



FROM G. F. EATON IN "MEMOIRS OF THE CONNECTICUT ACADEMY OF ARTS AND SCIENCES"

FIG. 2.—SKELETAL RESTORATION OF PTERANODON

generally of much larger size. They are best represented by *Pteranodon* of the Kansas chalk. in which the largest known specimen is estimated to have had a wing spread of 25 ft., making it by far the largest flying animal of which there is knowledge.

The skull was about four feet in length; the long jaws were toothless and presumably covered by a horny bill; a long crest extended back from the point of attachment of skull to body in weather-vane fashion. Despite its great size, the animal was very lightly built; the wing bones consist merely of a thin shell of bone surrounding a central cavity which was presumably air-filled in life.

No pterosaur remains are known beyond the end of the Cretaceous; their place in nature was taken over by their avian cousins. (A. S. Rr.)

PTOLEMAIS, an ancient coastal city of Cyrenaica (the modern Tolmeta in Libya). Naturally attractive, with adequate seasonal rainfall and with arable land and some timber in the neighbourhood, the site was also easily defensible and provided the only safe anchorage between Euhesperides-Berenice (modern Bengasi), 66 mi. S.S.W., and Apollonia (modern Marsa Suza), 61 mi. E.N E. The small settlement that had existed on this site as the harbour for the city of Barca (Al-Marj, 15 mi. inland) since the 6th century B C. was laid out in the early 3rd century B.C. as a city about one mile square, with a gridiron-shaped street plan.

Later in the same century the city received the name Ptolemais from Ptolemy III, who united Cyrenaica with Egypt. It was enclosed with walls and towers ending in an acropolis fort on an adjacent spur of the inland plateau and had five gates. Its economy being based on trade with the interior, the city flourished in Hellenistic times, in the early period of the Roman empire and again from late in the 3rd century A.D., when Diocletian made it the metropolis of the Roman province of Upper Libya.

From the beginning of the 5th century it suffered greatly from raids of the nomadic inland Austuriani, as recorded in the letters of its best-known historical personage, Bishop Synesius. The Byzantine emperors Arcadius, Anastasius I and Justinian I attempted to revive it by rebuilding streets, baths and an aqueduct, using stones of the old city wall to erect forts and blockhouses within.

Some occupation continued after the Arab conquest (A.D. 634) to the 11th century. The small modern Arab town occupies the ancient harbour section.

Italian excavations (1935–42) cleared the main gate, foundations of part of the city wall, a church, a large covered reservoir, a theatre, part of a street with remains of a triumphal arch and an imposing dwelling. American excavations (1956–58) disclosed a villa of the Roman period, a public building and city baths, all apparently rebuilt in the 5th century A.D.

Other remains, visible but unexcavated, included further large reservoirs, a theatre, a temple, a hippodrome, an amphitheatre, fortresses and blockhouses. Sculptures, geometric mosaics, remains of wall paintings, inscriptions and coins were found.

See G. Caputo, "La Protezione dei monumenti di Tolemaide negli anni 1935–42," *Quaderni di archeologia della Libia,* vol. iii *(1954)*; and the report on the American excavations in the series *Oriental Institute Publications.* (C. *H.* Kr.)

PTOLEMIES, a dynasty **of** Macedonian kings who ruled in Egypt from 323 to 30 B.C.

Ptolemy I, the founder, son of Lagus, a Macedonian nobleman of Eordaea, was one of Alexander the Great's most trusted generals, and among the seven "bodyguards" attached to his person.

Ptolemy plays a principal part in the later campaigns of Alexander in Afghanistan and India. At the Susa marriage festival in 324 Alexander caused him to marry the Persian princess Artacama; but there is no further mention of this Asiatic bride in the history of Ptolemy.

When Alexander died in 323 the resettlement of the empire at Babylon is said to have been made at Ptolemy's instigation. At any rate he was now appointed satrap of Egypt under the nominal kings Philip Arrhidaeus and the young Alexander. He at once took a high hand in the province by killing Cleomenes, the financial controller appointed by Alexander the Great; he also subjugated Cyrenaica. He contrived to get possession of Alexander's body which was to be interred with great pomp by the imperial government and placed it temporarily in Memphis. This act led to an open rupture between Ptolemy and the imperial regent Perdiccas. But Perdiccas perished in the attempt to invade Egypt (321).

In the long wars between the different Macedonian chiefs nhich followed, Ptolemy's first object was to hold his position in Egypt securely, and secondly to possess the Cyrenaica, Cyprus and Palestine (Coele-Syria). His first occupation of Palestine was in 318. and he established at the same time a protectorate over the petty kings of Cyprus. When Antigonus. master of Asia in *315*, shoned dangerous ambitions, Ptolemy joined the coalition against him, and, on the outbreak of war, evacuated Palestine. In Cyprus he fought the partisans of Antigonus and reconquered the island (313). A revolt of Cyrene was crushed in the same year.

In 312 Ptolemy, with Seleucus, the fugitive satrap of Babylonia, invaded Palestine and beat Demetrius, the son of Antigonus, in the great battle of Gaza. Again he occupied Palestine. and again a few months later, after Demetrius had won a battle over his general and Antigonus entered Syria in force, he evacuated it.

In 311 a peace was concluded between the combatants, soon after which the surviving king Alexander was murdered in Macedonia, leaving the satrap of Egypt absolutely his own master. The peace did not last long, and in 309 Ptolemy commanded a fleet in person which detached the coast towns of Lycia and Caria from Antigonus and crossed to Greece, where Ptolemy took possession of Corinth, Sicyon and Megara (308). In 306 a great fleet under Demetrius attacked Cyprus, and Ptolemy's brother, Menelaus, was defeated and captured in the decisive battle of Salamis. The complete loss of Cyprus followed. Antigonus and Demetrius now assumed the title of kings; in 305 B.C. Ptolemy, Cassander, Lysimachus and Seleucus, answered this challenge by doing the same. In the winter (306–5) Antigonus tried to follow up the victory of Cyprus by invading Egypt, but here Ptolemy was strong, and held the frontier successfully against him. Ptolemy led no further expedition against Antigonus overseas. To the Rhodians, besieged by Demetrius (305–4), he sent such help as won him divine honours in Rhodes and the surname of *Sotēr* ("saviour"). When the coalition was renewed against Antigonus in 302, Ptolemy joined it, and invaded Palestine a third time, whilst Antigonus was engaged with Lysimachus in Asia Minor. On a report that Antigonus had won a decisive victory, for a third time he evacuated the country. But when news came that Antigonus had been defeated and slain at Ipsus (301) by Lysimachus and Seleucus, Ptolemy occupied Palestine for the fourth time. The other members of the coalition had assigned Palestine to Seleucus after what they regarded as Ptolemy's desertion, and for the next hundred years the question of its ownership becomes the standing ground of enmity between the Seleucid and Ptolemaïc dynasties. Henceforth, Ptolemy seems to have mingled as little as possible in the broils of Asia Minor and Greece; his possessions in Greece he did not retain, bur. Cyprus he reconquered in 295–4. Cyrene, after a series of rebellions, was finally subjugated about 300 and placed under his stepson Magas (Beloch, Griech. Gesch. III. [ii.], p. 134 seq.).

In 285 he abdicated in favour of one of his younger sons by Berenice (*q.v.*), who bore his father's name of Ptolemy; his eldest (legitimate) son, Ptolemy Ceraunus, whose mother, Eurydice, the daughter of Antipater, had been repudiated, fled to the court of Lysimachus. Ptolemy I. Soter died in 283 at the age of 84. Shrewd and cautious, he had a compact and well-ordered realm to show at the end of fifty years of wars. His name for *bonhomie* and liberality attached the floating soldier-class of Macedonians and Greeks to his service. Nor did he neglect conciliation of the natives. He was a ready patron of letters, and the great library, which was Alexandria's glory, owed to him its inception. He wrote himself a history of Alexander's campaigns, distinguished by its straightforward honesty and sobriety.

PTOLEMY II. PHILADELPHUS (309–246) was of a delicate constitution, no Macedonian warrior-chief of the old style. His brother Ptolemy Ceraunus found compensation by becoming king in Macedonia in 281, and perished in the Gallic invasion of 280–79. (See BRENNUS.) Ptolemy II. maintained a splendid court in Alexandria. Not that Egypt held aloof from wars. Magas of Cyrene opened war on his half-brother (274), and Antiochus I., the son of Seleucus, desiring Palestine, attacked soon after. Two or three years of war left Egypt the dominant naval power of the eastern Mediterranean; the Ptolemaïc sphere of power extended over the Cyclades to Samothrace, and the harbours and coast towns of Cilicia Trachea ("Rough Cilicia"), Pamphylia, Lycia and Caria were largely in Ptolemy's hands (Theoc. *Idyll.* xvii. 86 seq.). The victory won by Antigonus, king of Macedonia, over his fleet at Cos (between 258–56; see Beloch, III. [ii.], p. 428 *seq.)* did not long interrupt his command of the Aegean. In a second war with the Seleucid kingdom, under Antiochus II. (after 260), Ptolemy sustained losses on the seaboard of Asia Minor and agreed to a peace by which Antiochus married his daughter Berenice (250?). Ptolemy's first wife, Arsinoe (I.), daughter of Lysimachus, was the mother of his legitimate children. After her repudiation he married, probably for political reasons, his full-sister Arsinoë (II.), the widow of Lysimachus, by an Egyptian custom abhorrent to Greek morality. The material and literary splendour of the Alexandrian court was at its height under Ptolemy II. Pomps and gay religions flourished. Ptolemy deified his parents as the *θεοὶ ἀδελθοὶ* and his sister-wife, after her death (270), as *Philadelphus.* This surname was used in later generations to distinguish Ptolemy II. himself, but properly it belqngs to Arsinoe only, not to the king. Callimachus, made keeper of the library, Theocritus, and a host of lesser poets, glorified the Ptolemaïc family. Ptolemy himseif was eager to increase the library and to patronize scientific research. He had the strange beasts of far-off lands sent to Alexandria. But, an enthusiast for Hellenic culture, he seems to have shown but little interest in the native religion. The tradition which connects the Septuagint translation of the Old Testament into Greek with his name is not strictly historical. Ptolemy had many brilliant mistresses, and his court, magnificent and dissolute, intellectual and artificial, has been justly compared with the Versailles of Louis XIV.

PTOLEMY III. EUERGETES I. (reigned 246–221), son of Ptolemy II. and Arsinoe I. At the beginning of his reign he reunited the Cyrenaïca to Egypt by marrying Berenice the daughter and successor of Mágas (who had died about 250). At the same time he was obliged to open war on the Seleucid kingdom, where Antiochus II. was dead and his sister Berenice had been murdered, together with her infant son, by Antiochus's former wife, Laodice, who claimed the kingdom for her son Seleucus II. Ptolemy marched triumphantly into the heart of the Seleucid realm, as far at any rate as Babylonia, and received the formal submission of the provinces of Iran, while his fleets in the Aegean recovered what his father had lost upon the seaboard, and made fresh conquests as far as Thrace. This moment marks the zenith of the Ptolemaïc power. After Ptolemy returned home, indeed, Seleucus regained northern Syria and the eastern provinces, but the naval predominance of Egypt in the Aegean remained, although there are traces of its being replaced locally, towards the end of Euergetes' reign, by that of Macedonia—in Amorgos, Naxos, Syros, Nisyros, Cos and parts of Crete. (See Beloch, III. [ii.], p. 463.) After his final peace with Seleucus, Ptolemy no longer engaged actively in war.

PTOLEMY IV. PHILOPATOR (reigned 221–204), son of the preceding, was a wretched debauchee under whom the decline of the Ptolemaïc kingdom began. His reign was inaugurated by the murder of his mother, and he was always under the dominion of favourites, male and female, who indulged his vices and conducted the government as they pleased. Self-interest led his ministers to make serious preparations to meet the attacks of Antiochus III. (the Great) on Palestine, and the great Egyptian victory of Raphia (217), at which Ptolemy himself was present, secured the province till the next reign. The arming of Egyptians in this campaign had a disturbing effect upon the native population of Egypt, so that rebellions were continuous for the next thirty years. Philopator was devoted to orgiastic forms of religion and literary dilettantism. He built a temple to Homer and composed a tragedy, to which his vile favourite Agathocles added a commentary. He married (about 215) his sister Arsinoe (III.), but continued to be ruled by his mistress Agathoclea, sister of Agathocles.

PTOLEMY V. EPIPHANES (reigned 204–181), son of Philopator and Arsinoe, was not more than five years old when he came to the throne, and under a series of regents the kingdom was paralysed. Antiochus III. and Philip V. of Macedonia made a compact to divide the Ptolemaïc possessions overseas. Philip seized several islands and places in Caria and Thrace, whilst the battle of Panium (198) definitely transferred Palestine from the Ptolemies to the Seleucids. Antiochus after this concluded peace, giving his own daughter Cleopatra to Epiphanes to wife (193–192). Nevertheless, when war broke out between Antiochus and Rome Egypt ranged itself with the latter power. Epiphanes in manhood was chiefly remarkable as a passionate sportsman; he excelled in athletic exercises and the chase.

PTOLEMY VI. PHILOMETOR (181–145), the elder of his two sons, succeeded as an infant under the regency of his mother Cleopatra. Her death was followed by a rupture between the Ptolemaïc and Seleucid courts, on the old question of Palestine. Antiochus IV. Epiphanes invaded Egypt (170) and captured Philometor.

The Alexandrians then put his younger brother PTOLEMY VII. EUERGETES II. (afterwards nicknamed *Physkon*, on account of his bloated appearance) upon the throne. Antiochus professed to support Philometor, but, when he withdrew, the brothers agreed to be joint-kings with their sister Cleopatra as queen and wife of Philometor. Antiochus again invaded Egypt (168), but was compelled by the Roman intervention to retire. The double kingship led to quarrels between the two brothers in which fresh appeals were continually made to Rome. In 163 the Cyrenaïca was assigned under Roman arbitration to Euergetes as a separate kingdom. As he coveted Cyprus as well, the feud still went on, Rome continuing to interfere diplomatically but not effectively. In 154 Euergetes invaded Cyprus but was defeated and captured by Philometor. He found his brother, however, willing to pardon and was allowed to return as king to Cyrene. In 152 Philometor joined the coalition against the Seleucid king Demetrius I. and was the main agent in his destruction. The protégé of the coalition, Alexander Balas, married Philometor's daughter Cleopatra (Thea), and reigned in Syria in practical subservience to him. But in 147 Philometor broke with him and transferred his support, together with the person of Cleopatra, to Demetrius II., the young son of Demetrius I. He himself at Antioch was entreated by the people to assume the Seleucid diadem, but he declined and installed Demetrius as king. In 145 in the battle on the Oenoparas near Antioch, in which Alexander Balas was finally defeated, Philometor received a mortal wound Philometor was perhaps the best of the Ptolemies. Kindly and reasonable, his good nature seems sometimes to have verged on indolence, but he at any rate took personal part, and that bravely and successfully, in war. Philometor's infant son, Ptolemy Philopator Neos (?)[1], was proclaimed king in Alexandria under the regency of his mother Cleopatra. Euergetes however, swooping from Cyrene, seized the throne and married Cleopatra, making away with his nephew. He has left an odious picture of himself in the historians—a man untouched by benefits or natural affection, delighting in deeds of blood, his body as loathsome in its blown corpulence as his soul. Something must be allowed for the rhetorical habit of our authorities, but that Euergetes was ready enough to shed blood when policy required seems true. He soon found a more agreeable wife than Cleopatra in her daughter Cleopatra, and thenceforth antagonism between the two queens, the "sister" and the "wife," was chronic. In 130–1 Cleopatra succeeded in driving Euergetes for a time to Cyprus, when he revenged himself by murdering the son whom she had borne him (surnamed *Memphites*). Massacres inflicted upon the Alexandrians and the expulsion of the representatives of Hellenic culture are laid to his charge. On the other hand, the monument and papyri show him a liberal patron of the native religion and a considerable administrator. In fact, while hated by the Greeks, he seems to have had the steady support of the native population. But there are also records which show him, not as an enemy, but a friend, like his ancestors, to Greek culture. He himself published the fruit of his studies and travels in a voluminous collection of notebooks, in which he showed a lively eye for the oddities of his fellow kings. The old Ptolemai'c realm was never again a unity after the death of Euergetes II. By his will he left the Cyrenai'ca as a separate kingdom to his illegitimate son Ptolemy Apion (116–96), whilst Egypt and Cyprus were bequeathed to Cleopatra (Kokke) and whichever of his two sons by her, PTOLEMY VIII. Soter II. (nicknamed *Lathyros)* and PTOLEMY *IX*. Alexander I., she might choose as her associate. The result was, of course, a long period of domestic strife From 116 to 108 Soter reigned with his mother, and at enmity with her, in Egypt, whilst her favourite son, Alexander, ruled Cyprus. Cleopatra compelled Soter to divorce his sister-wife Cleopatra and marry another sister, Selene. Cleopatra plunged into the broils of the Seleucid house in Syria and perished. In 108 Cleopatra Kokke called Alexander to Egypt, and Soter flying to Cyprus took his brother's place and held the island against his mother's forces. The attempts which Soter and Cleopatra respectively made in 104–3 to obtain a predominance in Palestine came to nothing. Alexander now shook off his mother's yoke and married Soter's daughter Berenice. Cleopatra Kokke died in 101 and from then till 89 Alexander reigned alone in Egypt. In 89 he was expelled by a popular uprising and perished the following year in a sea-fight with the Alexandrian ships off Cyprus. Soter was recalled (88) and reigned over Egypt and Cyprus, now reunited, in association with his daughter Berenice. This, his second, reign in Egypt (88–80), was marked by a native rebellion which issued in the destruction of Thebes.

[1]Or according to another view, Eupator. On the obscure questions raised by these two surnames, *see* L. Pareti, *Ricerche sui Tolemei Eupatore e Neo Filopatore* (Turin, 1908).

PTOLEMY X. ALEXANDER II.—On his death Berenice assumed the government, but the son of Alexander I., Ptolemy X., entering Alexandria under Roman patronage, married, and within 20 days assassinated, his elderly cousin and stepmother. He was at once killed by the enraged people and with him the Ptolemai'c family in the legitimate male line became extinct. Ptolemy Apion meanwhile, dying in 96, had bequeathed the Cyrenai'ca to Rome.

The Alexandrian people now chose an illegitimate son of Soter II. to be their king, PTOLEMY XI. Philopator Philadelphus Neos Dionysus (80–51), nicknamed *Auletes*, the flute-player, setting his brother as king in Cyprus. The rights of these kings were doubtful, not only because of their illegitimate birth, but because it was claimed in Rome that Alexander II. had bequeathed his kingdom to the Roman people. Two Seleucid princes, children of Soter's sister Selene, appeared in Rome in 73 to urge their claim to the Ptolemai'c throne. Ptolemy Auletes was thus obliged to spend his reign in buying the support of the men in power in Rome. Cyprus was annexed by Rome in 58, its king committing suicide. From 58 to 55 Auletes was in exile, driven out by popular hatred, and worked by bribery and murder in Rome to get himself restored to Roman power. His daughter Berenice meanwhile reigned in Alexandria, a husband being found for her in the Pontic prince Archelaus. In 55 Auletes was restored by the proconsul of Syria, Aulus Gabinius. He killed Berenice and, dying in 51, bequeathed the kingdom to his eldest son, aged ten years, who was to take as wife his sister Cleopatra, aged seventeen.

In the reign of PTOLEMY XII. Philopator (51–47) and Cleopatra Philopator, Egyptian history coalesces with the general history of the Roman world, owing to the murder of Pompey off Pelusium in 48 and the Alexandrine War of Julius Caesar (48–47).

In that war the young king perished and a still younger brother, PTOLEMY XIII. Philopator, was associated with Cleopatra till 44, when he died, probably by Cleopatra's contriving. From then till her death in 30, her son, born in 47, and asserted by Cleopatra to be the child of Julius Caesar, was associated officially with her as PTOLEMY XIV. Philopator Philometor Caesar; he was known popularly as Caesarion. (For the incidents of Cleopatra's reign see CLEOPATRA, ARSINOË.) After her death in 30 and Caesarion's murder Egypt was made a Roman province. Cleopatra's daughter by Antony (Cleopatra Selene) was married in 25 to Juba II. of Mauretania. Their son Ptolemy, who succeeded his father (A.D. 23–40), left no issue'.

See Mahaffy, *The Empire of the Ptolemies* (1895) and *Egypt under the Ptolemaic Dynasty* (1899); Strack, *Die Dynastie der Ptolemaer* (1897); Bouché-Leclercq, *Histoire des Lagides* (1904, 1907); Meyer, *Das Heerwesen der Ptolemäer und Rdmer* (Leipzig, 1900).

(E. R. B.)

PTOLEMY (CLAUDIUS PTOLEMAUS) (fl. 2nd century AD.), celebrated astronomer, geographer and mathematician Virtually nothing is known of his life. but according to Theodorus Meliteniota of Byzantium Ptolemy was born in the Grecian city Ptolemais Hermii. The period during which he flourished is known from the dates of certain astronomical observations which he made His main work was carried out at Alexandria and while he certainly observed between A D. 127 and 145, it may nell be that he was still at work as late as 151. Arabian traditions claim that Ptolemy died at the age of 78.

Astronomical Work.—Ptolemy's astronomical work. which exerted so profound an influence on subsequent generations and, indeed, for more than 1 200 years after it was completed, was enshrined in his great book *The Mathematical Collection (He Mathematike Syntaxis)*. This became known. in due course. as

The Great Astronomer (Ho *megas astronomas*), to distinguish it from a collection of works of Autolycus, Euclid, Aristarchus, Theodosius, Hypsicles and Menelaus which was known as The Little Astronomer. The Arabian astronomers of the 9th century referred to his work by the superlative Megiste and from this term, with the definite article *al* prefixed, its title became known as the Almagest, the name which is still in use today.

The Almagest is divided into 13 books. Book i gives, in broad outline, the geocentric system together with arguments in its favour. Book ii contains a table of chords and what is the equivalent of spherical trigonometry with the theorem of Menelaus (fl. c. A.D. 90) as its basis; sample problems are also worked out. Book iii deals with the motion of the sun and the length of the year. Book iv is concerned with the moon's motion and the length of the month and book v deals with the same subjects, as well as discussing the distances of the sun and moon and giving details for the construction of an astrolabe. Eclipses of the sun and moon are dealt with in book vi, as also are planetary conjunctions and oppositions. The next two books, vii and viii, concern the fixed stars, contain a discussion of precession, Ptolemy's star catalogue and a method for constructing a celestial globe. The remaining five books are devoted to the planets and are, in fact, the most original part of the work.

It was, no doubt, the encyclopaedic nature of the work that rendered the Almagest so useful to those who followed and gave the views contained in it so profound an influence. In essence, it is a synthesis of the results attained by Greek astronomy and is, of course, our one source of knowledge of the work and hypotheses of Hipparchus (*q.v.*); indeed, it is often difficult to determine which results are due to Ptolemy himself and which to Hipparchus. It is, however, incorrect to assume that Ptolemy himself carried out but few observations, for he extended some of the work of Hipparchus and appears to have used somewhat similar instruments—a type of mural quadrant for determining the altitude of the sun, an armillary sphere (in which the circles were set parallel to their counterparts in the sky and from which, utilizing open sights, celestial latitude and longitude could be read off) and an instrument known as "Ptolemy's rules" which was designed for measuring the altitude of heavenly bodies.

While Hipparchus had carried out much work on the stars and had completed the first star catalogue, Ptolemy extended this work. The catalogue of Hipparchus contains 850 stars and that of Ptolemy lists 1,022. However, Ptolemy used the observations of Hipparchus and, in order to bring them up to date with his own, had to make a correction for precession; unfortunately, he erred in the annual value which he adopted for this correction. Hipparchus had discovered precession and determined the value as 45″ or 46″ per year, but Ptolemy obtained a value of 36" which is, of course, far too small (present determinations give 50.26").

On the motions of the sun, moon and planets, Ptolemy followed Hipparchus and took a thoroughgoing geocentric viewpoint, and it was this approach which became dogmatically asserted in western Christendom until, by the 15th century, further detailed observations had made the Ptolemaic system so complex that the validity of such a view became seriously questioned. As is well known, it was Copernicus who took the bold step of proposing a heliocentric system.

Ptolemy considered the earth to be the centre of the universe, and in the Almagest he gives various arguments to prove that it must be immovable. Not least, he showed that if the earth moved, as some earlier philosophers had suggested, then certain phenomena should in consequence be observed, and he was able to show that no such observations had ever been obtained.

He accepted the order: earth (centre), moon, Mercury. Venus, sun, Mars, Jupiter and Saturn. He realized, as Hipparchus had done, that the inequalities observed in the motions of these heavenly bodies necessitated a system of deferents and epicycles in order to keep uniform circular motion as the basis. Yet, even so, the observed phenomena could not be fully taken into account. It was here that Ptolemy showed a brilliant ingenuity by introducing the concept of the equant He supposed that the earth lay a little way from the centre of the deferents for each planet and that the centre of the planet's epicycle described uniform circular motion around the equant which he placed on the diameter of the deferent but at the opposite side of the centre to the earth and at a distance equal to that by which the earth was displaced on the other. He was thus better able to account for the observed planetary phenomena.

Ptolemy also improved substantially the lunar theory of Hipparchus by varying the distance of the centre of the moon's epicycle from the earth. The motion, as with the planetary equant, was uniform, but while the centre of the moon's epicycle rotated around an equant, the position of the latter was on the opposite side of the earth to the centre of the deferent. With this mathematical device he more precisely accounted for the moon's motion and discovered the inequality of the lunar motion known as evection, an inequality which is due to the rotation of the apse line. He then prepared tables of the moon's motion. and these were in use down to the time of Copernicus. 1,400 years later. His value for the evection was close to that accepted today, and although his new theory of lunar motion did not fully account for the observations, Ptolemy made every effort to perfect it. He did not, however, discover any further inequality in the moon's motion, and it was not until the work of Tycho Brahe in the 16th century that any further development of this kind was made.

Ptolemy realized that the planets were much closer to the earth than the fixed stars, and he seems to have believed in the physical existence of the crystalline spheres to which the heavenly bodies were supposed to be attached. Outside the sphere of the fixed stars, Ptolemy proposed other spheres ending with the *primum* mobile or prime mover, the latter providing the motive power for the remaining spheres which constituted his conception of the universe.

Ptolemy's text was translated into Arabic for the caliph al-Ma'mun in 827, and other Arabic translations followed. The *Almagest* was also the subject of many commentaries One in Greek and written by Pappus in the 4th century A.D. is still in existence; a commentary by Theon of Alexandria (fl. 4th century A D) was published in Basel in 1538 and in the same year the first edition of the Greek text was also published there. The Greek text which has now superseded all others is that edited by J. L. Heiberg, published between 1899 and 1907.

Mathematics.—The mathematical work of Ptolemy was important and he was a geometrician of the first order. He proposed a new proof in place of that of Euclid on parallel lines; he showed in "Ptolemy's theorem" (which concerns a quadrilateral inscribed in a circle) how the formulas $\sin(A \pm B)$, $\cos(A \pm B)$ could be derived and how, with this and a few other simple geometrical theorems, a table of chords could be drawn up. Although it appears that the main theorem was actually due to Hipparchus, Ptolemy deals with the whole matter with a conciseness and elegance which it would be hard to surpass, and was able to calculate a table of chords in increments as small as $\frac{1}{2}°$.

In a work entitled Analemma, Ptolemy discussed the details of the orthogonal projection of points on the celestial sphere onto three planes which are mutually at right angles—the horizon, the meridian and the prime vertical. The full Greek text has not survived, but there is a Latin translation made by William of Moerbeke (13th century) from an Arabic original. The *Planisphaerium,* which survives only in a Latin translation from Arabic, is concerned with stereographic projection, and here Ptolemy used the south pole as his centre of projection.

He also prepared a calendar (*Phaseis* aplanon *asteron*) giving the risings and settings of the stars in morning and evening twilight together with weather indications, and a work in two books entitled Planetary Hypothesis (Hypothesis ton planomenon) still exists, the first book in Greek but the second in an Arabic translation only.

Early commentators mention two separate geometrical works. One, On dimension (Peri diastaseos), is concerned with proving that there cannot be more than three dimensions of space; the other contains Ptolemy's alternative proof for Euclid's parallel line postulate. Ptolemy has also been credited by Simplicius (*c.* 6th century) with a mechanical work, On Balancings (Peru ropon), while Suidas (*c.* 10th century) claims that he wrote three books on mechanics.

The *Optics,* which contains Ptolemy's work on optical phenomena, does not exist in the original Greek but only in a Latin translation made from a 12th-century Arabic copy. It appears that the original was in five books. in the last of which Ptolemy deals with a theory of refraction and discusses the refraction suffered by celestial bodies at various altitudes; this is the first recorded attempt at a solution of this observational problem.

He also wrote a treatise in three books on music. This is known as the *Harmonica* and was edited by John Wallis and published in Latin and Greek in 1682.

Geographical Work.—Ptolemy's reputation as a geographer is mainly due to his *Guide to Geography* (*Geographike Huphegesis*), which, like the *Almagest,* exerted a great influence on future generations. Again, this was due to his scientific approach to his subject and the consequent ease of reference which the book possessed. An eight-book manuscript version was prepared in 1400 and was translated into Latin nine years later. Sumerous editions were published in Europe in the zoo years which followed. and the Greek text appeared at Basel in 1533, edited by Erasmus. All these early editions are full of textual errors.

Hipparchus, three centuries earlier, had already pointed out that a map with any pretensions to accuracy could only be prepared by knowing the longitude and latitude of the principal points on its surface. At the time Hipparchus made his suggestions, little information was available and he seems to have contented himself with his method of dividing the then known world into zones. or *klimata* as he termed them. However, Marinus of Tyre (2nd century A.D.). who lived a little before Ptolemy and to whose work Ptolemy refers in his *Guide,* used determinations of position based on itineraries of travelers and other rough methods. In his treatise. which is lost. Marinus discussed the determinations of the authorities he used, but it is not possible now to assess the scientific value of the results he obtained. Ptolemy considered them in general to be satisfactory and used them as a basis for his own work on the Mediterranean countries. although he showed more reserve in accepting them for remoter regions.

Ptolerny's astronomical work and his studies of map projections made him especially fitted for the kind of geographical work he undertook. but his general views were not unlike those of Eratosthenes and Strabo (*qq.v.*). I-Ie continued the method. which Hipparchus had originated. of dividing the equator into 360 parts (degrees) and supposing other great circles (meridians) to be drawn through this. His framework consisted also of parallels of latitude. Although Eratosthenes in the 3rd century B.C. had measured the circumference of the earth and had given a value very close to that accepted today. Ptolemy used the later determination of Poseidonius (*c.* 135–50 B.C.) which was nearly 30% smaller. and so his conclusions as to distances were incorrect by this amount. Moreover, as he plotted the positions of many places purely by using measures of distance. many of his values of latitude and longitude were also incorrect. As prime meridian Ptolemy followed Marinus, taking the great circle through what was supposed to be the most western point of Europe, the Fortunate islands (corresponding approximately to the Canaries and the Madeira group). He placed the equator too far north and his principal parallel was correct only at Rhodes. In addition. it should he noted that there are some contradictions between the text and the maps in the *Guide.*

In spite of all these faults, Ptolemy's monumental work exerted a great influence. His idea that Asia extended-much farther east than is the case strengthened the belief of Columbus that Asia could be reached by traveling westward. and Ptolemy's suggestion that the Indian ocean was bounded by a southern continent was not disproved until the voyages of Captain Cook in 1773. Some of these ideas were prohahly derived by Ptolemy from Hipparchus.

The *Guide* was divided into seven books. Book i begins with general explanations and there follow corrections made from astronomical observations of some of the results obtained by Marinus. The question of maps and their construction is next discussed. beginning with a conical projection in which the meridians are represented as straight lines all meeting at a certain point (a kind of north polej and the parallels of latitude (especially that through Rhodes) as circles with the "north" point as centre. Then follows a more elaborate projection, with meridians as actual arcs of a circle. Books ii to vii contain a list of places tabulated according to longitude and latitude. Ptolemy deals here with Europe and the Mediterranean. then Africa, Asia, Palestine, Mesopotamia, Arabia. India, etc. The work is accompanied by maps (usually referred to as book viii).

As a whole. Ptolemy's geographical work cannot be considered "good geography." No mention is made of climate, natural products, inhabitants or peculiar features of the countries with which he deals. Moreover, although Strabo, for example, was well aware of the geographical importance of rivers and mountain ranges, Ptolemy's treatment of these factors is careless and of little real use. However, it is the profound influence which the *Guide* exerted on later generations which makes this work so important from a historical point of view.

BIBLIOGRAPHY.—Works of Ptolemy ed. by J. L. Heiberg (1898–1907); German trans. of *Almagest* published in *Des Claudius Ptolemaiis Handbuch der Astronomie* (1912–13) by *C.* Manitius. A photographic reproduction of a manuscript of the *Guide* was published by V. Langlois (1867). A 2-vol. ed. by C. T. Fischer and C. Müller was published between 1883 and 1901. Ptolemy's *Catalogue of Stars,* ed. by *F.* Baily, was published as a memoir of the Royal Astronomical Society (vol. 13) in 1843, and by E. B. Knobel and C. H. F. Peters in 1915. (CN. A. R.)

PTOMAINE POISONING is a popular term used to describe food poisoning caused by toxic substances of bacterial origin. The term is misleading since the toxic substances are known to be subitances synthetized by the bacteria with or without obvious evidence of decomposition of the food rather than ptomaines, *i e.,* organic bases. such as putrescine and cadaverine, resulting from bacterial degeneration of proteins. Examples include botulism and staphylococcus food poisoning, a violent but usually nonfatal type of poisoning, generally associated with the eating of éclairs and cream puffs. *See* FOOD POISONING, *BACTERIOLOGICAL.* (F. L. A)

PUBLIC ADMINISTRATION is the application of a policy of a state through its government. Policy is given general legal formulation by legislative institutions in statute law; hut there then remains the defining of that law for specific application. A statute is the product of a law-making agency which is not always in session. whose memhers are usualiy selected to represent general attitudes and opinions rather than to possess expert knowledge. After a statute is adopted, rules are needed for its detailed application in the enforcement of both the statute and rules to the situations it was designed to affect. Thus, a statute adopted to facilitate traffic may authorize in general terms the regulation of the movement of motor vehicles. by specifying reasonahle speeds on public streets and highways with due regard to density of population. location of schools and hospitals and the existence of intersecting streets! and also will prohahly provide for some agency in continuous operation. and presumably with knowledge, experienced personnel and material equipment, with power to translate the general objectives into more specific regulations (*e.g.,* as to coming to a full stop at main arteries or obeying light signals) and to enforce the statute and regulations, with penalties for those who violate them.

Thus, public administration is interrelated with public opinion in that it follows upon the decision of the political leaders to undertake or abandon collective activities or to support or accept laxity in the enforcement of laws; with the legislative process in that effective administration may be rendered difficult or impossible by faulty legislation, and also because the experience and knowledge of the administrative agency are of value to the lawmaker, just as its possible corruption or ignorance may mislead or handicap him; and to the judicial process since the action of the administrator may be challenged in the ordinary or in special courts by a citizen, and the administrative agency may be required, under the terms of a particular statute, to apply to the courts for judicial action against those presumed by the agency to be violating the law. While there is a theory that administration and policy are two separate processes of government, in fact they are constantly merging and interfused. This is because policy-making is inadequate if there is no consideration of the means for making the law effective. and administration of a general objective raises questions of choice, and hence policy. in any specific situation. It is a policeman who arrests a traffic violator, and not a statute, which remains within the covers of a book.

Administration and Policy.—The problems of public administration reflect, therefore, these interrelations with opinion, legislation and adjudication. They also reflect the stage of civilization, the time, place and environment generally of the particular political unit. Thus. at the top of the administrative structure is an official who can speak for, and to, the dominant political power of the society. This need for making the administrative agency subservient to the original intent for which the activity was authorized and the political forces, party or factional or personal, which took the responsibility for the legislation authorizing the program explains why the headship of an administrative agency, at least of national agencies, is generally a politician and nonexpert. He is chosen because he must interpret to the experts what the judgment of those in political power is, and to the politicians and the lay public what the more technical considerations that will affect their political objectives are. The greatest quantity of public administration is in the substantive functions of government such as those of public safety and order, public health, public works, education, the development of natural resources, the facilitation of transportation, the care of the handicapped and the facilitation and regulation of finance, business and industry. Roads and harbours are built. Social insurance payments are made. Forests are guarded from fire or disease. Each field of activity has its accumulated technical knowledge, personnel. forms of organization and procedure, vocational and professional ties, associations and corporate interests, loyalties and issues. For any particular jurisdiction in which a number of these functions are administered. the problem of allocating available revenue to each, of determining priorities and of co-ordinating the application by each agency of policies in which account should be taken of what other agencies are doing is one of the most important responsibilities of the highest administrative authority. At this point in the structure and process of government there is a meeting and mingling of political policy, general management and the conduct of the particular functional departments.

MANAGEMENT

Direction and General Staff.—The heads of the administration in any jurisdiction have a double responsibility of helping to formulate legislation on the one hand, and of directing and co-ordinating the administrative agencies to carry out the authorized policies on the other. This latter task becomes difficult in those stages of civilization in which many functions are undertaken through government since it includes the proper assignment of activity to organization units and the co-ordination of several organization units, each of which has some necessary share in the activity but each of which is also likely to develop its own personality, attitudes and jealousies. Hence, the top administrative policy group, in modern times often called a "cabinet" from the meeting place in the king's quarters (hence his "cabinet council"), and its chairman or chief—prime (*i.e.,* "first") minister, premier or president—need to have the problems presented to them analyzed by persons of integrity, competence and experience. This has come to he called "general staff service" from the influential and famous Prussian general staff. Elements of this important step in the administrative process are to be found wherever government has been effectively used. Thus, planning, inherent in the process of formulating policy, becomes essential also in its wise application, whether in the conduct of war, the prevention of epidemics, the facilitation of transportation or the relief of destitution.

Auxiliary Services.—The responsible political chiefs of administration have been found by widespread experience to need other aids to ensure economical and efficient application of policy. These are agents for obtaining and facilitating the best use of personnel, physical materials and equipment, architectural and engineering services and finances. Since such tools are aids both to general direction and to the operating officials (who are on the front lines in the field, building highways. waging war or constructing irrigation projects), they are frequently called the auxiliary services.

Characteristic auxiliary services are those which recruit and examine applicants for government employment, budget offices which prepare estimates and supervise expenditures authorized by the appropriating and taxing authority, purchasing agencies which prepare specificaiions describing needed materials. purchase them and inspect, store and deliver them and printing, architectural and construction agencies. They are also frequently known as the "housekeeping services" since they perform them for the various operating agencies. Their justification lies in their ability to perform for all the operating departments these specialized tasks more effectively and economically, and to maintain general standards of salaries, prices and procedures.

There is inevitably some clash between such auxiliary agencies with their responsibility to the administrative chiefs for over-all policy, and the particular operating agency with its enthusiasm for and special knowledge of its own field, and hence resentful of controls that are often called "red tape" (used historically to tie up documents for filing). To the operating official, there looms the threat of what is termed in the British civil service the "treasury mind"; its cousin is found in all large organizations in all times and places. To the official zealous in pressing forward his project, the scrutiny of some part of it by another agency which has no immediate apparent responsibility for the success or failure of the project or its initiator, is irksome. The auxiliary or general staff official, however, is equally impressed with the necessity of relating the single project to the other activities of the government, of bringing the enthusiasm of the official within the bounds and standards which the accumulated experience indicates as effective norms and economical expenditures.

Personnel and budget policies illustrate the fact that auxiliary and general staff services (which intermingle through day-to-day activities) are more than narrow technical matters. They are of central importance in the operation of any political system.

Personnel.—Long and varied experience in all parts of the world demonstrated the necessity, for effective administration, of a reservoir of accumulated knowledge of the administration of a function—a knowledge that can be obtained only from persons of ability and integrity who have been given an opportunity for a career, within the appropriate general political, legislative and judicial controls, in administration. That is not the only reason why spoils systems, wherever they exist, have been disastrous (except in situations in which they may have served as alternatives to more costly revolutions). Their primary evil is that they undermine any use of parties and legislatures as reasonably accurate instruments of recording political sentiment and ideas, since they replace the relationship of agency for the public by agency for the chief spoilsman and turn responsible public affairs into irresponsible private rackets. Their administrative evil is that they prevent the accumulation of knowledge that only experience can give. No person of ability and integrity would be willing under spoils conditions to seek a satisfying career, and inevitably the agency sinks in effectiveness and in public confidence and any public objective is lost. Even in revolutionary conditions a new government is generally reluctantly forced to rely upon such officials of experience and knowledge as it can find for carrying on those services necessary for the safety and welfare of populations—especially in a society partly urban. The knowledge referred to here is not only the knowledge of a substantive problem, such as preventive medicine, for example, or highway construction, but the more subtle knowledge for which long experience inside the working of human institutions is required. This is the knowledge of who knows what, of how to use procedures and codes to hasten or delay business, of how to avoid arousing group and individual jealousies, of "moving through the correct channels" and of winning the agreed consent of all those necessary to a policy. The term "bureaucracy" is sometimes given, often in disparagement, to governments in which the "permanent" or "career" officials exercise or condition power. Such a dependence on officials, however, is inevitable and necessary in governments exercising many and interrelated functions.

The selection and training of civil servants has therefore been an important problem of government since early times. The system of widespread recruitment on the basis of examinations in the classics was a feature of the government of China for hundreds of years. The training of officials for the administrative posts in the mediaeval papacy and empire included courses in such universities as Bologna and Naples. The palace school of the Ottoman empire was the nursery of the civil, military and naval officer classes. The ruling families of the German principalities founded universities in which their civil servants (often jealously opposed by the feudal nobility) were educated. In both 19th-century Germany and France, the rise of a larger and more varied civil service was accompanied by the development of opportunities for secondary, university and specialized education that reflected also the enlargement of the middle class. The École Libre des Sciences Politiques in Paris and the development of careers in municipal administration in Germany illustrate these tendencies. The Trevelyan-Northcote report on the civil service in Great Britain in 1853 was influenced by such educators as Benjamin Jowett of Balliol and John Stuart Mill. The expansion in the functions of government in the Cnited States prior to World War I created an interest in the education of administrators which revived strongly with another expansion in the decade 1930–40.

In general, educational qualifications for administration reflect the general social conditions of the time and place and the classification of the positions to be filled. A more fluid and democratic society opens its opportunities for secondary and higher education widely and this tends to prevent the formation of a special official caste sheltered by inherited privileges. The "single-party" system of government tends to create a new form of special privilege dependent upon party allegiance. But in all systems, a job analysis will reveal the need for continuous education after entrance if there is to be an adequate supply of recruits for the higher directive and technical positions. Hence, the questions of "in-service" training, of educational leave and the recruitment through promotion and from outside the service are as much the subject of discussion and experiment as the older question of "pre-entry" training. At this point the interest of students of public administration turns to developments in education and psychology generally as well as to experience in industry and commerce.

The Budget.—The outstanding instrument whereby the total program of a government for a given period of time is set forth by organization unit, types of expenditure and in other detail is the budget. In most states (notably Great Britain, which contributed most to its development as an important tool of government) the budget originates in the executive departments in the form of estimates of proposed expenditures and the revenues to cover them, is submitted to the legislature for investigation, amendment and legal authorization and is then administered by the budget and other finance agencies. The budget process ends with an audit to determine whether expenditures have been properly based upon the legal authorization—an audit frequently made by an agency of the legislature, or otherwise independent of the administrative chiefs. The budget as authorized by the lawmaking process is thus inevitably the total plan for all the activities of the government for the next fiscal period (generally a year), including the provision for personnel and materials. The long evolution of representative government has centred largely in the development of a good budget system, including "the control of the purse strings" by the elected representatives of the people; that is, the submission to them by the executive (usually in name, at least, by the king) of the proposals for expenditure, taxation and loans and the scrutiny and amendment, acceptance or rejection of these by the representatives, sometimes with the aim and result of forcing the king's administrative chiefs and policy advisers from office. The cabinet system, whereby the chief executive officials must possess the support of the majority of the legislature, thus had its origins; while the importance of legislative control over expenditure, and of the appropriation process, is illustrated also by provisions concerning them in the constitution of the United States and in the development of government everywhere.

The Planning Process.—The function of cabinets and chief executives as well as the heads of large departments in the preparation of policy for submission to the legislative authority became complex and difficult with the widening and interdependence of the functions of government. Thus, in a metropolitan area the design of streets and highways, water supply, parks and schools is dependent upon population, industrial, commercial and' technological trends as well as changes in the ideas held by citizens as to standards of living. As a result, the usual budget processes are sometimes supplemented by special staff agencies for investigation and analysis. or by regular and continuing agencies to which the term planning is applied. Planning as an inherent need in the structure and process of administration was diagnosed and recommended by Frederick W. Taylor in his pioneer work in scientific management, although, as noted above, it has been called into existence in some form, as in military affairs, wherever thought has been applied to the problem of the improved preparation of programs.

The "mercantilist" and "cameralist" policies of the early modem state caused the rise of career civil services and methods of training for them. A similar increase in collective services, whether in the U.S.S.R. with its elaborate central, regional and local programs of state action, or a cut-over region of sparse population requiring long-time land policies in the United States, or a great urban agglomeration such as London, Bombay or New York, made desirable and necessary the establishing of planning agencies. Their function is to gather and analyze data concerning the problems of the political organisms they serve and to submit reports on their studies to the political chiefs, the legislatures and the electorate. Sometimes these agencies are also given some operating responsibility and power. Thus, they may be given the enforcement of controls over land use or authority to determine priorities in the allocation of resources to projects. Whether such planning agencies should be exclusively research and advisory in their functions or should have in addition operating functions and powers is a subject of controversy among students of administration. It is agreed, however, that there should be close and sympathetic working relations and an interchange of personnel between them and the budget and other general staff and auxiliary services and the substantive departments.

It may again be stressed that the budget should reflect, as the most comprehensive record of operations proposed for the next fiscal period, the result of the planning process as registered in the working and financial program which the chief executive and his associates are responsibly proposing to the highest lawmaking body of the jurisdiction. Thus, the estimates which are proposed will presumably be supported and justified by the analyzed data. Viewed in this light the planning process in administration is not, as sometimes argued, in opposition to legislative authority but essential to it. A legislature, in fact, may rightly demand that such preliminary collection and analysis of data be undertaken by the executive to ensure a better preparation of proposals placed before it. The use of the fiscal policy of a government to affect general economic conditions by its influence on investment and employment increases the need for careful planning of the estimates.

Internal Operation.—The directive, general staff and auxiliary agencies exist to serve the substantive or operating departments, and it is through them that the functions of a political system are applied. In these basic substantive departments there is a division of labour reflected in an organization of units whose heads are related in some line of responsibility and power. The system may be recorded on organization charts and in standard specifications for every position whereby the duties, qualifications, rates of payment and official titles are set forth. The relation of the different levels, the flow of correspondence, reports, memoranda and dockets of official business and the arrangements for conference between units (bureaus. divisions, sections, branches, regional offices, etc.) may also be guided by written and official codes of procedure. The procedure to be followed in relations with the public generally by correspondence, interview, investigation or inspection, or hearings of an informal or formal type, tends to become standardized and codified. This results in a standardizing of practice that leads to charges of red tape, bureaucracy and the stultifying of initiative, A failure to regularize procedures, however, leads to criticisms of unfairness, capriciousness and abuse of power and an invitation to corruption. The interests affected by the function administered are generally organized in economic or professional associations. Sometimes representatives of these interests are brought into official participation in the administrative process through committees advisory to the agency or committees given some power of administering the program for which the agency is ultimately responsible. At its extreme, such a system might be termed "the corporative state" so much discussed in political theory in recent decades, although never actually embodied in any completeness.

Among the groups involved in the administrative process with some special interest or emphasis of their own are various organizations of the civil servants. Since the number of civil servants in a modern state may be great, collective action in the effort to affect rates of pay and conditions of employment generally developed despite opposition. In some systems, a regular procedure was established (as notably in the "Whitley councils" in the British civil service) for consultation between the directive and personnel officials and the representatives of the civil service organizations.

Thus, the maintenance of some balance in modern administration between the interests and attitudes of legislatures, parties, executive leaders, auxiliary service agencies, interest groups affected and the civil servants themselves is no easy task. The systems appear sprawling, cumbersome and unwieldy and too far removed from the situation from which the call for governmental action originated. Internal operation is complicated further by the relating of decisions taken at the centre to the varied conditions in the field.

The problem of clarifying and explaining the complex task of a department led to increased interest in methods of reporting. Experiments in the use not only of printed and illustrated reports but of the motion picture, the radio, television and direct face-to-face discussion and conference were undertaken. Legislatures are inclined to oppose these on grounds that they may become an alternative to the party system as a means of consulting public opinion and may stimulate public pressure for legislation favourable to the agency employing them.

The problems of internal operation in public administration are in many ways akin to or identical with those in other social institution., including industry and commerce. The comparative study of institutions, including the relation of individuals in the smaller face-to-face groups, brought scholars and administrators together from many fields to share experience and plan and conduct research. Psychologists, personnel managers, anthropologists, sociologists and many other workers find a common field in what is given various names, such as social relations, human relations or the study of the human group. A special challenge was raised by growth of international programs and agencies in which the problems of a substantive field such as health are complicated by the need for co-operation by peoples of different cultures. The training of administrative personnel for such programs began to reflect the new emphasis on human relations, and also the area or regional studies whose origins may be found long ago in the policies of missionary societies and colonial offices, as well as in World Wars I and II.

DECENTRALIZATION AND DEVOLUTION

Whenever the size in area and population of the jurisdiction served by an administrative system is large, the adjustment of general policies and standards to varied local or otherwise specialized circumstances constitutes a major problem. If too great freedom is given to officials to adjust standards to the particular instance, effective general legislation becomes difficult or impossible, and programs may get distorted and special interests may injure the general good. Partisan, sectional, factional or other special favours and corruption may follow. And yet the particular knowledge of the persons whose life work is in an industry, or is concerned with a commodity or profession, or with a particular region or locality, should be employed if a policy is to be wisely administered. The states of the world have in all times, from ancient China or the Roman empire to the present, attempted to meet this problem either by leaving or giving some measure of local self-government to local areas, or by creating regional units in their central administrative agencies to which some discretionary powers for making decisions within the general rule for problems arising within the area are given.

A variant of the same principle is the assigning of powers for the administration of a statute or general policy of the state to a professional, commercial or industrial association or representatives of such interests. Thus, we may find, as in the Germany of the Weimar republic, not only Lander or member states within the Reich but local units within them and also an economic council. Similarly, in Great Britain, which we ordinarily think of as a unitary or relatively centralized state, there are county councils, rural district councils. boroughs and also boards possessing statutory powers in the steel industry or dealing with a commodity such as milk or bacon. In the United States the same problem of relating general policies to the particular situation confronted the constitution makers in 1787, resulting in a federal system, but persists to the present and indeed becomes more complicated as new units such as soil-conservation districts or local housing authorities are created with direct relations with national agencies.

The grant or taking of power by economic groups was advocated perhaps more strongly at about the time of World War I, and a political theory designated "pluralism" or "functionalism" had a period of success. It was indeed supposed to have been reflected in the doctrines of the Russian bolshevists and the fascists in Italy, as well as in the creation of economic councils in France and Germany. Probably local circumstances and situations in the latter two states, just as in the establishment of the National Recovery administration in the United States, with its industrial codes, had a much greater importance, while the Russian and Italian systems quickly revealed themselves as highly centralized single-party controlled governments struggling to secure and retain power and therefore in no position to yield power to regional or commodity or other groups except as forced by circumstances to do so.

The point is, however, that circumstances (*i.e.*, the increasingly complex nature of the activities that go to make up modem economy, the strong pull of neighbourhood and region and all kinds of provincialisms and the necessity to achieve political as well as administrative success for policies) do press for the adjustment of general policies to particular situations and do require the consultation at least by administrators with persons and organizations affected by those policies. It is characteristic of modern legislation affecting industry in some states, for example, that councils on which employers and employees, or members of a profession, are represented, participate in drafting rules and regulations under the act.

Relations of a national or central authority with provincial and local governments are made more complicated by the rise of metropolitan cities that spread over several separate political jurisdictions, the inequality of tax resources of local units, the pressure for national minimum standards of public services and the interdependence of economies. A partial answer to these conditions is found in the grants distributed from national funds to local units on condition of meeting certain required standards, with resulting inspection from the centre, generally entitled "grants-in-aid," and in the employment of officials of one level of government for enforcing the laws of another. The relation of levels of government remains, however, as one of the most difficult and perplexing problems of public administration.

CONTROLS AND STANDARDS

Obviously public administration is certain to be subjected to criticism in part because the objectives sought are disliked or the methods employed are viewed as unjust or inefficient or corrupt.

Over the centuries various devices for its control have evolved. These efforts are designed to confine it to the political objectives for which a particular administration is established, which we may call political control; or to ensure most economical and efficient methods, which we may call executive control; or to ensure observance of the accepted rules of fair conduct as understood by the particular society to apply to the relation of officials with the public, which we may call judicial control; but they necessarily intermingle, and broadly speaking, with the rise of representative government, a somewhat stronger emphasis inevitably was placed in most states upon political control. This is exercised through making the chiefs of administration politically responsible either to the legislature or to the electorate by some form of popular election.

Probably the most famous example of the evolution of political control is the wresting of power from the king and its allocation to a committee of party leaders representing a majority of the house of commons in Great Britain. This system, called "cabinet" or "parliamentary" government, was a model for most states to follow (with varying success). The U.S. "presidential" or "congressional" system makes the chief executive, except in city manager-council government cities, responsible to the electorate. Both systems, however, operate through parties; and at times the British prime minister takes on presidential attributes, and the U.S. president similarly at times plays a role in relation to congress somewhat akin to that of the prime minister in relation to the house of commons.

The more detailed devices of party and legislative control vary greatly; but most legislatures employ committee investigations of administration, scrutiny of budget estimates, the control over expenditure and audit and frequently the questioning of executive chiefs on the floor as well as in committee. These matters are usually topics of discussion at meetings of the Interparliamentary union, the conference of delegates from the legislative bodies of the states of the world.

Executive control is exercised through general staff and auxiliary services as described, and in modern complicated and large structures necessarily employs the techniques of the formulating of general standards, as of personnel, enforced by special auxiliary agencies. Probably the most important control is wielded through the analysis of budget estimates by the central financial control agency of the chief executive and his colleagues.

The struggle of legislatures first for independence of the monarchy and later for supremacy is paralleled historically in many states by a similar effort of the courts for independence; and in some states, notably the United States, the system of written constitutions and a federal distribution of powers has been the basis upon which has been constructed the exercise of judicial review not only of the acts of officials but of the constitutionality of the statutes whereby the officials may have justified their actions.

In many states, notably those influenced strongly by the traditions and precedents of the Roman law, a series of special courts evolved in which controversies involving official acts of civil servants are adjudicated, and the resulting case law, as in France, constitutes an important part of the public law. Administrative law is thus everywhere a branch of public and constitutional law that grows in importance as the extent and complexity of the functions of government increase. Questions of the competence of the authority, the adequacy and justice oi the procedure, the extent of the grant oi discretionary power, the adequacy of the evidence in support of the administrator's action and the finality of the administrative decision are typical issues. The study of comparative government, and in particular oi comparative jurisprudence and administration, is resulting in a greater familiarity on the part of scholars and of some practitioners with the similarities between different systems and a tendency to discover devices in one system that may usefully be adopted in another. Many precedents and theories framed long ago during the struggles with monarchy are being reappraised in the light of the contemporary complexities oi administration.

While legislative, executive and judicial controls are of basic importance, it should not be forgotten that in the daily life of the administrator his own knowledge, character and sense of persona1 and professional responsibility, constituting a series of inner standards and checks, are probably more immediately and intimately influential. Hence, the rise of professional organizations, of research, of in-service training, of journals devoted to administrative questions have increasing importance and constitute a proiessionai control which has operated, indeed, at times in all societies.

The increasing association of citizens through advisory committees with administration, and their sharing in fact with the exercise of some of the discretionary power in rule making, and the necessity for many types of administration of winning the understanding if not the active support of the citizen, characteristic increasingly of many types of administration, is another less recognized but important control over public administration. Many statutes and programs involve matters touching intimately the lives of great numbers of citizens; it is impossible to enforce them (as, for example, systems of social insurance or of highway safety or disease prevention) without extensive efforts to acquaint citizens concerning them. But in that process, the official is often educated himself as to attitudes, habits, capacities and problems of those whom he is supposed to serve; he is probably less concerned with possible legislative, judicial or even higher executive action regarding his work than with the people and problems immediately at hand. In this sense, we may consider administration as moving into a stage in which a two-way educative process is discernible; and while it may seem a far cry from the edicts of ancient rulers, one suspects that even they, too, had sometimes to consider how far they could go with subjects unaware of or opposed to their aims and measures.

BIBLIOGRAPHY.—L. D. White, *Introduction to the Study of Public Administration,* 4th ed. (New York, 1955), *The Federalists* (New York, 1948); John Stuart Mill, *Representative Government,* ch. v, xiv, xv (New York, 1910 *et seq.)*; C. D. Waldo (ed.), *Ideas and Issues in Public Administration* (New York, 1953); P. H. Appleby, *Policy and Administration* (University, Ala., 1949); R K. Merton, *et al, Reader In Bureaucracy* (Chicago, 1952); Louis L. Jaffe (ed.), *Administrative Law* (New York, 1954); Harold Stein (ed.), *Public Administration and Polzcy Development* (New York, 1952); Solomon Fabricant, *The Trend of Government Activity in the United States Since 1900* (New York, 1953); J. W. Fesler, *Area and Administration* (University, Ala., 1949); Charles McKinley, *Uncle Sam in the Pacific Northwest* (Berkeley, Calif, 1952); Coleman Woodbury (ed.), *The Future of Czties and Urban Development* (Chicago, 1953); D K. Price, *Government and Sctence* (New York, 1954); U. S. Commission on Intergovernmental Relations, *Report to the President* (Washington, 1955); *The Public Administration Review,* Am. Soc. for Public Adm. (quarterly).

(J. M. G.)

PUBLICAN: *see* LICENSED VICTUALLER.

PUBLICANI, the name given in ancient Rome to a body of men who either hired state property or monopolies to farm for their own profit or bought for a fixed sum the right to farm the taxes due to the treasury from the public land in Italy, or the land held by Roman subjects in the provinces. In early times the senate entrusted to officials the control of the sale of salt (Livy iii, 9), and it was a development from this that the state, instead of appointing officials to manage its monopolies, let out those monopolies to individuals. A regular system was established by which the censors who held office every fifth year placed the sources of public revenue in the hands of individuals or companies, who on payment of a fixed sum into the treasury, or on giving adequate security for such payment, received the right to make what profit they could out of the revenues during the five years elapsing before the next censorship. The assignment was made to the highest bidder at a public auction. The same system was applied to the public works, the *publicanus* in this case being paid a certain sum, in return for which he took entire charge of a certain department of the public works. That this system was well. established at the time of the Second Punic War is assumed in Livy's account of the various offers made by the wealthier class of citizens to relieve the exhausted treasury after the battle of Cannae (216 B.C.). On the one hand we have companies offering for branches of the revenue a price which was calculated rather to meet the needs of the state than to ensure any profit for themselves (Livy xxiii, 49). On the other hand individuals are represented as undertaking the management of public works on the understanding that they would expect no payment until the conclusion of the war *(ibid.* xxiv, 18).

Since wealth was a necessary qualification for the post, and wealth at Rome became more and more confined to the commercial class, the *publicani* became identical with the class of capitalists and traders. This was distinct at Rome from the senatorial class, which was excluded from it by definite enactment *(see* SENATE), 'and, except in face of common danger, was often hostile to it. It was in their capacity of *publicani* in the wealthiest provinces that the capitalist or equestrian *iudices (see* EQUITES) became a menace to the provincial governors who represented the senatorial power. When the demands of the equestrian party determined the policy of the state we can trace the interests of the *publicani* as the motive of its action. Thus the fate of the Roman businessmen in Cirta led to the Jugurthine war in 112 B.C.; the disorganization of Asiatic commerce by the pirates led the *equites* to support the proposal to confer extraordinary powers on Pompey in 67 B.C.; and the quarrel over the contracts for the taxes of Asia in 60 B C. led to the downfall of the senatorial party.

Under the empire the *publicani* were subject to close supervision. The name appears as "publicans" in the New Testament.

PUBLIC AUTHORITIES PROTECTION ACT (1893): see PETITION OF RIGHT.

PUBLIC ENTERPRISE. Although there is no standard definition of public enterprise, the term usually refers to government ownership and active operation of agencies engaged in supplying the public with goods and services which alternatively might be supplied by privately-owned profit-motivated firms (private enterprise). Typically, public enterprise operations. the same as private, are financed wholly or largely by receipts from the sale of goods or services.

There is no clean-cut distinction between public and private enterprise, however. Rather. the two concepts may be regarded as the opposite ends of a spectrum, with many mixed forms of enterprise between. On the private enterprise side, the chief motivation and focus of decision is making the maximum of profits for the benefit of owners and managers. On the public enterprise side, the chief emphasis usually is on the welfare of the whole community, rather than upon revenue. Honever. an important objective of many public enterprises in Great Britain and the United States is to produce net revenues for nonenterprise purposes. In the middle of the spectrum are such forms of enterprise as co-operatives (producer and consumer) not operated primarily for profit, and mixed enterprises in which the government supplies part of the capital or participates actively in management. or both.

There have been two basic questions respecting the development and scope of public enterprises in Great Britain and the United States. (1) Which goods and services are better provided under private enterprise and financed by user charges, and which are better supplied by ordinary governmental organizations and financed by taxes? (2) Where goods or services are provided, is public or private enterprise to be preferred?

On the first basic question, there is a case for charging for services or goods if the following conditions are met. (a) The service should be such that a charge (price) can be successfully imposed. Among other requirements, the service must be capable of division into measurable units, as kilowatts of electricity or gallons of water. (b) The immediate benefits of the service should go largely to the individual paying for it. If the community as a whole benefits from the service, there is an argument for financing it by general taxation. From about 1800 there has been a growing recognition of the public benefits attaching to many services (*e.g.*, education) and a corresponding increase in the number and scope of services financed by general taxation. (c) Charges should encourage economy in the use of resources. On the other hand, there is an argument against charges which result in the underutilization of already existing resources.

On the second basic question, there is in Great Britain and the United States a range of views concerning the proper role of government in economic affairs which parallels the range of enterprise forms. At one end is the view that all possible production and distribution should be in the hands of private profit-motivated firms; at the other end is the extreme socialist view that the state should own and operate the means of production.

The case for private enterprise, which found classic expression in Adam Smith's *The Wealth* of *Nations* (1776–99), has always rested on the proposition that private firms in a competitive system are more efficient and venturesome than government enterprise, because of the incentives afforded by the profit motive and the spur of competition, and because of their freedom from the restrictions of government bureaucracy. The case for state socialism has rested on a variety of propositions. Most important are the doctrinaire socialist assumptions that private ownership of the means of production results in inequitable distribution of income and wealth and exploitation of workers and consumers; that the profit motive encourages such unsocial conduct as monopolistic behaviour (see MONOPOLY) ; and that only the state can efficiently plan and direct economic production in the modern highly interdependent industrial society.

Ideological considerations have not predominated in the development of public enterprise in either Great Britain or the United States, except in Britain during the period of nationalization of industry under the Labour government (1945–51). In the main, public enterprises have been established to meet immediate and pressing needs, not as a part of any general plan for a socialized economy.

Public enterprise should be distinguished from other types of direct government intervention in economic affairs—including public regulation—which involve establishing rules of conduct for private firms and policies for stabilizing prices and maintaining employment.

Some government activities are difficult to classify. For instance. the large-scale housing programs both in the United States and Great Britain have been undertaken to promote the welfare of low-income groups. yet the major part of the costs of housing projects in both countries is made up by rentals of dwellings.

Development in the 19th and 20th Centuries.—With the exception of the enterprises operated by the post offices, there mas no instance of an entirely socialized industry in either Britain or the US. prior to the 1920s. The postal services have been generally recognized as appropriate areas of government enterprise and have been operated as government monopolies in both countries. In Britain the post office operates the national telegraph and telephone services, having taken over telegraph in 1869 and telephone in 1911. The U.S. post office during the past century has ordinarily incurred annual deficits, while the British post office, with a greater variety of services, regularly shows an operating surplus, part of which is turned over to the treasury.

Economic undertakings by governments were less common in Britain than in the U.S. during most of the 19th century. Powers of British municipalities to own or trade mere sharply restricted by legislation of the early 19th century, and for some time special acts had to be obtained even for such functions as street cleaning and lighting. The restrictions were in part responsible for the deplorable conditions of towns in the Victorian period. Toward the latter part of that century, the area of municipal enterprise gradually widened, partly as a result of the impact of Fabian socialist propaganda. which began in the 1880s. Such municipal services as sewage disposal, medical officers' and hospital services, vaccination, refuse collection and maternity care were first undertaken on a commercial basis. By the late 1800s, many local governments were starting, or taking over and developing, public utilities—water! gas, electricity and transportation, and later, airports. Ultimately, local authorities came to control about one-third of the gas and two-thirds of the electrical industries.

A forerunner of the public authority device was the Mersey Docks and Harbour board created under an act of 1857, which acquired ownership of the Liverpool and Birkenhead docks and assumed responsibility for conserving, lighting and buoying the harbour and control of pilotage. This organization pointed the way for other local public bodies, including the Port of London authority (1908), and the London Passenger Transport board, established in 1933 to take over the trams, buses, tubes (subways) and suburban railways of metropolitan London.

The national government in Great Britain took small part in public enterprise until after World War I, when a number of new enterprise forms and administrative techniques were developed. The principal new enterprises were: the forestry commission, established in 1919 for the purpose of creating and maintaining state forests to protect national timber resources and supply part of the timber requirements; the British Broadcasting corporation (1927), which monopolized radio and television broadcasting; the Central Electricity board (1927), to construct and operate an integrated national network of transmission lines; the British Overseas Aircraft corporation (1939), to develop and operate air routes outside the United Kingdom and Europe.

With the end of World War II and the coming to power of the

Labour party in 1945, British economy moved toward the socialist objectives of centralized planning and economic controls and nationalization of industry. During Labour's six-year tenure, the Bank of England, the coal industry, civil aviation, overseas telecommunications, electricity, transport, the gas and iron and steel industries were nationalized.

The principal purposes of nationalization, as formulated by the Labour party, were: (1) to remove concentration of economic power from private hands in the interest of a more democratic society; (2) to increase efficiency by expanding operations and improving organization' and interindustry co-ordination; (3) to improve labour relations and provide greater opportunity for promotion and worker participation in management; (4) to permit direct investment of public funds and to lower costs by substituting low interest-bearing government securities for private shares in companies; (5) to give the government greater power to combat unemployment through control over production and power to locate industrial plants in depressed areas; (6) to improve the periormance of private firms by using nationalized industries as models and holding out the threat of iurther nationalization; (7) to eliminate monopolistic practices and to substitute direct public action for regulation of private industries.

The Labour party disavowed any intention of 'taking over all industry, and the nationalization program (despite its ideological motivations) did not involve a drastic reconstruction oi the economy. Of the nationalized industries, electricity, gas, transport, civil aviation, telecommunications and central banking were already closely controlled, as in most advanced economies. Coal was failing rapidly under private ownership, and the way to nationalization had already been prepared by cartelization under close government supervision. Nationalization of iron and steel was the most notable, and most hotly opposed, departure from the private enterprise system.

In 1950, before the iron and steel industry was taken over, nationalized industries employed about 10% of the working population, distributed as follows:

Coal	735,000
Electricity supply	167,000
Gas	135,000
Transport, other than air	906,000
Air transport	24.000
Broadcasting	11,600

The Conservative party came to power in 1951 pledged to reduce economic controls and promote private enterprise. The iron and steel and most of the trucking industries were denationalized, in the face of labour's threat to nationalize them again when it next came to power. But later. government enterprise engaged in another large-scale program —the development of atomic energy ior commercial purposes under the U.K. Atomic Energy authority. Electricity produced by nuclear power was first ied into the national grid in 1956.

As experience accumulated, it appeared that nationalization had fallen short of its original objectives to such a degree that support for further nationalization notably waned, even in the Labour party.

The giant organizations that emerged from nationalization were far greater in scale than business-type organizations of previous experience; only the post office had been comparable in size. There were no precedents ior the type of management organization needed ior enterprise oi such scale or ior the pattern of relations and responsibility between public enterprise inanagements and responsibility between public enterprise managements and parliament. Too little attention had been paid to the many factors which limit efficiency in large organizations. The act of nationalization in itself did nothing to solve worker motivation, industrial efficiency, development of capital plant, adaptability to changing conditions and interindustry co-ordination.

To many workers, nationalization represented only the substitution of one control ior another. Hopes for improved conditions, reduction of income inequalities, greater opportunity ior workers and identification oi the workers' interests with those of the industry were not immediately realized. There remained the question of whether they could be better achieved under the giant public corporations than under smaller private corporations.

Underdevelopment in the United States led to much more government participation in public and mixed enterprise in the 19th century than was the case in Britain. But the responsibility for public improvements was left mainly with the states and the local governments. Except for land grants and financial assistance to transcontinental railways: the federal government did not contribute importantly to the development of public improvements in the 19th century. It participated in the ownership and operation of the first (1791–1811) and second (1816–36) Banks of the United States, and operated iur-trading ventures early in the century; otherwise its role in public enterprise was inconsiderable.

Most of the states and many local governments promoted internal improvements. Unsubsidized enterprise was less important than mixed enterprise in railway building until well into the 1900s. Railways were assisted by state constitutional or legislative provisions for state and local government assistance in the form of loans, stock subscriptions or outright donations. In some cases, the assisting governments actively participated in enterprise management, *e.g.,* Baltimore for many years was represented on the board of the Baltimore and Ohio Railroad company.

Most of the canal ventures were entirely public enterprise. The Erie canal, most important of the early improvements, a-as built and operated by the state of New York. The canal's success stimulated the undertaking of many other canals by states and municipalities. Few of these ventures were long-lived or successful, partly because of the advent of railways.

State governments also engaged in financial enterprises during the early 1800s. Several states established and operated banks, some of which were successful. However, losses on poorly planned and mishandled ventures subsequently led to many financial crises and the repudiation of many state and local government debts. As a result of such conditions many states amended their constitutions and enacted legislation to control public borrowing powers and otherwise to prohibit or restrict government participation in enterprise. In some cases, restrictions were later relaxed as a result of continued pressure ior improvements.

With the growth of cities and development of technology, many municipalities in the United States, as in Britain, began to operate water, gas, electric and public transport systems. In 1955, 74% of municipalities over 5,000 owned water supply and/or distribution systems; 21% owned and operated airports; and 20% owned electric generation and/or distribution systems. Only 1.5% owned and operated public transportation systems, but this number included six of the nation's twelve largest cities. In addition, local governments carried on a variety of other largely or wholly self-supporting activities which could be performed by private enterprise. Incinerator and sewage treatment plants, and such sports facilities as golf courses and swimming pools were common. Municipalities operated public markets, docks, piers, ice plants, coal yards, laundries, cemeteries, liquor stores and telephone systems; some established public corporations to construct and operate toll-financed facilities, including bridges, tunnels and parking lots.

State governments in the 20th century also experimented with various forms of public enterprise. The major enterprises in the 1950s were liquor distribution, insurance, transportation and electric power. Sixteen states operated state liquor store systems in 1954. These systems, all monopolies, served the double purpose of controlling the distribution of liquor and earning substantial revenues for the states. The most important state insurance systems (besides the unemployment compensation systems operated by all states) were workmen's compensation insurance systems, found in 18 states (in seven the state iund was a monopoly). Most states owned the harbour iacilities within their jurisdictions, including docks, wharves and warehouses. A state board of port commissioners operated many facilities serving the port of New Orleans, including grain elevators, coffee terminals, cranes and derricks, a belt line railway and a free trade zone. One of the largest enterprises was formed by a compact between New York and New Jersey, the Port oi New York authority, which operated the tunnels and bridges connecting New York city and New Jersey, the three major airports in the New York metropolitan area, a railway freight terminal, two truck terminals, a bus terminal, several docks and piers and other facilities. Faced with restricted taxing and borrowing powers, several states revived an ancient device, the toll road, as a means of providing needed highways. Toll highways had been built or were under construction in 10 states in 1952. Typically, they were operated by semi-autonomous authorities.

South Carolina, Oklahoma, Texas and Nebraska constructed multipurpose projects involving the production and sale of hydroelectric power. In Nebraska, all production and distribution of electricity was handled by two public power districts. In New York, the state power authority has been given responsibility ior developing and distributing power from large projects on the St. Lawrence and Kiagara rivers.

The U.S. federal government also entered into a number of ventures in the 20th century; by 1950 it owned or was financially interested in approximately 100 enterprises in five major categories: (1) transportation, (2) loans and insurance, (3) enterprises concerned with public lands, (4) miscellaneous manufacturing enterprises and (5) production and distribution of electricity. Most oi the enterprises were established or acquired before World War II.

The government's first major enterprise (other than the post office) was the Panama canal (*q.v.*) and associated enterprises of the Canal Zone, including a railway, fueling plants, public utility systems and other facilities. Other transportation enterprises included the Alaskan railway (begun in 1914); construction and operation of merchant ships, under programs designed mainly for war and defense purposes; operation of barges on the Mississippi, Missouri, Illinois and Warrior rivers—begun during World War I to supplement railway transportation and sold to private interests in 1950.

Many of the federal loan programs, established during the depression' of the 1930s, were designed to assist farmers, home builders and buyers and business firms unable to obtain credit at suitable terms from private sources. The Reconstruction Finance corporation specialized in business loans, and from 1934 to 1954 when it mas terminated, was the nation's largest lender. It was succeeded by the Small Business corporation, with the main function of lending to small firms.

Important insurance agencies include the Federal Housing administration (1934), which insures home mortgages held by financial institutions; the Federal Crop Insurance corporation (1938), which insures crops against natural risks; and the Federal Deposit Insurance corporation (1933), which insures bank deposits up to $10,000.

In its capacity of landlord, the federal government sells rights and privileges to private interests, builds and operates irrigation dams and ditches, operates recreation facilities and carries on numerous other business activities.

Most of the articles manufactured by federal government agencies are ior internal consumption; they range irom naval ships to mail bags. A feu· enterprises sell manuiactured goods to the public, notably the Government Printing office and the Virgin Islands company—organized in 1934 to promote employment—which produces sugar, molasses and rum. During World War II, the government built synthetic rubber plants and a tin smelter, iormer major sources of rubber and tin having been cut off by enemy conquests in southeast Asia. The rubber plants were eventually disposed of to private interests.

The federal government's interest in the production and sale of electricity initially stemmed irom irrigation and flood control projects which could also generate hydroelectric power. In 1906, congress authorized the sale of such power, specifying that preference be given to municipal interests. Activities were on a small scale until the 1930s, when a number of projects were initiated for the development of river valleys; mainly on the Tennessee, Colorado and Columbia rivers, involving such iunctions as flood control, navigation, irrigation and water supply, in addition to power production *(see* **Electric** Power: *United States).*

Under the New Deal and World War II programs, power became increasingly important; hydroelectric facilities were expanded and supplementary steam plants were added to the great federal systems. Federally-owned enterprises in 1930 produced less than 1% of the nation's electricity; in 1954, 12½%.

In the mid-1950s, public enterprise in the United States accounted for less than 2% of the national income. As in Great Britain, the philosophy of the national government administration was antipublic enterprise. However, expansion of the government role appeared inevitable. One reason was the great potential of industries based on nuclear physics and nuclear chemistry, the development of which is directed by the Atomic Energy commission. By 1956, the commission's investments in facilities amounted to approximately $9,000,000,000.

Most public enterprises in the United States and Great Britain are operated by public corporations which own property and are managed by boards or commissions appointed in Britain by the government, and in the U.S. by the chief executive, o'ften with the concurrence of the legislative bodies. A leading problem in both countries has been the working out of democratic controls which assure efficient management, the devotion of enterprise policies to the public interest and accountability ior the use of public funds; while preserving independence from irresponsible political meddling and the complex operating restrictions imposed on regular government agencies, and freedom to meet current situations.

Bibliography.—Commission on the Organization of the Federal Branch of the Government, reports on *The Post Office* and *Federal Business Enterprises;* reports of task forces on *The Post Office, Lending Agencies* and *Revolving Funds and Business Enterprises of the Government* (Washington, D.C., 1949). Clair Wilcox, *Public Policies Toward Business* (Homewood, Ill., 1955). Warren M. Persons, *Government Experinzentation in Business* (New York, London, 1934). Edward Goodman, *Forms of Public Control and Ownership* (London, 1952). William A. Robson (ed.), *Public Enterprise* (Chicago, London, 1937) and *Problems of Nationalized Industry* (New York, London, 1952). (L. C. F.)

PUBLIC HEALTH.

Elementary efforts to control epidemic disease are mirrored in the early pages of recorded history. The books of Leviticus and Deuteronomy give a fairly complete picture of isolation and quarantine procedures for dealing with "leprosy" and basic essentials of community sanitation. The Romans built great public water supplies, sewers and bath houses. The epidemic of plague in the 14th century led to the establishment of quarantine stations at the principal ports of Europe.

The public health program, in a broad and comprehensive sense, was initiated by Edwin Chadwick's report on *The Sanitary Condition of the Labouring Population of Great Britain* (1842) as a result of two forces set in motion during the 18th century. The first was the development of the fundamentals of modern science, which made it clear that the forces of nature may be controlled by man; the second was the humanitarian movement, which gave a powerful impulse toward the application of such knowledge. First based on primitive empirical theories with regard to sanitation, the public health movement was given its scientific direction by the germ theory of Louis Pasteur and by Robert Koch's isolation of the tubercle bacillus in 1882.

By the beginning of the 20th century, the first two phases of the modern public health campaign were launched: (1) the purification of nater supplies and control of the disposal of wastes and of insect carriers of disease and (2) scientific isolation and quarantine practice and immunization by the use of vaccines and serums. About 1910 the founders of the movement for the control of tuberculosis inaugurated the third and fourth phases by developing programs of health education in the principles of personal hygiene to build up the vital resistance of the human body and by establishing clinics for the early diagnosis and preventive treatment of incipient disease. Movements for the control of venereal diseases and infant mortality, mental disease, heart disease and cancer quickly followed. The visiting nurse became a public health nurse. a messenger of health as well as a minister of healing. The physician became a builder of health and not merely a repairman for disease. The boundaries between preventive and curative medicine began to disappear.

Finally. as the middle of the 20th century approached, the fifth phase of public health opened with a new and vital interest in social and economic factors as they relate to housing, nutrition, medical care and social security.

In the United States, early emergency boards of health were created to deal with imminent threats of epidemics or with particularly offensive nuisances. Boards were created in many large cities in the face of yellow fever epidemics in the early 1800s. Several of these—as in Baltimore, Md., New York city and Philadelphia. Pa.—were made permanent. and Baltimore has probably the oldest health organization with a continuous history, dating back to 1793. It was, however, the reorganization of the New York city board in 1866 which keynoted the more modern developments. H. M. Biggs in New York and C. V. Chapin in Providence, R.I., were outstanding pioneers. From 1915 the American Public Health association rendered notable service in studying and standardizing the techniques of health administrative practice.

(C.-E. A. W.; R. M. Ar.)

UNITED STATES

Local Health Services.— An authority on public health in the United States. Harry S. Mustard, in *Government in Public Health* (New Tork: The Commonwealth Fund and the Harvard University Press, 194j), stated that

> The vast majority oi routine health service received by the people of the United States is delivered by local agencies. The Federal Government may subsidize and indirectly shape local health departments, the state health department may determine major policies for local agencies. set standards, promulgate regulations, and even directly supervise them, but the final determining factor in the effectiveness of a public health program rests with the workers in the locality where the problems are occurring.

The size and scope of local health programs vary, but following are some of the typical functions: (1) control of communicable and chronic diseases; (2) operation of clinics for mothers and children and for various preventive and diagnostic services; (3) provision of public health nursing services; (4) environmental health services, including inspection, supervision and sanitary control of water supplies, sewage disposal facilities, milk production and distribution and food-handling establishments; (5) public health education and information; (6) collection and analysis of vital statistics; (7) operation of community hospitals, nursing homes and rehabilitation centres; and (8) community health planning, consultation and co-ordination.

A modern local health department consists of a corps of health specialists. such as physicians, nurses, dentists, engineers, sanitarians, health educators, psychologists and medical social workers, and supporting technical, statistical and administrative personnel.

The 20th century witnessed a great expansion of local public health services in the United States. In 1915 only 14 counties had full-time health services. By 1953 more than 70% of the 3,070 counties in the United States (which included about 88% of the nation's total population) were organized for full-time local health services or were covered by state health district organizations. However, many of these units were operating with minimum or skeleton staffs.

In addition to the work of official health agencies, other local governmental and nongovernmental agencies often assume responsibility for special health services or activities. For example, boards of education may deal with school health programs, departments of public works with construction and maintenance of sanitation facilities, and welfare agencies with provision of medical and hospital care.

State Health Services.—Within a single state, health services may be dispersed among numerous separate agencies of state government. Every state. however, has a specific agency, usually termed the department of health, which is charged with over-all health responsibilities. State health work ranges from regulatory or advisory activities to the operation of certain direct services.

State governments usually carry on five types of health functions: (1) public health and preventive services. such as demonstrations of new techniques and programs, and supervision over utilities of public health importance; (2) medical and custodial care, such as the operation of hospitals for tuberculosis and mental illness; (3) expansion and improvement of hospitals, medical facilities and public health centres; (4) licensure for health reasons of individuals, agencies and enterprises serving the public; and (5) provision of financial assistance and technical consultation to local units of government for conducting health programs. In addition, most states maintain regulatory authority over most health matters and promulgate rules and regulations which are applicable throughout the state.

Federal Health Services.--Official federal health agencies are responsible for controlling interstate health hazards and for protecting the United States from communicable diseases from abroad. The public health service, for example, maintains inspection and quarantine services at ports of entry to the United States to prevent the spread of infectious diseases. Federal agencies also co-operate with other countries to reduce the danger and stamp out the sources of such infections wherever possible and, through the World Health organization and bilateral agreements, to help the governments of underdeveloped areas of the world to raise their health standards.

Other direct health functions of the federal government include protection of the purity, potency and sanitation of foods, drugs and cosmetics; control of serums, vaccines and other biological products; provision of medical and hospital care for certain designated beneficiaries of the federal government; and conduct and support of research, investigations and demonstrations in the causes, prevention and control of disease. Federal agencies also help, through grants-in-aid and consultative services, to expand and improve public health services throughout the country. Finally, they make national surveys and studies to identify health problems, to determine the need for health facilities and programs and to develop plans of action for meeting family and community health needs.

The U.S. public health service is the chief federal health agency, but several other agencies have health interests and responsibilities related to their broader functions. Prominent among these are the Food and Drug administration, the children's bureau and the office of vocational rehabilitation, all within the department of health, education and welfare, the departments of agriculture, commerce, defense, interior, labour, state and treasury, the Atomic Energy commission, the Federal Civil Defense administration and the Veterans administration.

Voluntary Health Agencies.—The work of official public health agencies in the United States is supplemented and reinforced by voluntary health effort. In the mid-1950s there were more than 20,000 separate agencies concerned with the promotion of public health and preventive services. Most of these agencies operated at the city or county level, but nearly 300 had state-wide activities and about 30 were national in scope. Supported largely through private sources, they make substantial contributions to public and professional education, to research and to programs of medical and hospital care in their respective fields of interest. These interests may centre on a certain specific disease, such as tuberculosis, cancer or poliomyelitis; on safeguarding specific organs or functions, such as vision or hearing; or on promoting the health of speciai groups, such as mothers and children, the aging or the handicapped.

Two other types of nongovernmental or voluntary health organizations in the United States are the agencies which provide hospital and medical care insurance and the nonprofit and proprietary hospitals. Finally, there are a number of other groups which contribute to total health services or resources in the United States. Among these are foundations, private laboratories. professional organizations such as the American Public Health association, schools and universities, industrial and labour groups and civic organizations.

Progress in Public Health.—There is great variety in the type, content, scope and quality of performance of health services in the United States. Moreover, these services are provided by a multiplicity of independent agencies. There is a unifying factor in public health work, however, which gives it form and structure and which makes substantial progress possible. For example, the three levels of government—federal, state and local (city or county)—represent distinct and separate entities. Actually, however, they constitute a working partnership for the protection and promotion of human health. Moreover. they work closely with voluntary agencies, with professional groups, with schools and foundations, with industry and labour and with families and communities to control disease and improve well-being.

As a result, the trend of both individual and community health in the United States has been consistently upward for many years. Measured by the gains in general and specific death rates, the improvement in health was remarkable. In 1900 there were 17.2 deaths from all causes per 1,000 population. In 1954 the estimated rate was 9.2 deaths per 1,000, the lowest in the country's history and the sixth consecutive year in which the death rate was below 10 per 1,000 population. The estimated infant death rate for 1954 was 26.6 per 1,000 live births, compared with 100 per 1,000 births in 1915. In 1935, for each 10,000 live births, 58 mothers died; in 1954 there were fewer than 6 maternal deaths per 10,000 live births.

There was a gain of nearly 20 years in life expectancy at birth after the turn of the century—from about 47 years to $68\frac{1}{2}$ years for the total population.

Most dramatic was the continuing success against communicable diseases, which descended steeply after 1900. In that year the infectious diseases accounted for about 4 of every 10 deaths from all causes. By 1953 the ratio had changed to about 1 of every 13 deaths.

The principal communicable diseases of childhood—diphtheria, whooping cough, measles and scarlet fever—were virtually eliminated as causes of death. Such other infectious diseases as smallpox, typhoid fever, pneumonia, gastrointestinal infections and trachoma were greatly reduced or put under effective control.

Tuberculosis mortality dropped about 95% in the first half of the 20th century in the United States, from a rate of 194 per 100,000 in 1900 to about 10.6 in 1954. From 1945 to 1951 the average annual decline for this disease rose to 10%, and after 1951 there was an average 21% drop in the death rate each year. The venereal diseases also responded favourably to modern control methods in the United States. The death rate for syphilis fell from 16 deaths per 100,000 in 1938 to about 3 per 100,000 in 1953.

Although the communicable diseases were by no means eradicated, the major health problem in the United States in the 1950s was chronic disease. These diseases had been on the rise for several decades. Together, cancer and diseases of the heart and blood vessels accounted for two-thirds of all deaths in the United States in 1954. These, plus diseases such as diabetes, arthritis, rheumatism and mental illnesses, as well as accidents, also caused the most disability, long-term illness and hospital care in the U.S.

Public health agencies in the United States are turning increasingly to the control of these diseases, to the problems of an aging population and to the health problems associated with a complex industrial and social environment. Among these are water and air pollution, hygiene of housing, accident prevention, the dangers involved in the widespread use of chemicals and ionizing radiation, and the promotion of mental health. (X.)

GREAT BRITAIN

The term "public health" as used in Great Britain connotes in the broad sense principles and methods which aim at promoting and safeguarding the health of the community in contradistinction to those nhich are concerned in the main with the treatment of declared disease in the individual It depends for its operation upon the study of disease in the group which is epidemiology. Public health is not synonymous with either preventive medicine or social medicine It makes use of both and seeks to apply all relevant scientific and medical learning to the prevention of ill health and disease and to the promotion of positive health.

Growth of Services.—The 18th century witnessed the early gron th of ideas. official and otheruise, to protect the health of people in Great Britain. Richard Mead of St. Thomas's hospital outlined the measures necessary to prevent the spread of plague in his *Discourse on the Plague* (1720); John Pringle in his *Observations on the Diseases of the Army* (1752), James Lind (1757) and Gilbert Blane(1785). in manuals about seamen, outlined the means to preserve the health of soldiers and sailors; George Baker(1767) studied endemic colic due to lead poisoning in cider drinkers. On the continent Johann Peter Franck from 1779 to the end of the century published the first complete textbook on the public health of a community. As the Industrial Revolution pained momentum the environment of the new conglomerations of human dwellings, particularly in the midlands and north, gave rise to increasing disquiet. Thomas Percival, a Manchester practitioner, emphasizing, as others had done before him the risks. particularly to mothers and children, of overcrowded town living and factory life, pioneered the first British hoard of health(1795).

During the early part of the 19th century when much of Europe had taken active steps to create some protection of the public health by the establishment. at least in the large towns, of councils of health, Britain. absorbed in political reform took no further action. The population grew fast, resulting in great congestion, industrial development produced new hazards especially to women and children, revolutionary changes in agricultural life vastly increased the number of paupers. and epidemics of infection with heavy mortality swept through the towns In 1829 cholera began to spread over Europe and reached Britain in 1831. A central board of health was set up, and attempts were made, not with much success, to establish local boards.

In 1834 the measures taken to reform the poor law were of great significance to the growth of public health, although this was not immediately apparent. Poor law reform was the result of a royal commission of which Edwin Chadwick nas a member and largely responsible for the report. Chadnick s scheme of a centralized machinery with local boards of guardians, very much that of Jeremy Bentham. whose declining years he had shared, was to influence the growth of public health services in Britain for nearly a century. The boards of guardians. operating universally over unions of parishes and made responsible for providing medical care for paupers, appointed medical men in an official capacity. Chadwick nho became secretary to the central Poor Law commission, relied upon this large new body of official medical opinion for his social survey *The Sanitary Conditions of the Labouring Population of Great Britain* (1842).

The boards of guardians were made responsible for the appointment of local registrars of births and deaths under the registration act of 1836, and in 1840 they became responsible for public vaccination. However, the baneful influence of poor lam upon public health was not in the mere fact that the poor law machine undertook these and other forms of public health. or even in that its existence delayed the creation of complete public health cover, but rather because of its dominating note of "repression" and "less eligibility," which were so long to deny the basic needs of public health In later years when the central administration of poor law and public health were fused (from 1871) in the Local Government hoard, poor law became a dominating influence and retained its mastery until the creation in 1919 of the ministry of health.

No sooner had Chadwick succeeded in his designs for refashioning the poor law than he realized that expenditure on the pauper and prevention of disease were two sides of a single coin. This was the burden of his 1842 report. His interests now changed almost wholly to public health. A barrister by profession. he mastered the elements of sanitary engineering. then a little-understood science. He came to the conclusion (1) that health depended upon sanitation; (2) that sanitation was an engineering matter; (3) that an arterial system of water and sewage. nhich alone could solve the problems of the new towns, must entail one local authority to administer all sanitary matters; and (4) that expert advisers in engineering and medical matters were essential. A royal commission appointed in 1843 to inquire "into the state of the large towns" consolidated Chadmick's findings. The course was now set for legislation. The Public Health act, 1848, which followed after an interval of long debate, established the General Board of Health with powers to create local boards.

Medical officers of health now began to be appointed, first under private acts of parliament to Liverpool (William Duncan, 1847) and London (John Simon. 1848). The Public Health act, 1848, authorized their appointment to all local boards. but the appointments were not made obligatory as had been advocated in Chadwick's report of 1842 and by the royal commission of 1843. In 1855 the 38 newly formed London vestries mere required to appoint medical officers of health, and many famous medical men took office. At first no special qualification was prescribed, although Trinity college in 1870 and Cambridge university in 1875 provided diplomas in public health, as regulated by the rules of the General Medical council in 1871. In the Local Government act of 1888 a clause was inserted requiring that after Jan. 1, 1892, every medical officer of health of a county or a district containing a population of 50,000 or more inhabitants should be not only legally qualified in medicine but also the registered holder of a diploma in sanitary science, public health or state medicine. By an order issued by the ministry of health in 1922, this requirement was extended to all medical officers of health.

The General Board of Health. a subject of much controversy, lasted ten years; in 1858 it was dissolved and the powers transferred to the privy council. It created about 183 local boards, covering 3,000,000 persons. This was a relatively small achievement in contrast with the poor law unions. At this time 276 towns with more than 5 000 inhabitants had no health authority. John Simon was appointed medical officer of health to the central government. He remained in office until 1876, witnessing many changes. In 1871 the Local Government board, with responsibility for both poor law and public health. was created. In 1872 the country was divided into sanitary areas. to become later the urban and rural districts, each with a medical officer of health. In 1875 the Public Health act, a charter in environmental hygiene. was passed. The 343 sections of the act were designed to secure (1) wholesome and sufficient water supplies; (2) prevention of pollution of water; (3) provision of sewerage; (4) regulation of streets, highways and new buildings; (5) health of dwellings; (6) removal of nuisances; (7) inspection of food; (8) suppression of disease; (9) sanitary burial; (10) regulation of markets. These were the recommendations of the royal commission of 1869. The Housing act. 1890, the first charter for working-class housing, required medical officers of health to report insanitary houses and areas and gave authorities powers. with appeal to the courts, of demolition and closure. Infectious diseases began to be notifiable (1875, 1889.1899), and many other acts were passed to further environmental hygiene.

By the turn of the century the machinery for dealing with the health aspects of the environment had been laid down and the long and often bitter struggle to remedy the ills of the Industrial Revolution was well advanced. Public health began to grow out into the fields of social medicine. The social surveys of Charles Booth (*Life and Labour of the People in London*, 1889–97) and Seebohm Rowntree (*Conditions in York*, 1901) and the findings of the 1904 interdepartmental committee on physical deterioration strengthened the growing belief in the importance of personal health care, as a counterpart of environmental hygiene. Attention turned first to maternal and child welfare. Infant welfare. with advice centres and trained nurses for home visiting and with antenatal clinics, became a function of the new county and county borough councils created in 1888. The Maternity and Child Welfare act (1918) required these authorities to "attend to the health of expectant and nursing mothers and of children under five years of age not yet at school." The Midwives act (1902), which established the Central Midwives board and began professional midwifery, made county and county borough councils responsible for supervision. The large authorities were also made responsible for the Education act (1907), which began the school health service; the regulations of 1912 and 1916 to establish tuberculosis and venereal disease services; and the Mental Deficiency act, 1913, which required the discovery and care of all mental defectives "subject to be dealt with." Births became compulsorily notifiable in 1915. Two further subjects of great importance to public health, factories and children, were dealt with at this time by the Factory act, 1901, and the Children act, 1908. With the growth of county government, public health functions were divided under separate jurisdiction; environmental hygiene was the duty of the smaller authorities and personal hygiene that of the county council. This dichotomy did not occur in county boroughs.

National health insurance (1911) was at first to have a much deeper significance than that which would arise out of the provision of public medical care. with medical, sickness. maternity, disablement and sanatorium benefits for 16,000,000 workers. It was to be the basis of a new approach to public health in which every doctor in the course of his public work would be concerned to seek out adverse social and environmental factors. The insurance committees. it was supposed, could claim compensation for excess sickness due to remediable factors, where these had been neglected. The Insurance commission, an ad *hoc* body, at the centre. and the insurance committees at the periphery with public health functions, whimsically devised, were testimony to the great dissatisfaction felt with the Local Government board, whose undesirable poor law outlook still persisted 3j years after Simon's resignation.

The same dissatisfaction was expressed in the separate office of the registrar general, in the powers of the privy council both under the Midwives act and for research, in those of the Board of Control under the Lunacy act. and those of the home office under the Children's act and the Factory act. The final eradication of poor law influence at the centre was effected in 1919 by the creation of a ministry of health. with a medical man (C. Addison) as its first minister, a chief medical officer (George Newman) with direct approach to the minister and a permanent secretary (Robert Morant), formerly chairman of the Insurance commission. The new ministry took over most central functions concerned with health. Unfortunately the Board of Control remained in charge of lunacy. It was not until the National Health Service act, 1946, that mental health took its rightful place alongside physical health as a subject for preventive medicine. The home office likewise remained responsible for industrial hygiene, and this service, now under the ministry of labour, was, in 1955, still separately administered.

The ministry of health introduced a scientific approach, hitherto lacking, into public health. It also began to give encouragement and advice to local authorities. Medical officers of health found themselves at last sympathetically linked with the centre. Newman's admirably written annual reports set a new tone and embodied a new spirit of preventive and social medicine. The ministry was advised by a consultative council under a first chairman, Lord Dawson of Penn. This committee produced (1920) the interim report of the Consultative Council on Medical and Allied Services, the first plan for a national health service in which health centres were to play a prominent Dart.

Public health, both environmental and personal, now advanced at a great rate. A succession of Housing acts, 1921, 1923, 1924, 1930, 1935 and 1936, began a spate of new building and slum clearance; the Tuberculosis act, 1921, extended sanatorium benefit to everyone; the Mental Treatment act, 1930, introduced outpatient clinics and voluntary treatment as recommended by the 1926 royal commission on lunacy and mental disorders; the Midwives act, 1936, required all counties and county boroughs to establish midwifery services; existing legislation was consolidated by the Public Health act (1936), the Housing act (1936), the Factories act (1937) and the Food and Drugs act (1938).

In 1929, 650 boards of guardians were abolished and the functions transferred to counties and county boroughs, with a strong recommendation to give assistance wherever possible by other means than poor relief. Poor law infirmaries became the municipal hospitals (the London County council took over 76 institutions with 42,000 beds). Public health now sought to humanize the poor law, hospitals, children's homes and infirmaries, a vast undertaking that was little more than begun before World War II. The Local Government act, 1929, also required county coupcils to frame proposals, in consultation with district councils, for the appointment of full-time medical officers of health precluded from private practice. In the 25 years following this act the reorganization of county public health administration proceeded gradually. For the country as a whole there were in 1955 about 600 medical officers of health in senior positions, of whom about 150 were part-time. A further 1,200 doctors, mostly with diplomas, were employed whole-time, as deputies (119), as senior medical officers (156) and as assistants (981).

After World War II public health was, as it were, engulfed in the flood of social legislation. Acts dealing with education (1944), family allowances (1945), national insurance (1946), national insurance (industrial injuries) (1946), national health (1946), town and country planning (1947), national assistance (1948) and children (1948), all provided the framework of the welfare state in which the problems of community health had to be reassessed. The emphasis of public health began to shift toward the social aspects of disease, a change which was accelerated by the transfer of hospitals to a new authority and by the provision of comprehensive free medical care.

Changing Character of Public Health **Problems.**—*General* Health.—The public health picture of Great Britain has changed over the course of about 200 years from that characteristically exhibited by an "underdeveloped" to that of a "developed" country. High mortalities coupled with a high birth rate, which tended to maintain a small stationary population of about 8 000,000 with large numbers of children and few aged persons, have been replaced by low mortalities and a low birth rate; the present population of about 50,000,000 is again static, with fewer children and more aged persons. In the middle of the 19th century, of 1,000 persons, 66 were aged 65 years and over and about 340 were children under 1j; in 1953 there were 224 children and 113 aged persons in every 1,000. The expectation of life had advanced from around 30 to 40 to between 60 and 70 years. The high specific death rates of the major infectious diseases had diminished to near vanishing point. Of 500,000 yearly deaths. only 12,700 were (1953) attributable to notifiable infectious diseases, and of these 70% were attributable to tuberculosis. The death rate from tuberculosis, which remained a major menace, had declined during the preceding century from 3,000 per 1,000,000 of the population to 200, and as a cause of death it had changed in the incidence of its greatest danger from the young, particularly female, worker to those over 45 years of age.

Infant mortality had declined from near 250 to 28 and the stillbirth rate, since first registered in 1928, from 38 to 22. The largest part of this enormous reduction related to deaths of infants after the first month of life. Of the remaining infant deaths 60% were the result of immaturity and congenital malformations. Thus the major loss of infants had become perinatal; *i.e.*, occurring before, during or shortly after birth. The decline of deaths in children was equally spectacular. William Far', the first compiler of statistics to the registrar general after the Registration of Births and Deaths act, 1836, recorded that between two and three out of five children died before reaching five years of age. The mortality of children from birth up to four years fell from 66 to 6.36. and for children of five to nine years from 9.05 to 0.49, per 1,000 living between 1841–jo and the mid-1950s. In 1850, 64%, and in 1953, 4%, of total deaths were in children under five years of age.

Ninety per cent of deaths in 1953 were in persons over 40 years, 75% in those over 60 years and 50% in those over 70 years. Rather more than half the deaths (255,940) were attributable to diseases of the circulatory system. Neoplasms accounted for 89,860 and diseases of the respiratory system for 62,347. Thus, four out of five deaths were now attributable to conditions that were basically caused by the processes of wearing out. Infectious disease, although not the cause of high mortality, still occasioned much morbidity. The returns of the ministry of national insurance (1952) showed that 41,260,000 days were lost (*i.e.*, more than 25% of the total) from influenza, bronchitis, pneumonia, acute pharyngitis, tonsillitis and the common cold. Most of this resulted from viral conditions.

The amount of mental illness exhibited in psychoses, neuroses and psychosomatic disease is almost certainly very great, although from lack of information there is no exact knowledge. Half the number of hospital beds are filled with patients suffering from mental illness; a large fraction of the absenteeism from industry is attributable to neurosis or psychosomatic disease.

Social, *Occupational* and Geographical Differences.—Disease and death vary greatly in different areas and occupations and among sections and groups of the population. In general the north suffers more. Rural areas of developed counties are more healthful than towns for persons over 40. In particular the toll of degenerative disease is lower in the country. Infant mortality in Britain increases proportionately with density of living. Widely divergent mortalities of various occupations reflect the different nature of hazards: for example, the standardized mortality ratio of agricultural workers is half the average for all workers. whereas that of slate quarry workers is three times as great. Many diseases also vary with social grouping; for example, infant mortalities, including stillbirths and premature births, increase from the professional classes to the unskilled worker; in contrast, coronary thrombosis takes the opposite course.

National Health Service and Public Health.—The Beveridge scheme for social security, which sought to abolish poverty by comprehensive insurance, was based upon the assumption that there would be a national health service designed to reduce sickness, and its disabling effects, to a minimum. The National Health Service act of 1946. which came into operation on July 5, 1948, provided free medical care by general practitioners and in hospital. The service incorporated mental health by placing all the functions of the Board of Control, other than judicial, in the ministry of health and by making local authorities responsible for prevention and aftercare. Unfortunately the industrial medical service was not included and school health remained the function of the education authorities.

Part iii of the National Health Service act placed a variety of duties upon county and county borough councils, acting as local health authorities. These duties were designed to emphasize the expanding functions of public health in the fields of social medicine. They included (1) the provision of a health visiting service to give "advice as to the care of children, persons suffering from illness. and expectant and nursing mothers, and as to the necessary measures to prevent the spread of infection"; the health visitor's work was thus extended to the whole family and the opportunity was given to integrate her social work with medical care by the family doctor; (2) the provision of a home nursing service for those "who require nursing in their own homes"; (3) the provision of a home help service "for providing domestic help for households where such help is required owing to the presence of any person who is ill, lying-in and expectant mother, mentally defective, aged or a child . . ."; (4) responsibility for "the prevention of illness. care of persons suffering from illness or mental defectiveness or the after care of such persons." For the new work in mental health authorized officers were appointed for problems concerning removal to hospital and mental health workers for aftercare work.

The National Health Service act brought about far-reaching changes in the interpretation of public health. Emphasis came to be placed upon the social aspects of disease that can be seen in the new attention to the aftercare of patients leaving all types of hospitals; in the development of a partnership with family doctors for care in the home; in the increasing attention paid to mental health through infant nelfare and antenatal clinics and by aftercare schemes; in the growing understanding of the social aspects of handicaps such as epilepsy, mental deficiency and physical defo ities; in the arrangements, in conjunction with welfare, for the social care of the aged; in arrangements to detect the problem family and to prevent its downhill progress. The medical officer of health of the second half of the 20th century had become a social physician, the partner. not the antagonist as often in the past, of his colleagues in hospital and general practice. Developments in this neu field had been much assisted by the remarkable achievements of social security. backed by national assistance, in eliminating poverty and by the parallel development of free medical care.

The local administration of the service for national health in three distinct parts, hospitals under regional hospital boards, general practitioners under executive councils and public health under local health authorities, proved a handicap to the full development of the social and preventive approach. This could be seen in many different spheres. as, for example, in antenatal care, which could now be given from four different sources—by the midwife, the general practitioner, the welfare centre or the hospital. The difficulties were enhanced by differences of finance, boundaries and electoral systems. Hospital boards and executive councils obtained their money from the treasury, whereas health authorities were supported by the local rate with block grants from the treasury.

Executive councils and health authorities covered the areas of counties and county boroughs. whereas the hospital boards. 14 in England and Wales, covered wide areas often cutting across local government boundaries. Health authorities were elected by popular franchise, whereas hospital boards and executive councils were selected by the minister. Another handicap was the continued dichotomy, within counties, of public health functions, but administrative devices, including divisional administration in counties by the employment of the same medical officer for local and county work, were overcoming these handicaps.

U.S.S.R.

Public health in Russia was almost lacking until the late 19th century. The beginning is to be seen in the introduction of local government by Alexander II in 1864, when district assemblies, known as zemstva, became responsible for organizing medical services in rural areas. The development of local government physicians to give free medical care. of whom there were about 2,000 in 1892, was a remarkable achievement. These salaried doctors formed themselves into public health councils. to advise the district assemblies, but medical care and public health continued at a low level. About 1900 there was an average of one physician to 25.000 persons. In 1918 was formed a commissariat of public health the equivalent of a British or French ministry of health, with more complete control over all aspects of health. The Soviet republics, created in 1922 under the constitution ratified in 1923, established commissariats or ministries throughout the union. In 1936 a central department for the union was established to co-ordinate the health work of the republics. The evolution of services proceeded in a series of five-year plans, which prescribed development schemes for all medical departments. institutions and industries. By 1950 the facilities available for the whole union were approximately as follows: hospital beds 1,470,000 (*i.e.*, about 7 beds per 1,000 persons); medical centres 31,880: tuberculosis dispensaries 1,192; venereal disease centres 1,498 (1941); maternal and child welfare centres 6.190.

Polyclinics—in essence the envisaged health centres of the British system—are designed not only to give medical care but to prevent disease and to promote health. They exist in every district and in every factory of more than 5,000 workers, and the majority of Soviet physicians occupy posts in them. In rural areas they are combined with hospitals and are supported by smaller units in the villages. There are also dispensaries, either associated with polyclinics or separate from them, and serving wide territories, to deal with particular conditions or diseases. From the polyclinic the district visiting physicians undertake therapeutic and prophylactic work. One of the objects of the polyclinic system is to provide frequent medical examinations and yearly "dispensarizations." The term "dispensarization" denotes a full examination by a team of specialists.

Administration.—Under the ministry of health of each republic there exist regional, district and village health departments, each with an elected committee. The health department is in charge of all medical activities both curative and preventive. Village committees supervise local sanitary facilities. undertake health education and a variety of social functions; they appoint guardians for the insane; blind, deaf and dumb and disperse insurance benefits. District committees, of which there are about 3,000 averaging 70,000 population, have a health officer as do also at a higher level the regional committees 'and the autonomous republics that exist within many of the union republics. Larger cities have a status of their own and many have separate divisions. The standards of the polyclinics, the framework of the whole organization of public health and medical care, are laid down by the union ministry to be administered by the republic ministry through a special department; the day-to-day work is conducted by the regional and district health departments. The degree of autonomy of the local committees is restricted.

Special Services and Health Education.—The school health services and maternal and child welfare services, particularly the latter, have been elaborately planned. Antenatal care, preparation for childbirth and insurance safeguards seem to be universal. Occupational health appears to have received considerable attention, with 25 medical institutions for the study of occupational diseases and by the extensive use of industrial polyclinics. The development of services for industry has no doubt been assisted by an industrial expansion which makes use of large factories. Labour codes to protect women and children and limitation of hours of work seem to resemble those of Britain and the U.S.

Health education is regarded as one of the most important means to prevent disease and to promote health. A special department of the union ministry is guided by a central institute for research in health education; routine work is conducted through committees in villages, farms and apartments. A strong cult of health can be seen in many different mays; e g, in the attention given to sports and physical culture, and in the rest homes to which large numbers are admitted yearly for active rest under medical supervision and which form an interesting part of the public health system

Health in the **U.S.S.R.**—Before World War I, Russia exhibited the characteristic health picture of an underdeveloped country, with high general mortality and birth rates, high infant and child mortality much infectious disease with heavy mortalities, low expectation of life and the balance of population weighted toward the younger end. The general death rate averaged 28–30, the infant mortality about 250, and 98% of women had no medical care at childbirth. The present state of public health is largely a matter of conjecture, since published information is scanty. Statements which have appeared in the Russian press suggest a general death rate of 9 in 1953 and an annual excess of births over deaths of 3,000,000 in the period 1949–51.

t'accination against smallpox and tuberculosis and immunization against diphtheria are compulsory. The age structure of the population is probably similar to that of Great Britain in the 19th century. Infant mortality is said to have declined substantially but the exact figure is not stated. It has been claimed, on slender evidence. that there is much less mental ill health in the Soviet Union than in other European countries; on one estimate only 3 per 1,000 have serious mental disorder.

BIBLIOGRAPHY.—*Annual Reports* of the chief medical officer, ministry of health, of education and of pensions and national insurance; M Greenwood, *Epidemics and Crowd-Diseases* (London. New Tork, 1935); S E Finer, *Thr Life and Times of Sir Ed-win Chadwick* (London, 1952); J. M. Mackintosh, *Trends of Opinion About the Public Health, 1901–1951* (London, 1953), W. M Frazer, *A History of English Public Health, 1834–1939* (London, 1950; Baltimore, 1951); C. Fraser Brockington, *The Health of the Community* (London, 1954)

(C. F. BN.)

INTERNATIONAL PUBLIC HEALTH ACTIVITY

Historical **Development.**—International action in the field of public health had its origin in attempts to lessen the inconvenience caused by the wide variety of quarantine laws that had developed over several centuries throughout the countries and ports of Europe. By the middle of the 19th century these had become an intolerable nuisance to the expanding steamship routes. The first international sanitary conference was held in Paris in 1851. Before the turn of the century ten such conferences had been held at Paris (1851, 1859), Constantinople (1865) Vienna (1874), Washington (1881), Rome (1885), Venice (1892). Dresden (1893), Paris (1894) and Vienna (1897). By 1890 knowledge of the epidemiology of infection had advanced sufficiently to make it possible to limit the spread of certain diseases. Particular attention was paid in 1892. 1893 and 1894 to the spread of cholera and in 1897 to plague, spread by the Mecca pilgrimages.

In 1903 the first effective convention. as the Lancet said. "to realise and not to theorise," codified previous work: yellow fever was discussed for the first time since the discovery that the mosquito was a carrier As a part of these early arrangements and to some extent preceding them, two regional organizations had been created at Alexandria (1831) and Constantinople (1839) at nodal points of epidemic spread. In 1902 the Pan American Sanitary bureau (originally named International Sanitary bureau) with headquarters at Washington, D.C.. was formed. The first effective office of epidemic intelligence to cover the nhole globe. however. was the Office International d'Hygiène Publique (the "Paris office"). established under an agreement signed Dec. 9, 1907. This centre proved to be effective and although regulated further by revisions of the conventions in 1912, 1926, 1938 and 1944 it continued. undisturbed by later developments elsewhere. until after World War II. Information was distributed through a monthly bulletin and by other publications. The Pan American Sanitary code, in 1924, required the notification to Washington of ten diseases. By 1926 international conventions had extended world-wide control to cover yellow fever, cholera. plaque typhus and smallpox. In 1933 a convention on air navigation was signed.

Health Organization of the League of Nations.—The scope of international public health was widened in 1923 by the creation of the Health organization of the League of Nations. From the new centre at Geneva, Switz., an epidemic intelligence system of greater efficiency was gradually produced. In addition to the Paris office, which continued to function, regional bureaus were set up in Washington Alexandria. Singapore and Sydney. The bureau at Singapore. a focal point in trade routes. was of great value as an intelligence centre for the east. Within the limits of a slender budget. never exceeding E78 500, the Health organization of the League was able also to give some practical assistance, particularly in Greece and China, toward the control of epidemic spread.

For three-quarters of a century international health thus concerned itself mainly with the spread of infectious disease. The time had come to consider international health in a wider sense. The Geneva office extended the work to international standards for the preparation of various biological materials and to international codes of vital statistics; it took an active part in technical discussions on the control of opium. The Commission on Standardization of Sera. Serological Reactions and Biological Products introduced uniformity of potency for the protective serums, hormones and antibiotics The League's Committee of Statistical Experts helped to carry forward the standardization of causes of death which had begun as long ago as 1853, with the first international statistical congress at Brussels The Geneva office also organized international study tours, and it began the system of expert committees. Committees sat to study malaria, cancer leprosy, housing and nutrition. Their findings were to prove of far-reaching importance to public health everywhere. International conferences on rural hygiene (Europe, 1931; far east. 1937) produced %ell-documented statements. There were also two pan-African health conferences. The League was helped in much of its work by the international health division of the Rockefeller foundation.

UNRRA.—World War II greatly interfered with the work of the Paris and Geneva offices. In 1943 UNRRA (the United Nations Relief and Rehabilitation administration) was created to help the devastated norld. For somewhat more than two years. UNRRA acted as an international health organization, with a staff of 1,134 persons. including nationals of 35 countries. It spent more than £58,000,000 and helped the health departments of liberated countries with both advice and practical aid. It administered the maritime and aerial quarantine conventions (1944), which brought up to date the older conventions of 1926 and 1933. These required each signatory nation to notify UNRRA of outbreaks of all communicable diseases which might be a menace to other countries, including the prevalence of the yellow fever mosquito and *Aedes aegypti,* and to report the measures taken to combat their spread. Disinfection, deratization, provision of safe water, destruction of mosquitoes, delousing and vaccination against smallpox could be ordered.

World Health Organization. — In 1946 the Interim commission of the World Health organization. which followed an International Health conference of more than 60 states convened by the United Nations at New York city, took over the functions of UKRRA. A permanent World Health organization, supported at first by 54 states, came into being on April 7, 1948. This absorbed, in addition to UNRRA, both the Paris office of epidemic intelligence and the Health organization of the League of Nations WHO thus became the sole international health organization, excepting the Pan American Sanitary bureau, which continued to work independently but in close association with WHO. In 1947 the U.S.S.R. and the other Cominform countries withdrew from active participation in the work of WHO.

The World Health organization operated, with a high degree of autonomy, as a specialized agency of the United Nations. It had offices in New York city. to maintain liaison with the United Nations and other agencies. but the bulk of the work was carried on by the staff at WHO headquarters in Geneva. The organization was directed by the World Health assembly, which met annually and in which all members might be represented, and by an executive board of 18 persons, representing 18 nations, of whom one-third retired each year. The administration was conducted by a secretariat, headed by a director-general, with 11 divisions as follows: (1) public information, (2) co-ordination of planning and liaison, (3) communicable disease services. (4) organization of public health services, (5) professional education and training services, (6) health statistics, (7) epidemiological services. (8) therapeutic substances, (9) editorial and reference services, (10) management and personnel and (11) budget and finance. There were six regional offices for Africa, the Americas, the eastern Mediterranean, Europe, southeast Asia and the western Pacific.

Article i of the constitution of WHO defined the organization's objective as "the attainment of all peoples of the highest possible level of health." This was to be regarded "as one of the fundamental rights of every human being without distinction of race. religion, political belief, economic or social condition" (preamble). "Governments," according to the constitution, "have a responsibility for the health of their peoples which can be fulfilled only by the provision of adequate health and social measures" (preamble). The relatively small budget, which had risen by the mid-1950s to more than $9,000,000, proved insignificant in comparison with the vastness of the field to be covered. It was spent in (1) giving direct help. (2) publishing information of world-wide significance and (3) organizing expert committees and international conferences to further knowledge of public health matters. Direct help was given in the form of expert guidance, with or without technical aid. In the main the help provided was designed to stimulate further activity. Assistance was given over a wide field; for example, in infant mortality, malaria or syphilis where these presented particular problems. Malaria, tuberculosis, venereal disease, maternal and child welfare, nutrition, environmental sanitation and mental health were given priority in the planning program.

Publications included a newsletter, the *Chronicle;* weekly, monthly and quarterly bulletins of vital statistics; a quarterly digest of health legislation; a quarterly *Bulletin,* the principal scientific periodical; and, in a "Technical Report Series," the findings of expert committees. Committees reported on malaria, tuberculosis, venereal diseases, school health, adoption, alcoholism and mental health among other matters. Many of the international conferences proved of exceptional value; for example. that on malaria held at Bangkok in Sept. 19j3, which 50 persons of 20 different Asian countries attended to pool their experience and to plan programs. An important function of the annual meeting of the assembly was to hold technical discussions on outstanding public health problems, experts in different fields of work presenting their views to the delegates. The World Health organization made a great beginning. The objective of health for the whole world, as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity," still lies far ahead.

BIBLIOGRAPHY.—F. G. Boudreau in W. C. Palmer (ed.), *Nelson New Loose-Leaf Medicine,* vol. vii, ch. 1A (New York); Ruth E. Bacon, *ibid.,* ch. 1B; Ruth D. Masters, *International Organization in the Field of Public Health,* Carnegie Endowment for International Peace (Washington, 1947); *Epidemiological Information Bulletin,* vol. i (1945) and ii (1946); Neville M. Goodman, *International Health Organizations and Their Work* (London, Philadelphia, 1952).

(W. A. SR.; C. F. BN.)

PUBLIC HOUSE, in its general English acceptation. a house in respect of which a licence has been obtained for the consumption of intoxicating liquors. Public houses are frequently distinguished as "tied" and "free." A tied house is one rented from a person or firm from whom the tenant is compelled to purchase liquors or other commodities to be consumed therein. A free house has no such covenant.

(*See* LIQUOR LAWS AND LIQUOR CONTROL; PROHIBITION; TEMPERANCE.)

PUBLIC OPINION. There has been little agreement among political scientists, sociologists and social psychologists on the exact meaning of public opinion. The term has been loosely used. sometimes in reference to widespread beliefs, climate of opinion. consensus, the mores and the more settled convictions of a group; at times, to the process of developing opinions, as distinguished from the product; elsewhere to statements that are the result of a reasoned, logical process, as contrasted with those which have been arrived at by illogical means.

A people or group in essential agreement has little to discuss except the sporadic individual variations from the norm. In such a situation, knowledge is limited to the common traditions of the folk, the happenings of the immediate area and the occasional infiltration of alien lore. Hence, there is little public opinion. An opinion is some expression on a controversial point, and a public opinion is that which is formulated in any group of whatever size. This is a logical delineation of public opinion, though not a definition agreed upon by all scholars. A public opinion includes the expressed opinions of all the members of a public. The expression of the majority and also of the minorities constitutes the public opinion. If the differences are so great and persistent that the minorities will not acquiesce in functioning with the majority, then there is no one public—there are several separate publics.

The 19th-century social theorists quite generally included both the materials on which consensus existed and also the controversial items as part of the general content of public opinion. A. V. Dicey wrote of public opinion as a body of convictions, beliefs and prejudices, as well as of what he called crosscurrents due to controversy. But consensus and opinion and proof, fact and opinion may be logically distinguished. Plato confined opinion to that which is subject to change.

Nineteenth-century commentators stressed the rationality of the opinion process; those of the 20th century do not. In 1828. W. A. Mackinnon declared, "Public opinion may be said to be that sentiment on any given subject which is entertained by the best informed, most intelligent, and most moral persons in the community, which is gradually spread and adopted by nearly all persons of any education or proper feeling in a civilized state." Later, A. L. Lowell wrote that, "An opinion may be defined as the acceptance of one among two or more inconsistent views which are capable of being accepted by the rational mind as true" (A. L. Lowell, *Public Opinion in War and Peace,* Harvard University Press, Cambridge, Mass., 1923). After 1900 the developing science of social psychology increasingly emphasized nonrational factors involved in the opinion process; and the manipulative techniques of the practitioners of publicity, advertising and propaganda further eroded faith in rationality. Political democracy, however, holds to the principle that the opinions of some men are based on reason and that it is possible to bring popular judgments to positions that are rationally defensible.

There are relatively stable beliefs which, at any given time; are not involved in the opinion process. A state of agreement following an opinion controversy is a consensus. Publics reach consensus on ethical. political and economic issues. Even large publics may be in substantial agreement. There is consensus of the type that hlontesquieu designated the *esprit général,* that Rousseau spoke of as the *volonté générale* and that the English theorists called "public will." Wilhelm Bauer wrote of organic opinion as the relatively fixed views. aside from the current transient opinions. But one may consider that public opinion deals with those topics which are controversial and discussible within the publics. and not with those aspects of mind-life which are comparatively fixed.

History.—Plato denied the value of any general public opinion. In the main, Roman authors had little respect for mass opinion. It was not until the late 18th century that Alcuin's statement to Charlemagne, *Vox populi, vox Dei* ("The voice of the people is the voice of God"), was quoted approvingly by any substantial group of political theorists. In France. Rousseau and later Necker gave approbation to public opinions and frequently used the term *opinion publique.* In England. in the writings of Jeremy Bentham there was insistence on the significance of public opinion as a basic social control on the excesses of misrule and as a basis for the democratic state.

In the ancient civilizations, public opinion played some part, but the publics were limited in number and size, the mechanisms for expression of opinion were rudimentary and communication was limited. Among the Greeks, public opinion developed to an extent unequaled until modern times. but the publics were the approximately one-third of the adults who were free citizens. Among these. argumentative conversation developed and the art of dialectics was codified. The urban culture and wide-ranging conquests of Rome, the latter of which provided information about many peoples with their values. religions, economic and political systems, gave increased scope for the opinion process. There was a growing emphasis upon news: hence the professional newsmongers and. in the later periods. the publications of the *Acta Diurna.* There was much to discuss, the culture was dynamic, the opinion process was stimulated and the Romans came to speak of the *vox populi.*

Through the middle ages. with diverse, scattered, small groups and agrarian communities and with cultures blanketed under a common religious ideology oriented toward revelation and the supernatural. there could be little of dynamic popular opinion. Rather. there were consensus and traditional mores—popular acceptance of the forms of government and submission to the religious hierarchy, not the support of popular opinion.

The opinion process was vivified when the Reformation questioned clerical authority and emphasized the individual. Arts, letters and science began to cast off the bonds of authoritarian revelation. Public opinion began to develop as larger groups became concerned with religious issues. political systems, relative values and with ideologies in general and the new means of communication, printing. coupled with a slowly growing literacy, distributed the ideas. The enlightenment of the 17th and 18th centuries marked a further turning from the authority of divine revelation to the authority of reason and human understanding. When "natural reason" was posited. then individual opinions became important, and the theorists turned to an examination of the opinion process.

Modern **Public** Opinion.—It is evident that the opinions of large publics became increasingly important during the 20th century. Economic groups depended upon the convincing of large publics by publicity and advertising. Through publicity agents, notable personages attempted to create their own legends in the minds of the general public. Commercial advertising became a partial science and the arts of publicity and propaganda were cultivated. The struggle for power and the control of opinion was conducted by interest groups implemented with the newer means of communication. Authoritarian states meticulously organized propaganda bureaus. while democracies were reluctantly drawn into political and cultural publicity. The problem became one of values. Was the objective the unity of mass opinion for the furtherance of the purposes of the state and of private interest groups? Or was the pre-eminent value the integrity of the individual's psychological experience? For both objectives the modern facilities of press. radio and television provided the channels. Opinions were solicited and expressed upon the widest variety of controversial topics ever presented simultaneously to large publics on matters of morals. religion. education. the details of government. the choice of consumers' goods and the administration of justice. Advertisers of consumers' goods, politicians and representatives of interest groups clamored for attention.

Measurement and Polling.—In the democracies, the many interest groups attempting to mold opinion desired an effective check on their results. The multiplying numbers of publicity agents. advertisers and propagandists wished for instruments to measure opinion. Though there had long been those who sought to discover public opinion by means of interviews and straw votes. it was not until the emergence of the public opinion polls in the mid-1930s that systematic representative sampling of large publics occurred. Two fundamental problems were involved in the measurement of public opinion:

1. Developing tests sufficiently comprehensive to include at least the more typical opinion positions of most of the individuals of a public. Such tests were conducted by interviews, questionnaires. observations of behaviour, "yes"-"no"-type questions, multiple-choice tests. rating and ranking tests and attitude scales, such as those of L. L. Thurstone and Louis Guttman. Motivation research testing for advertising and marketing purposes utilized word tests, picture and cartoon tests. thematic apperception pictures and Rorschach tests (*see* PSYCHOLOGICAL TESTS AND MEASUREMENTS).

2. Developing adequate methods to report on the opinions of large publics. numbering millions of individuals. by means of the smallest possible representative sample. The representative sampling procedure in public opinion surveying is called polling, and early polls on candidates and issues were referred to as straw polls. The pioneer commercial pollsters, or pollers, in the United States were Elmo Roper and Paul T. Cherington, who established the *Fortune* survey, George H. Gallup. originator of the American Institute of Public Opinion, and Archibald Crossley who originated the Crossley poll. They used polling in an attempt to predict the results of the national elections of 1936. The pioneer pollers had had previous experience as market research men. In addition to the commercial pollers, various university-sponsored polling organizations, some polls maintained by newspapers, and a few by governmental agencies, both state and national, were established. Similar polling organizations were later set up in more than a score of other countries.

Sampling.—In public opinion measurement, the objective is the selection and polling of a representative sample of the group which constitutes the public under consideration. The public selected for sampling might be the adult inhabitants of a town, the lawyers of the state of Illinois, the population of the United States or any other of the multithousands of publics. Samples used for the entire population of the United States range from small samples of possibly 2.500 to large samples of 10,000. After the persons to be interviewed are selected (the sample) from the public under consideration (the "universe"). they are questioned by interviewers from the field staff of the polling organization.

Before the use of specially selected samples (made representative by stratified and area-probability sampling), polls were conducted by ballots printed in newspapers or magazines. which could be clipped and returned, by ballots left in stores, by interviews among crowds and on the streets and by mailed ballots sent to address lists variously obtained. In 1936 the *Literary Digest* mailed over 10,000,000 ballots. received back 2,376,523, and incorrectly predicted the 1936 national election by understating the vote for Pres. Franklin D. Roosevelt by 19.3%. Large numbers alone do not assure representativeness of the sample.

More scientific polling stressed the selection of representative samples of publics. Prior to 1952, most pollers used chiefly the quota sampling methods in which the sample was a small-scale model of the larger universe. For example, a sample of 10,000 individuals to represent the entire voting population of the United

States would be selected. The sample would be based on appropriate quotas in proportion to the frequencies in the general population of individuals by age, sex! economic position, community size, past party affiliation and sometimes a few other criteria. These were the strata. The interviewer would then seek for individuals who would fit the requirements of his assigned interviews. Such stratified sampling permits tailoring the sample to those in the population who are expected to be more significantly involved in the particular opinion topic than the generality. This is an advantage. Moreover, stratified sampling can be carried on in smaller geographic areas than area sampling and is, therefore, much cheaper. Also, it is not necessary to call back again and again to interview the person at a particular address as is true of area sampling. But an objection to the method was that it depended upon the often inexpert judgment of the interviewer in selecting the particular individual to be interviewed and also that the poller could not always be certain as to the frequency and significance of the various factors used as the strata.

Probability, or random, sampling. on the other hand, a more recent and less tested procedure, aimed to choose the sample in such a way that theoretically every individual in the universe would have an equal chance to be included in the sample. Such sampling originated from making selections by random methods from finite, discrete objects. Applied to populations, it would mean selecting every *n*th person from the total population as recorded in lists of names or other complete censuses. In polling practice the selection is generally made in terms of location of the individuals in space. From the 3,000 counties of the United States a sample would be drawn; from the counties selected, a sample of rural-urban population drawn; and within these areas, households and individuals would be systematically selected. Area sampling is not based on assignment of quotas, thus eliminating interviewer judgment and possible bias. In area sampling, certain areas (block, section, ward divisions of city or town, section, township or other area of county, county or other division of state) are assigned to the interviewer. Within these areas he interviews every nth individual or member of a family located at an assigned position (the second house from the northeast corner of a block, etc.). The area units are selected randomly in various ways. Due to travel expenses, time consumption for the interviewer in proceeding from one interview to another remote interview and other costs, area sampling is very much more expensive than quota sampling.

The 1944 area sampling procedures of the U.S. census bureau provided the first serious use of area sampling. In 1952 area sampling was first seriously used by commercial pollers to supplement quota sampling in the election of that year. Subsequently it was increasingly used by pollers.

Criticism of Opinion Polling Methods.—Possibilities of error exist at every stage of polling. Sample selection, question selection and formulation, the interview with its possible misunderstandings, the coding and interpretation of answers require experienced, skillful and honest pollers. Prophecy as to future opinion trends, which is involved in election predictions, is an art of a still higher order.

Some political theorists, congressional investigating committees and social scientists object to widespread use of public opinion polls for such reasons as their alleged employment to force premature executive and legislative decisions, the possibly adverse implications for political parties of election predictions. supposed methodological errors, and an inferred desire for vague, unfathomable public mind-life in preference to attempted exactitudes. The partial failures of the pollers on some election predictions have elated some political theorists who really disapproved of the polls on grounds other than their accuracy (for example, the numerous polls might encourage popular, rather than representative, democracy); have aroused partisan politicians who were fearful of the polls' influence on voters; have given some social scientists an opportunity to criticize polling methods; and have delighted many aesthetes, comedians and competing prophets. Others vaguely resent public opinion polls as another threat to privacy in an age in which privacy is already grievously assaulted. The polls may, however, be defended as reasonably accurate reporting on both the significant, matured opinions and the ephemeral sentiments of large publics.

See also PROBABILITY; PROBABILITY AND STATISTICAL THEORY; PROPAGANDA; PUBLIC RELATIONS; ADVERTISING; PSYCHOLOGY, HISTORY OF: *Social Psychology;* PSYCHOLOGICAL WARFARE; VOTING BEHAVIOUR.

BIBLIOGRAPHY.—*General:* W. A. Mackinnon, *On the Rise, Progress, and Present State of Public Opinion in Great Britain* (1828); W. Bagehot, *Physics and Politics,* ch. 5 (1872); G. C. Thompson, *Public Opinion and Lord Beaconsfield,* 1:29–50 (1886); G. Tarde, *L'Opinion et la foule* (1910); A. V. Dicey, *Law and Public Opinion in England* (1905); J. B. Bryce, *The American Commonwealth,* 2:261–403 (1889); C. H. Cooley, *Social Organization,* ch. 12, 13, 34 (1909), and *Social Process,* ch. 31 (1918); A. L. Lowell, *Public Opinion and Popular Government,* new ed. (1926), *Public Opinion in War and Peace* (1923); C. L. King, *Public Opinion as Viewed by Eminent Political Theorists* (1916); W. Lippmann, *Public Opinion* (1922); J. Dewey, *The Public and Its Problems* (1927); W. Bauer, "Public Opinion," *Encyclopedia of the Social Sciences,* 12:669–674; J. W. Albig, *Modern Public Opinion* (1956).

Measurement and Polling: H. Cantril. *Gauging Public Opinion* (1944); G. H. Gallup, *A Guide to Public Opinion Polls* (1948); Linsay Rogers. *The Pollsters* (1949); M. B. Parten, *Surveys, Polls, and Samples* (1950); H. H. Remmers, *Introduction to Opinion and Attitude Measurement* (1954); J. W. Albig, *Modern Public Opinion,* ch. 9, 10, 11 (1956). (J. W. A.)

PUBLIC RELATIONS, the activities connected with interpreting and improving the relationships of an organization or an individual with the public. The persons in charge of these activities are usually known as public relations directors, public relations consultants, etc.

Professional associations in the public relations field have maintained that the use of titles of this kind is justified only in the case of those who operate on a policy-making level, so that they have a voice not only in securing publicity for the activities of their employers, but also in making those activities conform to the public interest. However, the term has been widely used by publicity men without regard to this distinction.

The first industries to make general use of the term public relations were U.S. railways and public utilities. For example, the *Electric Railway Journal* for Dec. 13, 1913, said in an editorial that "the subject of the public relations of public utility companies occupied almost exclusively the attention of three important conferences this week in New York." Earlier uses of the term include an address by Dorman B. Eaton on "The Public Relations and Duties of the Legal Profession" to the graduating class of the Yale Law school in 1882. Thomas Jefferson used the term in his address to the 10th congress in 1807, but in the sense of foreign relations.

Forerunners of Public Relations.—While the term public relations did not come into general use until after World War I, many of its basic activities are as old as history. Primitive priests and medicine men performed public relations functions on behalf of their tribes when, in order to eliminate customs that were found to endanger the health or safety of the tribe, they built bodies of legend to give sanctions to their prohibitions.

In the 5th century B.C., the Greek poet Simonides put his muse at the service of publicity, selling songs of praise. This practice seems to have been generally considered in bad taste. However, even the fastidious Pindar accepted money from those he glorified in his odes. Among his patrons were the great merchant princes of Aegina. Plato in his *Republic* attacked poets as special pleaders, and advocated the suppression of all except those hired by the state to serve its welfare.

The Rosetta stone is an example of the governmental public relations work of the priests of ancient Egypt. The inscription, made in accordance with a decree passed by a general synod of priests in 196 B.C., informs the reader that the boy king Ptolemy V has been generous and just, and his policies conducive to prosperity.

In 60 B.C., shortly after he had become consul, Julius Caesar decreed that the acts of the Roman senate should be publicized. A bulletin, the *Acta Diurna,* was posted, and also issued in manuscript form. This publication announced that Caesar had been offered the crown, and had refused it.

Augustus Caesar, foreshadowing a feature of Benito Mussolini's policy ordered publicity gixen in the *Acta Diurna* to citizens who were rearing large families.

Gaius Maecenas, friend and adviser of Augustus, helped direct the genius of Virgil and Horace into channels that greatly enhanced the public prestige of the emperor. John Buchan, in his biography *Augustus* (Houghton Mifflin Co., 1937), sums up the role of Maecenas: "It was his task to feel the pulse of public opinion and to advise the blunter intelligence of the Princeps, and not less to create opinion for his day and for all time."

Under the influence of his friend and patron Maecenas, Horace portrayed Augustus as a symbol of enlightenment and peace. Similarly, Virgil in the *Aeneid* bolstered the pride of citizens by telling that the greatness of Rome had been foretold from the earliest days. In this feat of retroactive prophesy, he included the statement that Rome's ultimate grandeur was to be achieved by the men of the Julian house—the family of Augustus.

In the dark ages. wandering minstrels were made welcome at great castler largely because of the influence on public opinion they were able to exert on behalf of their patrons. The Anglo-Saxon scop or bard had become a respected personage by the 5th century.

The mediaeval guilds performed a public relations function for their members by maintaining the standards and dignity of their crafts. However, in contrast to modern trade associations, which publicize their methods, the guilds emphasized the "mysteries" of their vocations. Thus business became wrapped in a tradition of secrecy nhich tended to leave it defenseless against its critics.

A powerful handicap to the mediaeval businessman was the doctrine of St. John Chrysostom that "whoever buys a thing in order to make a profit selling it. whole and unchanged, is the trader who is cast out of God's temple." St. Thomas Aquinas amended this doctrine to permit a profit, but at a "just price" which involved a small margin.

In Augsburg, Ger.. the house of Fugger, extending its banking and trading interests internationally on a large scale in the early 16th century. was hampered by restrictive laws and adverse public opinion. Jakob Fugger took his problem to Konrad Peutinger, a humanist scholar and an adviser to Emperor Charles V. Peutinger, a great forerunner of the modern public relations man, wrote a series of essays on the moral and legal aspects of trade. He pointed out that merchants were frequently forced to sell their goods at a loss, and maintained that accordingly every trader should be free to get as high a price for his wares as they could command. He argued also against restrictions on monopolies and cartels. Largely because of Peutinger's activities, the Augsburg council voted to do away with restraints on business.

In England, up to the middle of the 18th century, when it became possible for writers to look to the public for their livelihood, it was not unusual for authors who lacked private patrons to be in the pay of political groups. Swift put his talent at the disposal of the Tories Prior and Addison of the Whigs. From 1731 to 1741, Walpole used nearly £50,000 of secret service funds for the pay of writers and printers

In France Racine and Molière were among the distinguished writers who supplemented their incomes by writing eulogies of royalty.

Napoleon Bonaparte made adroit use of opinion-moulding techniques throughout hia career. In 1793, when there was a general revolt by Southern federalists or counter-revolutionaries against the new constitution, Napoleon's regiment was among the units engaged in suppressing the uprising. Sent on a mission to Beaucaire. he wrote a pamphlet, *Souper de Beaucaire,* to prove that the rigours of the revolutionary government were mild compared to the aengeance that the *ancien régime* would exact if disunion opened the way for its return. The pamphlet brought the young officer to the approving notice of the Contention.

In 1796, placed in charge of the army of Italy, Napoleon drafted a proclamation to his unpaid. badly equipped soldiers that gave a dramatic lift to their morale. William Milligan Sloane. in *The Life of Napoleon Bonaparte,* says of the French entry into Milan: "No scene in the history of warfare was more theatrical. The pageant was arranged on the lines of a Roman triumph, and the distances so calculated that Bonaparte was the one impressive figure."[1]

Having used pomp as an effective publicity instrument, Napoleon now showed that he could do likewise with simplicity. On his return to France he dressed plainly, visited minor officials who would normally have been expected to make the overtures—and saw to it that the modesty of his conduct was reported in the official journal, *Le Moniteur universel.*

In colonial America the talent of Samuel Adams for wooing public opinion proved a great asset to the Revolutionary cause. Typical of his practical approach to such questions is the letter he drafted for the Committee of Correspondence on Dec. 16, 1773. "We inform you in great haste that every chest of tea on board the three ships in this town was destroyed the last evening," the letter begins, and continues: "without the least injury to the vessels or any other property."

Developments in 19th **and** 20th Centuries.—In the early 19th century, U.S. newspapers frequently granted the hospitality of their news columns to publicity stories in return for paid advertisements. Other papers, inadequately staffed, accepted contributions without too close a scrutiny as to the motives of the writers. Shortly after the Civil War. land promoters, railroads, politicians and financial groups were making systematic use of such opportunities.

In 1869 James McHenry, press representative of the Fisk-Gould financial group, obtained wide publication of material in their interest. Shortly after this. a number of business and political organizations installed publicity departments, under the name of "literary bureaus."

Promotion-minded businessmen realized that it was possible to create news events that the newspapers mould report as a matter of course. An outstanding instance of this occurred in 1892 when the manufacturers of "Sapolio" sent a 14-ft. sloop to Spain to participate in the 4th centennial of Columbus' voyage to America.

The technique of creating news events had already been brought to England by Thomas J. Lipton, who in 1881 arranged to have the world's biggest cheese manufactured in the United States, and created an effective fanfare of publicity when it reached his main store in Glasgow, Scot.

In the last decade of the 19th century and the first of the 20th, publicity men were multiplying in New York city. Almost all of them were former newspaper reporters. Knowing the ingredients of a lively newspaper story, some of them—particularly theatrical press agents—drew freely on their imaginations.

In 1909 the American Newspaper Publishers association, alarmed at the spread of press agentry, appointed a Committee on Free Publicity. One bulletin issued by it listed 757 "space grabbers."

However, most newspapers continued to use a substantial amount of material from publicity sources. A parallel situation occurred later in Britain. *Report on the British Press,* published by Political and Economic Planning in 1938, stated: "Some newspapers are very much opposed to accepting material from press agencies, and not long ago the Home and Southern Counties Newspaper Federation, representing nearly 300 newspapers, made a concerted attempt to eliminate it. Nevertheless, many of these newspapers continued to print such material, the news-value in them proving too strong a bait."

In both instances the attempted boycotts resulted in a more objective attitude toward publicity. In an article entitled "The Press Agent, His Rise and Decline," published in *Collier's* in 1911 (Crowell-Collier Publishing Co., New York, N.Y.), Will Irwin said: "No more may such as Channing Pollock trick the newspapers by having a popular actress develop a case of aphasia on the steps of the Eden Musee; no more may Toxen Worm draw column after column of space by strewing tanbark before the theatre to 'save the nerves' of an overstrung English star."

Irwin's epitaph for trickery was premature; many years later some of the old press agent devices were still in use, together with

[1]From *The Life of Napoleon Bonaparte,* vol. 1. Copyright, 1939, D. Appleton-Century Company, Inc. Reprinted by permission of Appleton-Century-Crofts, Inc.

such new ones as obtaining mention of clients in syndicated columns by attributing to them witty remarks invented or borrowed for the occasion. However, the article included a defense of the better type of press agent that might well stand as a vindication of his successor. the public relations man:

"A press agent, a special pleader it is true, but perhaps a fair one. helps wonderfully to mutual understanding. . . . The corporation head, associating only with his kind, may be as foolish as any man in misunderstanding the public. The press agent is always a graduate newspaperman. As such, he is an expert on public opinion. He can counsel against these unsympathetic follies; and often he does."

Leaders of business and finance had already begun to think along these lines. Until recently they had been opposed to any publicity except commercial puffs, and had strongly rebuffed newspapermen. The prominent banker George F. Baker told a reporter: "It's none of the public's business what I do." J. P. Morgan said to another "I owe the public nothing." William H. Vanderbilt, when pressed for a statement about reduction of train schedules on his railroad by a reporter who talked insistently of the public interest, exclaimed: "The public be damned!" Associated Press editor Melville E. Stone said in his memoirs that Vanderbilt's ire had been directed at the reporter rather than the public. However, great damage had been done.

The businessman's belief in his right to secrecy was an honest one. rooted in a tradition dating back to the mediaeval guilds. But it was dangerous to rest on real or supposed rights, in view of popular antagonism toward big business. This attitude was equally traditional; in fact, one of the motivations of the Boston Tea Party had been the fear that the British East India company would crush small merchants by selling directly to consumers.

A clash between the two traditions was forestalled for a long time by the availability of homestead lands in the west, which tended to mitigate causes of discontent. The drying up of this source of opportunity was accompanied by an epidemic of attacks on big business.

In 1886 there was a series of strikes, some marked by violence. Edward Bellamy's *Looking Backward, 2000–1887*, published in 1888, held out to a million readers the promise of a future utopia without the debasing effects of trade. In 1894 Henry D. Lloyd attacked the trusts in *Wealth Against Commonwealth*. In 1902 *McClure's Magazine* launched a series of articles indicting municipal politics and big business. Theodore Roosevelt gave the name of "muckraking" to this type of journalism. However, he had given encouragement to it by his rebuke to "malefactors of great wealth."

A series of harrying congressional investigations of big business accompanied the attacks. "We are passing through a reform —yea, a revolutionary period in business affairs," Henry Clews wrote in the *Annals* of the American Academy of Political and Social Science for July 1906. He called on banking and insurance interests to drop their policy of secrecy, which, he said, was "obviously in defiance of public sentiment."

Another development of 1906 was the appointment of Ivy L. Lee, a former newspaperman, as publicity adviser to a group of anthracite operators. The mine owners had stirred the anger of the press by their haughty attitude in labour disputes.' Soon after Lee's appointment it was announced that they would supply the press with all possible information.

Lee then sent to city editors a declaration of his policies, in which he said: "This is not a secret press bureau. All our work is done in the open. . . . If you think any of our matter ought properly to go to your business office, do not use it."

Retained by the Pennsylvania railroad the same year, Lee made information concerning accidents available to the press for the first time. In 1921 his firm issued its bulletin, previously called *Notes and Clippings*, under the title of *Public Relations*.

In 1923 Edward L. Bernays published *Crystallizing Public Opinion*. This book, describing publicity functions and techniques with an emphasis on social responsibility, did much to popularize the term public relations and to gain recognition for specialists in the field.

Meanwhile, men were being hired in the service of the federal government under such titles as "director of information," "editor" and "supervisor of information research." These provided a loop-hole in a congressional act of 1913, which forbade the spending for "publicity experts" of any funds not specifically designated by congress for that purpose.

In Britain, the Empire Marketing board began using large-scale publicity for the promotion of trade in 1924. *Report on the British Press* says of the Empire Marketing board that "before its demise in 1933 it had established the archetype of Government Public Relations Departments."

In Britain, as in the United States, appointment of public relations directors by government departments during World War II was the prelude to increased postwar emphasis on public relations. The British public relations journal *Persuasion* pointed out in its issue for the winter of 1949: "The war made a great difference to the relation between a local authority and its people. . . . When peace came, the climate for formalized public relations was good."

One indication of the greatly heightened interest in the United States was the fact that many colleges were adding courses in public relations to their curriculums. Boston university established the first school of public relations in 1947.

Philosophy of Public Relations.—A realistic view of the public relations field avoids over-idealization on the one hand, or a cynical view on the other.

The basic purposes of a public relations department are the establishment and maintenance of good will. It is obvious that the more the organization does to merit this good will, the easier the task of the public relations director will be. When he invites public attention to his company in connection with some attractive phase of its activities, he cannot be sure of limiting the interest of the press or public to that particular area. The efficient public relations executive therefore works forcefully for the elimination of policies that he believes to be open to criticism.

A typical illustration of this point occurred at a conference in which plans for the construction of a winter resort were being discussed. Business executives associated with the project started with the assumption that it would provide only high-priced accommodations, since inexpensive ones would be unprofitable. The public relations consultant argued that low-priced rooms and meals should be offered also, in view of the fact that the project was backed by a railroad. His view was that a public service corporation would be inviting antagonism if it were associated with an appearance of exclusiveness. This opinion prevailed.

Following is another example of enlightened self-interest in public relations, cited by Glenn and Denny Griswold in *Your Public Relations* (Modern Industry Books, 1948):

"Suspicion and resentment had existed for years between neighboring small towns and agriculture on the one hand and San Francisco and its business interests on the other. . . . Mr. Lundborg" (general manager of the San Francisco Chamber of Commerce) "organized a committee of 83 leading farmers and of businessmen whose enterprises depended on agriculture. They sponsored a program of doing things to help farmers instead of boasting about the city's virtues. First they enlisted the help of newspapers, radio stations and grocery store chains to help dispose of an apple crop so abundant that it threatened ruin to many farmers. Within two weeks the surplus was lifted, prices had been maintained and farmers began to see some good in city business."

A significant sidelight on this story is the fact that it involved the public relations policy with which chain stores were combating campaigns to tax them out of existence. The method of an earlier day would have been merely to fight propaganda with propaganda. In this instance, propaganda was one of the weapons employed; but it was given powerful assistance by an intensive effort to win good will through service. Helping farmers to dispose of surplus crops was part of that program.

The public relations director or consultant frequently needs a high degree of persuasiveness in order to gain a hearing for a long-range point of view in councils concerned with immediate commercial objectives. In order to be an efficient representative of his company he must also be a representative of the interests of its employees, of the local communities in which it has factories, of the retailers who distribute its wares, of the consumers who buy them. and of the public at large. It is not necessary for him to be an altruist in order to do this; he need only realize that it is easier to correct sources of irritation than to justify them.

Public relations consultants have stated that they could not have secured a serious hearing for some of their plans, involving immediate sacrifices for long-range objectives, if not for the respect engendered by their extremely high fees. On the other hand there have been many occasions, before as well as after the term public relations came into use, when businessmen have shown an innate talent in this area. For example, the suggestion box system. which later became a feature of thousands of public relations programs for maintaining employee morale, was used by the William Denny Shipbuilding company of Dumbarton, Scot., in 1880. Denny, after he had given many awards for ideas submitted by employees, said: "The scheme has the effect of making the workmen of all departments into active thinking and planning beings instead of mere flesh and blood machines."

Another Scotsman who showed a keen insight into some phases of public relations was Andrew Carnegie. During his boyhood, when he was an employee of the Pennsylvania railroad, Carnegie submitted to the *Pittsburgh Journal* an article on "the attitude of the city toward the Pennsylvania Railroad Co." In his memoirs Carnegie tells that this article brought him to the notice of the counsel for the railroad. Also, though he shared the weaknesses of industrialists of his era in other ways, he gave a building rent-free for the use of a co-operative store for employees.

Nevertheless, though early parallels can be found for every basic phase of public relations, as an organized activity it represents a major change in the philosophy of business—the recognition of the ultimate authority of public opinion. At the halfway mark of the 20th century, thousands of top-ranking business executives were devoting a major share of their time and planning to an activity that had been trivial or nonexistent in the programs of their companies a generation before.

Publicity as a Public Relations Tool.—When a policy has been set and the public relations representative is seeking publicity for it in news media, he must put his reliance not on techniques of persuasion but on his judgment as to what constitutes an acceptable story.

A story with intrinsic news value, simply and clearly presented, usually receives an objective hearing. A statement made in 1926 by Louis Wiley, business manager of the *New York Times,* is representative of a policy that gained wide acceptance with mass media: "If so-called publicity is legitimate news, it should be printed for the readers of the newspaper regardless of whether it benefits private interests or not. If it is not legitimate news, then it should not be printed, regardless of who may be pleased to have it appear."

In both large and small organizations, public relations departments are usually watchful for such publicity opportunities as anniversaries that may be of local or general interest, public events in which it would be logical for the president or some key official of the company to participate, incidents involving celebrities, and developments susceptible to treatment in text or photography as human-interest stories. In the handling of adverse news, such as that of accidents, experience indicates that the harm is minimized by candid answers to inquiries.

The policy on publicity expressed by Louis Wiley represented an important step forward for the public relations worker; but this did not mean that he was on an equal footing in a newspaper office with the paper's own reporters. The news value of a story had to be such as to be clearly and quickly apparent to the editor, who was constantly being flooded with copy by his own staff and the wire services.

In some cases the solution to this problem was found in the creation of news events—a practice that was not new but which was now followed with much greater respect for the judgment of editors. It became an important factor in the public relations programs of trade groups. For example, a group of soap manufacturers, anxious to combat the statement by some cosmeticians that soap was bad for the skin, turned to a public relations consultant, who advised formation of a cleanliness institute. This was not a dummy organization but one that conducted an actual cleanliness campaign, welcomed in public schools. It received widespread publicity. On another occasion a public relations counsel initiated soap sculpture contests on behalf of the industry. This type of oblique publicity was found to be of great value.

Similarly, when the National Cotton council was faced with the competition of paper bags with cotton ones as containers for feed, its public relations department sent emissaries to show farm wives how they could convert cotton feed bags into attractive dresses. Photography editors of newspapers and magazines were attracted by the novelty of the idea, which proved an effective stimulant for the sale of cotton.

The attitude of many editors toward this type of public relations was summed up by Stanley Walker in *City Editor:* "Once Irene Castle cut her hair, and her photograph was attractive. Barber shops, beauty parlors, hairnet manufacturers, the comb industry and the hat business were affected for better or worse. Businessmen are at the mercy of a million such whims. It is better for them to attempt some intelligent direction of these whims, so that they will know what to expect. Otherwise some morning they may find themselves ruined." [1]

A classic example of the unexplainable whims mentioned by Walker is chronicled by J. Henry Harper in *The House of Harper.* Discussing the publication of the novel *Lorna Doone,* Harper tells that at first this novel attracted little attention. Later, when the marriage of the marquess of Lorne (who had no connection with the book beyond the accidental similarity of his name) was headlined in the press, the novel was somehow associated in the public mind with this glamorous event, and its sales rocketed.

Publicity, which is capable of this freakish power, is a versatile instrument in the hands of a resourceful man or woman with newspaper experience. It proved a major factor in removing a once widespread prejudice against the game of billiards; it helped greatly to popularize bowling and other sports; and it has contributed to the making of fashions and literary and theatrical reputations.

Given an assignment that has a reasonable justification for its existence, a publicity man has many avenues of approach. A favourite one is to interest celebrities in the project, and use their names as a springboard. Another is to devise contrasts of a striking nature.

An illustration of a combination of the two methods occurred in New York city in the early 1920s, when a publicity man, admiring the work of an unknown artist, volunteered to bring it to public notice. A private exhibition was arranged for the artist's work, which included a series of panels depicting a boxing match. Several well-known fighters were then induced to come to a tea at which the pictures were shown. A Sunday newspaper devoted a full page to photographs of the artistic-pugilistic tea.

Publicity of this harmlessly playful type survived as an effective aid to some public relations programs. An instance of this was the formation, on behalf of doughnut manufacturers, of a mock-serious society known as the National Dunking association.

Perhaps the major significance of this type of publicity is that it permits imagination, judgment and energy to do the work of money. It is capable of putting a low-budget public relations office, representing a small business, a college, a church group, or a philanthropy, on a par with the most powerful organization.

Public Relations Advertising.—As some big corporations became increasingly aware of the importance of courting public opinion, they supplemented their publicity efforts with a new type of advertising—one that was not designed to gain business

[1] From *City Editor*, copyright 1934 by Stanley Walker. Published by J. B. Lippincott Company.

but to clarify their policies and improve their relationships with their employees, the local community and the public at large.

The Bell Telephone company was active in this field as early as 1908. After World War II Bell Telephone, unable to supply the demand for new installations, published a series of advertisements explaining why delays were unavoidable. The flood of complaints subsided to a point below the prewar average.

Several public opinion surveys revealed that the average American believed the profit margins of industry to be excessive. However, the popular idea of what constituted a fair percentage of profit proved to be substantially higher than the percentages that industry was actually earning. This was the basis for effective educational campaigns.

In public relations advertising by management in connection with labour disputes, a temperate policy, anticipating the day when the strike will be settled, has been found to be a wise one. During the strike at the General Electric plant in Bridgeport, Conn., in 1946, the company presented the view that wages must be geared to production, but avoided strident controversy. One advertisement was devoted to announcing that the strikers' insurance under the company's employee plan was being kept in force.

Industrial Relations.— Winning the good will of its employees is one of the major objectives of every industrial organization. The morale of a factory's workers affects many economic factors. Among these are the quantity and quality of production; the company's position in competing in a tight labour market for the services of skilled workers; its popularity or unpopularity in the local community, which in turn affects the treatment it receives from the municipal administration; and its reputation through the country as a whole.

No public relations technique can offset substandard wages or unsatisfactory working conditions. However, even a policy that is intended to be equitable may run into trouble if administered in impersonal, bureaucratic fashion. Accordingly, an efficient public relations director makes a strong effort to keep management sensitive to human values. Employees are informed of new developments promptly, before there has been an opportunity for these to be distorted by rumours. They are encouraged to submit complaints as well as suggestions. Advance proofs of institutional advertising are posted on factory bulletin boards. Facts on the company's earnings and prospects are made available. In some organizations, regular "job holders' meetings," similar to stockholders' meetings, are held. Issuance of publications for employees has become a standard practice.

An illustration of the scope of this work in a large organization was provided by the program of the International Harvester company. *Employee Relations*, a report by E. M. Claypool in *Public Relations Handbook*, edited by Philip Lesly, (copyright 1950 by Prentice-Hall, Inc.) states: "Organization of the Harvester employee relations program is divided into six main groups: labor relations, personnel, wage administration, salary administration, education and training, and group insurance. The activities of these groups are coordinated by a vice-president in charge of industrial relations who works in close harmony with the director of public relations. They use such industrial relations techniques as apprentice courses, student training, job training, supervisory training, vacations, collective bargaining, employees' benefit associations, group life insurance, hospital and surgical benefits, accident compensation, and scientific personnel selection and placement.

"An outstanding feature of the Harvester educational program is that any group of reasonable size may arrange for a course in any desired subject, whether the course is related to their present jobs or not. This policy encourages employees to develop hobbies and to broaden their intellectual horizons.

". . . Each plant has its own publication that acquaints employees with persons, departments, and activities removed from their immediate vicinity as well as those with whom they work."

Scope of Public Relations Departments.— Almost every form of the printed and spoken word, and of photography, is used in public relations work. At mid-20th century, many public relations departments included the following activities in their routine responsibilities: issuing news releases to newspapers, radio stations, trade journals and popular magazines; arranging press conferences; answering queries from the press and public; preparing text and illustrative matter for public relations advertising, pamphlets, employee magazines, manuals for the training of new employees, reports to stockholders and form letters; planning documentary motion pictures, recorded television programs, film strips, lantern slides, charts and recorded talks; planning and publicizing exhibitions and "open house" days at factories; and planning research surveys for gauging the opinions of employees, customers, or the general public. In addition, in cases where the product of the company is an expensive one, such as an automobile, the public relations department may have the duty of preparing a magazine for free distribution to listed customers. Some corporations issue special magazines for their stockholders. Public relations directors of trade organizations, long-established companies, and various institutions also have arranged for the publication of books, sometimes by well-known writers, telling the history of the organization or industry. These books are usually placed on sale through normal channels, but often are subsidized to assure the publisher against loss.

Some organizations employ not only a public relations director, with a staff under his supervision, but also a public relations consultant, to provide an outside point of view on questions of policy, or the public relations department of an advertising agency.

Most public relations work involves a combination of logical and psychological methods. Experience has repeatedly proved that exaggeration and distortion defeat their own purpose; but often it is possible to switch from an unpopular concept, expressed in a standardized term, to a popular, or at least an acceptable one, without doing violence to truth. Walter Lippmann, using the word stereotypes to describe these concepts of the mass mind in *Public Opinion*, influenced many public relations experts. An illustration of this type of thinking is the substitution in public relations advertising by labour unions of the term "union security" for "closed shop." Another is the use by manufacturers of "billiards" for "pool," which had taken on the connotations of shabby poolrooms.

Much specialization has developed in public relations work in areas such as banking, agriculture, education, philanthropy, etc. Also, many public relations executives specialize in the use of various media, such as audiovisual materials and stockholder reports.

BIBLIOGRAPHY.—Alfred McClung Lee, *The Daily Newspaper in America* (1937); John William Albig, *Public Opinion* (1939); Francis Williams, *Press, Parliament and People* (1946); Rex F. Harlow and Marvin M. Black, *Practical Public Relations* (1947); Eric F. Goldman, *Two-way Street; The Emergence of the Public Relations Counsel* (1948). (*J.* AY.)

PUBLIC SCHOOLS. In the United States this term is used to describe free, tax-supported, public controlled and directed, nonsectarian schools. The term public school in England includes not only the schools of ancient foundation such as Eton, Harrow and Winchester, but also schools of comparatively recent creation such as Clifton, Cheltenham and Marlborough. As forming part of the secondary school system of England (see SECONDARY EDUCATION) they are included in the official statistics as non-aided schools.

PUBLIC UTILITIES, a designation for a special grouping of industries legally "affected with a public interest" and conducted under government regulation. They occupy an intermediate position between state services or public works. which are administered as public functions and hence supported by taxation, and the variety of business undertakings usually included under the heading of competitive private enterprise. Public utilities, properly so-called, need not be privately owned. In almost every country a varying number of them are owned and operated by the state. But these publicly managed enterprises, instead of looking to the state for financial support, sell their services to the general public. Both publicly and privately owned utilities sell their services at prices which are not fixed in the open market but are governmentally fixed. This aspect is the most important part of the process known as public-utility regulation.

Although economic and technical evolution is continually changing the character of these industries, besides creating new ones, public utilities may be classified according to the generalized function which they perform in economic life. The main public services supplied through public utilities are: (1) transportation (common carriers), including railroad. highway and local transit, oil and gas pipelines. waterways and air lines; (2) communications —telephone. telegraph, radio and television; (3) power, heat and light—gas and electric; (4) community facilities for water, sanitation and irrigation.

HISTORICAL SURVEY

Public utilities are closely associated with developing civilization, supplying wants so fundamental for communal living that government has at all times subjected them to some measure of control. With the groath of trade in ancient empires facilities providing transport and communication were set up. The governmentally maintained highway system of the Roman empire and its many aqueduct systems are celebrated ancient public works. The need of some system of public communication was so great that even the postal system has its ancient parallel. In the more populous ancient cities. systems of sanitation also became a necessity. With these needs came the recognition that services used collectively should be supplied by the state. Public utilities thus began as state functions. By the middle ages most of the ancient public utilities had declined or virtually disappeared. By slow stages, upon the manors and in the mediaeval cities, these public facilities again appeared. Of great importance in British and American legal history is the fact that out of the economic and legal relationships of feudalism there arose the concept of a "public calling" upon which is based the modern policy of public-utility regulation.

The modern national state gradually supplanted the elements of the feudal system of social control. The expanding domestic system of manufacture was displacing the guild and manorial system of production; foreign trade was growing. National systems of transport involving highways and canals mere undertaken and the regulation of utilities became national rather than local.

Effects of the Industrial Revolution. — The greatest impetus in the expansion of public utilities came with the industrial revolution. Under the stimulus of the factory system cities grew as never before, creating a municipal need of systems of water supply, sanitation, transport, communication, illumination and power. But the philosophy of *laissez faire* was not fertile ground for extending public functions. While the rapid industrial changes intensified needs, the tendency was to give greater scope to private enterprise.

However, the evils of a system which left the supply of basic economic wants to private industry insufficiently regulated by government became too flagrant to be overlooked. Beginning about 1840 the revolt against *laissez faire* doctrines caused an enlargement of the scope of governmental action. The older public utility services were continued for the most part as public enterprises, while the newer services were supplied by private initiative under some form of public supervision and assistance. Thus emerged the modern notion of a public utility, distinct from strictly governmental services and strictly private business.

Need for New Utilities. — The beginning of the modern postal system dates back to the 15th century. In the 18th century England was covered with improved roads built by public authority or by private turnpike companies. The first canal in a new era of canal building was completed in 1761. The first steam railroad was built in 1825, and the first regular steamboat began operation in 1812. The railroads lost a promising source of freight with the development in the 1860s of pipelines for transporting petroleum. The pipeline network for oil was supplemented by pipelines for natural gas after the turn of the century. With the advent of the automobile, highway systems were reorganized on an unprecedented scale. The motorbus and motor truck made use of this development and soon were rapidly cutting into the short-distance traffic of steam railroads. Following World War I railroad traffic was further challenged by the use of the aeroplane for regularly scheduled postal service, passenger and freight traffic. The British introduced regularly scheduled service from London to Paris in 1919.

After 1850 systems of rapid world-wide communication emerged as the telegraph and telephone were perfected. (*See* TELEGRAPH; TELEPHONE.) At the close of the 19th century wireless telegraphy emerged. After 1915 radiotelephony was added to the means of communication developed through public utilities.

Radiobroadcasting systems were introduced both in Europe and in the United States in the 1920s. (*See* BROADCASTING.) The International Broadcasting union, formed in 1925, paved the way to a uniform allocation of wave lengths. The introduction of regular television broadcasting may be credited to the British Broadcasting corporation which inaugurated a daily schedule in Nov. 1936. Commercial television in the United States was started by the National Broadcasting corporation in July 1941. (*See* TELEVISION.)

In the field of municipal public utilities local transportation was supplied to British and American cities by fleets of omnibuses in the 1820s. The horsecar was introduced in the 1830s. Artificial gas for illumination was introduced commercially in London in 1813 and was in wide use by 1840. A new development in water-supply systems was introduced with the completion of the river reservoir which channelled water to London from springs in Hertfordshire. Boston. Mass., in 1652 installed the first modern central water-supply system of the gravity type in the United States. Central water-supply systems became general in large cities by 1820. The systematic treatment of sanitation services as a municipal public utility dates from the 1870s both in England and in the United States.

New public utilities centring in cities developed out of the industrial applications of electric power. In 1882 the first central station for electric lighting began operation in the United States. By 1885 electric power was applied to street railways. The first hydroelectric plant began operation in 1882, the precursor of a new movement in power production.

In this historical survey it is important to note that public utilities were not definitely segregated from public functions until the *laissez faire* philosophy of the 18th century restricted the scope of governmental activity and created institutions and processes so that the supplying of the public needs could be left to private initiative. Public utilities. although privately owned, were subjected to governmental regulation. The term socialization has been chosen to describe this latest phase of utility development because it implies that government may actively promote these enterprises through public ownership or arrive at the same result by creating private agencies and controlling them through well-conceived policies of regulation.

ECONOMIC CHARACTERISTICS

Developments in the engineering arts bring changes in economic organization. For instance: lighting of the home was transformed first from a self-sufficient household industry (as the making of candles) to a commercial competitive industry (the supply of candles, lamps, whale oil and petroleum), and then to monopolistic industry (electric lighting), where central sources of supply satisfy all demands. Perhaps the most significant economic conclusion founded upon these changes is that the social value of public-utility services is increased and the economic cost of rendering them is reduced by a consolidation of enterprises. The individual user of water in urban centres no longer had to depend for his supply upon his own well, nor did he have to buy from one of several competing sources. He resorted to a single common source of supply along with other users. This was found to be more convenient, economical and, indeed, the only practical solution. But this process of integration of supply was a long process. In some public service industries it was not completely realized. The tendency toward monopoly, however, whether the result of a competitive struggle or brought about by legislation, became a fundamental characteristic of public utility business.

Every public utility must be in possession of the natural resource upon v-hich that industry is based. A gas or electric company must have possession of sites for the location of its works; a transportation company must have rights of way and terminal sites. These properties must have strategic locations. Limitation in the choice of this agent of production tends to make the cost of acquiring or leasing these facilities greater than it would be if the industry had a wider range of choice. Furthermore, utilities must make allowances in advance for probable increase in the required capacity. For these reasons utilities are provided with the governmental power of eminent domain which makes possible the compulsory sale of private property. Thus the law recognizes that, socially considered, these properties are being put to the highest uses of which they are capable.

Fixed Capital Characteristics. — The typical public utility—railroad. telephone system or electric power plant — serves an area of the economy where duplication of facilities is regarded as economic waste. Public-utility facilities entail a much higher investment of fixed capital in relation to sales or receipts than is required for industry in general. The liquid capital solicited irom investors is converted into durable, specialized structures and equipment. The facilities must be designed to insure the regular and adequate supply of the utility for which the franchise is granted. At the same time the service must be produced and sold on terms that will provide a return on the invested capital sufficient to permit adequate maintenance and replacement, and to attract additional investment funds for expanding demand. This reconciliation of the interests of the enterprise with the public interest is a basic objective of government supervision of public utilities.

The expansion of metropolitan areas and the interdependence of communities in the use of joint facilities are reflected in the enlarged scope of public-utility operations. These developments have accompanied technological improvements in which fuller advantage is taken of the economies of size. This is exemplified in the utilities supplying power, where economical operation is secured by combining power sources into so-called super power systems in which the power stations are interconnected by transmission lines. The reciprocal sale of power from one system to another is thus possible when the common reserve serves a large area. The co-operative action insures the utilization of surplus power, safeguards the service from interruptions, and secures the advantages of full use of investment by building up the diversity of use.

Availability of Utility Services.—All public utilities must stand ready to supply their services on demand, and utilities may be divided into two classes according to the method by which they meet this situation. The first class, or service type, comprises the utilities that cannot store their services but must adjust to demand variations by maintaining productive capacity equivalent to peak demand, with a resulting tendency toward increased cost of operation. This class includes electric, telephone, telegraph and transportation utilities, as well as the postal service. The second class, the product type, consists of utilities that may be stored, so that output can be uniform and excess production in periods of slack demand set aside for use when customer requirements are high. The ability to limit producing capacity to the equivalent of average demand tends to lower costs, but storage requirements are an added cost item.

The additional cost of being ready to meet all demands without delay must be taken into account in determining the conditions under which the public utility may operate and the rates it must charge to provide reasonable earnings. The problem is to balance the interests of the management and investors with the interest of the community in obtaining the most efficient service.

SOCIAL CONTROL OF PUBLIC UTILITIES

Public service enterprises are regulated by governments throughout the civilized world. It is impossible in this article to trace this development or to outline the modern structure of regulation. Those desiring a detailed presentation are referred to the bibliography. In this summary is mainly given a discussion of the development of social control of public utilities in Anglo-American countries. The regulation of national systems of transportation and communication is also excluded except in so far as their prior development has influenced the course of public-utility regulation.

Munn v. Illinois **Decision.**—A common legal background of public-utility regulation both in the United States and in Great Britain is disclosed by the decision of the U.S. supreme court in *Munn* v. *Illinois* (94 U.S. 113 [1877]). The *Munn* case involved the validity of an Illinois statute fixing maximum rates for storing grain in elevators. Munn had been engaged in the elevator business since 1862, long before the enactment of the statute, and had been in the habit of charging rates fixed by agreement among the elevator owners in Chicago, Ill., and had continued to charge these rates although they were in excess of those fixed by the act. Munn mas convicted and fined in the state courts but appealed to the U.S. supreme court upon the ground that the act violated the 14th amendment in that it deprived him of his property without due process of law.

Chief Justice Morrison Waite, in upholding the validity of the statute, said in substance that under the circumstances in which the elevators were being operated in Chicago (*i.e.*, standing in "the very gateway of commerce and taking toll from all who pass") they had become business "affected with a public interest and had ceased to be *juris private* only." This was not his own language but was quoted from Lord Chief Justice Matthew Hale who had penned it about 200 years before in England. This legal doctrine, he said, had been a rule of the law of property ever since; that under this rule and in exercising the police power of the state, "it had been customary in England from time immemorial and in America from its first colonization to regulate ferries, common carriers, hackmen, bakers: millers, wharfingers, innkeepers. and so forth," and to fix maximum charges. In further explanation of this "public interest" doctrine, the court said that private property is being used "in a manner to make it of public consequence, and affecting the community at large. When, therefore. one devotes his property to a use in which the public has an interest, he, in effect, grants to the public an interest in that use. and must submit to be controlled by the public for the common good, to the extent of the interest he has thus created. He may withdraw his grant by discontinuing the use; but, so long as he maintains the use, he must submit to the control."

In a later case (*Charles Wolff Packing Co.* v. *Court of Industrial Relations of the State of Kansas,* 262 U.S. 522 [1923]), Chief Justice W. H. Taft of the U.S. supreme court gave further precision to this "public interest" doctrine by saying: "In a sense, the public is concerned about all lanful business because it contributes to the prosperity and well-being of the people. The public may suffer from high prices or strikes in many trades, but the expression 'clothed with a public interest' as applied to a business means more than that the public welfare is affected by continuity or by the price at which a commodity is sold or a service rendered. The circumstances which clothe a particular kind of business with a public interest, in the sense of *Munn* v. *Illinois* and other cases, must be such as to create a peculiarly close relation between the public and those engaged in it, and raise implications of an affirmative obligation on their part to be reasonable in dealing with the public."

Between 1923 and 1934, and particularly during the depression years, a series of cases involving the constitutionality of price regulation was decided by the United States supreme court. With a dissenting minority of liberals, the court ruled against the regulation of the resale price of theatre tickets in New York city and of the fees of private employment agencies in New Jersey. Without dissent it forbade the regulation of the retail prices of gasoline in Tennessee. A divided court decided against the regulation of competition among artificial ice plants in Oklahoma. This negation of the extension of regulatory power was halted in 1934 when New York was upheld in its efforts to stabilize the fluid milk supply industry and rescue it from price-cutting tactics through the fixing of minimum prices by a milk control board. The seeming confusion behind these contradictory opinions can be explained by noting that the trend was in the direction of extending the use of the police power in the interests of public health, safety, morals and the general welfare, while the hard core of public-utility regulation in the interests of monopoly control continued without abatement.

Obligations of Public Utilities.—The affirmative obligations upon public utilities arising out of their peculiarly close relation to the public are usually spoken of as that system of rights and duties which constitutes the law of public service undertakings. Briefly, this law places upon a public utility the extraordinary duty to render reasonably adequate service to all who apply. It is required to serve them up to the limit of its capacity, with capacity being defined as the limit of profitableness. It may not let customers' wants go unsatisfied. Nor may it attach unreasonable conditions to contracts for service so as in effect to negative its duty "to serve all comers." Furthermore, it must serve without discrimination all customers similarly circumstanced. Finally, a public utility must observe more than ordinary care in the rendition of service in view of the dependence of the public upon such service and the hazards associated therewith. On the other hand, the same law concedes a public utility the right to collect a reasonable price, to render service subject to reasonable rules and regulations and to withdraw service under prescribed conditions after giving notice to customers. While customers are given the right to demand that a public utility live up to its duties, they are, on the other hand, required to accept reciprocal obligations formally imposed by the regulatory body or implicit in the franchise.

Economic and Legal Determinants.—In determining whether a given industry is subject to this coercive law of public utility the courts have adopted certain practical tests of both a legal and an economic nature. The economic tests look to the presence of elements of natural monopoly in such number and strength that competition cannot work successfully. The power of the state will be used either to regulate industries so as to restore equality of bargaining power by maintaining competition and controlling competitive practices. or used to promote the inherent trend toward monopolistic organization by conferring upon such industries legal monopolies and then controlling their economic relations.

From an economic point of view it is clear, therefore, that the concept of a public utility is made up of two ideas: (1) the idea of monopoly; and (2) the idea of common necessity. Both must be present in order that an industry may become a public utility. Neither alone will suffice. The supply of housing facilities is a necessary economic function, and when it is furnished upon a competitive basis the customer is not coerced. But when, in emergencies such as the acute housing shortage (see HOUSING) during World Wars I and II, the consumer is forced to bargain for a necessity under conditions of temporary monopoly. the courts will uphold the regulation of rents. Yet the character of regulation will be such as to enable the industry to reachieve normal condition. The emergency having passed, as building operations are resumed competition again sets in and the reason for regulation disappears. The housing industry therefore represents a borderline case which, nevertheless, ought not to be classed as a public utility under normal conditions.

When freedom of choice is seriously restricted—that is. when the coercion residing in private property makes itself felt as a monopolistic power—public interest arises in proportion as equality of opportunity to choose is restricted, provided that the wants supplied are recognized as a common necessity. The concept of public utility thus becomes a legal instrumentality to achieve an improvement of the standard of life. In a society which is accustomed to look to governmental initiative for the supply of common needs, the facility will be supplied as a public function. On the other hand, a society which is distrustful of the state will leave the supplying of such common needs to a private agency under a franchise privilege, not as a matter of common right. but as an agency of the state.

Since the law had long recognized the rights and duties of public utilities, this legal conception attained a certain fixity in the form of legal rules. But the number and kind of industries that may be subjected to these rules is not fixed. It may be said that the legal notion of public utility is that of a fixed concept with a changing content. The industries at any time recognized as "clothed with a public interest" are not necessarily the industries which may legally be classified as public utilities at another time. The industrial and political situation as mirrored in public opinion will determine: (1) the number and kind of industries classified as public utilities; (2) the elaboration of the system of rights and duties which make up the institution; (3) the regulating agencies and instrumentalities employed (whether the legal rules and decrees of courts or the charters, special franchises and statutes of legislatures); and (4) the subordinate administrative standards which are evolved in practice. The trend in the development and application of the institution will be a resultant of the amount of social inertia, of the pressure of the economic environment and of the influence of intellectual progress.

Regulation in the United States has been accomplished in three distinct ways: (1) judicially by means of suits at law where the common-law duties and rights of public utilities are applied in specific cases; (2) legislatively by means of corporate charters or special franchises; (3) legislatively by means of the police power of the states or its federal equivalent, the power of congress over interstate and foreign commerce. Judicial regulation is the oldest and constituted almost the only form of control during the first half of the 19th century. Legislative regulation later largely supplanted judicial regulation, but the latter remained in the background as a potential agency which might become active again if legislative regulation should disappear. The function of the judiciary by 1898 had been restricted to the review of legislative and administrative acts.

Legislative regulation by means of the charter or special franchise was the next to be tried. The special franchise is now generally conferred under constitutional or statutory authority by local governments The method of special franchise regulation is applied to so-called local public utilities, furnishing telephone, gas. electric, water and transportation services in local communities.

The weakness of legislative regulation by charter was that the maximum rates therein provided were largely in excess of those actually charged by the companies. Competition of carriers with each other. the decreasing unit cost of operation on account of increased utilization of plant capacity, the decline in the level of prices after the Civil War, continuous improvements in technique made necessary and possible the rendition of service at rates below those fixed in the charters. The failure to provide adequately for financial and accounting control enabled the issuance of more stock and the padding of investment accounts, thus vitiating the control based upon net income. Special franchise regulation followed the procedure applied in the case of carriers. Maximum rates were fixed in the local franchise of telephone, gas, electric and water undertakings. These maximum rates soon became obsolete because the growing business of the companies required more complex and flexible rate schedules. Moreover, the companies began to appreciate that incredsed earnings, both gross and net, could be secured by means of rate reductions.

When state legislatures in the case of national carriers and local councils in the case of local utilities attempted to adjust these rates downward, they were met by the objection that the change would violate a contractual obligation and confiscate the property of the companies. Only when the franchise was silent on rate questions or when the power to alter. amend or repeal the terms of franchises was reserved. could the power to regulate rates or service be exercised by state or local legislatures. Another evil that had crept into the administration of public utilities as a result of the ineffectiveness of rate control was discrimination in rates. This was also induced by the fact that competition had never been entirely eliminated. Added to this, in the case of the limited term franchises of local utilities, was the groning insecurity of tenure. Failing to obtain a renewal the properties would be worth only their scrap value. Often there were no provisions for public purchase or for purchase by some other grantee at the end of the franchise period. The inducement mas too great, therefore, to manipulate operations so as to enable investors to recoup their capital out of earnings.

About 1870–80 a policy was adopted of fixing rates by direct legislation. Legislatures reaiized that statutory regulation should be general rather than specific; that the rate and service problems require continuous attention; that the subject matter of statutes should be the laying down of principles and standards; that the new policy of continuous regulation required an effective agency, sufficiently informed by experience to carry legislative standards and principles into effect. This agency is the modern administrative commission, acting as an agent of the legislature. All states set up regulatory commissions with varying jurisdictions. The first federal agency to regulate a public utility was set up in 1887 to control the interstate commerce of the railroads. As new public-utility industries arose, additional agencies were established or the jurisdictional scope of existing ones broadened. Their authority was strengthened as the need for more adequate control became apparent. Federal regulation in the mid-1950s covered the three major fields of transportation, power and communication. Control over transportation is effected through: (1) the Interstate Commerce commission, established in 188; to regulate the railroads, jurisdiction being extended to cover pipelines other than water and gas (1906), motor carriers (1935), interstate and coastal water carriers (1940), and freight forwarders (1942); (2) the Federal Maritime board and the Maritime administration, set up in 1950 (stemming from the U.S. Shipping board of 1917) to regulate offshore shipping: and (3) the Civil Aeronautics board, created in 1940 (as a reorganization of the Civil Aeronautics authority of 1938), with jurisdiction over air carriers. Authority in the area of power is exercised by the Federal Power commission (organized as an independent commission in 1930) which regulates hydroelectric projects and the transportation and sale of electric power and natural gas. Communication by wire and radio, both interstate and with other countries. is regulated by the Federal Communications commission, established in 1934. In 1935 the Securities and Exchange commission was empowered to regulate transactions in securities and other assets of public-utility holding companies.

With the exception of the Securities and Exchange commission, which is concerned only with financial ownership, these agencies are in general charged with fostering adequate service at reasonable rates. Their powers vary according to the nature of the utility involved but. in addition to regulation of rates, commonly cover such matters as licensing of operations, ruling on maintenance of services, promoting safety regulations and passing on intercompany agreements. The administrative commission applies the common-law rule of reasonableness to the concrete facts in each case and names the particular rate or service regulation deemed appropriate to the circumstances.

Regulation of all public utilities was hampered by the insistence of the courts after 1898. when the epoch-making case of *Smythe* v. *Ames* was decided, upon defining the basis for rate-making which cominissions might use. The major conflict was over the weight to be accorded reproduction costs as compared with actual original costs in the determination of the "fair value" of the investment. With the rise in the levels of prices, particularly after 1914, commissions were inclined to use the standard of actual investment costs while the utilities were contending for reproduction costs. In a series of decisions culminating in *McCardle* v. *Indianapolis Motor* Co. (272 U.S. 400 [1926]) the courts upheld the position of the utilities. But the courts receded from this extreme position after the depression set in and in Federal Power *Commission* v. *Natural* Gas *Pipeline Co.* (315 U.S. 575 [1942]) conceded that the particular formula of rate determination was within the discretion of commissions, so long as the result was not arbitrary or confiscatory. The Hope case (Federal Power Commission v. Hope *Natural* Gus, 320 U. S. 591 [1944]) further strengthened the position of the commissions by specifically rejecting "fair value" as the determining factor in rate-making, thus leaving commissions free to take into account "prudent investment" in fixing rates designed to provide adequate earnings and attract new capital.

BIBLIOGRAPHY.—M. G. Glaeser, *Outlines of Public Utility Economics* (New York, 1927) ; G. L. Wilson, *et al., Public Ctility Industries* (New York, 1936) ; F. X. Welch (ed.), *Cases on Public Utility Regulation* (Washington, D.C., 1946) ; Charles Emery Troxel, *Economics of* Public *Utilities* (Sew York, 1947) ; J. Bauer and P. Costello, *Public Organization of Electric Power* (New York, 1949); E. W. Clemens, *Economics and Public Utilities* (Sen- York, 1950). (M. G. G.; A. D. H. K.)

REGULATION IN EUROPE

On the continent of Europe practically all telephone and telegraph systems and many railroad systems are nationally owned and operated and there is little opportunity for anything similar to the Anglo-American system of public-utility control. This also holds true in a large measure of local utilities. Where local utilities are privately owned they are operated under franchise contracts with the municipalities.

Great Britain. — Although in Great Britain before World War II the railroads were privately owned but subject to a large measure of regulatory control, a great number of other public utilities, notably local transport undertakings and gas and electricity, were owned and operated by local municipalities. Many had originally been started by private enterprise and later acquired by the local authorities but in the case of transport in particular the municipalities were responsible from the start. Before the war, the trend mas toward increased municipalization through acquisition. Public and private utilities were both subject to considerable statutory regulation but the former enjoyed greater freedom particularly in regard to charges. Establishment of public utilities was by private bill legislation, separate acts being necessary to confer franchises and determine the regulatory conditions of operation of each undertaking. In certain cases of common occurrence special legislation by parliament to establish each public service undertaking was made unnecessary by enabling the appropriate department of the government to issue provisional orders under general legislation after due inquiry. But full parliamentary control was retained by requiring confirmation of provisional orders, either by parliament itself or, in some cases, by an agency such as the board of trade, made effective by resolution of each house of parliament.

The English system of regulation was, accordingly, comparable to the charter or special franchise system in the United States. Laws of this type mere the Gas Regulation act of 1920, and the Electricity Supply acts of 1919, 1922 and 1926. The focal point of control was the regulation of rates. In the case of private gas companies the first method of control, after a brief preliminary period of competition, was the so-called official revision system, Maximum rates and maximum dividends were fixed in special acts but the power to reduce rates was given to the court of quarter sessions. Later another method, the system of sliding scales, was used, the adoption of which was optional. There was established a standard selling price for gas and a standard maximum rate of dividend. Then it was provided that the dividend rate might vary in inverse ratio to the rate of charge.

Local passenger transport undertakings, whether private or public, were made subject to a licensing system under the Road Traffic act, 1930. Regional traffic commissioners were appointed and made responsible for licensing public-service vehicles to regulate competition between road and rail by regulating numbers of vehicles to traffic requirements; by regulating fares, service and frequencies; and by establishing standards of construction, use and maintenance of vehicles. Under the Road and Rail Traffic act, 1933, a licensing system was also introduced to regulate road haulage vehicles operating for hire or reward.

Communication facilities (postal services, telephones and telegraphs) have been a government monopoly since the 17th century. An exception is the city of Hull which operates its own municipal telephone service. Between World Wars I and II cable and wireless services were merged compulsorily and were finally acquired by the state after World War II and handed over to the post office for operation. The British Broadcasting corporation was established in 1927 as a public corporation with a monopoly for sound radio which it retains but a second public corporation, the Independent Television authority, was established in 1955 to provide commercial television in competition with the B.B.C.'s television service.

Between the wars regulation was also directed to creating larger units of operation through amalgamations. Thus the Railways act, 1921, compulsorily merged the railways into four main line companies and the main purpose of the Electricity (Supply) act, 1919, was to bring about mergers and reorganization of the electricity industry to enable more economic generation by larger units. It established an electricity commission of five members, appointed by the minister of transport, to which were transferred many of the regulatory powers previously vested in government departments. The inadequate mandatory powers of the commissioners and insufficient co-operation from the undertakers were largely responsible for the act's failure. It was accordingly superseded by the Electricity (Supply) act, 1926, which vested responsibility for the wholesale distribution of electricity over a national "grid" in the Central Electricity board. This public corporation constructed the "grid"! which it fed with power generated both by itself and by municipal and private concerns. Local distributors remained unchanged until April 1, 1948, when under the Labour government's nationalization program both generation and distribution of electricity were transferred to public ownership. The Central (formerly British) Electricity authority became responsible for generation and the "grid" and its 12 (formerly 14) area boards for local distribution in England and Wales. In Scotland responsibility was transferred to two public boards independent of the central authority. At the same time control of the manufactured gas industry, which had been slower to integrate and comprised 1,056 municipal and private concerns, was transferred to the Gas council and its area boards. The former had mainly supervisory functions as the boards were made responsible for both production and distribution.

Railways, which had been under government control throughout the war, were not returned to their former owners but nationalized, together with their ancillary undertakings, long-distance commercial road haulage and the inland waterways. The British Transport commission was made the responsible body from Jan. 1, 1948. Under the Transport act, 1953, a large section of road haulage was denationalized but the commission retained under a subsequent measure, the Transport (Road Haulage Disposal of Property) act, 1956, a substantial proportion including its nation-wide trunking services.

It can be seen therefore, that in Great Britain regulation of public utilities has evolved from statutory regulation of private and public concerns to direct ownership on a monopoly basis through public corporations. (*See* also GOVERNMENT CORPORATIONS.)

Continental Europe.—Before World War II the trend in continental Europe was toward generation of electricity on a larger scale, particularly in France, Italy and Germany. In Germany "mixed undertakings" were established similar to the German Railways companies with the shares in both public and private hands and frequently with cities served co-operating. After World War II with the great development of hydroelectric power, the trend was toward greater co-operation between the countries of western Europe for exchange of power across frontiers. The Organization for European Economic Co-operation greatly assisted in this.

BIBLIOGRAPHY.—F. N. Keen, *The Law Relating to Public Service Undertakings* (London, 1925); William A. Robson (ed.), *Public Enterprise* (London, Chicago, Ill., 1937), *Problems of Nationalized Industry* (London, 1952); Marshall E. Dimock, *British Public Utilities and National Development* (London, 1933; Chicago, Ill., 1934); I. R. Barnes, *The Economics of Public Utility Regulation* (New York, 1942); Ernest Davies, *National Enterprise* (London, 1946); H. H. Trachsel, *Public Utility Regulation* (Chicago, Ill., 1947); The Twentieth Century Fund, *The Power Industry and the Public Interest* (New York, 1944), *Electric Power and Government Policy* (New York, 1948); O.E.E.C., *The Electricity Supply Industry in Europe* (Paris, 1956).

(E. A. J. D.)

PUBLIC WELFARE LAW: *see* POOR LAW.

PUBLILIUS (less correctly **PUBLIUS**) **SYRUS,** a Latin writer of mimes, flourished in the 1st century B.C. He was a native of Syria and was brought as a slave to Italy, but by his wit and talent he won the favour of his master, who freed and educated him. His mimes, in which he acted himself, had a great success; he was perhaps even more famous as an improvisatore, and received from Caesar himself the prize in a contest in which he vanquished all his competitors, including the celebrated Decimus Laberius. All that remains of his works is a collection of Sentences (*Sententiae*), a series of moral maxims in iambic and trochaic verse, which has been much interpolated with later extracts.

The best texts of the *Sentences* are those of E. Wölfflin (1869), A. Spengel (1874) and W. Meyer (1880), with complete critical apparatus and index verborum; recent editions with notes by O. Friedrich (1880), R. A. H. Bickford-Smith (1895), with full bibliography; *see* also W. Meyer, *Die Sammlungen der Spruchverse des Publilius Syrus* (1877).

PUBLISHING. Publishing is the selection, reproduction and circulation of written matter. It is older than both printing and paper, though in modern times it has come to depend upon both. Printing from blocks was invented in China some time before the middle of the 9th century; printing from movable type was invented there by the middle of the 11th century. But at neither time was printing thought of or encouraged other than as an excellent device for avoiding the errors of transcription that often marked the work even of the best manuscript scribes and copyists. In Europe, printing from movable type was invented by the middle of the 15th century. But there, as in China, its major advantage over older methods of reproduction was thought to be the standardization of scripture and of official texts. Neither in Asia nor in Europe was printing viewed at first as being useful in the wide dissemination of literature, learning or political or religious discussion. As an instrument of publishing, indeed, printing had to fight its way; it became a great instrument of spiritual and intellectual development and theological and scientific discourse, but the earliest reaction, which persisted for centuries in the west as in the east, was one of opposition by church, government, university or other powerful interests, such as the Brahmin caste in India, to its use in giving wide publicity to certain ideas and information.

The Earliest Books.—Before the invention of printing and of paper, publishing was carried on by means of professional scribes or skilled slaves making numerous transcriptions of manuscripts on papyrus or parchment. Flourishing industries producing papyrus or parchment rolls for sale on which were inscribed the classics of ancient literature, religion and law were to be found in Egypt under the Ptolemies and in the major cities of Greece and republican Rome. Often under the Roman empire, as often under later western kings, princes, parliaments and presbyteries, censorship and intimidation controlled or attempted to control publishers' output, thus interrupting the continuous history of commercial publishing for long stretches. Yet these ancient enterprises were authentic prototypes of modern publishing houses. Their work consisted in selecting manuscripts for reproduction in quantity, in taking the risks of compensating authors in advance of public sale for rights to such manuscripts, in determining the size, price and format of editions of different titles, and in developing markets in which such editions could, by various means, profitably be sold. They were publishers in every modern sense of the word, even though their products were not yet books.

Books in the form with which the world has long been familiar, that is, made up of pages bound together at one side, had a long and obscure development of their own. By the 4th century the bound book had become moderately well-known, at least among the jurists of the later Roman empire. Its first real vogue, however, was in Ireland, two or three centuries later, the climax of the remarkable flowering of intellectual and religious spirit there being the Book of Kells, not infrequently mentioned, according to one authority, as "the most beautiful book in the world."

To distinguish it from the old *volumen,* or "roll" (from which, oddly enough, the word "volume," often used interchangeably with "book," is derived), the early bound book was called a codex. The codex became the typical book of the middle ages, and theological codices were produced in large quantities especially in the monasteries of various church orders, which were the publishing centres of the day. Codices in law, medicine, rhetoric and other fields of learning came from the rising universities which, in certain cities, early grasped control over the publishing industries from the church and the state. In such centres, the second-hand market was as well-known to mediaeval students as it became to those of the 20th century and to 20th-century textbook publishers as well. The difference was that the universities, as publishers but not commercial ones, strove (in these early efforts at price-fixing which became such a feature of publishing in the 20th century) to keep prices down for the students and thus encouraged the use of old copies. This also relieved the universities of producing large new editions every year.

The codex, of course, like the papyrus and parchment rolls that it replaced, was written entirely by hand. In the scriptorium or "writery" of the monastery, scribes more or less devoted to their work toiled during the daylight hours (fear of fire from artificial light prompted the monasteries to forbid work on books at night) copying page after page of ancient classics, thus laboriously accomplishing the great task of preserving them as well as the Bible. "After the scribe had finished his quaternion, or group of four sheets in eight leaves," writes Douglas C. McMurtrie, "his work was proofread in comparison with the original by a second person, and the sheets were then sent to the rubricator, who inserted titles, headlines, chapter and other initials, notes. and the like. If the book was to be illustrated, the sheets next went to the illuminator. After he had completed his work on the volume, it was ready to be bound." This procedure was not very different, in essence, from manuscript preparation in a modern publishing house—except that with modern printing and illustrating methods, these and related publishing tasks need be performed only once for an edition of many thousands, and not over and over again for every individual codex or book.

Printing and Publishing in Modern Europe.—Though the early history of publishing owes nothing to printing, Johann Gutenberg's invention of printing from alphabetical type gave a great boost to publishing in Europe after the middle of the 15th century. Gutenberg probably was not the first European to use movable letter type successfully. After his epochal achievement, however, Mainz, his home in Germany, became the indisputable publishing centre of the continent, and Germany itself the source and fount of subsequent printing and publishing developments in the western world. Before 1500 about 30,000 books were printed in Europe; of these, more than two-thirds came from such great German centres of learning as Leipzig, Cologne. Basel, Nuremberg, Augsburg and Strasbourg. More important, it was Germans, trained in these cities, who introduced modern printing and publishing into Italy about 1460, where it played an important part in the spread of Renaissance culture and trade. Similarly, it was Germans, trained in turn in Italy, who carried the printing industry and modem publishing to France in the early years of the 16th century.

It was only then that a broadening of the lay market for books took place. In 1501 Aldo Manuzio designed the first books in small format, which eventually replaced the huge, elaborate and costly codex, just as the codex had replaced the awkward *volumen.* In succeeding decades, especially in France, much attention was given to typography, and names still commonly used for type faces in the 20th century became –ell-known, from the work, for example, of Claude Garamond and Robert Granjon. A customer of both of these typographical artists, Christophe Plantin, was the most famous of the early printers who became publishers. Born in France in 1514, Plantin fled from Paris in 1548 to escape religious persecution. He settled in Antwerp, Belg., and there made his fortune. In the end he returned to the good graces both of the church and the university, gaining from the Holy See the monopoly of publishing liturgical books for the Spanish empire, and becoming late in life, printer to the University of Leyden, itself a great publishing centre of the time.

Though many early printers remained faithful to the church and to their princes, the publishing of printed works quickly became one of the major means of organizing protestant and radical opinion in the late 15th and early 16th centuries. This naturally led to reprisals against the new publishing industry, especially in Germany, and in self-defense the publishers and printers organized into independent corporations and guilds of their own. These lasted until the 19th century in many countries. Where printing and publishing was not shut down or forced underground, as was the case in Nuremberg and Augsburg early in the 16th century, it was controlled by other means. Thus in France, as early as 1474, the new independent printers and their printed books were brought under the same licensing regulations by which the University of Paris alone had monopolized the work of the old scribes and the publication of their manuscripts. This was indeed a signal recognition of the rapid rise of the printer to publishing eminence: yet it was also an onerous burden to the new publishers who were out of sympathy with officialdom.

Between them, official controls on the one hand and guild restrictions on the other impeded the development of printing and publishing for centuries. On the continent, one result was the emigration of printers and publishers to England where, from 1476 to 1536, it is estimated two-thirds of all printers, binders and stationers were aliens. But even in England from 1534, when the Stationers company or guild was first organized into the monopoly of all English book publishing, to 1710, when the first copyright act was passed in the reign of Queen Anne, there was constant harrassment of publishers, nhich, in due time, was carried across the ocean to America as well. It was on an occasion during this epoch, when some freedom of publishing, bitterly won, was challenged by new efforts at control, that John Milton wrote his *Areopagitica* in 1644.

In France, control was more or less thorough until the revolutionary copyright law of 1793 freed publishing and printing from all existing monopolies. This freedom was short-lived, however, ending under Napoleon's First Empire and not restored until the declaration of the republic in 1870. French restrictions had a salutory effect on the publishing industries in the Netherlands and Belgium where, during the 17th dnd 18th centuries, large editions of the works of Moliere, Boileau, Voltaire, Rousseau and others were issued clandestinely for the French market.

As is usual with excessively rigorous controls, they often were poorly enforced; and as is usual with official monopolies, they often bred strong, if *sub rosa,* competition. Both of these situations, whatever the prevailing atmosphere, permitted printed literature and learning to spread rapidly in Europe between the 16th and 20th centuries, and authorship and publishing to flourish because of it. The English Copyright Act of 1710 freed the individual author and enterprising publisher from monopolistic printers and recognized the right of both to negotiate for the best royalties and other terms for the publication of literary property. But this right had been recognized as early as Roman times, when publishers of the empire bid competitively for the exclusive privilege (for which they paid fees, not royalties) of duplicating literary creations. What was significantly new about the English act was its recognition of the right of the whole public to literary property after a specified term. That is the nub of modern publishing copyright; it protects authors in their rights to literary property and publishers in their acquisition of such rights; but more than that, it gives the public, increasingly eager for great published works, freer access to such property after a limited number of years — under Queen Anne's act the term was 14 years, with the author retaining the privilege of renewing for another 14 years; in the United States in the 20th century, it was 28 years, with the same privilege for another 28 years; in most other countries, the term is the remaining years of the author's life, plus 20 to 50 years.

The development of copyright practice since the early 18th century is an authentic clue to the growth of professional authorship and commercial publishing, and by the protection copyright gave it was a stimulus to both. The limitation in the copyright period, in turn, is an authentic clue to the thirst for learning among the populace who, with the centuries, became more and more literate. Roman usage and common law had acknowledged the author's right—if he could assert it—to his property in perpetuity. English and later continental statutes freed this property for public use after protecting the author and publisher for specified periods of time.

Toward Contemporary Publishing Practice. — Just as the monasteries gradually yielded their monopoly of publishing to the universities, and the universities to the corporations and guilds, and the guilds to the competitive printers, so the printers, under the pressure of this growing market for literary works, gradually surrendered their dominant position to the booksellers.

None of these transitions took place in a day. Even as early as the 1580s in England, the pressure of costs for printing equipment and the like forced printer-publishers to appeal to booksellers for capital and credit. Thus in 1582 Christopher Barker complained to the queen: "The booksellers being growen the greater and wealthier number have nowe many of the best Copies and keepe no printing howse, neither beare any charge of letter, or other furniture but onlie paye for workmanship . . . [with] the artifice printer growing every daye more and more unable to provide letter and other furniture, requisite for any good worke; or to gyve mayntenaunce to any such learned Correctours as are behovefull. . . ." Yet it was not until the 18th century that the bookseller had his great day as publisher. By then the reading public, especially in England, was growing much faster than before and trade in popular new books (as distinct from the earlier staples of the whole industry: Bibles, commentaries, textbooks, dictionaries and the like) was booming. To meet the new demands circulating libraries were established as early as the 1720s, and new authors were developing sufficiently large popular followings to be able to insult and dispense with their former aristocratic patrons. By the late 18th century booksellers whose names continued to adorn modern publishing houses as late as 1950—such as Constable and Longmans — had already become kingpins of the publishing industry. Only a few decades later in the new world itself, Harper, Scribner, Dutton, and Little, Brown had become well-known.

Thus, with the rise of the bookseller, contemporary publishing began, and with the more or less simultaneous rise of the novel and the novelist it flourished. Both developments reflect the ascendancy of the middle classes. and thus had their greatest vigour in England and the United States. They followed more deliberately on the continent, where literacy was slower to become nation-wide and where extremes of wealth and poverty kept the middle-class markets small.

The unity of bookselling and publishing, in turn, persisted far longer in England than in the United States, where the great development of new writers (after piracy of English titles was successfully abated late in the 19th century) gradually stimulated the creation of independent publishing houses which were neither printers nor booksellers. This change brought with it new independent printers, binders and booksellers — the first two to produce, under contract, books arranged for by the new publishers; the third to sell those books to an ever growing public.

By the third decade of the 20th century still newer publishers appeared in numbers in England and the United States and in Germany and France on the continent, devoted almost exclusively to so-called trade books — that is, general books of fiction, popular biography and history, books of memoirs and inspirational psychology, books of sentiment and sentimental learning. Many houses among the older group and some among the newer ones as well continued to have all kinds of special departments for Bibles, other religious books, school and college textbooks, medical books and similar works that once were the foundation of the entire publishing industry. But the newer vogue was the trade publisher as such. The age of specialization had indeed set in, and nowhere more strongly than in the United States, where the industry was less encrusted with old traditions and thus afforded the most suitable soil for the new flowerings.

Subscription Books. — One of the widest and most extensively developed methods of distributing books is by subscription: sales are assured by the canvassing and pledging of subscribers. Today reference works of all kinds — encyclopaedias, sets of children's books, some dictionaries, collections of popular novels — are distributed almost solely by this method and the value of the sales in the United States and elsewhere amounts to many millions of dollars.

Sales by subscription, it is believed, began in the 15th century when William Caxton is said to have initiated this method to finance the publication of *Mirror of the World*. The purpose was to ensure moneys for the production of this work and differed from the traditional practice, of having one sponsor or patron for the book, by enlisting the interest and money of many.

The idea proved attractive to printers and to authors but it was not until the turn of the 17th century that this form of distribution flourished. In most instances, the issue remained a single volume and the cost of production was assured by the persons who promised to buy the book. The method fell into disrepute after a time when some printers, selling a book in advance of publication, sold trash or no book at all.

In the 18th century larger sets of books were distributed by subscription. *Encyclopædia Britannica* in 1768 was one of the first. In some instances, where the cost of the initial production is excessive, prepublication offers are made and subsequent sales are continued under instalment or, as it is known in Great Britain, the hire-purchase plan. Mark Twain in the United States adopted this idea for the distribution of Gen. Ulysses S. Grant's *Memoirs*. Albert Bigelow Paine says in his monumental biography of Mark Twain. that Twain was able to present General Grant, who needed it, the largest single royalty check, $20,000, ever given to an author up to that time, and, of course, before the volumes actually were made.

Perhaps the greatest recent venture in prepublication subscription was the publication of *Great Books of the Western World* in 54 volumes by Encyclopaedia Britannica, Inc., in 1952. It was the generosity of 500 founder prepublication subscribers which facilitated the general distribution of this costly work.

According to the American Textbook Publishers institute the subscription sales of reference books to homes and offices and to schools and libraries in the 'United States alone were estimated at about $125,000,000 for the year 1954.

The Age of Specialization. — In the 20th century in the United States, as elsewhere, the number of new titles published each year grew steadily, except for dips in war years or their immediate aftermaths. At their peaks, about 35,000 new titles were published in Germany, 15,000 in Great Britain and 12,000 in the United States. These figures are not altogether commensurable, since the definition of a book has always remained vague. But whatever the actual figure, the relative size of the industry in the 20th century can be judged by comparing even its smallest annual volume of titles with that of earlier centuries. In the first half of the 18th century in England, for example, it has been calculated that the average annual number of new titles was about 93. The first quarter of the 19th century saw a jump to an average annual total of about 600. By comparison, the 20th-century totals make it clear why specialization in publishing could so readily be supported, indeed, why specialization had to come.

Within trade publishing itself the 20th century saw the development of hard cover reprinters, paper cover reprinters, specialized western story and detective story publishers. science-fiction publishers and others who profited greatly by concentrating on special books for special, but sufficiently large, markets. In distribution, moreover, the old-fashioned bookseller — even the one who himself came to specialize in trade books — was supplemented by the book club, by other types of mail-order houses and by the ordinary newsstand which accounted for the bulk of the sales of the paper cover reprints. While most regular trade publishers still printed editions ranging from 3,000 to 10,000 copies for most of their titles, for book clubs and paper cover reprinters editions often ran to more than 100,000 copies and not infrequently for the latter to more than 200,000 copies. Clearly the old middle-class market had become, by mid-20th century, a mass market, especially but not only in the United States. In the 1950s in the United States a new departure was the publishing in paper covers in editions ranging from 20,000 to 50,000 copies and at prices ranging from 65 cents to $1.95, of reprints of great works of scholarship, science, religion, literature and art. Many had long been out of print; often they had been issued originally by university presses or other specialized publishers and had had total sales of less than 2,000 copies. The great market for these books was found among college students and professors. So successful were these new editions, that many publishers began reprinting their serious books in paper cover editions of their own. Some even issued new learned titles in this form for the new student market. The specialized reprinters and even the publishers of the mass editions of detective stories and the like, in turn, began also to seek original manuscripts of a scholarly nature. In the main, however, those publishers, such as the book clubs and others selling in mass markets, continued to look to the regular publishers for titles to reprint. Thus literary production in the form of books, and hence the literary health of their countries, remained such publishers' responsibility throughout.

Some bore it better than others, but virtually all sought to share it. To discover manuscripts for this publishing industry, new occupations thus became prominent after the first quarter of the 20th century. Two of these were most important: the manuscript scout, who often worked for publishers under contract by which his remuneration was a stated percentage of the retail price (usually ranging from 1% to 2%) ; and the literary agent, who universally worked for authors, handling all their business relations with publishers for compensation in the form of 10% of the author's royalties and other income from his literary production. The growth of the agency business reflected further specialization in the publishing industry by which the publisher, becoming more a business manager, passed over his editorial functions to others. It also reflected the broadening of the market for the work of authors, especially authors of fiction. In the 20th century to the old magazine and newspaper serial rights were added motion-picture rights, dramatization rights, radio rights, television rights, digest rights and a series of others, the sale of which required complicated negotiations and contracts and which, however much it might enrich them, most authors were themselves incompetent to handle.

In facilitating distribution of books, further specialized agencies appeared in many countries in the 20th century. These were advertising agencies, some of which merely added books to all the other products for which they sought to stimulate demand, others concentrating on books alone. In Germany and England, typically, about 5% of a publisher's net return was spent for advertising and promotion; in the United States. the percentage was likely to be ta-ice as high for books of average sales; and the actual amount proportionately even greater. For books with great sales possibilities much more was often set aside. Spending this money most effectively required skill and experience which the publisher often did not have; thus the development of advertising agency business in books.

Though trade books were the fastest growing part of the whole publishing industry in the 20th century. and paper cover reprints the fastest growing part of trade publishing, growth elsewhere also added measurably to the flow of books. Especially notable in the United States was the growth of the federal government as publisher—a development that reflected not only the rapidly increasing number of all kinds of government investigations. but also the growth of federal services to farmers and others not ordinarily reached by regular publishers and regular means of book distribution. Far smaller in volume was the production of the American university presses. Their work was largely in books of importance to science and learning which would, without these presses. probably have gone unpublished and thus unknown.

All told. in 1945, according to the United States census bureau, almost 500,000,000 copies of books were printed in the United States alone. The history of the technological improvements in printing that made such production possible is a long one in itself, including the history of such familiar machinery as linotypes. cylindrical presses, rotary presses and attachments to them. Most of these came in around the turn of the 20th century; subsequent great improvements in their performance allowed them to keep up with the demand for books.

In the 20th century: motion pictures, radio entertainment, television broadcasts. the automobile, the massive illustrated magazines and other vehicles of entertainment and enlightenment occupied the attention of growing populations. All competed with the traditional book; but the book publishing industry itself enjoyed the most remarkable growth in its long and troubled history. In mid-century it was rising on the continent once again from the devastation of two wars. In the United States it remained one of the major channels of communication. one of the major forums from which were fed the spirit and the intellect.

BIBLIOGRAPHY.—G. H. Putnam, *Books and Their Makers During the Middle Ages,* 2 vol. (1896–97); O. H. Cheney, *Economic Survey of the Book Industry, 1930–31* (1931); F. G. Kenyon, *Books and Readers in Ancient Greece and Rome* (1932); T. F. Carter, *The Invention of Printing in China and Its Spread Westward,* rev. ed. (1931); D. C. McMurtrie, *The Book; the Story of Printing and Bookmaking,* rev. ed. (1944); S. Unwin, *The Truth About Publishing,* rev. ed. (1947); F. Mumby, *Publishing and Bookselling,* rev. ed., with new and extensive bibliography on the subject in England (1949); W. Miller, *The Book Industry,* selected bibliography (1949); H. Lehmann-Haupt, *Thv Book in America,* rev. ed., extensive bibliography of the subject in the U.S. (1951); R. L. Duffus, "Printing and Publishing," *Encyclopaedia of the Social Sciences,* vol. xii, bibliography (1948).

(WI. MR.)

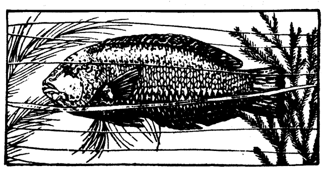
PUCCINI, GIACOMO (1858–1924), Italian operatic composer. was born at Lucca on Dec 22 or 23, 1858, of a family already distinguished in music. his great-great-grandfather Giacomo, great-grandfather Antonio, grandfather Domenico, and father Michele. having all been professional musicians. He was educated at the Milan conservatoire where he studied under Ponchielli In 1889, *Edpar* was performed at La Scala, and in 1893 his *Manon Lescaut* in Turin The former, based on *La Coupe et les lèvres* of Alfred de Musset was a failure, but the latter, founded on the well-known story of the Abbé Prévost (which had been previously treated by three other composers, Halévy, Auber and Massenet) was favourably received, and still holds the stage. Its success was as nothing compared with that of the work which followed it, the sparkling *La Bohème* (Turin. Feb 1. 1896). The libretto is based on Mürger's novel from which four scenes are taken, and the skill and resource and effectiveness with which they are treated leave no room for doubt as to the merits of the work. In La *Tosca* (Rome: Jan. 14, 1900), based on Sardou's tragedy, Puccini had an altogether different task, of which, however, he acquitted himself no less successfully. The work contains some of the strongest and most genuinely dramatic music which he ever wrote, and like *La Bohème* has enjoyed unlimited popularity at the hands of the general public from the first.

Madame Butterfly, on its first performance at La Scala on Feb. 17, 1904, was pronounced an absolute failure. Probably the libretto of the opera, with its unusual setting in Japan. had at least as much to do with this result as its music, but the Milan public's unfavourable verdict was reversed when the work was heard again at Brescia three months later, and since then its popularity has been prodigious and world-wide. If equal success did not attend its successor *La Fanciulla del West* (The Girl of the Golden West), this was accounted for by the unsatisfactory character of its "book" and by the undoubted inferiority of its music, so that the work, though favourably received when first performed in New York (Dec. 10, 1910), has never found general favour. Of the one-act operas *Il Tabarro, Suor Angelica* and *Gianni Schicchi,* which followed, all contain clever and characteristic music, but only the third, based on a most amusing libretto, has kept its place in the general repertory. *Turandot,* not quite finished at the time of Puccini's death, was completed by Alfano, and produced at La Scala, April 25, 1926. While some critics condemn this last work severely, others reckon it the composer's finest achievement.

Puccini died at Brussels on Nov. 29, 1924.

See A. Weissmann, *Giacomo Puccini* (1922); A. Fraccarroli, *La vita di G. Puccini* (1925); W. Dry, *Giacomo Puccini* (1906); V. J. Seligman, *Puccini among Friends* (1938); R. Specht, *Giacomo Puccini, the Man, His Life, His Work* (1933).

PUDDINGWIFE. A tropical American fish of the wrasse family (Labridae), called also doncella. It has a deep, compressed body, which is covered with large scales except on the head, has strong canine teeth in the front part of the jaw, and attains a length of 18 in. In colour the puddingwife is a vivid blue-green tinged with bronze or soft orange, though varying somewhat with sex and age. Spots and streaks of blue, especially on the head. fins and through the eye, add to its attractive appearance.



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PUDDINGWIFE (IRIDIO RADIATUS)

PUDOVKIN, VSEVOLOD ILLARIONOVICH (1893–1953), Soviet film director, one of the greatest of the era of silent films. was born at Penza, Russia, on Feb. 21, 1893. Wounded and imprisoned for three years in World War I, he returned to the study of chemistry but was attracted to the theatre. D. W. Griffith's film *Intolerance* moved him to apply for admission to the State Institute of Cinematography in Moscow. He worked with Lev Kuleshov in certain early film experiments, directed an educational feature *(Mechanics of the Brain)* and collaborated on a comedy, *Chess Fever.*

Pudovkin's best-known theatrical films are *The End of St. Petersburg* (1927), *Storm Over Asia* (1928) and *Mother* (1926), based on Maksim Gorki's novel. He was also occasionally an actor. His sound films included *Deserter* (1933), *General Suvorov* (1941) and *Admiral Nakhimov* (1948).

Pudovkin died on June 30, 1953.

In two books, *Film Technique* and *Film Acting,* written for Russian film classes and first published outside Russia in 1929, Pudovkin explained his principles of scenario, directing, acting and editing. His early films emphasize individuals within the Revolution somewhat more than did Sergei Eisenstein's (*q.v.*), but Pudovkin shared his great contemporary's liking for elaborate crosscutting of images (montage) to represent complex ideas.

(R. D. MACC.)

PUDSEY, a municipal borough (1899) in the Pudsey parliamentary division of the West Riding of Yorkshire, Eng., lying between Bradford and Leeds. Pop. (1951) 30,280. Area 8.3 sq.mi. The trade of the town is principally woolen textiles, but there are tanning mills and light engineering works. Fulneck, in the south of the borough, was chosen in 1743 as a Moravian settlement.

PUDUKKOTTAI, a former princely state of southern India, lying between Tanjore and Madura districts of Madras, with which it was merged in 1948 as part of the Tiruchirapalli (Trichinopoly; *q.v.*) district. The area of the state was 1,185 sq.mi. Pop. (1941) 438,348. The chief, whose title was *tondaman,* was of the Kallan or robber caste. His ancestors received a grant of territory for loyal services to the British during the wars in the Carnatic at the end of the 18th century.

The town of Pudukkottai (pop. [1951] 44,527) is well laid out with several fine public buildings. A college affiliated to Madras university and a training school were established there.

PUEBLA, an interior plateau state of Mexico. Pop. (1960) 1.957.380; area. 13,126 sq.mi., with its capital at Puebla. On the southeast corner of the Anáhuac plateau, Puebla varies in elevation (5.000–8.000 ft.). with numerous fertile valleys formed by the Sierra Madre Oriental which runs through the state. Endowed with a temperate, semihumid climate, crossed by main highways running southward from the national capital, and traversed by rail and air lines, Puebla is one of the most densely populated states of Mexico.

Its strategic location and natural endowments in pre-Hispanic times are attested by innumerable archaeological sites and by its many towns and villages, notably Cholula (*q.v.*), Atlixco and Tehuacán, a noted health resort. Coffee, sugar cane, fibres. maize and cereals are its main crops. Onyx, gold and other metals occur in its richly veined mountains. Numerous short, fast rivers provide hydroelectric power.

Its Nahuatl-speaking native peoples were highly developed at the coming of the Spaniards in the 16th century, and the latter founded many estates in this region, a main focus of their religious and economic activities. In the 19th and 20th centuries Puebla developed as an agricultural-industrial area in the important corridor between Mexico City and its main seaport at Veracruz.

(HD. C.; J. A. CW.)

PUEBLA (PUEBLA DE ZARAGOZA), city of Mexico and capital of the state of the same name. Pop. (1960) 285.284. The centre of an important agricultural and industrial region of central Mexico, Puebla is 80 mi. N. of the federal capital and from viceregal days has been considered the military key to the nation. The city was founded as Puebla de los Angeles by the Spaniards in 1532. According to church chronicles, the site was chosen as the result of a dream by Fray Julian Garcés who saw two angels with a line and rod pacing a beautiful plain flanked by tall volcanoes. Puebla is on a broad, healthful plain 7,050 ft. above sea level in the foothills of the Sierra Madre Oriental within view of Mexico's three highest snow-topped volcanoes, Citlaltépetl, Popocatépetl and Ixtacihuatl.

Puebla is characteristically Spanish with noteworthy architecture similar to that of Toledo, Spain's great fortress city. The sumptuous cathedral, whose interior is rich with onyx, marble and gold, was made a bishopric in 1550 and an archbishopric in 1903. Overshadowing the cathedral is the all gold leaf chapel of the Rosary in the church of Santo Domingo. The Casa del Alfeñique, the "almond-cake house" (now a museum). was built in the 17th century of polychrome blue, white and red tiles with white decorations and black ironwork balconies. The Teatro Principal (1790) was one of the first permanent theatres in the hemisphere. Puebla is the seat of a university, founded 1537.

A conservative, strongly Catholic city, Puebla was often considered politically reactionary in the history of Mexico. U.S. forces under Gen. Winfield Scott occupied the city (1847) during the Mexican War. Most famous of the battles fought in Puebla was the repulse of the French on May 5, 1862. In honour of its defender, Puebla was officially renamed Puebla de Zaragoza after Gen. Ignacio Zaragoza. The French again besieged the city, May 17, 1863, and captured it. Gen. Porfirio Diaz took the city April 2, 1867, and ended the imperialist occupation.

As an industrial centre, Puebla is known for its onyx working, Talavera tiles, cotton and woolen textiles, glass, soap, pottery, leather goods and other light articles. (H. R. HY.)

PUEBLO. The agricultural, town-dwelling Indians of the semidesert southwestern United States. They are of four distinct linguistic groups: (1) Shoshonean, comprising the seven Hopi (*q.v.*) villages in Arizona; (2) Zufii, one town in western New Mexico; (3) Keres, comprising Acoma (*q.v.*), Laguna, Sia, Cochiti, Santa Ana, Santo Domingo, San Felipe, all but the first two in the Rio Grande valley; (4) Tano, consisting of three divisions, all near the Rio Grande; (a) Tiwa, five towns, of which Taos is the most northerly and best known; (b) Tewa, six pueblos (including Hano among the Hopi); (c) Jemez. The aggregate population is not far from 10,000, stationary or slowly decreasing, and approximately equally divided between the four speech groups. At the discovery in 1540 the Hopi, Zuñi and Keres may have been twice, the Tano three or four times, as numerous as to-day; the number of towns has also decreased, though some new ones have been founded. The Pueblos live on ancestral lands and cultivate these much as in the prehistoric period, though they have added wheat to maize and acquired some sheep, cattle, horses and asses; their houses, though larger, are of the old type; their religion has been successfully maintained by the Hopi and Zufii and partly preserved alongside Roman Catholicism by the Keres and Tano. They are peaceable, gentle, unenterprising, quietly industrious and conservative. Physically they are fairly uniform; below average in stature, generally brachycephalic, with the skull somewhat flattened occipitally from the cradle board.

Of all the tribes of the United States the Pueblos are most similar to the advanced native peoples of southern Mexico, and the bases of their culture — maize-beans-squash agriculture, cotton growing and weaving, turkey rearing, painted pottery, masonry architecture, ritualism — are no doubt derived from these Mexican civilizations. They lack, however, a number of accomplishments characteristic of the Aztec, Toltec and Maya, such as metallurgy, political organization, calendrical system, ideographic writing, temples and pyramidal substructures. Since some of these traits have an age of about 2,000 years, the main influences emanating from Mexico are likely to have reached the Pueblos perhaps as much as three millennia ago.

South-western archaeology reveals a development through several stages: (1) Basket maker, possessing maize but apparently no other cultivated plants; no pottery or stone houses; spear thrower, but no bow; the physical type mas long-headed. (2) Post-basket-maker, with crude pottery, slab-lined pit houses, the bow and arrow. (3) Proto-Pueblo, with the short-headed type which has persisted to the present; masonry, painted and neck-corrugated pottery, cotton, the turkey, the essentials of historic Pueblo culture, are already present. (4) Early Pueblo, in small house clusters; black-on-white and body-corrugated pottery; this is the era of most of the cliff dwellings and of the greatest geographical extension of Pueblo culture, ruins in Nevada and well north in Utah belonging to this period. (5) Great Pueblo period, with large towns like Pueblo Bonito and Aztec, centring in the San Juan drainage; the northernmost area had been given up, but the ruins in Chihuahua, like Casas Grandes, seem to be of this epoch. (6) Late Prehistoric Pueblo, with glaze-painted pottery; the San Juan area and Chihuahua extension had been given up, but there were still Pueblos on the middle Rio Grande near El Paso. The Spanish discovery of 1540 falls in this period, which may be assumed to have continued until the influence of the missions became strong in the early 17th century, or until the general Pueblo rebellion of 1680. (7) Historic Pueblo, after the unsettlement caused by the rebellion; pottery is again painted instead of glazed, but both black-on-white and corrugated ware are long since forgotten; domesticated mammals have been introduced and sheep's wool tends to take the place of cotton for clothing.

In general, the Pueblos did not irrigate, although they knew how to choose farmlands containing sub-soil water. They are matrilineal and matrilocal, women owning the houses; but men order all public and religious matters. On the Rio Grande the clans weaken and moieties appear, until in the extreme northern towns clans are, to-day at least, lacking. The religious edifice is the kiva, Spanish estufa, a small semi-underground structure for the performance of esoteric rites. Temporary altars are erected in these, often with ritualistic sand or meal paintings; feathers are "planted" as offerings at outdoor shrines; and for all religious organizations, offices and clans there are fetish bundles. The mythology is characterized by tales of emergence from the lower world and long tribal wandering. Cults take three chief aspects: (1) Youths are initiated into a communal men's society performing masked dances representative of gods and ancestors — kachinas. (2) Men and women are initiated individually into "fraternal" societies whose main function is curing, although there are also war and hunt societies; masks are little used. (3) Hereditary priests fast, entreat and pray for rain for the crops and communal welfare, and ultimately direct not only all religious affairs but the civil oificials.

Ritual symbolism is rich, especially as regards the idea of fertilization and number-colour-direction symbol patterns.

BIBLIOGRAPHY.—F. R. Eggan, *Social Organization of the Western Pueblos* (1950); J. O. Brew, *Archaeology of Alkali Ridge, Southeastern Utah* (1946); Carl Seltzer, *Racial Prehistory in the Southwest and the Hawikah Zunis* (1944). (A. L. K.; H. B. Cs.)

PUEBLO, a city of Colorado. U.S., situated on the Arkansas river at the mouth of Fountain creek, 120 mi. S.E.of Denver, at an elevation of 4.685 ft.; the seat of Pueblo county. Pop. (1960) city 91.181; standard metropolitan statistical area (Pueblo county) 118,707 (for comparative population figures see table in COLORADO: *Population*). Pueblo lies near the great coal fields of the state and is an important manufacturing. retail and trucking centre. At Minnequa, on the mesa south of the city, is one of the largest steel plants in the U.S. The irrigated region of 50.000 ac. adjacent to Pueblo produces large quantities of red clover, onion. squash and cantaloupe seed as well as a major portion of the cucumber seed grown in the C.S. The Pueblo ordnance depot of the U.S. army (established in 1942) is on a mesa 13 mi. E. of the city. The Colorado state fair (established in 1886 and provided for by the state legislature since 1907) is held annually in August. The Colorado State hospital (psychiatric) is in Pueblo. Pueblo Junior college, a public school: was opened in 1933.

The site of Pueblo was visited by Lieut. Zebulon Montgomery Pike, who erected a temporary log breastwork on Nov. 23. 1806. In 1823 John McKnight established a trading post, which was soon wiped out by Comanches. From 1843 to 1854 there was a small settlement of mountain men as well as an adobe fort which was destroyed by Utes. A party of gold seekers located there in 1858. Gen. W. J. Palmer's Denver and Rio Grande railroad reached Pueblo in 1872 and he organized the Central Colorado Improvement company with the purpose of creating an industrial city. Reorganized in 1882 and again in 1892, it became the Colorado Fuel and Iron company and fulfilled the original purpose.

In June 1921 a sudden flood of the Arkansas river struck Pueblo. causing severe property damage and about 200 deaths. A $4,000,000 flood-control system was immediately built, which effectively prevented any recurrence of the disaster.

The city established a council-manager form of government in 1950. (HY. L. C.)

PUENTE GENIL, a town of southern Spain, in the province of Cordova; on the right bank of the river Genil or Jenil, a tributary of the Guadalquivir. Pop. (1950) mun., 30,656. It is on the Cordova-Malaga railway and is the starting point of the line to Linares.

A bridge across the Genil, from which the name of the town is derived, joins the lower part of Puente Genil with the higher. The principal industry is the manufacture of olive oil. There are also flour mills and linen factories.

PUERPERAL FEVER, a medical term implying infection of some part of the genital passages following childbirth or abortion. The infection is most commonly of the raw surface inside the womb left after separation of the afterbirth, but pathogenic organisms may also gain entry through laceration of the mouth of the womb or other parts of the birth canal and may invade the blood stream, causing septicaemia.

History. — The disease has been recognized from the earliest days, and some of the greatest names in medicine have contributed to its study. In the 5th century B.C. Hippocrates stated, "If a woman in childbed have erysipelas of the womb she will usually die"; and this truth was manifest in the appalling mortality from the disease that persisted down to the 1930s. William Harvey (1651) was the first to describe the raw placental site as "one vast ulcer" in cases of puerperal fever. Charles White of Manchester, Eng. (1773), drew attention to the identity of puerperal and "surgical" fever; advised postural drainage of the womb in the lying-in period; and, by his vigorous insistence on cleanliness in the conduct of deliveries and on isolation of cases of puerperal fever, made a famous advance in the art of midwifery. Alexander Gordon (1795) noted that puerperal fever was a contagion, since it seized only such women as were visited or delivered by a practitioner or nurse who had previously attended patients affected by the disease. Jean Louis Baudelocque (1789) noted the greater incidence of the disease when hands or instruments had been introduced into the birth canal. I. P. Semmelweiss (*q.v.*) of Vienna (1847) rediscovered White's teaching and, noticing that the mortality from the disease among women attended by doctors and students who also practised dissection upon cadavers was far greater than among the women delivered by midwives, strenuously advocated washing of the hands in antiseptics before attending women in childbed.

During all this time, contagions were held to lurk in "humours" or miasmata which affected the air and the clothing and were thus borne from. patient to patient directly or by an attendant. But in 1879 Louis Pasteur demonstrated a dotlike microorganism grouped in short chains which he had isolated from the lochial discharge of a woman with puerperal fever, and the bacteriologicdl era of the study of disease had arrived.

These streptococci (Streptococcus pyogenes, S. *haemolyticus*) are only one, although the most deadly. of the causes of puerperal fever; others uncovered later are the anaerobic streptococci (which flourish in dead and dying tissues such as are to be found in the genital tract after long and injurious labour and difficult or injudicious instrumental delivery); the Bacterium coli and Clostridium welchii, inhabitants of the lower bowel; and various staphylococci commonly found on the skin and in skin eruptions of a pustular nature. Many of these organisms can be demonstrated in the vagina during pregnancy, and for some time the endogenous or autogenous theory of puerperal sepsis excused the neglect of rigid antiseptic precautions by the attendants of labour on the grounds that pathogenic germs were already present in the birth canal. However, in 1930 Leonard Colebrook stressed the fact that the anaerobic streptococci do not assume dangerous significance unless provided with the medium of bruised and lacerated tissues in which to grow and multiply and that such a development could be avoided by the utmost skill and gentleness in operative obstetrics.

In 1935 Rebecca Lancefield (U.S.) and Ronald Hare (England) showed that the haemolytic streptococci causing severe puerperal fever, scarlet fever, dangerous wound infections and tonsillitis were all of an easily identifiable group (A) which were not found in the normal birth passage before labour. Leonard Colebrook and his sister, Dora, then showed that in a series of cases of puerperal fever caused by the haemolytic streptococcus the infection had been conveyed by medical and nursing attendants or by other contacts who harboured the organisms in nose or throat. Thus was established overwhelming proof that puerperal fever is an easily preventable infection.

Infection and Symptoms. — The severity of the disease varies with the nature of the infective organism (that is, its powers of invasion of local tissues or the blood stream) and with the local and general resistance of the patient. In the gravest cases, the infecting organisms are commonly the pus-producing haemolytic streptococci and anaerobic streptococci and rarely staphylococci and pneumococci. Infection with the germs of gas gangrene (Cl. welchii) are rare but carry a very high mortality. Milder cases of puerperal fever are caused by infection with the nonhaemolytic streptococci and coliform bacilli.

The symptoms and course of the disease are similar to those of an acute wound infection. Fever with rigours usually arises on the third day after delivery, the pulse rate quickens and general prostration develops. The womb remains enlarged and tender. the discharges from it may be profuse and foul-smelling. Serious symptoms are persistent high fever and pulse rate, repeated rigours, sleeplessness, delirium and diarrhoea. Should the infection remain localized to the genital tract (as with coliform bacteria and nonhaemolytic streptococci), recovery is usual after a more or less severe illness (complicated by pelvic abscesses, etc.); but should invasion of the blood stream or peritoneum occur (as with haemolytic streptococci, anaerobic streptococci, Cl. *welchii*) the disease assumes the utmost gravity and, until about 1935, when sulfonamides were first used, accounted for about half the total maternal mortality in childbearing.

Prevention. — A main concern of those caring for women in childbirth is, therefore, to prevent infection from reaching or spreading among their charges. Until the development of antiseptic principles, the incidence and mortality of puerperal fever were horrifying, and the improvement reached by the first third of the 20th century was still unsatisfactory in comparison with that accompanying the prevention of sepsis after surgical operations. The more natural the labour and the less the interference, the lower the incidence of fever. Conversely, the more prolonged and extensive (*i.e.*, the higher up the genital canal) the interference and the greater the injury caused, the higher the risk of infection. Cleansing of the external genitals, disinfection of instruments and dressings and the wearing of sterilized gloves lessen the risk but will not wholly eliminate infection as it is impossible to render the skin surrounding the external genitals and anus absolutely germ-free. Hence the introduction of hands and instruments into the genital passage carries with it the risk of conveying organisms. Careful antenatal assessment of the size of the maternal passages by radiographic means increasingly prevented the necessity for these dangerous manoeuvres, and the discovery and use of powerful, yet saie, skin antiseptics with a prolonged action greatly lessened their risks. The local resistance of the tissues of the genital tract is lowered by bruising and injury and these can in large measure he avoided. The readiness with which infection may be conveyed by doctors and nurses harbouring organisms in the nose and throat has been clearly realized, and the wearing of an impervious mask over the nose and mouth during ministrations to childbearing women much decreased the danger. Antenatal measures directed to the general health of the pregnant woman — the treatment of coexistent disease such as diabetes, anaemia, tuberculosis or malnutrition — tend to raise the maternal powers of resistance to infection.

Treatment.—Treatment is, therefore, first of all preventive; the most stringent care is taken to adopt the same antiseptic and aseptic precautions in labour as for a major surgical operation and further by antenatal care to maintain the vitality at its best, avoiding all foreseeable complications in labour and generally securing natural delivery without interference. Loss of blood and exhaustion should be prevented or remedied by transfusion and restoratives. Complete emptying of, and free drainage from, the womb are essential, as are good nursing and attention to every detail of the mother's comfort and hygiene in the lying-in period. Until the middle of the 1930s, the curative treatment of puerperal sepsis consisted entirely of the above measures and, as has been said. they were successful in cases where the patient's good power of resistance, or the low virulence of the organisms, prevented the development of a generalized infection. Later, the sulionamide group of drugs, first used by L. Colebrook and Meave Kenny in 1935, specific antidotes for infection by haemolytic streptococci, gonococci and pneumococci and Bacterium *coli,* caused a spectacular drop in the mortality of the disease; and, from the early 1940s, penicillin carried this victory over sepsis still further — more than three-quarters of the women who would previously have been doomed to die in this way now being saved. Before the era of chemotherapy, the haemolytic streptococcus accounted for about 75% of the total mortality froni puerperal infection; the major instrument of death thereafter was the anaerobic group of organisms against which neither the sulfonamides nor penicillin had yet been shown to prevail and for which the only remedy lies in measures directed toward avoiding gross injury of the genital tract in labour. Deaths from puerperal infection by mid-century accounted for about one-sixteenth of the total maternal mortality, but the saving of a woman from death to leave her barren or an invalid is not enough. The incidence of the disease showed some reduction after 1935; but it was likely that the published figures did not present the real picture of the prevalence of the disease since, with sulfonamides and antibiotics, the patient's fever might be restrained below notifiable levels.

BIBLIOGRAPHY.—H R. Spencer, The *History of British Midwifery from 1650–1800* (London, 1927); Munro Kerr, *Maternal Mortality und Morbidity* (1933); L. Colebrook, "Prevention of Puerperal Sepsis," *Journ. Obst. and Gynaec. Brit. Emp.,* 43 691 (1936); L. Colebrook and M. Kenny, "Treatment of Human Puerperal Infections and of Experimental Infections in Mice with Prontosil," *Lancet,* 1:1279 (London, 1936). (M. K.)

PUERTO BARRIOS, the principal port of Guatemala (pop. [1057 est] 19 268). served chiefly by cargo and passenger ships of the United Fruit company Named for Justo Rufino Barrios. president of Guatemala from 1873 to 1885, it was constructed as the Caribbean terminus of the railway, built by foreign contractors from the coast to Guatemala City, which realized a century-old Guatemalan dream of a national commercial outlet through a deep-water Atlantic port. The government became dissatisfied nith control of the facilities by foreign interests. however. and constructed a competing port at Santo Tomás (1955) and a highnay paralleling the railroad. Puerto Barrios is also connected with the capital by air. (W. J. G.)

PUERTO CABELLO is a city and port of Venezuela in the state of Carabobo. Pop. (1959 est.) 46,166. The mean average temperature of the port is 80° F. Puerto Cabello has a well-protected harbour accessible to the largest vessels calling at Venezuelan ports, nith docks, narehouses. a navy yard and dry-dock facilities. The city is connected with Valencia, the capital of the state, by a highway and railway over a 2,000-it pass and is considered a natural outlet for the agriculturally rich and commercially important Valencia basin. Commerce dominates the economy of the city, but there are small processing industries. Ten miles from the city, on the Pan-American highway, is a modern petroleum-chemical plant erected by the government. Puerto Cabello was sacked by pirates many times during the colonial period and was a favoured smuggling centre for the Dutch, operating from Curaçao. The city suffered much damage in the Wars of Independence. Simón Bolivar was defeated there in June 1812. Subsequently the port changed hands several times. José Antonio Páez, national hero and long-time president of the republic, led the attack which forced the final Spanish surrender at Puerto Cabello in 1823. The story goes that the waters of the harbour are so smooth that a single hair (*cabello* in Spanish) could moor a vessel to the dock. hence the name Puerto Cabello. (J. J. J.)

PUERTO DE SANTA MARIA, a seaport of southern Spain. in the province of Cádiz, on the right bank of the Guadalete river, nith a station on the railway from Cádiz to Seville. Pop. (1950) mun. 28.368. Puerto de Santa Maria, commonly called "El Puerto," is probably the Rlenesthei Portus of Ptolemy. Its most important industry is the nine trade; there are also glass, liqueur, alcohol, starch and soap manufactures.

PUERTO LA CRUZ, lying in northeastern Venezuela on the Caribbean is one of the country's outstanding petroleum-handling ports Pop (1959 est) 47,772. It is the petroleum metropolis and the shipping terminal for the large output of the Greater Oficina oil-producing area and for smaller oil fields of the state of Anzoátegui Important oil pipelines from these fields as well as from small ones in the neighbouring states of Guárico and Monagas focus upon Puerto La Cruz. The port is also the site of very large oil storage facilities and of refineries. It is connected aith Barcelona, just 6 mi. distant, by railway. (L. WE)

PUERTOLLANO, a town of central Spain in Ciudad Real province, on the Madrid-Ciudad Real-Mérida railway and at the northeast of the Valle de la Alcúdia. Puertollano is 2,345 ft.

above sea level and has mineral baths. Its population (34,621 [mun.] in 1950) more than doubled in the 20th century.

PUERTO MONTT, city and port of southern Chile, capital of scenic Llanquihue province, occupies a narrow plain between Reloncavi sound and large morrainal hills to the north. It is a popular lake district resort, adjacent Tenglo Island and the superb volcano-dominated scenery being major attractions. Pop. (1960) 64.775 (mun.). The city's strategic position between Chile's core area and the islands to the south makes it an important communications centre. It is a terminus for the state railway, serves as home port for state-owned and other shipping and offers air service to the north and south and to Argentina. There are naval and air stations, an important lumber industry and small-boat yards. The city. named for Manuel Montt (*q.v.*), was founded in 1853 by a group of German immigrants. (J. T.)

PUERTO PLATA, a province in northern Dominican Republic. Area 726 sq.mi. Pop. (1960) 163,896. Its southern boundary is the Cordillera Septentrional (to 3,993 ft.), which is the nation's leading coffee region. Puerto Plata is also one of the leading producers of corn (maize), bananas and tobacco and a significant dairying region. The province was established in 1875. Its capital, San Felipe de Puerto Plata (called Puerto Plata), pop. (1950) 14,843, was founded in 1503 by Columbus. It is the nation's second port and an industrial centre. Thirty miles to the west are the ruins of Isabela (reputed to be the first European town set up in the new world), founded by Columbus in 1493. (D. R. D.)

PUERTO RICO (COMMONWEALTH OF PUERTO RICO, ESTADO LIBRE ASOCIADO DE PUERTO RICO). an island and an independent commonwealth voluntarily associated with the United States. It is the smallest and the most easterly of the Greater Antilles, the major island group of the West Indies (*q.v.*), which form the broken northern boundary between the Caribbean sea and the Atlantic ocean. To the west and just out of sight beyond the 70-mi. Mona passage lies the island of Hispaniola. To the east lie the Virgin Islands, one of which, St. Thomas, can be seen on a clear day from the eastern shore. New York, the main U.S. port of departure for Puerto Rico, lies over 1,500 mi. N.W. Directly south, across about 600 mi. of Caribbean sea, is the coast of Venezuela. Puerto Rico is nearly rectangular with a iength from east to west of 113 mi. and a width of 41 mi. Its area is 3.349 sq.mi. (3,435 including adjacent islands).

This article is divided into the following sections:

I. PHYSICAL GEOGRAPHY

1. Geology and Physiography.— Puerto Rico and the other Greater Antilles are formed by the high parts of a 1.300-mi. chain of mountains whose base and bulk are buried beneath the sea. These mountaintop islands are the oldest of all the land masses in the West Indies. In contrast, the Lesser Antilles. which form the eastern boundary of the Caribbean sea, are of more recent formation, and voicanic activity is sometimes still apparent there. Near Puerto Rico the land mass offers its greatest relief contrast in height and depth. To the north of Puerto Rico, running more or less parallel to the island, exists the deep valley in the Atlantic floor known as the Puerto Rico trough (formerly called the Brownson deep). The deepest part of this trough lies about 75 mi. to the northwest of Puerto Rico; there the floor of the Atlantic goes down 30,246 ft. To the south too the land falls off sharply below sea level. Some 55 mi. S.W. of Puerto Rico the Caribbean reaches a depth of over 17.000 ft. If the base of this chain of mounlains were elevated to sea level, it would become one of the most imposing land masses in the world. Indeed, the highest point in Puerto Rico, Cerro de Punta. 4,389 ft., would attain an altitude greater than that of Mt. Everest.

The island's central mountain chain, the Cordillera Central, rises almost directly out of the sea on the west coast of the island and extends eastward, finally terminating in the Sierra de Luquillo in the northeast and in the Sierra de Cayey in the southeast. While this rugged terrain covers about 70% of the island's area, the fertile coastal plains extend like a fringe between the mountains and the Atlantic on the north and the Caribbean on the south. Geologists agree that while Puerto Rico cannot be considered a volcanic island, in the sense that some of the Lesser Antilles might be so classified, the land mass was formed by early volcanic activity during the upper Cretaceous. In general terms, the Cordillera Central is underlain by lavas and volcanically derived sediments resulting from this igneous activity. In the west a large body of serpentine occurs, and in the central and southeastern areas bodies of coarser plutonic rocks, quartz. diorites and granodiorites are found.

The coastal plain on the south side of the island is not so wide nor so naturally fertile as the northern coastal plain. The north-south drainage divide runs parallel to the Caribbean coast about 10 mi. from the shore line. As would be expected, thus, the southern side of the central mountain chain presents a more precipitous drop to the sea than that found on the north. To the north, most of the principal rivers, such as the Rio Grande de Loiza. Rio de la Plata or Rio Grande de Arecibo, descend to the Atlantic through foothills and slowly declining slopes. The flood plains formed by these rivers are extremely fertile.

2. Climate.— While Puerto Rico lies just within the tropics, its climate is usually agreeable. The average annual temperature is 76.3" F., and the island is without sunshine, on average. for only five days a year. On the coast the winter monthly average is 75°; for the summer months it is 80°. In the interior at an altitude of 1.500 ft. the average winter temperature is 70"; during the summer it is 75". The absolute minimum temperature recorded in Puerto Rico was 39° at an altitude of 3,000 ft. Frost may occur at higher altitudes but has never been officially recorded. The maximum recorded temperature in San Juan is 94". Cool, invigorating sea breezes, constantly brought by the trade winds which bathe the islands of the West Indies, help to soften the effect of the hot sun. During the summer months these winds come directly from the east or slightly southeast. During the winter they shift and come from the northeast. At night, gentle land breezes coming down from the mountainous interior bring cool and refreshing air to the coastal areas, causing a drop of 6° or 7° from the day temperature.

The trade winds also bring abundant rainfall, which for the island averages 74.4 in. annually. It rarely rains for more than a few hours at a time, even during the rainy season, which lasts from May to November. The coastal areas are cooled in the late morning or afternoon by light showers during the warmer months of the year. The variation in rainfall recorded in different parts of the island is much greater than the temperature variation. The rain forest of Sierra de Luquillo, the northeastern branch of the central mountain chain, which receives the trade winds first, recorded an average annual rainfall of 184 in. over a ten-year period. In the southwest corner of Puerto Rico annual rainfall drops to about 30 in. The island is subject to occasional tropical storms. The winds, which reach a velocity of 150–200 m.p.h., are usually accompanied by torrential rains. The storms, which rarely last more than a day, occur from July to October.

3. Vegetation. — The erosive effect of a heavy rainfall on the precipitous slopes of the central mountain range of the island is counteracted by a particularly tenacious soil bound together by clinging and abundant vegetation. The wide variation of rainfall, a fairly rich soil and different altitudes produce a great variety of plant life. Because of the extensive cultivation of the land, the vegetation in a relatively natural state is limited to the insular and national forest reserves located at higher altitudes in the western, central and eastern sections of the island. The tropical rain forest of the Luquillo National Forest reserve, located at the eastern end of the island, is composed of a great variety of trees, clinging and hanging vines and a thick undergrowth of shrubs, ferns and thickets. The junglelike density is almost impenetrable without the aid of a machete, a sharp, long, broad-bladed knife. In this area wild orchids can be found. Trees include bamboo, palm, cedar, ebony, calabash, whitewood, lancewood, boxwood and logwood.

Along the coastal plains, which probably were covered once with a thick forest growth, sugar cane and pineapples are grown. In the northwest corner of the island and in the mountain areas tropical fruits of all varieties are produced. In the western highlands, together with the coffee bush, can be found a great variety of citrus fruits. In addition to the common fruits such as bananas and oranges the island produces papayas, pomegranates, avocados, guavas and mangoes. Spices such as ginger, pepper, vanilla and chicory are also grown.

4. Animal Life. — Physically isolated at an early geological age and densely populated, Puerto Rico has very little wild animal life. Bats, birds, a scarce and harmless species of snake and several varieties of harmless lizards, together with the mongoose and rat, comprise Puerto Rican wildlife. For the patient bird watcher the island offers a wide variety of species of birds, nesting or in transit. About 190 species have been identified, and of these 89 are known to nest. Some 36 birds are endemic to Puerto Rico. Thrushes, tanagers, bullfinches, flycatchers, warblers, plovers, terns and sandpipers are the birds most commonly seen.

The waters around the island are excellent for sport fishing. Yellow-fin tuna, white marlin, sailfish, dolphins, kingfish and wahoo are only a few of the commoner varieties which can be found 2 to 5 mi. from the coast. There are fine black bass in the fresh-water reservoirs of the island.

II. GEOGRAPHICAL REGIONS

Puerto Rico may be divided into three geographical regions, using as the principal criteria the contrasting altitudes.

1. Lowlands and Coastal Plains. — Geographers have calculated that 27% of the island's land can be classified as flat or gently rolling lowlands. With one or two minor exceptions offered by small inland valleys, one near Caguas and the other near Cayey, this region is comprised primarily of land along the coastal fringe of the island. Depending upon the availability of water, the flat or rolling coastal lands are the most fertile areas of Puerto Rico. The abundant rainfall on the north coast assures production, but on the south coast and particularly in the southwest corner, in the Lajas valley sector, the flat rolling land needs irrigation. In the Lajas valley the insular government built an extensive and costly irrigation project which collects in artificial lakes the heavy rain that falls on the nearby highlands, brings the water down over hydroelectric dams and channels the distribution into the previously arid valley.

For the most part the coastal plains produce the bulk of the island's sugar crop. About 30 sugar mills, or *centrales,* located in this region produce more than 90% of the island's sugar. More than 20% of this sugar is produced on the north coast and about 30% is produced on the irrigated plains of the south coast. Some coastal land lacking in rainfall or fertility is used as pasture. Prior to the completion of the irrigation project, the Lajas valley was used primarily in this way. On the north coast about 50 mi. W. of San Juan, near the port of Arecibo, pineapple production has been expanding. The coastal area has some unproductive land in mangrove swamps and in limited areas where sand dunes have moved inland. By far the best of the island's beaches can be found on the sheltered west coast. The north coast also has excellent beaches wherever offshore reefs serve to break the heavy Atlantic surf. The Luquillo beach east of San Juan is perhaps the most popular and widely known.

2. Highlands. — In contrast to the coastal plains is the markedly mountainous terrain of the central part of the island, which accounts for about 36% of the land area. This extensive area is marked by high local relief with little flat land. Most of the slopes range from 30% to over 60% grade. This region, comprised of the Cordillera Central, the Sierra de Cayey and the Sierra de Luquillo, includes the highest peaks of the island drainage divide.

Heavy rainfall and fertile soil permit extensive cultivation of this region in spite of the sharp slopes. Coffee is the main crop in the area uhich extends from near the west coast to the centre of the island. The shrub which produces the coffee bean is very sensitive to temperature variations and grows best in shaded areas between 1,000-ft. and 3,000-ft. altitude; orange and grapefruit trees and the broad-leaf banana plants are utilized for shade. As a result of the cultivation of coffee in the western mountain area, the impression is given of a cleared, well-gardened forest. Two insular forest reserves, Maricao and Toro Negro, nith picnic facilities and lookout towers, can be found in the western and central mountain areas.

The eastern mountainous section, with the exception of the Sierra de Luquillo, receives less rain than the western highlands do, and the vegetation is less thick and the land unprotected by a covering forest. Tobacco is the principal commercial crop. Small farms produce subsistence crops, and extensive pasture areas can be found. The Sierra de Luquillo, where the tropical rain forest is located, has a recreation park with trails, swimming pools and lookout towers.

3. Rolling Hill Land. — The area of the island which lies between the two extremes of the flat coastal plains and the markedly mountain terrain can be described as rolling hill land; it comprises the remaining 37% of the land surface. Foothills adjacent to the central core of mountains are included in this area. In this region the unique limestone belts of the northeastern and north central section of Puerto Rico are found. This area, which is similar to the cockpit area of Jamaica (*q.v.*), is of a more recent geological age than the rest of the island, having been formed during the Tertiary period. The limestone plateau, at one time under the sea, once lifted and exposed to rain and wind erosion, was slowly converted into striking karst topography. The area is characterized by precipitous cliffs, caves and large caverns, deep depressions or sinkholes and undissolved limestone remnants or *mogotes,* which resemble conical haystacks. In this area rivers such as the Tanamá or Camuy disappear suddenly and, running underground, appear just as unexpectedly miles away. In spite of the rugged terrain, the irregular valleys among the *mogotes* and precipices are cultivated with some success by the small farmer. Subsistence crops, vegetables and fruit are the main products.

4. Mona, **Culebra** and **Vieques** Islands. — These small islands are politically and culturally linked to Puerto Rico. Fifty miles southwest of the western port of Mayagüez is Mona Island (*q.v.*), consisting of a limestone plateau of about 20 sq.mi. Light rainfall and infertile soil make Mona an island of poor vegetation

and no permanent inhabitants. Culebra Island (*q.v.*), half the size of Mona, is situated halfway between Fajardo, the east coast port of Puerto Rico, and the port of Charlotte Amalie in St. Thomas, Virgin Islands. Culebra's population of 887 lives mostly in a small town located in the excellent harbour of Puerto Grande. Vieques Island has an area of 57 sq.mi. and is located 10 mi. S.E. of Puerto Rico. While most of the island is used for naval installations by the U.S. government, the small population has struggled to maintain itself by cultivating the sparse soil.

III. THE PEOPLE

1. Racial Characteristics. — Puerto Ricans are mostly descendants of a European stock, specifically Spanish, with an admixture of Negro and some Indian (mainly Arawak or Boriquén) strains. The dominant Spaniards absorbed or eliminated the Indians within a very short time after the conquest of Puerto Rico, but physical characteristics of the aboriginal Indian are still evident in dental formation, colour and texture of hair and even facial structure, particularly of the people in the mountainous interior.

Negroes were introduced early in the 16th century as slave substitutes for the disappearing Indians. However, under the lenient Spanish treatment many of the slaves earned or were granted freedom. Partly as a result of this attitude the slave population was always smaller than that of free coloured people. In 1846, when Puerto Rico's slave population reached the top figure of 51,265, the number of free Negroes was 175.791 and the combined slave and free coloured population was slightly more than 50% of the total population. As Puerto Rico's population increased during the 19th century, with the slave trade effectively halted and slavery abolished, the percentage of Negroes in the over-all population declined rapidly until by the early 1960s less than 20% of the population was classified as nonwhite. However, to be socially considered white, it is not necessary to meet the strict biological requirements of having only white ancestors.

The *jibaro* is the small isolated independent farmer who has struggled for centuries to sustain himself in the rugged Cordillera Central. Within recent years the *jibaro* has been converted into an insular cultural, if not political, symbol.

2. Language. — Puerto Rico draws upon a rich Spanish cultural heritage. The Spanish language is spoken everywhere and is used throughout the school system. English is taught as a secondary language, and in the urban areas and particularly in the commercial establishments, English is commonly heard. Rare would be the businessman who could not carry on a limited conversation in English, and many are fluent bilinguists.

3. Religion. — For the almost 400 years of Spanish control over Puerto Rico the Roman Catholic Church occupied an exclusive place as the state-protected religion. Indeed, Puerto Ricans came to look upon the crown and the church as one. Almost every town on the island has, in true Spanish style, a Catholic church located on one side of the central plaza.

After the change of sovereignty in 1898, evangelical sects became active on the island. Most of their followers are drawn from the lower classes and the expanding urban middle class. Approximately 20% of the population is considered to be active in one or another of the evangelical groups. The cost of the insular evangelical work has been sustained by the various missionary boards in the United States, but the local churches have been encouraged to become economically independent.

A growing number of islanders are believers in some form of spiritualism. These people come from all classes of society but are said to be found most commonly among groups undergoing marked social change.

4. Customs and Culture. — Spanish influence is waning in the social customs of the people of the large towns and cities. The growing industrialization and increasing U.S. influence are converting Puerto Ricans from a two-class, stable, patriarchal, agrarian society to a mobile, three-class, modern, industrial society in which women are achieving a place of equality with men. The rising rate of divorce is an indication of these changing social conditions. Among adolescents of the large cities the chaperon is a thing of the past. Still, in some of the small towns of the interior on Saturday evenings or holidays, the custom of strolling around the plaza, boys in one direction and girls in the other, can be observed. Birthdays, weddings and deaths are occasions for social gatherings. Wakes, *rosarios* (nightly ceremonies in commemoration of a death) and *rogativos* (group supplications) are still observed in rural areas.

In music the fused influence of the African and Latin strains is most notable. Both popular and traditional music have a distinct local flavour. The island has actively cultivated an interest in classical music, and several symphonic groups function, one with the financial backing of the government. A chief contributor to this cultural renaissance was the cellist Pablo Casals.

The island government, concerned at the apparent lack of concerted efforts to preserve the historical and cultural heritage of the island, organized the Institute of Puerto Rican Culture, which, with local branches in all the leading towns, undertook to encourage, through scholarships and prizes, the expression of local artists, musicians and writers. Museums were established, traveling exhibitions were sponsored, drama groups were encouraged, and a series of scholarly publications was initiated, all with the purpose of making Puerto Ricans appreciate their cultural roots.

IV. HISTORY

The first inhabitants of Puerto Rico, originally from the Amazon basin of South America, reached the island by means of the archipelago of the Lesser Antilles some 600 years before the arrival of the Spaniards. These Arawak Indians, living in small villages, were organized in clans and led by a cacique or chief. They were a peaceful people who, with a limited knowledge of agriculture, lived on a variety of domesticated tropical crops such as pineapples, manioc and batatas supplemented by shellfish and other sea food. Anthropologists estimate their numbers to have been between 20,000 and 50,000. On an island naturally fertile, the Arawaks lived an easy life disturbed only by occasional visits from their cannibal Carib neighbours on the islands to the south and east. At the time of discovery, Carib Indians occupied most of the Lesser Antilles, the Virgin Islands and Vieques Island.

In 1493 Christopher Columbus, at the peak of his popularity, left Spain on his second voyage to the Indies with an elaborate expedition of 17 ships and about 1,500 men. At the island of Guadeloupe, the Spaniards rescued several Arawak Indians who had been taken from Boriquen, the Indian name for Puerto Rico, by the Caribs. Columbus agreed to return them to their island, and on Nov. 19, 1493, the expedition anchored in a bay on the west coast of Puerto Rico. Columbus formally took possession of the island in the name of Ferdinand and Isabella, the rulers of Spain, and named it San Juan Bautista. Two days were spent on the island before the ships moved westward to Hispaniola, where the first settlement in the new world was established.

A. Spanish Rule

1. Early Settlement. — For 15 years the island was neglected except for an occasional visit by a ship putting in for supplies, In 1508 Juan Ponce de León (*q.v.*), who previously had accompanied Columbus, was granted permission to explore San Juan Bautista in recognition of his valuable colonizing efforts in eastern Hispaniola. On the north coast, Ponce de León found a well-protected bay which could offer safe harbour for a large number of sailing vessels. The harbour was named Puerto Rico because of its obvious excellent potentialities. In this area was located the most important settlement on the island; through time and common use the port became known as San Juan while the name Puerto Rico came to be applied to the whole island.

The peaceful and friendly relations with the Arawak did not last long. The Spaniards expected the Indians to acknowledge the sovereignty of the king of Spain by payment of gold tribute. The Indians were to be instructed in Christian ways. In return for this education, which was rarely given, the Arawaks were expected to work and supply either more gold or provisions of food. In 1511 the Indians rebelled against the Spanish, who with their superior arms rapidly subjugated them.

Placer mining of gold was continued by Indians brought from other islands and by Negroes introduced from Africa by some of the early traders. After the 1530s, however, gold production markedly declined, and the Spanish colonists, with slave labour, turned to agriculture. By 1550, with financial aid from Spain, several small sugar mills were in operation on the island.

Puerto Rico did not prosper economically, however. Carib Indians from neighbouring islands made frequent raids, carrying off food and slaves and destroying property. The colony continued to lead a precarious existence, ravaged by plagues and plundered by French, British and Dutch pirates. Repeatedly during the mid-16th century the French burned and sacked San Germán, the second community to be established on the island. Under such adverse conditions people began to leave the island whenever opportunity offered.

In the second half of the 16th century Spain, recognizing the strategic importance of Puerto Rico, undertook to convert San Juan into a military outpost. The fortress El Morro, built with the financial subsidy from the Mexican mines, was well constructed and perfectly located to dominate the narrow entrance to the harbour. Later, a stronger and larger fortress was built to the east and on the Atlantic side of the city. In the early 17th century the city was surrounded by a stone mall, 25 ft. high and 18 ft. thick, two parts of which still stand. These defenses made San Juan almost impregnable.

Sir Francis Drake attacked the town in 1595 but failed to gain the harbour. Three years later George Clifford, 3rd earl of Cumberland, had complete military success but was forced to abandon his conquest owing to an outbreak of plague among his troops. In 1625 a Dutchman, Bomdoin Hendrik, burgomaster of Edam, boldly sailed into the harbour, captured and burned the town, but failed to subdue El Morro. .

San Juan as the most exposed military outpost guarding the heart of Spain's new world empire, received political and economic attention from the mother country. However, the rural inhabitants of the interior of the island were ignored by Spain and scorned by the presidia1 residents of San Juan. As the French. English, Danish and Dutch fought over and settled the Lesser Antilles during the 17th and 18th centuries, rural Puerto Ricans, ignoring the edicts of Spain, found profit in clandestine trade. Ginger, hides, sugar, tobacco and cattle from the island were in great demand, and while the colonial authorities of San Juan rarely ventured out of their walled defenses for fear of the reprisals of the buccaneers the rural settlers prospered in a modest way through contacts nith the non-Spanish European traders. No large plantations were established, and the farmer, with little help, cultivated his own land. Contrary to the fears of Spain, this contact with foreigners did not corrupt the islanders, who remained loyal and were willing to participate in aggressive expeditions.

2. Liberal Reforms. — In 1797 the British Gen. Sir Ralph Abercromby, who had captured Trinidad, unsuccessfully attacked Puerto Rico. The British considered the island — a centre of clandestine trade and of operations for quasi-piratical expeditions, and a refuge for runaway slaves — a weak link in the chain of defense of the Spanish empire. The failure of Abercromby was due in part to the important economic and administrative changes in the Spanish colonial empire which were carried out in the latter half of the 18th century by representatives of the Bourbon rulers of Spain. In the case of Puerto Rico it was hoped that the island might become an economic asset rather than a financial drain on the Spanish crown. Trade relations between the island and Spain were liberalized, agricultural production was stimulated, the island as a whole was integrated into the system of military defense, and, above all, concerted efforts were made to break down the social dichotomy which had developed between the walled city of San Juan and the interior.

The liberal reforms of the enlightened despotism of the Spanish Bourbons coincided with and encouraged rapid population growth, introduction of new products and the beginning of commercial agriculture. Population was estimated in 1765 at 45,000; in 1775 at 70,250; in 1787 at 103,051; and in 1800 at 155,426. By the end of the 18th century there were 34 towns on the island. Immigrants from the Canary Islands, French settlers from Louisiana or Haiti and Spaniards from Santo Domingo, which had been turned over to Napoleon, accounted in part for the increase in population. These newcomers brought with them new ideas and methods of producing marketable crops. Coffee, introduced into the island in 1736, became an important export item by 1776. Sugar production, which had always been small, was undertaken on a large scale by augmented slave labour. From 1765 to 1800 the slave population increased from 5,037 to 13,333.

When Napoleon invaded Spain and placed his brother, Joseph Bonaparte, on the Spanish throne (1808), the colonies of South and Central America asserted their right to govern themselves in the name of the imprisoned Bourbon king, Ferdinand VII. This claim to temporary self-rule eventually evolved into a revolutionary movement for independence. In Puerto Rico, however, for various reasons, the sequence of events and their results were different. The communities of the interior of Puerto Rico, with one exception, offered little objection to the strict rules of Spain's mercantilist policy, which for many decades had ceased to have effect on them. Most of the residents of San Juan, on the other hand, dependent upon administrative and military positions, were most willing to follow the orders of the central government of Spain acting in the absence of the king. Puerto Rico, which had asserted its loyalty by repelling the English, undertook to recapture Santo Domingo from the French.

As the revolutions progressed on the southern and central mainlands, loyal Spaniards reluctant to leave the colonies found refuge in Puerto Rico, which was being used as a supply depot for military movements on the continent. In recognition of its loyalty and in a belated move to liberalize an outmoded colonial system, the Spanish government granted Puerto Rico in 1815 ample economic liberties. The island was opened to all non-Spanish Catholics, the ports were permitted to trade with non-Spanish countries, and free land was granted to the new settlers.

3. Economic and Political Development. — By the end of the 19th century the population had increased to nearly 1,000,000, and the value of foreign trade had increased considerably from an estimated $1,000,000 in the 1820s to $30,000,000 annually. During the 1800s imports from the United States rarely dropped below 20% of the total goods received; exports to the U.S. fluctuated between 50% and 15% depending in part upon U.S. tariff restrictions. By 1899 the United States was buying 61% of Puerto Rican sugar production. The area devoted to sugar had been slowly expanding, and the processing was becoming more centralized. Coffee, in the late 19th century, provided the principal source of income for the island; its production quadrupled between 1862 and 1898.

Political development in Puerto Rico during the 19th century was characterized by periods of liberal advance counteracted by long periods of conservative reaction. In part, this was due to the changes occurring in the Spanish government, and in part due to the antiquated Spanish colonial administrative policy.

During the first half of the 19th century, two short periods of relative political freedom were enjoyed. From 1809 to 1814 and from 1820 to 1823 Puerto Rico was declared an integral part of Spain with the right to elect representatives to the Spanish *Cortes*, or parliament. Ramón Power y Giralt, an able liberal, was selected during the first period and succeeded in revoking the absolute powers of the island's colonial governor. In the latter period Demetrio O'Daly secured the separation of the military authority from the colonial administrator. Freedom of the press was also permitted. On each occasion moderate colonial rule was thwarted by the return of royal absolutism in Spain.

In 1837, when a fairly permanent constitutional monarchy was established in Spain, Puerto Rico failed to benefit because it was argued that the colonies were not true Spanish provinces and therefore should be governed by special laws. For more than 30 years Puerto Rico waited for special legislation to ease the despotic rule of military colonial governors. During this waiting period, political thought in the island began to crystallize. A liberal current of opinion, remembering the success of previous periods. requested assimilation into the Spanish government and permission to be represented in and governed by the *Cortes*. A bloc of conservative opinion strongly approved of the status quo. A small third group advocated complete independence.

4. Movements Toward Self-Government and Independence.—A local commission was elected in 1865 to draw up a report on the basis of which a governmental reform might be carried out. The majority report, which declared that the abolition of slavery was the *sine* qua *non* of any political reform, provoked a shocked reaction among the island and peninsular conservatives. The alarmed colonial government took steps to curtail what was feared to be a growing movement of rebellion. Some of the more outspoken and respected islanders were ordered to be arrested and sent to Spain for trial. Thus provoked, a small group of radicals committed to independence attempted an uprising, for which, however. inadequate preparation was made. El *Grito* de *Lares,* the abortive revolt of Sept. 23, 1868, brought forth severe reprisals on all island liberals. However, the abdication of Queen Isabella II of Spain was forced by a republican government, which pardoned all the political prisoners. The first Spanish republic extended to Puerto Rico its third period of constitutional government, 1868–74, during which slavery was abolished.

During the 1880s a movement for political self-government under Spain led by Román Baldorioty de Castro replaced the sentiment in favour of integrating Puerto Rico into the Spanish government. Again a liberal political movement, this time autonomy, was denounced as disloyal and was violently suppressed in 1887, an infamous year in Puerto Rican history. Such treatment only served to solidify the movement for local self-government, and in 1897 the Partido Unionista (Autonomy party), now guided by Luis Muñoz Rivera, through co-operation with the Liberal party in Spain, achieved its objective. The autonomous government granted was parliamentary in form but retained the governor general as a representative of the Spanish king. He was empowered to disband the insular parliament and suspend civil rights. The two-chamber parliament was empowered to legislate for the island, create and control an insular tariff and levy local taxes. Puerto Rico's representation in the Spanish *Cortes* mas also increased. Any change in the governmental organization had to be first approved by the insular parliament.

5. Spanish-American War.—The Spanish-American War (*q.v.*) prevented the islanders from putting into effect the new government. In May 1898 Adm. W. T. Sampson bombarded San Juan for a short time without serious results. Facing token military resistance and with general popular acceptance, Gen. Nelson A. Miles landed a U.S. force of about 3,500 men in July, and after a short campaign hostilities were ended on Aug. 12.

B. Under the United States

1. Early Years.—On Oct. 18, 1898, the island was turned over to the U.S. forces and Gen. John R. Brooke became military governor. Puerto Rico was ceded to the US. by the treaty signed in Paris. Dec. 10, 1898 (ratified by the U.S. senate Feb. 6, 1899). In the work of policing the country, in the accompanying tasks of sanitation, construction of highways and other public works, accounting for the expenditure of public funds and establishing a system of public education, the military control which lasted until May 1, 1900, proved effective in bridging the period of transfer from the control of Spain to the system under the United States civil government. The United States congress passed the Foraker act, under which civil government was instituted in May 1900. Under this act the U.S. element exercised the controlling power; this, however, having proved distasteful to many Puerto Ricans, the Organic law was subsequently amended to give a wider native participation in the government. The Olmsted act, approved by congress on July 15, 1909, placed the supervision of Puerto Rican affairs in the jurisdiction of an executive department to be designated by the president. The people, however, demanded a larger measure of local control. The majority also asked for U.S. citizenship and many other changes. As a result, congress passed a new Organic act (the Jones act), which came into effect on March 2, 1917. Under its terms Puerto Rico became a territory of the United States "organized but unincorporated," and citizenship of the United States was conferred collectively on Puerto Ricans, allowing the right to retain the old status if preferred. Only 288 persons declared in favour of the latter. The local civil government, however, even with modifications, fell far short of the measure of self-government which Puerto Ricans expected in light of the democratic tradition of the United States. Key officials, including the governor, were presidential appointees and thus beyond local control.

In spite of the legal limitations on political autonomy, a climate of freedom was slowly developed as a result of the change of sovereignty. At first this new order, being abrupt, new and imposed from above in some instances, was sometimes mistrusted, resented and misunderstood, but in the long run it was recognized as beneficial and assimilated by the islanders. For example, labourers were allowed to organize for collective bargaining and to affiliate with labour unions in the United States; the Anglo-Saxon legal procedure of assuming innocence until proved guilty brought slowly a feeling of security and freedom from political persecution; the separation of church from state, resulting in open competition for religious adherence, demonstrated the new climate in a practical way; government programs which dealt directly with the vital needs of the people for education, health and sanitation, regulation of working conditions and public facilities all reflected a change designed to remedy centuries of neglect.

2. Economic and Social Changes.—The economic reorientation of the island as a result of the change in sovereignty had almost an immediate and profound effect on all aspects of life. Included within the U.S. tariff walls, Puerto Rican agricultural products, particularly sugar, had a ready market. Aided by the adoption of G.S. currency and by unobstructed financial movement, Puerto Rico experienced within a short period a large capital investment which revolutionized the production of sugar. Sevenfold acreage expansion (1899 to 1939), new disease-resistant plants, rapid transportation facilities, large and efficient cane-grinding mills and complete corporate management within a generation converted the economy of the island into one in which 75% of the population directly or indirectly was dependent upon sugar. Land which had sustained small farmers producing crops and dairy products for local consumption was absorbed by the sugar corporations. The island was forced to import its foodstuffs. Coffee was neglected at a time when weather conditions and transportation problems dictated financial and government aid. Only tobacco production experienced growth, which failed to be sustained after the 1920s when United States smokers shifted from cigars to cigarettes.

The shock of these economic changes might have been absorbed in spite of the island's limited resources if at the same time Puerto Rico had not been undergoing a severe social change as a result of the application of modern sanitation means and medical knowledge to a people with a very high death rate. The population was threatening to double its number in two generations. The two counterpressures—expansion of corporate control over the limited productive land and increasing population pressure—reached an explosive stage at the time when the economic depression occupied the attention of government officials in the United States. Recurring hurricanes joined with declining exports to aggravate the economic distress of the island.

3. Political Development.—With one exception, political parties which had developed since the change in sovereignty had centred their attention on modifications in the political relations between the island and the U.S. federal government. The Republican party limited its program to a plea for statehood for the island. The Union party worked for greater autonomy. In the 1920s the Nationalist party rose to affirm the ideal of immediate independence. The one exception was the pro-U.S. Socialist party, led by the highly respected labour leader Santiago Iglesias. This party had expressed since its foundation a concern for the plight of the labouring classes of the island. Nevertheless, its effectiveness had been hampered by insufficient popular support, due primarily to the concentration of attention upon the issue of the political status of the island.

In the mid-1930s, with Pres. Franklin D. Roosevelt's New Deal policies radically enlarging the previously accepted concept of the function of government as that of maintaining order and protecting the citizens, Puerto Rico was not neglected. More important than the much-needed temporary relief were the steps taken by the Puerto Rican Reconstruction administration (P.R.R.A.), designed to readjust the distribution of economic power on the island. A restrictive quota was placed over sugar production. Legal procedures were initiated to enforce a long-neglected law limiting corporate holdings to 500 ac. Thus the process of increasing the sugar acreage was to be reversed and Puerto Ricans were to be returned to their small farms. A model sugar mill was to run on a co-operative basis to compete with the private mills. Coffee and tobacco growers were to receive long overdue attention.

This radical program provoked the open opposition of the sugar interests, locally vocal through the Republican party. The Socialists accepted the program in a tacit fashion. Their reluctance was due to the fact that the young radical wing of the heirs of the Autonomy party, led by Luis Mufioz Marín, the son of Luis Mufioz Rivera, was recognized in Washington and on the island as the local political proponent of the economic reform.

The success of the New Deal measures was jeopardized by two unconnected factors. Unforeseen administrative and financial problems forced a curtailment of the objectives of the P.R.R.A. No longer was a complete readjustment of the island's economic structure possible; the P.R.R.A. took on a more temporary or experimental nature. The second factor a-as the interjection of the status issue on the political scene by the U.S. government in answer to Nationalist violence. Taking the form of a vindictive offer of independence under adverse economic conditions, the proposal served to realign again the political parties into pro- and anti-independence groups.

The incipient political movement for economic reform originally fostered by the New Deal and temporarily sidetracked was surprisingly successful in the election of 1940. This new political movement took the form of a political party, led by Mufioz Marín, called the Popular Democratic party. Organized to improve the conditions of the louer classes, particularly the hard-working *jibaro* of the mountainous interior, the new party's platform was summarized by the slogan "Bread, land and liberty." The island electorate had agreed that the political status was not in issue and that economic and social problems took precedence. Tenuous control over the island legislature and a new-style colonial governor, Rexford Guy Tugwell, allowed the Popular Democratic party to initiate such economic reforms as redistribution of land, enforcement of minimum wage and hour laws, an enforced progressive income tax law and the establishment of an economic development program. In recognition of partial fulfillment of its announced aims the Popular party was overwhelmingly backed by the island electorate in 1944. In 1946 Pres. Harry S. Truman named Jesús T. Pifiero, a Puerto Rican, as governor, the first Puerto Rican to occupy that post. In 1947 the U.S. congress amended the Organic act of Puerto Rico to permit election of governors by popular vote. Mufioz Marín was elected Nov. 2, 1948, and took office in Jan. 1949. In spite of efforts at economic development, the post-World War II years were marked by large-scale emigration to the eastern United States, mainly New York city.

Governor Muñoz Marín and the Popular Democratic party turned to deal with the temporarily postponed problem of political status. The economic recovery experienced by Puerto Rico under the guidance of the *Populares*, rather than freeing the island from its economic ties to the United States, changed these relations from unrestrained exploitation by absentee sugar corporations to controlled industrial production which allowed the islanders to receive greater benefits from the original capital investment. Obviously any political change had to take into consideration these essential economic relations. The solution was found in the expansion of local political autonomy which did not affect adversely the economy.

4. Establishment of the Commonwealth. — In 1950 the U.S. congress offeredto Puerto Rico for its approval or rejection a series of changes in the law which governed the relationship between the federal government and Puerto Rico. These changes if accepted would eliminate all sections dealing with the creation of the local insular government and would turn over to the people of Puerto Rico the power to create their own government under a constitution of their own making. Under the guidance of Governor Mufioz Marín the islanders accepted the offer of congress and drew up a constitution. Duly approved by the people and the congress, Puerto Rico's constitution mas proclaimed on July 25, 1952, and the Commonwealth of Puerto Rico came into being. (See *Administration and Social Conditions*, below.) After some years of operation the full measure of self-government is still being explored and defined. During this period, Puerto Rican extremists dramatized their desire for independence with an attempt to assassinate President Truman on Nov. 1. 1950, in Washington. They attracted world-wide attention on March 1, 1954, when several members of the Nationalist party shot and wounded five congressmen in the house of representatives in the U.S. capitol. Nevertheless, in the judgment of the general assembly of the United Nations, expressed in a resolution of Nov. 27, 1953, Puerto Rico is a self-governing political unit associated voluntarily with the United States and is no longer considered a colonial territory.

V. POPULATION

The population of Puerto Rico, 2,349,544 in 1960. had more than doubled since 1899, when it was 953,243. The 1950 census gave a population of 2,210,703, of whom about 40% were urban and 60% rural; 79.7% were classified as white and 20.2% as Negro. This small island, with a population density of over 687 per square mile, is one of the most densely populated areas of the world. One of the principal reasons for the growth was the application of modern medical knowledge to a previously underprivileged island, resulting in a radically declining death rate. From 1901 to 1957 the island's death rate dropped from 36.7 per 1,000 to a subnormal 6.9. a lower figure than that in the United States. The birth rate declined at a much slower rate: from 43.2 in 1947 to 32.6 in 1957. The difference (+25.7) between the birth and death rates in 1957 left a high rate of natural increase (a ratio of four births to every death on the average), thus accounting for the high population density. If the United States were this densely populated. it would have 1,500,000,000 inhabitants or about 60% of the world's population. According to the demographers. by the 1960s the population of Puerto Rico should reach its maximum, an estimated 2,500,000 persons. The death rate should rise automatically to a more normal 12 per 1,000 as the age distribution approximates proportionately the same distribution attained in the United States. The birth rate can be expected to continue to decline as the standard of living rises and the middle class increases.

One factor which allowed Puerto Rico to keep pace economically with the rapidly growing population was emigration to the United States. The difference between the numbers of those leaving and those returning to Puerto Rico in the 1950s resulted in a net exodus of about 50,000 a year. This figure was only slightly under the average yearly natural increase of 60,000 for the same period. For the most part, Puerto Ricans who went to the United States were young persons of aorking age with an occupation or skill. Those who returned to the island were older people, already past their productive years.

The metropolitan areas have absorbed much of the island's population growth. The rural inhabitants, particularly in the western highlands where the coffee haciendas are found, have been migrating to the cities on the north and south coasts. Some indication of this migration can be seen in the growth of San Juan (merged with Rio Piedras), which in the 1950s doubled its population to well over 500,000.

VI. ADMINISTRATION AND SOCIAL CONDITIONS

1. Government. — The government of. the Commonwealth of Puerto Rico was established by a constitution drawn up by representatives of the Puerto Rican people meeting in a convention; approved by the electorate of the island, March 3, 1952; and ratified by the congress of the United States. This constitution, proclaimed July 25, 1952, provides for an autonomous form of representative government and guarantees the liberties and rights of its citizens through a bill of rights. The people of Puerto Rico are free to

modify the constitution as long as such modifications do not conflict with the U.S. constitution or the Puerto Rican Federal Relations act, which, as its title indicates, defines to a limited extent the relations between the commonwealth and the federal government. This act was adopted "in the nature of a compact" by the U.S. congress and the Puerto Rican people. To change this compact the consent of both groups would be required.

The constitution provides for a government whose powers are distributed among the executive, legislative and judicial branches. Franchise is restricted to citizens 21 years of age and over. The governor of Puerto Rico is elected by popular suffrage every four years, and unlimited re-election is permitted. He appoints, with the consent of the commonw ealthsenate, the heads of departments, who form, with other agency directors selected at the governor's discretion, his advisory council. Aside from the departments such as labour, education and justice, the commonwealth has a department of co-operatives.

The members of the legislative branch, composed of a senate and a house of representatives, are elected for four-year terms. There are eight senatorial (two members each) and 40 representative districts. Eleven senators and eleven representatives are chosen at large. The common ealth constitution guarantees, by means of automatic appointment based on island-wide voting strength, the representation of minority parties in the legislature.

The island is divided into 76 municipalities, each of which has an elected mayor and assembly whose primary functions are to administer schools, health centres, poor relief and other services of the commonwealth.

The Puerto Rican electorate sends a resident commissioner to the U.S. congress for a term of four years, but he has no congressional vote. Puerto Ricans do not vote in the U.S. presidential elections, but emigrants on the mainland may do so subject to local electoral laws.

2. Taxation. — Since the citizens of Puerto Rico (after one year's residence on the island all U.S. citizens fall into this category) are not represented with a vote in the federal congress, they are not subject to federal taxes. The commonwealth government is sustained in part by the local revenue laws, which in general provide for taxes about one-quarter to one-third lower than those of the mainland. A graduated personal and business income tax, an excise tax and a property tax are the main sources of local revenue. The excise tax, which has produced more than half of the commonwealth's locally collected revenue, was used to reduce spending on nonproductive luxury items, the purchase of which tended to drain off potential local capital.

3. Living Conditions. — The middle- and upper-class living conditions in Puerto Rico are comparable to those of the United States. The expected difference between rural and urban areas is marked, but the standard of living of the agricultural worker has improved. Federal and commonwealth minimum wage laws cover every important industry and areas of agricultural production. Strict enforcement and periodical revisions ensure a just compensation for the working class. The hourly wage received by labourers is considerably lower than that received by workers in similar industries in the United States, but private professional salaries for the growing middle class are generally on a par with salaries for similar occupations in the Gnited States. Government workers such as teachers, clerks or administrators are not so well paid as private professional workers or federal government employees in the U.S.

The labour force of the island has remained for some time slightly over the 635.000 mark. Unemployment, which fluctuates seasonally, has rarely dropped below 15% of the labouring force.

Since more than half the goods and services which Puerto Rico consumes come from the United States, the general price level follows closely the level on the mainland. Local products are naturally less expensive than imported items, but inability to expand local farm production has caused prices of local goods to be increased at a much faster rate than that of imported goods prices. Large supermarkets, including four large consumer co-operatives, serve the San Juan, Ponce and Mayagiiez metropolitan areas.

Faced with the increased migration from the mountains to the cities, particularly to the San Juan area, and a rapidly growing population, the commonnealth government working in close cooperation with the Federal Housing authority was able to undertake during the years after World War II extensive programs of construction of low-cost housing. Although the inadequately serviced housing areas were not eliminated completely, strict enforcement of government laws concerning zoning, new constructions and renovations, coupled with a methodically planned slum-clearing program, improved immeasurably the living conditions of the workers.

4. Welfare Services. — In the late 1950s more than 20% (in 1959, $60,000,000) of the total budget of the commonwealth was spent on providing health and public welfare services for the people of the island. An additional $11,000,000 was contributed by the federal government in 1959.

Several hundred public health clinics, functioning under the supervision of doctors and nurses, offered preventive and curative medical services. Six general district hospitals, six tuberculosis hospitals and a large psychiatric hospital were run by the commonwealth. The health department offered assistance to the aged, needy families and the handicapped. Almost half of those attending public school received free lunches, milk depots were conducted to supply free milk to preschool-age children, and annually about 80,000 pairs of shoes were distributed free to needy students.

All workers, both industrial and agricultural. are completely covered in case of accidents by a compulsory state insurance fund, which has rendered excellent service for over a generation.

5. Justice. — The commonwealth constitution provides for a uniquely unified judicial system consisting of a general court of justice comprised of the supreme court and the court of the first instance. The latter is organized in two divisions, the superior court nith 30 judges and the district court with 55 judges. The uhole judicial system is administered by the chief justice of the supreme court and his office of court administration. This integrated system permits maximum flexibility. Jurisdiction and venue questions do not prevent a case from being considered. Appeals may be carried to the supreme court in Washington.

6. Education. — Compulsory education has been in effect since 1899. To keep pace with the growing population, the commonwealth assigned to education during the 1950s a larger percentage of its budget than did any other Latin-American country, 30%, or $75,000,000 in 1959.

Over 95% of the elementary school-age children are registered and attend classes; about 85% of those eligible attend the secondary schools, and about 50% of those eligible attend high schools. The total attendance in 1958–59 was 573,000 in these three divisions, and in private schools were registered close to 50,000. Teaching is in Spanish in the public school system, but special emphasis is given to the teaching of English as a second language. In the 1950s, partially as a result of a successful adult education program, the island illiteracy rate dropped from 24% to less than 15%. Special English instruction for prospective migrant workers was provided.

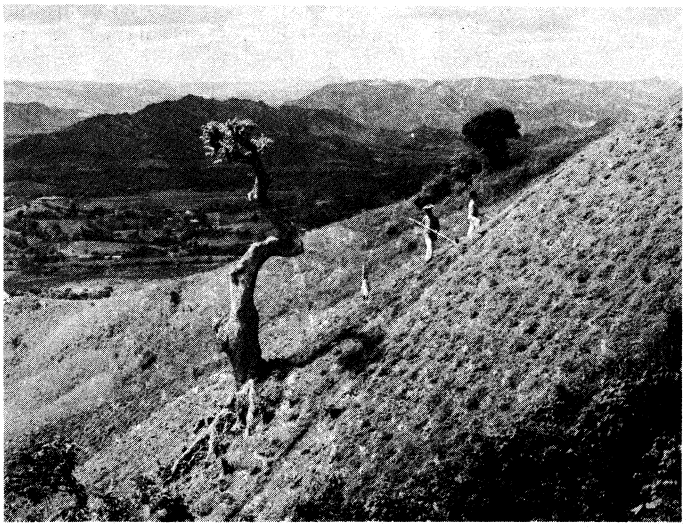
The land-grant government-financed University of Puerto Rico with 18,500 students in 1958–59, several graduate schools and a technical campus with a nuclear reactor in Mayaguez, has an international faculty and student body. The other island colleges include the Roman Catholic Sacred Heart college in Santurce and the Catholic University of Santa María in Ponce, as well as Inter-American university at San Germán which is affiliated with the Presbyterian Church of America.

VII. THE ECONOMY

The economy of Puerto Rico is closely tied to that of the United States. No trade barriers exist to prevent interchange of goods between the two areas. During the first half of the 20th century Puerto Rico's agrarian-based economy functioned primarily from the sale of sugar and its by-products. After 1956 the economy of the island shifted noticeably from one based on agriculture to one based on manufacturing and industry.

1. Agriculture. — The production of sugar, dairy products, to-

bacco, coffee, fruits and vegetables in the late 1950s accounted for about 17% of the island's total net income. Sugar, processed by 32 cane-grinding mills, accounted for 50% of the agricultural income. This production, subject to a federal quota of 1,125.000



BY COURTESY OF THE DEPARTMENT OF STATE, COMMONWEALTH OF PUERTO RICO

CULTIVATING TOBACCO ON A STEEP HILLSIDE NEAR TRUJILLO ALTO

tons annually, supplied about 10% of the sugar consumed in the United States. In 1957, due to adverse weather conditions, the island failed to fill its quota, and the island government extended limited aid to sugar growers. The government planned to stabilize the production of sugar at 1,263,000 tons produced on only 300,000 ac. of the most productive flat coastal land. Coupled with this stabilization is the mechanization of the cane-cutting process. With rising wages and increased rural emigration, large cane growers have turned to machine substitutes for human labour.

Livestock production, second only to that of sugar, contributed 30% of the agricultural income. Accounting for more than half the livestock income was the sale of milk and its by-products. Eggs, beef, pork and poultry accounted for the remainder. With 400 dairies and 13 large pasteurizing plants, the commercial dairy industry was well developed, and it was the only phase of agricultural production in xhich future growth is expected.

Although coffee production declined in the 20th century until it scarcely satisfied local demands, the haciendas in the western mountain area are still numerous. Land dedicated to coffee, 155,000 ac. on the average during the 1950s, produced anywhere from 150 to 200 lb. per acre, depending upon varying conditions. Some 35,000 ac. of tobacco, principally in the eastern central part of the island, brought an annual average return of about $8,000,000 to the growers.

2. Industry. — The remarkable industrial development which occurred in Puerto Rico was due to the government's Economic Development program, particularly that phase known as Operation "Bootstrap." xhich by the late 1950s had established nearly 600 nen factories on the island. These plants represented an investment of more than $400,000,000 and in large part explained why, after the mid-1950s, manufacturing and industrial production, accounting for 20% of the island's total net income, surpassed agriculture as a source of wealth. Stimulated by ten years of grace from taxes, availability of government-built factories for lease or purchase and ready access to the United States market. corporations did not hesitate to establish branch centres of production on the island. At first new industries were those which hoped to profit by low labour costs or mere associated with agriculture. After 1956 textile mills, chemical and metal plants (*i.e.,* industries which involved a higher capital investment) were established in growing numbers. The most important included oil refineries, fertilizer plants and chemical plants to develop petroleum by-products. On the south coast in Ponce there is a large cement factory, and in Santurce, near San Juan, there is an ironworks; both these industries have played an important part in the construction activity which accounts for 5% of the total net income of the island.

3. Power. — The electric power of the island is provided by a government agency, the Puerto Rico Water Resources authority, which came into existence in 1942. As a result of the government's program of rural electrification and a marked increase in industrial demand, the power production of the island during the late 1950s increased to well over 1,000,000,000 kw.hr. annually. Industrial consumption of power increased 134% between 1942 and the late 1950s.

4. **Trade.**—Between 80% and 90% of the value of imports comes from the United States; imports in 195i amounted to 60% of the gross insular product. Puerto Rico imports about 50% of its food, and 43% of consumers' expenditure is for food. Rice, lard, pork and dairy products are the most important imports. The island's expanding industrial climate has required the importation of capital equipment for productive uses, and raw or semi-processed goods for further elaboration and sale. About 40% of foreign imports were raw material, including crude oil from Venezuela and the Netherlands Antilles, to be refined and consumed or shipped to the United States.

All but about 5% of the value of Puerto Rican exports is sent to the United States. The total value exported in 1957 was 42% of the gross insular product. To the older exports of sugar, molasses and rum have been added electrical appliances, textiles, pharmaceuticals and plastic goods.

The deficit in this balance of trade (about $200,000,000 in 1957) is in part made up by payments and expenditures of the federal government on the island. About 90% of this is expenditures of the defense department and payments to veterans. The average capital inflow from 1952 to 1957 for investment purposes was $70,000,000. In 1957 some 186.000 tourists spent $28,000,000.

5. Banking and Currency. — Since Puerto Rico functions economically as an integral part of the United States. the currency of the island is the same as that of the U.S. The island's banking system is also integrated within the U.S. banking structure. A number of local banks, two Canadian banks and three United States banks operate under the close supervision of the insular government. Seven of the banks are members of the Federal Deposit Insurance corporation. The branches of the United States banks are indirectly related to the federal reserve system.

A legal maximum of insular indebtedness, placed at 10% of the aggregate tax valuation of property, has limited the financial operations of the government. Puerto Rico has never defaulted in the payment of principal or interest of the insular debt. Out of the 1959 budget, 5% or $13,800.000 was paid to service the current insular debt, which was estimated at nearly $77,000.000.

6. Transport and Communications. — The island has as extensive system of highways serving every community. In the late 1950s there mere nearly 3.000 mi. of paved streets and highways and more than 150,000 motor vehicles. No railroads for public use exist on the island; during the cane-cutting season some sugar corporations operate local railroads to bring cane to the *centrales.*

Eleven ports of widely varying importance are open for handling freight and some passenger service. San Juan, Ponce and Mayagiiez receive most of the cargo ships. First-class passengers are accepted in limited numbers on the freighters, but no passenger line links the island nith the United States. A French line passenger service connects Puerto Rico with the European continent. Most of the Puerto Rican visitors and migrants travel by air. The San Juan International airport. equipped for jet passenger service, is connected with the important cities on the U.S. Atlantic seaboard from Miami to Boston. British, French, Dutch, Spanish and Latin-American airlines have frequently scheduled flight services connecting Puerto Rico with other points around the Caribbean and abroad.

The Gnited States postal service offers complete service on the island. Three commercial cables extend from Puerto Rico to the mainland. There is a government and commercial wireless service. The island has about 25 small commercial radio stations and four commercial television stations. The government operates an educational radio and television station. *See* also Index references under "Puerto Rico" in the Index volume.

BIBLIOGRAPHY.—Clarence F. Jones and Rafael Pic6 (eds.), *A Symposium on the Geography of Puerto Rico* (1955); Earl S. Garver and Ernest B. Fincher, *Puerto Rico: Unsolved Problem,* (1945); Millard Hansen and Henry Wells (eds.), "Puerto Rico: A Study in Democratic Development," *Annals* of the American Academy of Political and Social Science, vol. 285 (1953); Earl P. Hanson, *Transformation: The Story oj Modern Puerto Rico* (1955); Arturo Morales Carrión, *Puerto Rico and the Non-Hispanic Caribbean* (1952); Julian Steward et *al., The People of Puerto Rico* (19563; Governor of Puerto Rico, *Annual Reports;* Puerto Rico Planning Board, Bureau of Economics and Statistics, *Anuario Estadistico Puerto Rico* (Statistical Yearbook).
(T. G. Ms.)

PUFENDORF, SAMUEL, BARON VON (1632–1694), German publicist and jurist: best-known for his treatise on natural law and international law, *De Jure Naturae et Gentium Libri Octo,* was born near Chemnitz, Saxony, on Jan. 8, 1632, the son of a Lutheran pastor. He commenced theological studies at Leipzig university but soon turned to jurisprudence and studied mathematics and natural law under Erhard Weigel at Jena. Leaving Jena in 1657, Pufendorf took service as a tutor in the household of the Swedish minister at Copenhagen. When Sweden declared war. the whole retinue was imprisoned. Pufendorf occupied his captivity of some eight months reflecting on what he had read in the works of Grotius and Hobbes and mentally constructing a system of universal law. On his release, he went to Leiden where he published in 1661 the fruits of his reflections in the work *Elementa Jurisprudentiae universalis,* in the plan and structure of which his mathematical training is very evident.

Karl Ludwig, the elector palatine, to whom the work was dedicated, created a chair of the law of nature and nations for Pufendorf at Heidelberg, the first chair of its kind in the world. His next work was written under a pseudonym, Severinus de Monzanibano: *De statu imperii germanici ad Laelium, dominum Trezolani, liber unus.* It took the form of a bitter attack, supposedly by a Yeronese nobleman, on the constitution of the Holy Roman Empire and the house of Austria, and created a great sensation.

In 1670 Pufendorf left Heidelberg for the University of Lund, Swed., where he produced in 1672 his great work, the *De jure naturae et gentium libri octo,* and, in the following year, the *De officio hominis et cicis* which is in the main a résumé of the *De jure naturae.*

Grotius had pointed out the dualism between a natural and a positive law of nations. Where Richard Zouche stressed the precedence of the latter, Pufendorf followed Hobbes in maintaining the priority of the natural law; he differed from Hobbes however in proclaiming that the natural state was one of peace, not of war, albeit a precarious peace unless given positive support. For, though originating from God in that God created men as social beings, natural law, for Pufendorf, is concerned with man in this life—as he is, with all his failings—and with external conduct. and it derives from human reason alone: man as a prospective citizen of heaven is the concern of moral theology. This search for natural law in the dictates of human reason understandably enables Pufendorf to maintain that international law is the common link of all men, not merely that of Christendom. In public law, while recognizing the state as a moral person, Pufendorf teaches that the will of the state is but the sum of the individual wills that constitute it, foreshadowing Rousseau and the *Corztrat social.*

In 1677 Pufendorf became historiographer royal at Stockholm and thereafter virtually abandoned international and natural lam for historical: political and theological studies. To this period belongs (in addition to, *e.g.,* histories of Sweden and the reign of Charles Gustavus) the *De habitu religionis christianae ad vitam çivilem.* This work, in which he traces the limits between ecclesiastical and civil power, was the basis of the *Kollegialsystem* of church government, which, developed by Christoph Pfaff (1686–1760), was the basis of church and state relations in Germany.

This theory makes a fundamental distinction between the supreme jurisdiction in ecclesiastical matters *(Kirchenholzeit* or *ius circa sacra)* which is inherent in the power of the state with respect to every religious communion and the ecclesiastical power (*Kirchengewalt* or *ius in sacra)* which belongs to the church but which is, in some cases, vested in the state by the consent—express or tacit—of the ecclesiastical body. Though naturally not accepted by the Roman Catholic Church, the theory did in fact facilitate a working compromise between the Protestant governments and Rome.

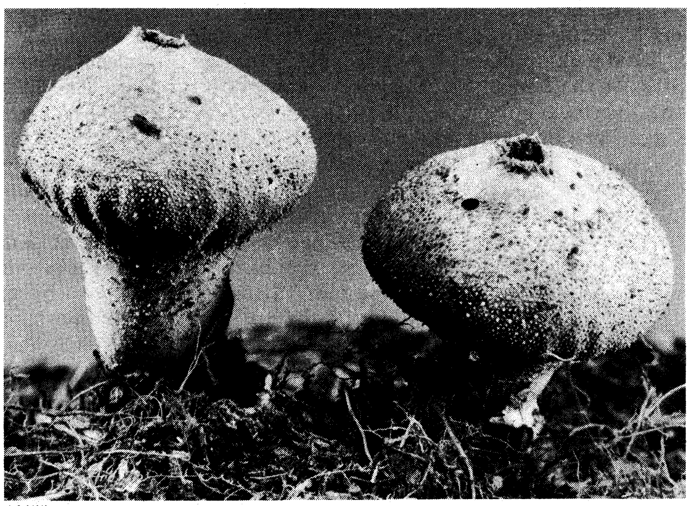
In 1686 Pufendorf went to Berlin as historiographer to the great elector of Brandenburg. He was created a baron and died at Berlin in 1694.

The value of Pufendorf's work was much underestimated by posterity. Responsibility for this rests largely with Leibniz, who would never recognize the greatness of one who was ever his adversary and whom he dismissed as *vir parum jurisconsultus et minime philosophus* ("a man not enough of a lawyer and scarcely a philosopher at all"). Modern scholarship, however, while conceding that he is not a pioneer in the category of Francisco Vittoria and Grotius, recognizes Pufendorf as a classic writer in the field of international law, and his *Jurisprudence* is the standard one for the 17th and 18th centuries.

BIBLIOGRAPHY.—H. von Treitschke, *Historische und politische Aufsätze,* vol. iv (1897); J. G. Droysen, *Abhandlungen zur neueren Geschichte (1876);* P. Meyer, *Samuel Pujendorf* (1894). *See* also introductions to the translations of *De jure naturae, Elementa Jurisprudentiae* and *De oj'icio* in "Classics of International Law."
(J. A. C. T.)

PUFF ADDER: *see* ADDER; SNAKES; VIPER.

PUFFBALL, the popular name of a group of fungi belonging to the Basidiomycetes *(see* FUNGI) and so called because of the cloud of bronn dustlike spores that is emitted nhen the mature plant bursts or is struck a blow. Puffballs are common in meadons and woods and on heaths or lawns, and nhen young resemble white balls, sometimes with a short stalk, and are fleshy in texture. While white and fleshy they are edible.



ROCHE

PUFFBALLS (LYCOPERDON PERLATUM)

The giant puffball, *Calvatia maxima,* may sometimes attain a weight of 15 lb. or more and measure up to four to five feet or more in circumference. It has been estimated that a specimen measuring 15.7 × 11.0 × 7.8 in. will produce approximately 7,000,000,000,000 spores.

PUFFBIRD, the popular name given to the bird family Bucconidae, of the order Piciformes. The order includes also woodpeckers, toucans, jacamars, etc. The Budconidae are confined to tropical America, from southern Mexico to Argentina; in the sub-Andean subregion they are, as regards species, abundant; only two seem to reach Guatemala and only one Paraguay. Most dwell in lightly forested areas near water; a few live in deep forest. The Bucconidae are plainly coloured, and the majority have a spotted or mottled plumage suggestive of immaturity. The smallest, *Micromonacha lanceolata,* of northern South America, is only five inches long. Most puffbirds are very quiet, but the nunbirds, of the same family, often emit whistling notes; typical' of this group is the white-bearded nunbird,,*Monasa morphoeus.*

PUFFIN, a sea bird (*Fratercula arctica*), known also as bottle-nose. coulterneb, pope. sea parrot and tammy-norie. Of old time, puffins were a valuable commodity to the owners of their breeding places, for the young were taken from the holes in which they were hatched, and were "kept salted and reputed for fish." Puffins resort in vast numbers to certain stations on the coast, reaching them in spring with remarkable punctuality. They lay their single egg (white, with a few gray markings at first: but which speedily becomes begrimed by the soil) in a shallow burrow, which they either dig for themselves or appropriate from a rabbit. The plumage of both sexes is glossy black above — the cheeks grey, encircled by a black band — and white beneath; the feet are of a bright reddish orange. The most remarkable feature of these birds is their huge bill. In the breeding season this is very deep, laterally flattened, parti-coloured—blue, yellow and red—and curiously grooved and embossed in places. The puffin's bill undergoes an annual moult, some of its most remarkable appendages, dropping off at the end of the breeding season. The puffin, when feeding its young, manages to arrange crosswise in its bill, a number of fish at a time. In the north Pacific we find the horned (F. *corniculata*) and the crested puffin (*Lunda cirrhata*).

BY COURTESY OF THE NATIONAL ASSOCIATION OF AUDUBON SOCIETIES

TUFTED PUFFIN (LUNDA CIRRHATA)
A blackish brown bird, with a white cheek, and a yellow plume over the eye

PUGACHEV, EMEL'YAN IVANOVICH (1741?–1775), Russianpretender, the date of whose birth is uncertain, was the son of a small Cossack land-owner. He married a Cossack girl Sofia Nedyuzheva, in 1758, and the same year was sent with his fellow Cossacks to Prussia, under the lead of Count Zachary Chernuishev. In the first Turkish War (1769–74) of Catherine II. Pugachev, now a Cossack ensign, served under Count Peter Panin and was present at the siege of Bender. Invalided home, he led for the next few years a wandering life; was more than once arrested and imprisoned as a deserter; and finally, after frequenting the monasteries of the "Old Believers," who exercised considerable influence over him, suddenly proclaimed himself (1773) to be Peter III. Pugachev asserted that he and his friends had escaped from Catherine, and were resolved to redress grievances, give liberty to the Cossacks and put Catherine in a monastery. He held a mimic court at which one Cossack impersonated Nikita Panin, another Zachary Chernuishev and so on. At the beginning of Oct. 1773 500 roubles was considered a sufficient reward for the head of the troublesome Cossack. At the end of November 28,000 roubles were promised. Still, Catherine, in her correspondence with Voltaire, affected to treat *"l'affaire du* Marquis de *Pugachev"* as a mere joke. By the beginning of 1774 the forts on the Volga and Ural were in the hands of the rebels; the Bashkirs had joined them; and the governor of Moscow reported great restlessness in central Russia. Pugachev captured Kazan, reduced most of the churches and monasteries there to ashes and massacred those who refused to join him. Panin, the conqueror of Bender, was sent against the rebels with a large army, but the innumerable and ubiquitous bands of Pugachev were victorious in nearly every engagement. Not till August 1774 did General Mikhelson inflict. a crushing defeat upon the rebels near Tsaritsyn, when they lost ten thousand in killed and prisoners. Suvorov completed their discomfiture. Pugachev was delivered up by his own Cossacks on attempting to fly to the Urals (Sept. 14), and was brought in an iron cage to Moscow, where he was executed on Jan. 11, 1775.

See N. Dubrovin, Pugachev and his *Associates* (Rus.; Petersburg, 1884); *Catherine II.*, Political Correspondence (Rus. Fr. Ger.; Petersburg, 1885, etc.); S. I. Gnyedich, Emilian Pugachev (Rus.; Petersburg, 1902); also the literature quoted *s.v.* CATHERINE II.

PUGET, PIERRE (1622–1694), French painter, sculptor, architect and engineer, was born at Marseilles on Oct. 31, 1622. He traveled in Italy as a young man, and was employed by Pietro di Cortona on the ceilings of the Barberini palace. On his return to Marseilles in 1643. he painted portraits and carved the colossal figureheads of men-of-war; he also painted numerous pictures for Aix, Toulon, Cuers and La Ciotat; his caryatids for the *hôtel* de *ville* of Toulon were executed between 1655 and 1657. Fouquet employed him to sculpture a "Hercules" for his château in Yaux. In 1655, because of a serious illness, he was forced to give up painting.

In 1660 he was in Genoa, where he executed his French Hercules (Louvre) and the statues of St. Sebastian and of Alexandre Sauli in the church of Carignano (c. 1664.). In 1669, at the summons of Colbert, he returned to France, and took up his old work in the dockyards of Toulon, until in 1685, disheartened by the destruction by fire of an arsenal he was constructing, he returned to Marseilles. There he continued the series of sculptures on which he had been employed by Colbert. His statues of Milo (1682), Perseus and Andromeda (1684) and the bas-relief Alexander and Diogenes (1685) are in the Louvre. In 1688 he visited Paris. but court intrigues obliged him to abandon the project of an equestrian statue of Louis XIV, and he retired to Marseilles, where he died on Dec. 2, 1694.

His best work, the St. Sebastian at Genoa, shows energy and life. In the museum of Aix-en-Provence is the bust of a long-haired young man, believed to be Louis XIV. made by Puget in 1660.

PUGILISM, the practice or sport of fighting with the fists. The first mention of such fighting in literature is found in the 23rd book of the Iliad; another full description is in Yirgil's *Aeneid.*

Although fist fighting was supposed by the Greeks of the classic period to have been a feature of the mythological games at Olympia, it was not actually introduced into the historic Olympic contests until the XXIII Olympiad after the re-establishment of the famous games by Iphitus about 880 B.C. Onomastos was the first Olympic victor.

The rules of Greek boxing were strict. No wrestling, grappling. kicking nor biting mere allowed: and the contest ended when one combatant owned himself beaten. On this account pugilism was forbidden by Lycurgus, lest the Spartans should become accustomed to an acknowledgment of defeat (Plutarch, *Lycurgus*). Moreover. it was strictly forbidden to kill an adversary, on pain of losing the prize.

Boxing was evidently in vogue in very ancient times in Italy, imported, in all probability, from Greece. During the republic boxing was cultivated as a gentlemanly exercise. The art remained popular in Italy down to a late period of the empire.

Pugilism in England. — The first references to boxing in England as a sport occur toward the end of the 17th century, but little mention is made of it before the time of George I. when "prize fighters" engaged in public encounters for money. The most celebrated of these fighters and the one who is generally considered to have been the first champion of England, fighting with the bare fists, was James Figg. who was supreme from 1719 to 1730. Figg was succeeded by Pipes and Gretting, both of whom made way in 1734 for Jack Broughton, who built the amphitheatre for public displays near Tottenham Court road and who was undisputed champion until 1750. Broughton seems to have been a man of intelligence, and to him is ascribed the scientific development of the art of boxing. During his time the sport became truly national and the prize fighter the companion of the greatest in the land. Among Broughton's successors were Slack, "Big Ben" Brain, Daniel Mendoza, J. Jackson, Tom Cribb, Jem Belcher, Pearce (called the "Game Chicken") and John Gully, who afterward represented Pontefract in parliament.

From the time of Cribb the English champions were Tom Spring (1824), Jem Ward (1825), Jem Burke (1833), W. Thompson, called "Bendigo" (1839–45), Ben Caunt (1841), W. Perry the "Tipton Slasher" (1850), Harry Broome (1851). Tom Sayers (1857–60), Jem Mace (1861–63), Tom King (1863) and again

Mace until 1872. In the U.S. boxing began to be popular about the beginning of the 19th century. The first recognized national champion was Tom Hyer (1841–48). who was followed by James Ambrose (born in Ireland), called "Yankee Sullivan"; John Morrissey (afterward elected to the U.S. congress); John C. Heenan; Tom Allen (of England); Jem Mace (of England); J. Kilrain; John L. Sullivan (1882–92). Sullivan was the last of these to fight with the bare fists. Pugilism (*i.e.,* fighting with the bare fists) was driven out in favour of boxing (*i.e.,* fighting with the glove) by public opinion and by the general adoption after 1866 of the Marquis of Queensberry rules.

See BOXING.

PUGIN, AUGUSTUS WELBY NORTHMORE (1812–1852), English architect, who worked on the designs for the Houses of Parliament, was born in London on March 1, 1812, and died on Sept. 14, 1852, at Ramsgate. In the office of his father, Augustus Charles Pugin, he helped prepare a series of works on the Gothic buildings of England. He was a skillful etcher, and made numerous drawings and sketches, in pen and ink or with sepia monochrome, perfect in their delicacy and precision. After his reception into the Roman Catholic Church in 1833, he became a leader in the English Gothic revival. In 1837–43 he assisted Sir Charles Barry in working out the details for the new houses of parliament at Westminster; and though his exact share was the subject of bitter controversy, there is no doubt that the excellence of the details was partly due to him and to his training of the masons and carvers. Many of his executed works, such as the cathedral of St. George at Southwark and the church in Farm street, Berkeley square, London, suffered from later alterations. The cathedral of Killarney and the chapel of the Benedictine monastery of Douai best express his original conception. He also designed his own house at Ramsgate and the stately Adare hall in Ireland built for Lord Dunraven.

Pugin published Contrasts; or a Parallel Between the Architecture of the 15th and 19th Centuries (1836); True Principles of Christian Architecture (1841); Glossary of *Ecclesiastical* Ornament (1844); and Treatise on Chancel Screens and Rood Lofts (1851).

See B. Ferrez, Recollections of *A. W. Pugin* and *His* Father (1861); Paul Waterhouse, "The Life and Work of Welby Pugin," Architectural Review, iii, iv (1898).

PUGLIA (or APULIA), a region (*compartimento*) of southern Italy, extends from the Fortore river in the northwest to Cape Santa Maria di Leuca, the "heel" of the peninsula, in the southeast. It has a total area of 7,470 sq mi., a population (1951) of 3,220,483'. and is composed of the provinces of Bari, Brindisi, Foggia, Lecce and Taranto (*qq.v.*). The northern third of the region is centred on the Foggia plain, or Tavoliere, flanked by the Gargano massif in the north and the Keapolitan Apennines in the west. The central third is occupied by the low plateau of the Murge Salentine, limited in the west by a depression, the "fossa premurgiana," while in the east it slopes gradually to the narrow coastal plains of the Adriatic. The southern third, southeast of the Taranto-Ostuni line, is the Salentina peninsula, consisting of the lowland of Lecce and the low plateaus east of Taranto and south of Lecce. The predominant rock material of Puglia is limestone, and karst phenomena of underground drainage and large cave formations are present in many areas.

The coast line for the most part is low and sandy, except in the Gargano peninsula and in the southeasternmost tip of Puglia The only rivers of significance are the Fortore and the Ofanto, but there are numerous springs, some under the sea near the coast line. The absence of surface water over large areas led to the construction of the Apulian aqueduct, the largest of its kind in Italy, that traverses the entire region as far as Cape Leuca (see AQUEDUCT).

Wheat and oats are the principal cereals, raised in the Foggia plain and in the more fertile parts of the plateaus; olives, grapes, almonds and figs are grown intensively in the coastal and some inland areas; tobacco is a speciality of the Lecce plain. The wines of Puglia are among the strongest of Italy and are used to fortify other, lighter varieties. Fishing is carried out in many ports; those of the Gargano, of Barletta, of Monopoli and of Taranto are the most important. Salt is produced from sea water at Margherita di Savoia, near Foggia. About 1,000,000 sheep once grazed on the plain but owing to cultivation it only supports half that number today. Bari is the largest city and the leading port, as well as the biggest industrial centre (especially chemicals and petrochemicals); other, lesser industries are located in Brindisi, Taranto and Foggia. The largest railroad centre is Foggia, with lines connecting it to Naples-Rome, Bologna-Milan, and Bari- Taranto- Brindisi- Lecce. The so-called "Ionian" railroad follows the Ionian coast from Taranto to Reggio di Calabria. After World War II Puglia became one of the principal areas of Italian land reform, and numerous small farms were created from the old landed estates, new farm houses and rural service centres built, new roads and aqueducts constructed, transforming the face of the land.

The southeastern extremity of Puglia was Roman (not modern) Calabria. For archaeology, Roman and early history see APULIA; CALABRIA. After the tumultuous times following the disintegration of the Roman empire, Puglia was ruled by the Byzantines for over two centuries, and came to know its greatest glory under the Hohenstaufen emperors. It was a favourite of Frederick II (1220–50) and cathedrals and palaces witness the flowering of Puglia at that time. Thereafter a long period of decline set in, accentuated by neglect by distant rulers (Aragonians, Spaniards, Keapolitans) and by slave raids along the coast. In 1860 Puglia became part of the Italian kingdom. (G. KH.)

PUISNE, a term in law meaning "inferior in rank." It is pronounced "puny" and the word. so spelled, has become an ordinary adjective meaning undersized. By the Supreme Court of Judicature act, 1877, a "puisne judge" is defined as a judge of the high court other than the lord chancellor, the lord chief justice of England, the master of the rolls, the lord chief justice of the common pleas and the lord chief baron and their successors respectively. The last two offices have been abolished.

PUKET, officially spelled PHUKET (the Chinese name is TONGKAH), leading Thai port on the west coast of the Malay peninsula, on Junk Ceylon Island (also called Puket) in 7° 50' N. and 98° 24' E. Pop. of Port (1957 est.) 25,847.

The island constitutes one of the 71 changwats (provinces) of Thaiiand. Pop. (1956 est.) 64,637, nearly half Chinese. Rich tin deposits have been worked by Chinese from ancient times. A European company commenced modern dredging operations in 1907. Among other exports are rubber and betel nuts.

European merchants began trading at Puket in the 16th century. It was besieged by the Burmese during the 18th century wars between Burma and Thailand, but was relieved by troops from the mainland.

PULA (Italian POLA), a seaport of Yugoslavia situated at the southern tip of the Istria peninsula at the head of the Bay of Pula with a safe, commodious and almost landlocked harbour.

The history of Pula begins with its capture by the Romans in 178 B.C. It was destroyed by Augustus because of its espousal of the cause of Pompey, but was rebuilt under the name of Pietas Iulia. In A.D. 198–211 an amphitheatre 79 ft. high, 400 ft. long and 320 ft. wide was built in honour of the emperors Septimius Severus and Caracalla and could accommodate 23,000 spectators. In the middle ages Pula became the capital of the margraves of Istria and in 1148 was captured by the Venetians. In 1379 the Genoese, after defeating the Venetians in a great naval battle off the coast, took and destroyed Pula, which disappeared from history for the next 450 years. It remained, however, under Venetian supremacy until 1797 and fell under Austria in 1815. During the 19th century it became Austria-Hungary's principal naval harbour and arsenal. Occupied by the Italians in Nov. 1918, it was transferred to Italy in 1919 by the treaty of St. Germain.

The modern town of Pula lies round the base of a hill formerly crowned by the Roman capitol and later by a castle of the 17th century. Besides the castle the chief buildings are the cathedral, burned down in 1923 and reconstructed on the lines of a 6th-century Ravenna basilica, and the 14th-century Franciscan church. On March 3, 1945, the Yugoslav army took Pula after heavy fighting during which the cathedral and many other buildings suffered damage. From June 12. 1945. to Sept. 15, 1947, the town was under Allied military occupation. On Feb. 10, 1947. the date of the signing of the Italian peace treaty, a 34-year-old woman, Maria Pasquinelli, at Pula assassinated Brig. R. W. M. de Winton, commander of a British infantry brigade, the nearest representative. she declared, of the Big Four who had ',betrayed" Italy.

As the Italian peace treaty stipulated that Pula was to be ceded to Yugoslavia, about 28,000 Italians out of a population of 34,090 (1938) left for Italy. The 1953 census revealed a population of 28,512, entirely Yugoslav.

PULASKI, CASIMIR, COUNT (1748-1779), Polish soldier, was born in Podolia in 1748, and took a prominent share. under his father, Count Joseph Pulaski, in the formation of the confederation of Bar and in the military operations which followed, becoming ultimately commander in chief of the Polish patriot forces.

Driven into exile about 1772, Pulaski went to America and joined the army of Washington in 1777. He distinguished himself at Brandywine, was made a brigadier general and chief of cavalry by congress, and fought at Germantown and in the battles of the winter 1777–78, after which he raised a mixed corps called the Pulaski legion, with which he defended Charleston in May 1779. Pulaski, mortally wounded at Savannah, died Oct. 11, 1779.

PULCI, LUIGI (1432–1484), Italian poet whose name is chiefly associated with *Morgante,* one of the outstanding epics of the Renaissance, was born in Florence, Aug. 15, 1432. For many years he lived under the protection of the Medici family, especially Lorenzo il Magnifico, who first introduced him into the circle of poets and artists which was gathering round him and later, after assuming power, entrusted him with various embassies and diplomatic missions. Nevertheless, poverty and other hardships caused him, nhen about 38-40, to enter the service of a northern *condottiere,* Roberto Sanseverino, with whom he remained until his death at Padua in Nov. 1484.

Pulci's literary output, all in Italian. was very large. Among minor works, his *Lettere* (mod. ed., 1886) and *Sonetti* (mod. ed., 1932) are worthy of mention as revelations of his extravagant character, wide but not always deep cultural interests and biting criticism of contemporary Florentine writers and philosophers. But his masterpiece is the *Morgante* or *Morgante Maggiore,* a chivalrous epic in 23 cantos, later expanded to 28, begun about 1460, of which the earliest surviving complete edition is dated 1483. The plot of the poem is simple. Orlando, the hero, driven from the court of Charlemagne, goes to Pagania, where he meets three giants, two of whom he kills. The third, Morgante, is converted and becomes his faithful squire. Orlando and Morgante are joined by Rinaldo, who has also quarreled with Charlemagne, and the poem then recounts their episodic adventures in Africa and Asia, which continue until Orlando and Rinaldo, hearing that the Saracens have reached the borders of France, hasten to its defense. The story ends with the battle of Ronceveaux and the death of Orlando. The predominantly comic and burlesque tone is varied by a more serious mood in which the author expresses at times deep and sincere feeling, at times a bitter experience of life. Similarly, Pulci's amoral attitude, typical of an age which considered success as the only criterion of salvation, contrasts aith his deeply felt religious problems, which constitute a large part of the poem. It is this complexity and richness of feeling which makes the *Morgante* both one of the most original poems in Italian literature, and an essential text for understanding of the Renaissance.

Modern editions of the *Morgante* include those by G. B. Weston (1930), G. Fatini (1948) and F. Ageno (1955).

BIBLIOGRAPHY. — A Momigliano, *L'indole e il riso di Luigi Pulci* (1907); C. Pellegrini, *Luigi Pulci: l'uomo e l'artista* (1912); A Sorrentino, *Astarotte e la cultura del Pulci* (1919); G. Getto, *Studio sul Morgante* (1944). (G. P. G.)

PULITZER, JOSEPH (1847–1911), U.S. editor and newspaper proprietor. was born in Mako, Hungary. April 10. 1847. Educated privately in Budapest he was induced by a U S. agent to emigrate as a recruit for the Cnion army. He was discharged from the army on July 7, 1865, and went to St. Louis, where he arrived penniless. In 1868 he became a reporter on the German-language daily newspaper, the *Westliche Post.* He was elected in 1869 to the lower house of the Missouri legislature. where he gained a reputation as a reformer, and in 1871–72 he helped organize the Liberal Republican party in Missouri and was one of the secretaries of the Cincinnati convention that nominated Horace Greeley for president.

Pulitzer became a newspaper proprietor in 1871 by buying a share of the *Westliche Post* on liberal terms. This he soon resold for $30,000, using part of the proceeds for an extended tour of Europe. On his return in 1874 he purchased a moribund German daily, the *St. Louis Staats-Zeitung,* and sold its Associated Press franchise to the *Globe* for $20,000. In 1878 he laid the foundation of his fortune by purchasing at auction the dying *St. Louis Dispatch,* and merging it with the *St. Louis Post* as the *Post-Dispatch,* which soon dominated the St. Louis evening field. The paper was independent in politics and devoted to "hard money" and tariff reform. In 1880 Pulitzer became sole owner, but unfortunately in Oct. 1882 his chief editorial aid, Col. John A. Cockerill, shot and killed Col. Alonzo W. Slayback, a lawyer, in a bitter political quarrel. Public reprobation was so great that the *Post-Dispatch* lost revenue and Pulitzer departed for the east in the spring of 1883. nhere he bought the *New York World* from Jay Gould for $346,000.

Under its new management the World won prosperitv. its annual earnings by 1886 rising to more than $500 000 In 1887 Pulitzer established the *Evening World.* To the *World,* as to the *Post-Dispatch,* Pulitzer gave a tone of aggressive editorial independence He supported Grover Cleveland for the presidency in 1884, 1888 and 1892. He was sympathetic to labour; in 1892 he took the side of the striking steel workers at Homestead, Pa He opposed William Jennings Bryan for the presidency in 1896 and became an advocate of aar with Spain.

The *World* was largely responsible for bringing on the New York state legislative investigation of insurance companies in 1905. In 1909 the U S. government successfully sought an indictment against Pulitzer for criminally libeling Pres. Theodore Roosevelt J P. Morgan, Elihu Root and others in connection with allegations about the disposition of the $40,000,000 paid the French Panama Canal Co. The case was never prosecuted

In his later years Pulitzer's health compelled him to live as an invalid, but he kept in intimate touch with the *World* until within a few weeks of his death in Charleston, S.C., Oct. 29. 1911.

Pulitzer was elected to the U.S. house of representatives from New York in 1885, and served briefly in congress. During his lifetime he endowed the school of journalism of Columbia university, opened in 1912.

He also established the Pulitzer prizes, awarded annually for fiction, drama, history, biography, poetry, music and various categories of newspaper work.

BIBLIOGRAPHY. — D C. Seitz, *Joseph Pulitzer, His Life and Letters* (1924); A Ireland, *Joseph Pulitzer* (1914); J. W. Barrett, *Joseph Pulitzer and His World* (1941); K. N Stewart and J. Tebbel, *Makers of Modern Journalism* (1952); E. H Ford and E. Emery, *Highlights in the History of the American Press* (1954).

PULLEY AND BELT, a mechanical arrangement for transmitting torque from one shaft to another. The torque originates at a wheel or drum, called the drive pulley, that applies torque to a continuous, flexible member called the belt. The belt passes around and delivers torque to a second wheel or drum, called the driven pulley.

A pulley may be made fast to a shaft by a setscrew or key in the pulley hub, or by a tapered bushing drawn between shaft and hub; or the pulley may turn freely on a shaft as an idler. Pulley rim and hub may be one solid piece connected by a flange, web or tapered arms, depending on the pulley diameter. Pulleys whose peripheral surfaces are grooved are called sheaves.

Belt drives are used when one or more of the following conditions prevail: (1) The distance between shafts is large; (2) flexibility is desired to absorb shock; (3) overloads can be absorbed by belt slippage without damaging machine parts; (4) low cost is desired; (5) quietness is desired.

Belts are suitable for approximate velocity ratios only, because overload causes slippage between the surfaces of the belt and each pulley; even when slippage does not occur, creep takes place. Creep is a small backward movement of the belt relative to the pulley because of belt elasticity. The higher tension of the belt (T_1) reduces to the lower tension (T_2) as the belt travels around the drive pulley (see fig. 1), hence the length of belt leaving the pulley is less than the length entering. Creep alone reduces operating speed about 1%, and slippage causes loss of another 2%.

In addition, excessive slippage causes belt damage. Belts are operated at about 5,000 ft. per minute; above this speed most of the belt strength is needed to withstand the tension from the centrifugal force rather than the load.

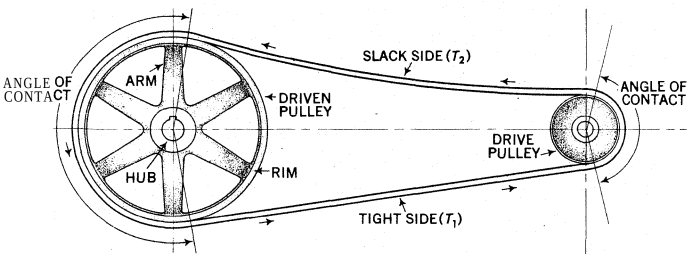


FIG. 1.— BELT ON PULLEYS

Solid pulley (at right) is driving a larger pulley (at left) with rim connected to hub by arms. In arranging pulleys, the slack side of the belt should be on top to increase angles of contact. (See text)

Both tight (T_1) and slack (T_2) sides of the belt pull on the pulley and result in a net force of their difference ($T_1 - T_2$) acting at the pulley surface to produce torque. The torque is dependent upon the ratio of effective forces which according to theory is $\frac{T_1 - T_c}{T_2 - T_c} = \epsilon^{\left(\frac{fa}{\sin\theta}\right)}$, where T_c is centrifugal force of one foot of belt, $\epsilon = 2.718$, f is the coefficient of friction between surfaces and a is the angle of contact in radians between belt and pulley, and θ is one-half the groove angle. The maximum value of T_1 is limited by the tensile strength of the belt.

Transmissive capacity is dependent upon the effective force ($T_1 - T_2$), hence will be greatest when the ratio of effective tensions, equal to $\epsilon^{\left(\frac{fa}{\sin\theta}\right)}$, is greatest. The frictional resistance to slip depends upon the coefficient of friction, the normal contact force and the angle of contact between belt and pulley. Combinations of materials, form of belt and angle of contact are selected to give the required capacity.

Types of Belts.—Belts are made of any material having suitable strength and flexibility and of any shape resistant to slipping (fig. 2). Combinations of material and cross section used are: flat leather operating on a flat or crowned pulley; round leather wedged in grooves of a sheave; V-belts or trapezoidal or sharp V section consisting of cotton cords, cotton sheets or steel wire vulcanized in rubber with a sheave; woven fabric on a pulley; spiral steel spring with a sheave; flat steel on a pulley for high speeds; hemp or Manila rope wedged into sheave grooves; stranded steel rope resting without wedging in the padded bottom of grooves in a sheave.

Leather Belts.—Leather belts of best quality are made of strips from the rear, back and sides of steer hides. The hide is cleaned, cured, dehaired, defleshed and then tanned in a solution of tannin to make the leather strong and pliable. Oak bark is used to produce a tannite solution in which the hides are cleaned. worked, "stuffed" with grease and stretched. Mineral salts such as chromium salts may be used for tanning. Chrome-tanned leather has greater tensile strength, a higher coefficient of friction (particularly until oak-tanned leather is used a while), greater flexibility and greater resistance to water, steam and certain chemicals. It is. howe er, softer than oak-tanned leather and lacks the lateral stiffness required to shift a belt by applying force at its edge. Combinations of oak and chrome tanning give a product with some of the advantages of each.

After preparation, the centre portion of the hide, which possesses the tightest texture, is cut into strips and squared. Pieces are then selected according to soundness and thickness. The pieces are scarfed to a feather edge and cemented together under pressure to make a continuous roll of belt. Belts of hide thickness are called "single ply." Double ply and triple ply belts for heavier loads are made by cementing together a number of strips. Belt thickness depends upon the hide thickness and varies from $\frac{1}{8}$ to $\frac{7}{32}$ in. for single ply, $\frac{1}{4}$ to $\frac{3}{8}$ in. for double ply, and $\frac{7}{16}$ to $\frac{9}{16}$ in. for triple ply.

Oak-tanned belting is the most generally used leather belt. Sandwiches of oak- and chrome-tanned belting have been used for special purposes, but such combinations are rare. Leather is used also for round belts. V-belts and link belts composed of overlocking leather links connected by steel pins.

Rubber Belts.—Rubber belts are made of natural and synthetic rubber, generally in combination with a load-carrying core. Flat belts are composed of plies (or layers) of cotton duck impregnated with a slow-aging rubber compound. Most generally used weight is 32 oz. cotton duck. The duck is folded to the desired number of plies and then vulcanized together. The rubberized cords may be left exposed or encased in a protective covering of rubber. Other constructions use load-carrying members of parallel longitudinal cords of fabric or steel within a vulcanized rubber covering. Strength is about 325 lb. per ply per inch.

V-belts of rubber are made of layers of duck or of various combinations of cotton cords encased in a rubber body of trapezoidal cross section, the strength of the belt depending upon the fabric rather than uwon the belt cross section. The layer type has raw edges. whereas the cord type body is covered with a rubberized fabric. Because the V-belt is stiff due to its depth, some constructions flute the inner edge to give flexibility without sacrificing contacting surface. Endless V-belts are molded in a press with five standard cross-section sizes available in various lengths. Multiple V-belt drives use a number of parallel belts of the same length running in parallel grooves in the pulley face. The belt does not bottom in the groove. Unreinforced rubber belts of round cross section are used for light loads a-here considerable elasticity is desired.

Other Types of *Belts*.—Balata belting is similar in construction to rubber belting. Balata is a gum from the bullet tree (*Manilkara bidentata*, formerly known as *Mimusops* balta) of Guiana and the West Indies. The belting is nonelastic and can be made waterproof.

Steel bands, carefully made and balanced, may be used as belts on accurately aligned pulleys. The high strength-weight ratio of steel allows large force transmission at high speeds with a relatively small reduction from centrifugal force.

Belt Fasteners.—Belt lengths may be connected by the following separate fastenings, accompanied, however, by a reduction in strength as indicated: machine wire lacing, 10%; hand wire lacing, 18%; lacing with rawhide strips, 40%; metal hooks. 65%.

Metal belt loops are bent into the end of each belt, the hooks placed side by side and a pin of leather or steel inserted through the loops to provide a connecting pivot. A stamped sheet may be used instead of separate wires.

The belt must be stretched over the pulleys and made into a continuous strip. The joint may be cemented together in position by stretching with screw clamps and cementing the prepared ends together. Cemented joints develop practically the full strength of the belt, which is about 4,000 lb. per square inch. The maximum working load is usually limited to about 400 lb. per square inch for safety.

Construction and Stresses of Pulleys.—Pulleys are usually made in one piece of cast iron. The hub has an outside diameter about tnice the bore and is fastened to the shaft by a key, setscrew or compression bushing. The width of the hub is approximately the same as the width of the pulley. The hub is connected to the rim by arms that are elliptical in cross section and tapered from hub to rim. The rim surface is adapted to the form of belt used.

Because of centrifugal force the rim, if free. is subjected to a tensile hoop stress of $\frac{12wv^2}{g}$ where w is the weight of one square inch of section, v is the rim velocity in feet per second, and g is 32.2 ft. per second per second. For cast iron this stress in pounds per square inch is closely $\frac{v^2}{10}$. The rim is partially restrained by the arms and so is subjected to a lesser hoop stress but, consequently, also to a bending stress. The resultant stress is difficult to assess but is greater than the full free hoop stress alone. An unannealed pulley contains shrinkage stresses of unknown amount, so a close calculation of working stress is of little practical use. The arms should be sufficient in number to limit the unsupported length of rim. Four to six arms are sufficient in most instances.

Surface speeds of cast iron pulleys are usually limited to 4,000 ft. per minute. Under favourable conditions webbed cast iron pulleys might be used up to 10,000 ft. per minute. Wooden built-up pulleys of maple have been used for high speeds because wood is lighter for its strength than cast iron. Pressed steel pulleys are lightweight and have a high strength-weight ratio but are more easily deformed because of the thin sections of which they are made.

Motor pulleys are made of wood, rawhide or pressed paper held between metal end plates. The diameter of a pulley for leather belts is recommended to be not less than 30 times the belt thickness to limit the flexing of the belt as it goes on and off the pulley. The rim of a pulley for a flat belt is made slightly wider than the belt. For cylindrical pulleys in the same plane the belt must be of the same length along each edge and must be mounted on pulleys which are properly aligned. If the pulley centres are not parallel the belt will ride toward the tight side and off the pulley. The belt lies flat on the pulley surface and, because of its lateral stiffness, is tilted toward the high side of the pulley. Thus each successive point of the approaching belt is nearer to the high end of the pulley face. Drive pulleys are crowned by being made with a larger diameter at mid-section; the crown amounts to about $\frac{1}{8}$ in. per foot of width and makes the belt run centrally (fig. 2). Thus the pulley surface is geometrically two

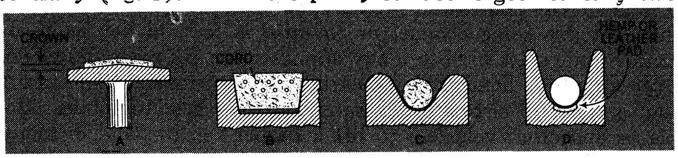


FIG. 2.— BELT AND PULLEY FORMS
(A) flat belt on crowned pulley; (B) V-belt on sheave; (C) round belt on sheave; (D) steel rope on sheave

slight cones base to base, and the belt rides to the greatest diameter in mid-face. Idler pulleys and pulleys on which the belt is shifted are not crowned.

Belt Arrangements. — An open belt arrangement rotates the driven pulley in the same direction as the driver. Crossed belts cause the driven pulley to rotate opposite to the driver. A crossed belt has considerably greater contact angle than an open belt, hence will transmit greater torque. Such an arrangement is usually avoided, however, because the belt surfaces rub together at the point of crossing and cause wear.

Pulleys with shaft centres in the horizontal plane transmit the greatest torque. As the line between centres departs from the horizontal the transmissive capacity is reduced. The slack side should be on top so that sag in the belt will increase the angle of contact.

Belts afford a simple means of connecting shafts which are not in the same plane. In order for the belt to stay on the pulleys the centre line of the approaching belt must lie in the centre plane of the approached pulley. This arrangement is shown in fig. 3. Note that if the direction of belt travel is reversed the required relationship is no longer satisfied and the belt will run off the pulley.

The addition of an idler pulley in accordance with the above rule would permit travel in either direction.

V-belt sheaves have grooves of the same angle as the belt section used with them. The grooves are deeper than the belt so that it contacts the sides and does not bottom. Wide wedge-shaped belts are used between adjustable sides so that as the sides are moved apart the belt lies lower on the sides and the pitch diameter decreases. As the lie of the belt is lowered, the belt velocity must be increased if the angular velocity of the pulley is to remain the same.

Belt Adjustments. — Short-centre drives are frequently employed when an electric motor is used to drive a machine. The small angle of contact on the smaller pulley caused by the short centre distance of the pulley limits the torque that can be transmitted. The driving motor may be mounted on a base that can be adjusted by a screw so the permanent stretch of the belt may be taken up by separating the pulleys. This adjustment can be made only occasionally and does not maintain tightness because the belt length changes elastically with load. One method of maintaining tightness and increasing the angle of contact is to use a gravity- or spring-loaded idler pulley. Another method is to use a motor base pivoted so the weight of the motor produces balancing tensions on the belt in an amount equal to the desired maximum capacity. The tight side of the belt should be between the pivot and the pulley centre.

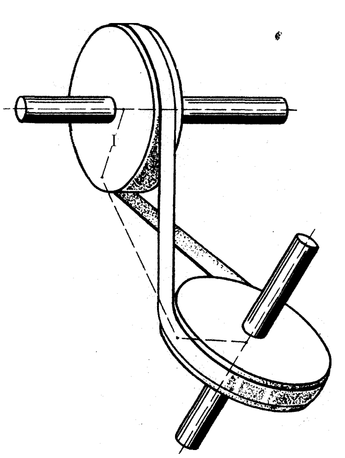


FIG. 3.—BELT CONNECTING SHAFTS IN DIFFERENT PLANES

(E. S. A.)

PULLMAN, GEORGE MORTIMER (1831–1897), U.S. industrialist and inventor of the Pullman car, was born at Brocton, Chautauqua county, N.Y., on March 3, 1831. He moved to Chicago in 1855, accumulated some capital as a contractor and began to work on his earlier idea of devising a better sleeping car. The first real Pullman car appeared in 1865, embodying Pullman's conviction that if he produced something better than anyone else, regardless of expense, someone would pay the price. He was president of the Pullman Palace Car company, organized in 1867, which built cars and operated Pullmans under contracts with railroads. His widely discussed social experiment, a paternalistic model town for his workmen, located south of Chicago, came to grief when a strike broke out that precipitated the great Pullman strike of Eugene Debs's American Railway union in 1894. The state later forced the company to give up control of the town. Pullman died on Oct. 19, 1897.

BIBLIOGRAPHY.—George A. Mortimer, in ***Dictionary of American Biography***, vol. xv (1935); Almont Lindsey, ***The Pullman Strike*** (1942), includes critical appraisals of Pullman and his model town; Joseph Husband, ***The Story of the Pullman Car*** (1917), is laudatory.

(D. L. McM.)

PULP: *see* PAPER.

PULPIT, a raised platform with enclosed front, from which sermons are delivered. The pulpit probably derived from the ambo (*q.v.*) in the early Christian church. There are many old pulpits of stone, though the majority are of wood. Those in churches are generally hexagonal or octagonal; some stand on stone bases, and others on slender wooden stems, like columns. The designs vary according to the periods in which they were erected, having paneling, tracing, cuspings, crockets and other ornaments. Some are extremely rich and ornamented with colour and gilding. A few also have rich canopies or sounding boards. Their usual place is in the nave, mostly on the north side, against the second pier from the chancel arch. Outdoor pulpits were common in the medieval period, and stood near a road or cross. Pulpits, for reading during the meals of the monks, are found in refectories. After the Reformation the English canons ordered pulpits to be erected in all churches. Many of the time of Elizabeth I and James are beautifully carved, and of Flemish workmanship. The pulpits in mosques, known as "mimbars," are canopied and approached by a straight flight of steps. These have a doorway at the foot, with an enriched lintel and boldly molded head; the work is of wood, often inlaid, gorgeously painted and gilded.

PULQUE (PULQUE FUERTE), the national beverage of the Mexican natives. It is prepared by fermenting the juice of a number of species of the agave (Agave americana, etc.). The cultivation of the agave for purposes of pulque manufacture constitutes a considerable local industry. Pulque has a heavy flavour, resembling sour milk, but it is esteemed by the natives because of its cooling and, according to them, nutritious properties. See AGAVE.

PULSE, throbbing or beating; in physiology the rhythmical beating due to changes of blood tension in the arteries consequent on expansion and contraction of their elastic tissues in response to the ejection of blood by the heart (see CIRCULATION OF BLOOD). In botany, a collective term for beans, peas, lentils and other members of the family Leguminosae (*q.v.*).

PULVERIZED FUEL: see FUELS.

PUMA (Felis concolor), which occurs only in the western hemisphere, is exceeded in size among cats of the new world only by the jaguar. Besides the term puma, which is derived from usage by the Incas of South America, it is also known by the following names: cougar, deer tiger, Mexican lion, panther, painter (corruption of panther), mountain lion and catamount. Sixteen geographic races of the puma are recognized; they range widely, from British Columbia in the north to Patagonia in the south, and formerly ranged coast to coast from the Atlantic to the Pacific. Man has eliminated pumas in many locations; they are now generally restricted to wilderness areas away from dense human populations.

WILFORD L. MILLER FROM NATIONAL AUDUBON SOCIETY

PUMA OR MOUNTAIN LION (FELIS CONCOLOR)

A wide range of coloration exists among puma races, from pale buff to reddish brown. The ears and tip of the tail are generally dark, while the belly as well as the rump extending to the first hind leg joints are white. There is no mane. Weights of adult puma range from about 75 to 275 lb.; shoulder height may be 2–24 ft., the males being larger than the females. From one to six kittens are produced after a gestation period of 90–96 days; they may be born in any month of the year. The young have rows of small, irregular black spots, which disappear at maturity.

The puma exists on a wide range of foods, its favourite, when available, being deer. When killing, the puma brings its victim to the ground with the stunning impact of its entire weight, generally attacking at the throat and breast. See also CAT. (S. P. Y.)

PUMICE, a very porous, frothlike, volcanic glass. Pumice has long been used as an abrasive, in cleaning, polishing and scouring compounds. After 1945 its uses multiplied in applications as railroad ballast and as a lightweight aggregate in precast masonry units, poured concrete, insulation and acoustic tile and plaster.

Pumice is an igneous rock which was almost completely liquid at the moment of effusion and was so rapidly cooled that there was no time for it to crystallize. When it solidified the vapours dissolved in it were suddenly released and the whole mass swelled up into a froth which immediately consolidated. Had it cooled under more pressure it would have formed a solid glass or obsidian (*q.v.*); in fact if we take fragments of obsidian and heat them in a crucible till they fuse they will suddenly change to pumice when their dissolved gases are set free. Hence it can be understood that pumice is found only in recent volcanic countries. Any type of lava, if the conditions are favourable, may assume the pumiceous state; but basalts and andesites do not so often occur in this form as do trachytes and rhyolites.

Pumices are most abundant and most typically developed from acid rocks, for which reason they usually accompany obsidians; in fact, in the Italian island of Lipari and elsewhere the base of a lava flow may be black obsidian while the upper portion is a snow white pumice.

Small crystals of various minerals occur in many pumices; the most common are feldspar, augite, hornblende and zircon. The cavities of pumice are sometimes rounded, and may also be elongated or tubular owing to the flowing movement of the solidifying lava. The glass itself forms threads, fibres and thin partitions between the vesicles. Rhyolite and trachyte pumices are white, contain 60% to 75% of silica and the specific gravity of the glass is 2.3 to 2.4; andesite pumices are often yellow or brown; while pumiceous basalts, such as occur in the Hawaiian Islands, are pitch black when perfectly fresh.

Good pumice is found in Iceland, Hungary, Teneriffe Island in the Canaries, New Zealand, Pantelleria Island and the Lipari Islands of Italy, West Germany and Greece. In the United States pumice is mined in Kansas, the Rocky mountain and Pacific coast states (as California, Nevada, New Mexico, Wyoming), Alaska and Hawaii. Pumice occurs, among the older volcanic rocks, but usually has its cavities filled up by deposits of secondary minerals introduced by percolating water. Pumice, in minute fragments, has been shown to have an exceedingly wide distribution over the earth's surface. It occurs in all the deposits which cover the floor of the deepest portion of the oceans, and is especially abundant in the abysmal red clay. In some measure this pumice has been derived from submarine volcanic eruptions, but its presence is also accounted for by the fact that pumice will float on water for months, and is thus distributed over the sea by winds and currents. After a long time it becomes waterlogged and sinks to the bottom, where it gradually disintegrates and is incorporated in the muds and oozes which are gathering there. After the great eruption of Krakatoa (*q.v.*) in 1883, banks of pumice covered the surface of the sea for many miles and rose in some cases for four or five feet above the water level. In addition much finely broken pumice was thrown into the air to a great height and was borne away by the winds, ultimately settling down in the most distant parts of the continents and oceans. See also TUFF; VOLCANO.

(J. S. F.; X.)

PUMP, a device for increasing the pressure of a fluid, usually a liquid. The increase in pressure, or head, is used to move the fluid through some channel or to raise it to a higher level, or both. Pumps are used in many applications; for example, to deliver water for home and industrial use; to transport oil across the country; to circulate oil, water and fuel in automobiles, airplanes and other vehicles; to lift a barber's chair; and in many industrial plants where fluids are used for power transmission or in manufacturing processes. In a pump, mechanical work is transformed into fluid energy; by contrast, in a turbine, fluid energy is transformed into mechanical work at some rotating shaft.

Pumps may be divided into two main types: the positive-displacement or static type; and the dynamic or kinetic type. In the positive-displacement type the characteristic action is a displacement by a decrease in volume in the working chamber of the pump. The increase in fluid static pressure is developed by a displacement action rather than by a velocity change or a kinetic energy change. The reciprocating pump, the rotary pump, the gear pump and the vane pump are illustrations of positive-displacement pumps. In the kinetic or dynamic type there is a kinetic or dynamic action between some mechanical element and a fluid; a force acting on the fluid causes a significant velocity change. The centrifugal pump and the jet pump are examples of the dynamic type.

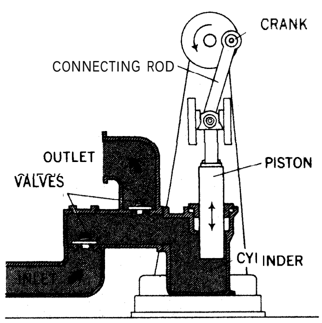
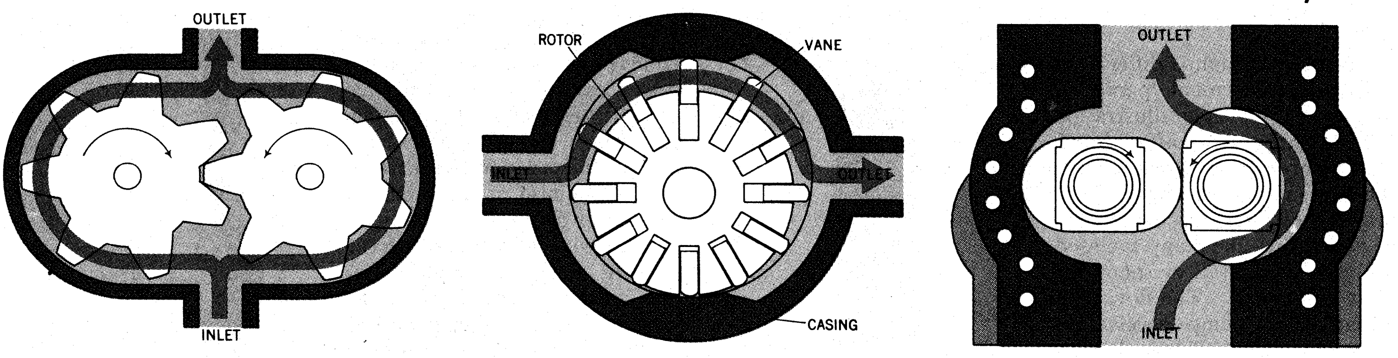


FIG. 1. — RECIPROCATING PUMP

Reciprocating Pumps. — In the common reciprocating pump a piston moves back and forth in a cylinder. An example is the hand bicycle pump, in which, as the hand pushes the piston back and forth, air from the atmosphere enters the cylinder and is pushed out of the cylinder into the tire by the piston action. Suitable valves are necessary to control the flow properly.



RIGHT, AFTER E. F. WRIGHT, "PUMPS," "MECHANICAL ENGINEERS' HANDBOOK"; REPRODUCED BY PERMISSION OF MCGRAW-HILL BOOK COMPANY, INC.

FIG. 2.— SCHEMATIC DIAGRAM OF (A) ROTARY PUMP; (B) HYDRAULIC VANE PUMP OR MOTOR: (C) LOBE PUMP

Fig. 1 illustrates the case in which the piston is moved back and forth in the cylinder by an arrangement of crank and connecting rod. As the piston moves toward the right, the outlet check valve is open, the inlet valve is closed, and the fluid flows from the cylinder through the outlet or discharge pipe. As the piston moves toward the left, the inlet check valve is open, the outlet valve is closed, and fluid enters the cylinder. If leakage past the piston is neglected, then the piston delivers the volume of fluid it displaces in moving through the cylinder; this explains the term positive-displacement.

A single-acting pump, in which fluid is pumped only by one side of the piston is illustrated in fig. 1. This can be turned into a double-acting pump—in which both sides of the piston are in contact with the fluid, and both sides pumpsimply by adding inlet and outlet pipes, with suitable valves, at the other end of the cylinder (and, of course, providing a proper seal at the opening where the piston rod enters the cylinder).

For a given volume rate of flow through the pump, the pressure at the pump outlet may be high or low, depending on the pressure necessary to force the fluid through the system connected to the pump; thus the discharge pressure is governed by the load or piping system. The pressure that a reciprocating pump can develop is limited only by the strength of the pump components and the power of the driving unit.

On some reciprocating pumps there is an air chamber on the discharge. The air trapped in the chamber acts as a cushion, making the pump operation smooth and quiet. Generally speaking, reciprocating pumps are best adapted for relatively low rates of flow, high pressures and high suction lifts. They are built of a wide variety of materials and for many different types of service. Reciprocating pumps are not well suited for pumping very dirty or very viscous liquids, because of the possibility of clogging.

Various methods are used for reciprocating the piston, such as different mechanical linkages or a fluid under pressure. For example, steam may be used on one side of the piston to drive it while water or some other liquid is pumped by the other side of the piston.

Diaphragm Pumps.—If, instead of the movable piston in fig. 1 a circular diaphragm–of rubber or other flexible material—is fixed at its outer edge to the cylinder, and if the crank and connecting rod linkage is fastened at its centre, the result will be a diaphragm pump. The central portion of the diaphragm is moved back and forth to provide volumetric displacement, and the inlet and outlet valve arrangement is similar to that of the reciprocating pump. Because there is no possibility of liquid bypassing the diaphragm and coming in contact with the connecting rod or other pump parts, diaphragm pumps are used for handling such materials as thick pulps, sewage sludge, acids, alkaline solutions, mine waters and fruit juices.

Rotary Pumps.—The rotary pump is classed as a positive-displacement pump, although its action is one of rotation, not reciprocation. It should not be confused with the centrifugal pump. The gear pump in fig. 2, an example of one type of rotary pump, has a pair of meshed gears in a casing. As the gears rotate, fluid is caught between their teeth and the casing, and is carried from inlet to outlet, the volume of fluid delivered during each revolution depending on the amount of space between the teeth and the case. Delivery is fairly steady, in contrast to the pulsating delivery of the reciprocating pump.

Rotary pumps are most suitable for applications requiring only low and medium delivery pressure. The absence of valves is an advantage in pumping heavy viscous liquids but because of the close clearances between gears and case, rotary pumps are not suitable for liquids containing any abrasive material that might damage the metal surfaces.

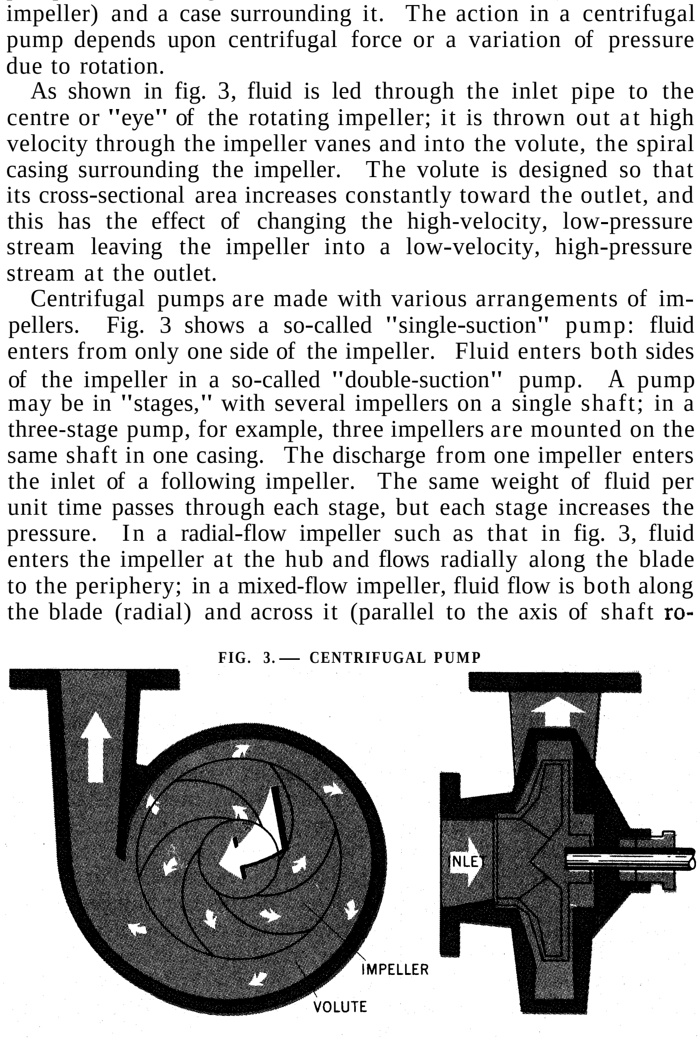
Different types of rotary pumps are available. In some pumps, rotating members with two or more lobes are used instead of gears. In the vane type of pump, there is a rotor set off-center in a casing. The rotor is fitted with vanes which slide in and out radially. The entering liquid is trapped between the vanes, which ride on the inside of the case, and is carried to the outlet.

Centrifugal Pumps.—The essential parts of a centrifugal pump are a rotating member with blades or vanes (the so-called impeller) and a case surrounding it. The action in a centrifugal pump depends upon centrifugal force or a variation of pressure due to rotation.

As shown in fig. 3, fluid is led through the inlet pipe to the centre or "eye" of the rotating impeller; it is thrown out at high velocity through the impeller vanes and into the volute, the spiral casing surrounding the impeller. The volute is designed so that its cross-sectional area increases constantly toward the outlet, and this has the effect of changing the high-velocity, low-pressure stream leaving the impeller into a low-velocity, high-pressure stream at the outlet.

Centrifugal pumps are made with various arrangements of impellers. Fig. 3 shows a so-called "single-suction" pump: fluid enters from only one side of the impeller. Fluid enters both sides of the impeller in a so-called "double-suction" pump. A pump may be in "stages," with several impellers on a single shaft; in a three-stage pump, for example, three impellers are mounted on the same shaft in one casing. The discharge from one impeller enters the inlet of a following impeller. The same weight of fluid per unit time passes through each stage, but each stage increases the pressure. In a radial-flow impeller such as that in fig. 3, fluid enters the impeller at the hub and flows radially along the blade to the periphery; in a mixed-flow impeller, fluid flow is both along the blade (radial) and across it (parallel to the axis of shaft ro-

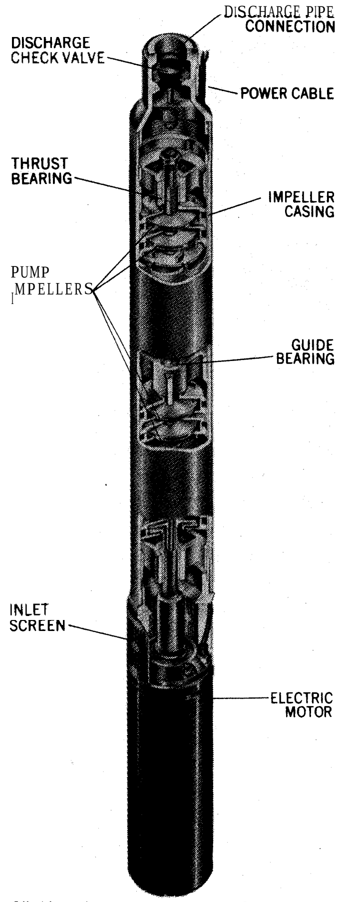
FIG. 3.— CENTRIFUGAL PUMP



tation).

Centrifugal pumps differ from positive-displacement pumps in various ways. As an illustration, the discharge valve of a centrifugal pump can be closed without the pressure rising above a certain value; if the discharge valve of a reciprocating pump is closed, the pump will stall or some part of it will break. The flow from a centrifugal pump is relatively smooth and steady, and these pumps can handle various liquids, sewage and liquids containing sand, gravel and stones of moderate size.

Centrifugal pumps are sometimes classified as volute or diffuser types. Fig. 3 shows a volute type, the fluid being discharged directly from the impeller into the volute. In the diffuser type, there is a series of fixed vanes, surrounding the impeller, that reduce turbulence in the volute by smoothing the flow of fluid and lowering its velocity; there is a decrease in kinetic energy and an increase in static pressure in the vane diffuser.



BY COURTESY OF JACUZZI BROS ' INC

FIG. 4.—SUBMERSIBLE PUMP

Axial-flow Pumps.—An axial-flow pump is a dynamic machine which may consist of a single runner in a cylindrical casing or of a runner with one or two sets of fixed guide vanes. In an axial-flow pump the fluid passes through the runner without essentially changing its distance from the axis of rotation (in principle and design, the axial-flow pump is much like a gas turbine). There is practically no centrifugal force effect within the true axial-flow pump. Generally speaking, the centrifugal pump is best suited for producing relatively high pressures and low rates of flow, while the axial-flow pump is best for producing relatively low pressures and high rates of flow.

Deep-Well Pumps.--Various types of pumps have been developed for pumping water or oil from deep wells. One, called the plunger pump, is essentially a reciprocating pump with a long piston rod. In the so-called turbine deep-well pump, a motor at the surface turns a vertical rotating shaft; this shaft drives a multistage centrifugal pump (with impellers rotating in a horizontal plane) which is installed in the well below the surface of the water or oil. For high lifts, the pump may have 20 or more stages.

Fig. 4 illustrates a submersible-motor pump; the motor is mounted below the centrifugal pump. The elongated, small-diameter electric motor operates submerged in the well liquid. The liquid being pumped does not come in contact with the electric parts or motor bearings, because these are enclosed in an oil-filled case which has a mercury seal where the rotating shaft passes through the top to the pump.

The pump and motor form a compact assembly that is fastened to and supported by the outlet pipe. A liquid-tight armoured cable connects the motor leads to the power supply at the surface, and a small copper tube provides a lubrication inlet at the surface for larger models; small models are provided with "permanent" lubrication and require no attention.

Each type of deep-well pump has its advantages. For a specific application in a well of moderate depth, the plunger pump usually is least expensive; and since it is the only one of the three that can be operated directly by a windmill it has often been used in remote locations. As in the case with the turbine pump, the power source is at the surface and readily accessible for maintenance. However, in both cases, trouble with the pumping unit necessitates withdrawing and disconnecting, section by section, the plunger rod or turbine shaft, to raise the pump to the surface; this is true also of the submersible-motor pump.

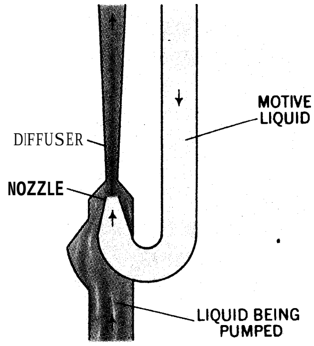


FIG. 5.—LIQUID JET PUMP

The limit of depth at which the plunger pump will operate economically. is reached when the power unit is expending almost as much, or more, energy lifting a long plunger rod than lifting fluid; and this type of pump does not work well except in very straight well bores. The economical limit of the turbine pump is reached when more energy is expended in overcoming bearing friction in the long shaft than in lifting fluid (the shaft must be supported at frequent intervals by "spiders" or frameworks that fit against the sides of the well bore and are fitted with bearings to keep the shaft centred in the bore); the turbine pump will work in an out-of-plumb well, but any deviation from straightness increases frictional losses at the bearings.

The submersible-motor pump overcomes some of these disadvantages (it will work in a very crooked bore, for example, the amount of deviation being limited only by the angle through which the pump unit and outlet pipe can be inserted and withdrawn easily), but it introduces disadvantages of its own. Principal among these is the fact that malfunctioning of either pump or motor necessitates withdrawing the entire unit from the well.

Jet Pumps.—In the reciprocating, rotary and. centrifugal pumps, there is a moving mechanical part which does work on the moving fluid. However, there is a dynamic type of pump which does not have any moving mechanical parts: it is called variously a jet pump, injector or ejector. In this type of pump the pressure of a fluid is increased as it flows through an arrangement of fixed channels. A "motive fluid" is used to pump, or induce the flow of, some other fluid.

Jet pumps are found in many applications, pumping many different fluids. A common type is one in which water is the motive fluid and water is the fluid being pumped; such pumps are used on domestic water well systems. As illustrated in fig. 5, water passes through the converging nozzle with a high velocity and acts as a motive or driving fluid; at the end of the nozzle the velocity is high and the pressure is low. The mixture of motive fluid and liquid being pumped, or induced, then passes through the diffuser where the velocity is reduced and the pressure is increased.

A number of pumping devices can be explained by reference to the venturi tube. As illustrated in fig. 6, the venturi tube consists of a converging nozzle and a narrow portion or throat. As motive fluid passes through the converging portion, the velocity is increased and the pressure is decreased, and this decrease in pressure can be used to move some other fluid. In the usual aspirator pump, water passes through a venturi channel, and air is drawn into the venturi throat by the low pressure; in the common atomizer, air passing through a venturi tube lifts liquid from the attached container, mixes with the liquid, and ejects it as a fine spray.

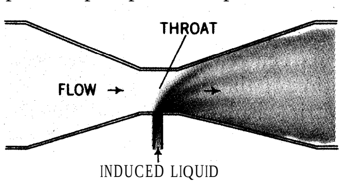


FIG. 6.—VENTURI PUMPING DEVICE

Air or Gas Lift Pumps.—In this type of pump there is a vertical lift pipe arranged with its lower end submerged in the liquid to be raised and its upper end connected to a discharge pipe or tank. Air or gas from a compressor is led through a separate pipe to the lower end of the lift pipe, where it bubbles through the liquid to form a gas-liquid mixture that has a lower density (or specific weight) than the surrounding liquid. The resulting buoyant force moves the lighter mixture (of gas and liquid) to the top of the vertical pipe. In this type of pump, air may be used to pump water, or a gas may be used to pump oil. The pumping action depends on the air or gas used, the nature of the liquid, the depth of submersion of the lower end of the lift pipe, and the manner of forming the bubbles.

Vacuum Pumps. — Atmospheric pressure is the force exerted on a unit area due to the weight of the atmosphere. The word "vacuum" is frequently used in referring to pressures below atmospheric. In many cases it is desired to exhaust or evacuate air (or some gas) from a vessel or a piece of equipment. The aspirator pump can be used to develop a partial vacuum; other types, to produce higher degrees of vacuum, are described in the article VACUUM.

Magnetic Pumps for Liquid Metals. — Certain characteristics of liquid metals make them attractive as heat-transfer liquids for cooling nuclear reactors. The electromagnetic pump has proved suitable for the circulation of some of these liquid metals.

The electromagnetic pump uses the same principle on which the electric motor is based; namely, that a conductor in a magnetic field, carrying a current flowing at right angles to the magnetic field direction, has a force exerted on it in a direction mutually perpendicular to both the field and current. In the electromagnetic pump, the fluid being pumped is the conductor, and the resultant force acts to propel the fluid if suitable arrangements are made. The current and field can be produced in many ways.

In one electromagnetic pump, the D.C.-Faraday type, the liquid metal flows through a thin-walled duct of square or rectangular cross-section. A constant magnetic field is passed through the fluid on an axis perpendicular to the flow direction. The magnetic field is developed by windings, carrying direct current, that are mounted on a magnetic core with pole faces that provide a magnetic return path through the fluid metal. Current is passed through the fluid by establishing a voltage drop along the axis of the duct, mutually perpendicular to both the flow direction and the magnetic field direction. In theory, the operation of this pump is similar to that of a direct-current shunt motor.

See also Index references under "Pump" in the Index volume.

BIBLIOGRAPHY. — F. A. Kristal and F. A. Annett, Pumps (1953); A. J. Stepanoff, Centrifugal and *Axial-Flow* Pumps (1957); R. C. Binder, Advanced Fluid Mechanics, vol. i (1958). (R. C. BR.)

PUMPKIN, the fruit of certain varieties of Cucurbita pepo or of *C.* moschata, members of the family Cucurbitaceae. The names pumpkin and squash, especially in America, are applied rather inconsistently to certain varieties of both these species. The quick-growing, small-fruited bush or nontrailing varieties of C. pepo (see SQUASH) are called squash in America, while the long-season, long-trailing, large-fruited varieties are called pumpkin. The fruits are large, generally 10–20 lb. or more, yellowish to orange in colour and vary from oblate through globular to oblong. The rind is smooth and usually lightly furrowed or ribbed; the fruit stem is hard and woody, ridged or angled, and in C. pepo not flared at its point of attachment to the fruit. The very largest varieties of "pumpkin" are more properly designated as winter squash, *C.* maxima, and may weigh 75 lb. or more. Varieties cross-pollinate readily within each of the three species, but the species do not cross naturally. A few interspecific crosses have been recorded but the hybrids were highly self-sterile and set no fruit with their own pollen. Neither pumpkins nor squashes will cross with cucumbers or with melons.

Pumpkins are commonly grown in North America, Great Britain and Europe for human food and also for livestock feed. They are used in the U.S. as Halloween decorations, the pulp being removed and a light inserted which shines through cut-out eyes, nose and mouth. The varieties commonly called pumpkin produce very long vines and are usually planted in hills of two to three plants each, about 8 × 8 ft. apart. They are also planted at wide intervals in fields of corn. Pumpkins mature in early fall and can be stored a few months in a dry place well above freezing. They are prepared for food in a variety of ways. (V. R. B.)

PUN, a witty play upon two or more meanings for the same word, or on two words with identical sounds. Example: "She was a good cook as cooks go, and as cooks go, she went." — H. H. Munro. This form of wit has been in and out of fashion many times. It was highly respected in Shakespeare's age, but Oliver Wendell Holmes, the poet, dubbed it "the lowest form of wit" — in which he freely indulged. It can be used seriously, as metaphor, as when Emerson says the poet "apprises us not of his wealth, but of the common wealth." With mingled humour and pathos Shakespeare declared: "Golden lads and girls all must,/ As chimney-sweepers, come to dust." See FIGURES OF SPEECH: Play Upon Words. (G. W. A.)

PUNAN. The name applied to a number of peoples in Borneo, all of them, except the Punan Ba, forest nomads in the area of the headwaters of the major rivers. They live in isolated groups of 30 to 40, subsisting on the wild sago palm and game hunted with the blowpipe. Physically and culturally they are very similar to the other peoples of the island; none of them is Negrito or demonstrably aboriginal in Borneo. Some of the groups differ widely from each other; as a result of the similarity of name European accounts of them are almost inextricably confused. Three "Punan" peoples, however, are certainly distinct. the settled Punan Ba of western Borneo; the Penan (wrongly named Punan) of the Baram and Balui; and the Punan Aput and Busang of the northern Apo Kayan. (R. NM.)

PUNCH, the abbreviated form of PUNCHINELLO (Italian Policianelo, *Pulcinella;* French, Polichinelle), the most popular of the marionettes and glove puppets and the chief figure in the Punch and Judy show. Many modern authorities tend to accept the opinion that the whole family of Italian maschere (masked characters of the commedia *dell'arte; e.g.,* Arlecchino and Brighella) are modified survivals of the principal Oscan characters of the atellanae, and that Pulcinella is the representative of Maccus, the country bumpkin, or Bucco, the comic servant (see ATELLANA FABULA). But there is a gap of 1,000 years between the last records of the Atellan farces and the first of the commedia dell'arte, and it would be ingenuous to follow the antiquaries of the 18th century in accepting a clear connection between the two. At the same time it is interesting to compare a bronze of Maccus with 17th-century pictures of Pulcinella in Italy and France.

It is not certainly known who was the first Pulcinella. Claims have been made on behalf of Silvio Fiorillo and Andrea Calcese, both of whom were performing at the beginning of the 17th century. But some facts of his early history are definite. One of the *zanni,* the comic servants of the company, he was indispensable when the troupe played in Naples but did not always appear in other localities. His characteristics were not clearly marked at first, and the hooked nose, the humped back, the tendency to wife-beating and outrageous lawlessness typical of the English Punch were acquired only gradually. This is clearly seen from the first pictorial representations. The earliest. in which he is called Policianelo, is dated 1618 and is one of a series made from birds' feathers by Dionisio Minaggio, the gardener of the governor of Milan. The second, in 1622, is of Pulliciniello in Jacques Callot's I *Balli di Sfessania.* In both he is depicted as large, shambling and stupid-looking, dressed in a loose white shirt and very full trousers.

PUNCH

From a drawing which appeared on a music cover of the mid-19th century

The Italian actors soon began to travel abroad. A few of them were in Nottingham, Eng., in 1573. The Gelosi, one of the most famous companies, visited Paris in 1577. It is not known exactly when Pulcinella arrived in these countries, but the French version, Polichinelle, was firmly established in France by the middle of the 17th century. When the actors came from Italy the puppet showmen came with them. By 1649 a showman called Jean Brioché, probably an Italian named Briocci, was displaying a puppet Polichinelle near the Pont Neuf in Paris. The marionette was grotesque, humpbacked and hook-nosed, but its origin may not have been entirely Italian. There was a French tradition of hunchbacked fools, as can be seen from a print of the entertainment at the marriage of Henry IV with Marie de Médicis in 1600, and the popularity of the Polichinelle puppet in France may be due to the fusion of these two traditions.

Similarly a tradition of the humpbacked fool existed in England when the first Italian puppeteers arrived after the restoration of Charles II. In 1662 a showman called Signor Bologna, alias Pollicinella, was performing in London, and by 1667 a more elaborate entertainment of Punchinello was established at Charing Cross by Antonio Devoto. In 1672 the king gave his patronage to this theatre, and then performances with human actors were permitted. Already the shortened form of the name had passed into general usage. Samuel Pepys mentions (1669) some people who called their fat child Punch, "that word being become a word of common use for all that is thick and short." This general popularity was probably caused by the traveling showmen, who carried puppets to the country wakes in the summer and visited London for the fairs in August and September.

Early in the 18th century Punch became famous in political circles through the use of the name by Martin Powell, a marionette showman, in a scurrilous attack on Robert Harley. This pamphlet, entitled *A Second Tale of a Tub* (1715), furnishes some details of Punch performances and has a frontispiece of Powell with Punch and his wife. But it was in the 1790s that the revival occurred which caused the preservation of Punch and Judy: as the marionettes at the fairs lost their popularity, there was a new interest in the humbler glove puppets, and in this form the Punch and Judy play became a success. *See* also COMMEDIA DELL'ARTE; PUPPETS AND MARIONETTES.

BIBLIOGRAPHY.—*Punch and Judy*, with illustrations by George Cruikshank and introduction by John Payne Collier (1828); P. J. Stead, *Mr. Punch* (1950); George Speaight, *The History of the English Puppet Theatre* (1955); Vito Pandolfi, *La Commedia dell'Arte*, 5 vol. (1957–). (I. K. F.)

PUNCHING AND SHEARING MACHINES: *see* MACHINE TOOLS.

PUNCTUATION. The consistent use of conventional signs for the division of the stream of speech into parts are, in the main, of modern origin. Early manuscripts are usually devoid of punctuation, and careful legal documents are still drawn in such a way that punctuation may be omitted without affecting the meaning. Ancient inscriptions either have no punctuation whatever or use interpuncts as separators between words. But the origin of the signs used in most European languages (and in their expansions overseas), their gradually increasing use and consistency of use, may be traced as far back as the pre-Christian era, yet the practice was neither standard nor obligatory before the middle ages. Moreover, since phrasing within a sentence varies in different languages, practice also varies, and details must be sought in the grammars of different languages, or in the rules established by printing houses to guide typesetters, proofreaders and editors. Some of the rules taught in schools, and particularly in secretarial schools, are artificial, not being in accord with the natural pauses of utterance.

BIBLIOGRAPHY.—Maunde Thompson, *Introduction to Greek and Latin Palaeography*, pp. 60–61 (1912), on early marks oi punctuation in Europe. For English *see*, for example, *Rules for Compositors*, ed. by H. Hart (Oxford University Press) or the style book published by the University of Chicago Press. A volume issued by the Permanent International Committee of Linguists for its 5th congress (*Dokumente zur Interpunktion europaischer Sprachen*, 1939) illustrates (with specimen samples) modern practice in Danish, English, Finnish, French, German, Icelandic, Italian, Lettish, Netherlandish (Dutch), Norwegian, Polish, Rumanian, Swedish, and Spanish. (J. WH.)

PUNIC WARS, a name specially appropriated to the wars between Rome and Carthage in the 3rd and 2nd centuries B.C. The origin of these conflicts is to be sought in the position which Rome acquired about 275 B.C. as suzerain and protector of all Italy. Her new obligation to safeguard the peninsula against foreign interference made it necessary that she should not allow the neighbouring island of Sicily to fall into the hands of a strong and expansive power. Carthage, on the other hand, had long been anxious to conquer Sicily and so to complete the chain of island posts by which she controlled the western Mediterranean.

First Punic War (264–241 B.C.[1]).—The proximate cause of the first outbreak was a crisis in the city of Messana, commanding the straits between Italy and Sicily. A band of Campanian mercenaries, which had forcibly established itself within the town and was being hard pressed in 264 by Hiero II. of Syracuse, applied for help to both Rome and Carthage. The Carthaginians, arriving first, occupied Messana and effected a reconciliation with Hiero. The Roman commander nevertheless persisted in throwing troops into the city, and by seizing the Carthaginian admiral during a parley induced him to withdraw. This aggression met a declaration of war from Carthage and Syracuse.

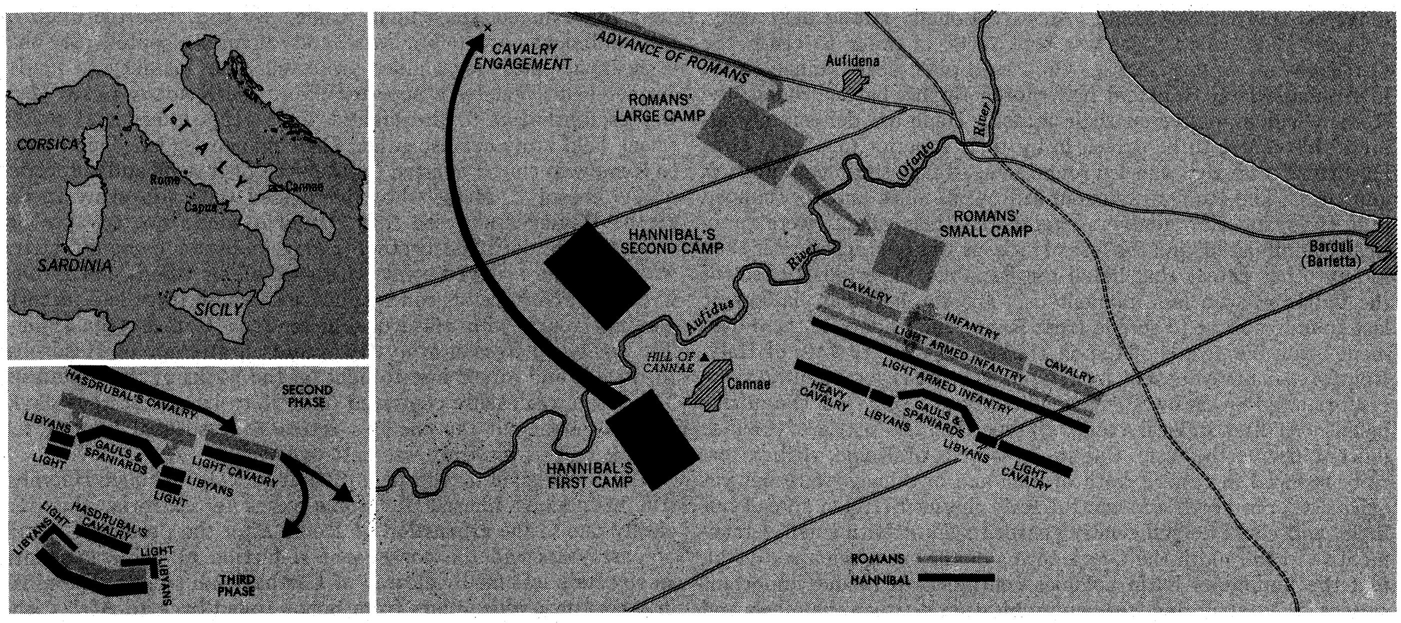
Operations began with a joint attack upon Messana, which the Romans easily repelled. In 263 they advanced with a considerable force into Hiero's territory and induced him to seek peace and alliance with them. In 262 they besieged and captured the enemy's base at Agrigentum. But they made little impression upon the Carthaginian fortresses in the west of the island and upon the towns of the interior.

In 260 the Romans built their first large fleet of standard battleships. At Mylae, off the north Sicilian coast, their admiral C. Duilius defeated a Carthaginian squadron of superior maneuvering capacity by grappling and boarding. This left Rome free to land a force on Corsica and expel the Carthaginians (259), but did not suffice to loosen their grasp on Sicily. A large Roman armament sailed out in 256, repelled the entire Carthaginian fleet off Cape Ecnomus (near Agrigentum) and established a fortified camp on African soil at Clypea. The Carthaginians, whose citizen levy was utterly disorganized, could neither keep the field against the invaders nor prevent their subjects from revolting. A single campaign compelled them to sue for peace, but the terms which the Roman commander Atilius Regulus offered were intolerably harsh. Accordingly they equipped a new army in which, by the advice of a Greek captain of mercenaries named Xanthippus, cavalry and elephants formed the strongest arm. In 255, under Xanthippus' command, they offered battle to Regulus, who had taken up position with an inadequate force near Tunis, outmaneuvered him and destroyed the bulk of his army. A second Roman armament, which subsequently reached Africa after defeating the full Carthaginian fleet off Cape Hermaeum, withdrew all the remaining troops.

The Romans now directed their efforts once more against Sicily. In 254 they carried the important fortress of Panormus (Palermo) by an attack from the sea; but when Carthage threw reinforcements into the island the war again came to a standstill. In 251 at last the Roman general L. Metellus brought about a pitched battle near Panormus in which the enemy's force was effectively crippled. This victory was followed by an investment of the chief Punic base at Lilybaeum by land and sea. The besiegers met with a gallant resistance, and in 249 were compelled to withdraw by the loss of their fleet in a surprise attack upon the neighbouring harbour of Drepanum (Trapani), in which the admiral Claudius Pulcher was repulsed with a loss of 93 ships. Meanwhile other losses in storms on the high seas so reduced the Roman fleet that the attack upon Sicily had to be suspended. At the same time the Carthaginians, who felt no less severely the financial strain of the prolonged struggle and had a war in Africa on their hands, reduced their armaments and made no attempt to deliver a counter-attack. The only noteworthy feature of the ensuing campaigns is the skilful guerrilla war waged by a new Carthaginian commander, Hamilcar Barca, from his strong positions on Mt. Ercte (247–244) and Mt. Eryx (244–242) in western Sicily, by which he effectually screened Lilybaeum from the Roman land army.

In 242 Rome resumed operations on sea. By a magnificent effort on the part of private citizens a fleet of 200 warships was equipped and sent out to renew the blockade of Lilybaeum. The Carthaginians hastily collected a relief force, but in a battle

[1]The chronology here given is the traditional one, but recent researches tend to show that many events have been antedated by one year.



PLAN OF THE BATTLE OF CANNAE. 216 B.C.

A major battle of the Second Punic War (218–201 B.C.) in which Hannibal was victorious over the Romans. Inset at lower left shows the second and third phases of the battle

fought off the Aegates or Aegusae islands (west of Drepana) their fleet was caught at a disadvantage and mostly sunk or captured (March 10, 241). This victory, by giving the Romans undisputed command of the sea, rendered certain the ultimate fall of the Punic strongholds in Sicily. The Carthaginians accordingly opened negotiations and consented to a peace by which they ceded Sicily and the Lipari islands to Rome and paid an indemnity of 3,200 talents (about £800,000).

The Interval Between the First and Second Wars **(241–218 B.C.)**.—The loss of naval supremacy not only deprived Carthage of her predominance in the western Mediterranean, but exposed her oversea empire to disintegration under renewed attacks by Rome. The temper of the Roman people was soon made manifest during a conflict which broke out between the Carthaginians and their discontented mercenaries. Italian traders were allowed to traffic in munitions of war with the mutineers, and a gross breach of the treaty was perpetrated when a Roman force was sent to occupy Sardinia, whose insurgent garrison had offered to surrender the island (239). To the remonstrances of Carthage the Romans replied with a direct declaration of war, and only withheld their attack upon the formal cession of Sardinia and Corsica and the payment of a further indemnity.

From this episode it became clear that Rome intended to use her victory to the utmost. To avoid complete humiliation Carthage had no resource but to humiliate her adversary. The recent complications of foreign and internal strife had indeed so weakened the Punic power that the prospect of renewing the war under favourable circumstances seemed remote enough. But the scheme of preparing for a fresh conflict found a worthy champion in Hamilcar Barca, who sought to compensate for the loss of Sicily by acquiring a dominion in Spain where Carthage might gain new wealth and form a fresh base of operations against Rome. Invested with an unrestricted foreign command, he spent the rest of his life in founding a Spanish empire (236–228). His work was continued by his son-in-law Hasdrubal and his son Hannibal, who was placed at the head of the army in 220. These conquests aroused the suspicions of Rome, which in a treaty with Hasdrubal confined the Carthaginians to the south of the Ebro, and also guaranteed the independence of Saguntum, a town on the east coast which pretended to a Greek origin. In 219 Hannibal laid siege to Saguntum and carried the town in spite of a stubborn defence. It has always been a debatable point whether his attack contravened the new treaty. The Romans certainly took this view and sent to Carthage to demand Hannibal's surrender. But his defiant policy was too popular to be disavowed; the Carthaginian council upheld Hannibal's action, and drew upon itself a declaration of war.

Second Punic War **(218–201 B.C.)**.—It seemed as though the superiority of the Romans at sea must enable them to choose the field of battle. They decided to embark one army for Spain and another for Sicily and Africa. But before their preparations were complete Hannibal began that series of operations by which he dictated the course of the war for the greater part of its duration. Realizing that so long as Rome commanded the resources of an undivided Italian confederacy no foreign attack could beat her down beyond recovery, he conceived the plan of cutting off her supply of strength at the source by carrying the war into Italy and causing a disruption of the League. His chances of ever reaching Italy seemed small, for the sea was guarded by the Roman fleets and the land route was long and arduous. But the very boldness of his enterprise contributed to its success; after a six months' march through Spain and Gaul and over the Alps, which the Romans were nowhere in time to oppose, Hannibal arrived in the plain of the Po with 20,000 foot and 6,000 horse, the pick of his African and Spanish levies (autumn 218: for details see HANNIBAL).

His further advance was here disputed by some Roman troops which had been recalled from the Spanish expedition. But the superiority of the Carthaginian cavalry and the spread of insurrection among the Gaulish inhabitants forced the defenders to fall back upon the Apennines. At the end of the year the Roman army was reinforced by the division from Sicily and led out to battle on the banks of the Trebia (*q.v.*). Hannibal, by superior tactics, repelled the assailants with heavy loss, and thus made his position in north Italy secure.

In 217 the campaign opened in Etruria, into which the invading army, largely reinforced by Gauls, penetrated by an unguarded pass. A rash pursuit by the Roman field force led to its being entrapped on the shore of Lake Trasimene (*q.v.*) and destroyed with a loss of 40,000 men. This catastrophe left Rome completely uncovered; but Hannibal, having resolved not to attack the capital before he could collect a more overwhelming force, directed his march towards the south of Italy, where he hoped to stir up the peoples who had formerly been Rome's most stubborn enemies. The natives, however, were everywhere slow to join the Carthaginians, and a new Roman army under the dictator Q. Fabius Maximus ("Cunctator"), which, without ever daring to close with Hannibal, dogged his steps on his forays through Apulia and Campania, prevented his acquiring a permanent base of operations.

The eventful campaign of 216 was begun by a new aggressive move on the part of Rome. An exceptionally strong field army, estimated at 85,000 men, was sent forth in order to crush the Carthaginians in open battle. On a level plain near Cannae (*q.v.*) in Apulia, which Hannibal had chosen for his battle-ground, the Roman legions delivered their attack. Hannibal deliberately allowed his centre to be driven in by their superior numbers, while Hasdrubal's cavalry wheeled round so as to take the enemy in flank and rear. The Romans, surrounded on all sides and so cramped that their superior numbers aggravated their plight, were practically annihilated, and the loss of citizens was perhaps greater than in any other defeat that befell the Republic. The moral effect of the battle was no less momentous. The south Italian nations at last found courage to secede from Rome, the leaders of the movement being the people of Capua, the second greatest town of Italy. Reinforcements were sent from Carthage, and several neutral powers prepared to throw their weight into the scale on Hannibal's behalf. At first sight it seems strange that the battle of Cannae did not decide the war. But the resources of Rome, though terribly reduced in respect both of men and of money, were not yet exhausted. In north and central Italy the insurrection spread but little, and could be sufficiently guarded against with small detachments. In the south the Greek towns of the coast remained loyal, and the numerous Latin colonies continued to render important service by interrupting free communication between the rebels and detaining part of their forces. In Rome itself the quarrels between the nobles and commons, which had previously unsettled her policy, gave way to a unanimity unparalleled in the annals of the Republic. The guidance of operations was henceforth left to the senate, which by maintaining a persistent policy until the conflict was brought to a successful end earned its greatest title to fame.

The subsequent campaigns of the Italian War assume a new character. Though the Romans contrived at times to raise 200,000 men, they could only spare a moderate force for field operations. Their generals, among whom the veterans Fabius and M. Claudius Marcellus frequently held the most important commands, rarely ventured to engage Hannibal in the open, and contented themselves with observing him or skirmishing against his detachments. Hannibal, whose recent accessions of strength were largely discounted by the necessity of assigning troops to protect his new allies or secure their wavering loyalty, was still too weak to undertake a vigorous offensive. In the ensuing years the war resolved itself into a multiplicity of minor engagements which need not be followed out in detail. In 216 and 215 the chief seat of war was Campania, where Hannibal vainly attempted to establish himself on the coast but experienced a severe repulse at Nola. In 214 the main Carthaginian force was transferred to Apulia in hopes of capturing Tarentum. Though Croton and Locri on the Calabrian coast had fallen into his hands, Hannibal still lacked a suitable harbour by which he might have secured his oversea communications. For two years he watched in vain for an opportunity of surprising the town, while the Romans narrowed down the sphere of revolt in Campania and defeated other Carthaginian commanders. In 212 the greater part of Tarentum and other cities of the southern seaboard at last came into Hannibal's power. But in the same year the Romans found themselves strong enough to place Capua under blockade. They severely defeated a Carthaginian relief force, and could not be permanently dislodged even by Hannibal himself. In 211 Hannibal made a last effort to relieve his allies by a feint upon Rome itself, but the besiegers refused to be drawn away from their entrenchments, and eventually Capua was starved into surrender. Its fall was a sign that no power could in the long run uphold a rival Italian coalition against Rome. After a year of desultory fighting the Romans in 209 gained a further important success by recovering Tarentum. Though Hannibal still won isolated engagements, he was being slowly driven back into the extreme south of the peninsula.

In 207 the arrival of a fresh invading force produced a new crisis. Hasdrubal, who in 209–208 had marched overland from Spain, appeared in north Italy with a force scarcely inferior to the army which his brother had brought in 218. After levying contingents of Gauls and Ligurians he marched down the east coast with the object of joining hands with his brother in central Italy for a direct attack upon Rome. By this time the drain of men and money was telling so severely upon her confederacy that some of her most loyal allies protested their inability to render further help. Yet by a supreme effort the Romans raised their war establishment to the highest total yet attained and sent a strong field army against either Carthaginian leader. The danger to Rome was chiefly averted by the prompt insight and enterprise of the consul C. Nero, who commanded the main army in the south. Having discovered that Hannibal would not advance beyond Apulia until his brother had established communications with him, Nero slipped away with part of his troops and arrived in time to reinforce his colleague Livius, whose force had recently got into touch with Hasdrubal near Sena Gallica (Sinigaglia). The combined Roman army frustrated an attempt of Hasdrubal to elude it and forced him to fight on the banks of the Metaurus. The battle was evenly contested until Nero by a dexterous flanking movement cut the enemy's retreat. Hasdrubal himself fell and the bulk of his army was destroyed.

The campaign of 207 decided the war in Italy. Though Hannibal still maintained himself for some years in Calabria, this was chiefly due to the exhaustion of Rome after the prodigious strain of past years and the consequent reduction of her armaments. In 203 Italy was finally cleared of Carthaginian troops. Hannibal, in accordance with orders from home, sailed back to Africa, and another expedition under his brother Mago, which had sailed to Liguria in 205 and endeavoured to rouse the slumbering discontent in Cisalpine Gaul and Etruria, was driven back on the coast and withdrawn about the same time.

Campaigns in Sicily and Spain.—Concurrently with the great struggle in Italy the Second Punic War was fought out on several other fields. It will suffice merely to allude to the First Macedonian War (214–205) which King Philip V. commenced when the Roman power seemed to be breaking up after Cannae. The diversions which Roman diplomacy provided for Philip in Greece and the maintenance of a patrol squadron in the Adriatic prevented any effective co-operation on his part with Hannibal.

In view of the complete stagnation of agriculture in Italy the Romans had to look to Sardinia and Sicily for their food supply. Sardinia was attacked by a Carthaginian armament in 215, but a small Roman force sufficed to repel the invasion. In Sicily a more serious conflict broke out. Some isolated attacks by Punic squadrons were easily frustrated by the strong Roman fleet. But in 215 internal complications arose. The death of Hiero II., Rome's steadfast friend, left the kingdom of Syracuse to his inexperienced grandson Hieronymus. Flattered by the promises of Carthaginian emissaries the young prince abruptly broke with the Romans, but before hostilities commenced he was assassinated. The Syracusan people now repudiated the monarchy and resumed their republican constitution, but they were misled by false threats of terrible punishment at the hands of Rome to play into the hands of the Carthaginians. The attacks of a Roman army and fleet under Marcellus which speedily appeared before the town were completely baffled by the mechanical contrivances of the Syracusan mathematician Archimedes (213). Meantime the revolt against Rome spread in the interior, and a Carthaginian fleet established itself in the towns of the south coast. In 212 Marcellus at last broke through the defence of Syracuse and in spite of the arrival of a Carthaginian relief force mastered the town by slow degrees. A guerilla warfare succeeded in which the Carthaginians maintained the upper hand until in 210 they lost their base at Agrigentum. They were dislodged from their remaining positions, and by the end of the year Sicily was wholly under the power of Rome.

The conflict in Spain was second in importance to the Italian war alone. From this country the Carthaginians drew large supplies of troops and money which might serve to reinforce Hannibal; hence it was in the interest of the Romans to challenge their enemy within his Spanish domain. Though the force which Rome at first spared for this war was small in numbers and rested entirely upon its own resources, the generals Publius and Gnaeus Scipio by skilful strategy and diplomacy not only won over the peoples north of the Ebro and defeated the Carthaginian leader Hasdrubal

Barca in his attempts to restore communication with Italy. but carried their arms along the east coast into the heart of the enemy's domain. But eventually their successes were nullified by a rash advance. Deserted by their native contingents and cut off by Carthaginian cavalry. among which the Numidian prince Massinissa rendered conspicuous service, the Roman generals were slain and their troops were destroyed in detail (212 or 211).

Disturbances in Africa prevented the Punic commanders from reaping the full fruit of their success. Before long the fall of Capua enabled Rome to transfer troops from Italy to Spain, and in 209 the best Roman general of the day, the young son and namesake of the recently slain P. Scipio, was placed in command. The new leader signalized his arrival by a bold and successful coup-de-main upon the great arsenal of Carthago Nova (see CARTAGENA). Though he was unable to prevent Hasdrubal Barca from marching away to Italy, Scipio profited by his departure to push back the remaining hostile forces the more rapidly. A last effort by the Carthaginians to retrieve their losses with a fresh army was frustrated by a great victory at Ilipa (*q.v.*), near Corduba, and by the end of 206 they mere driven out of Spain.

The War in Africa.—In 205 Scipio, who had returned to Rome to hold the consulship, proposed to follow up his victories by an attack upon the home territory of Carthage. Though the presence of Hannibal in Italy at first deterred the senate from sanctioning this policy, the general popularity of the scheme overbore all resistance. Scipio was granted a force which he organized and supplemented in Sicily, and in 204 sailed across to Africa. He was there met by a combined levy of Carthage and King Syphax of Iiumidia, and for a time penned to the shore near Utica. But in the winter he extricated himself by a surprise attack upon the enemy's camp, which resulted in the total loss of the allied force by sword or flame. In the campaign of 203 a new Carthaginian force was destroyed by Scipio on the Great Plains not far from Utica. their ally Syphax was captured, and the renegade Massinissa (*q.v.*) reinstated in the kingdom from mhich Syphax had recently expelled him. These disasters induced the Carthaginians to sue for peace. but before the very moderate terms which Scipio offered could be definitely accepted a sudden reversal of opinion caused them to recall Hannibal's army for a final trial of war. and to break off negotiations. In 202 Hannibal assumed command of a composite force of citizen and mercenary levies stiffened with a corps of his veteran Italian troops. After an abortive conference with Scipio he prepared for a decisive battle at Zama (*q.v.*), an inland site not yet identified with certainty. Scipio's force was smaller in numbers, but well trained throughout and greatly superior in cavalry. His infantry. after evading an attack by the Carthaginian elephants. cut through the first two lines of the enemy, but was unable to break the reserve corps of veterans. The battle was ultimately decided by the cavalry of the Romans and their new ally hlassinissa, which by a manoeuvre recalling the tactics of Cannae took Hannibal's line in the rear and completely destroyed it. The Carthaginians having thus lost their last army again applied for peace and accepted the terms which Scipio offered. They were compelled to cede Spain and the Mediterranean islands still in their hands. to surrender their warships, to pay an indemnity of 10,000 talents (about £2,400,000) within 50 years and to forfeit their independence in affairs of war and foreign policy.

The Second Punic War, by far the greatest struggle in which either power engaged, had thus ended in the complete triumph of Rome. This triumph is not to be explained in the main by any faultiness in the Carthaginians' method of attack. The history of the First Punic War. and that of the second outside of Italy, prove that the Romans were irresistible on neutral or Carthaginian ground. Carthage could only hope to win by invading Italy and using the enemy's home resources against him. The failure of Hannibal's brilliant endeavour to realize these conditions was not due to any strategical mistakes on his part. It was caused by the indomitable strength of will of the Romans, whose character during this period appears at its best, and to the compactness of their Italian confederacy, which no shock of defeat or strain of war could entirely disintegrate. It is this, spectacle of individual genius overborne by corporate and persevering effort which lends to the Second Punic War its peculiar interest.

The Third Punic War (149–146 B.C.).—The political power of Carthage henceforth remained quite insignificant, but its commerce and material resources revived in the 2nd century with such rapidity as to excite the jealousy of the growing mercantile population of Rome and the alarm of its more timid statesmen. Under the influence of these feelings the conviction—sedulously fostered by Cato the Elder. the Censor—that "Carthage must be destroyed" overbore the scruples of more clear-sighted statesmen. A *casus belli* was readily found in a formal breach of the treaty, committed by the Carthaginians in 154, when they resisted Massinissa's aggressions by force of arms. A Roman army was despatched to Africa, and although the Carthaginians consented to make reparation by giving hostages and surrendering their arms, they were goaded into revolt by the further stipulation that they must emigrate to some inland site where they would be debarred from commerce. By a desperate effort they created a new war equipment and prepared their city for a siege (149). The Roman attack for two years completely miscarried, until in 147 the command was given to a young officer who had distinguished himself in the early operations of the mar—Scipio Aemilianus, the adopted grandson of the former conqueror of Carthage. . Scipio made the blockade stringent by walling off the isthmus on which the town lay and by cutting off its sources of supplies from oversea. His main attack was delivered on the harbour side, where he effected an entrance in the face of a determined and ingenious resistance. The struggle did not cease until he had captured house by house the streets that led up to the citadel. Of a population probably exceeding half a million only 50,000 remained at the final surrender. The survivors were sold into slavery; the city was razed to the ground and its site condemned by solemn imprecations to lie desolate for ever. The territory of Carthage, which had recently been much narrowed by Massinissa's encroachments, was converted into a Roman province under the name of "Africa."

BIBLIOGRAPHY.—1. *Ancient Authorities.* For the First Punic War Polybius, bk. 1, provides a trustworthy and impartial account, but owing to his conciseness leaves many problems oi chronology and strategy unexplained. For the Second War bk. 2 and 3 of Polybius present a complete and detailed record down to Cannae; bk. 7–15 contain fragmentary notices of which the most continuous deal with the campaigns of Scipio. Livy (bk. 23–30) gives a continuous and detailed narrative, partly based upon Polybius and other good authorities, partly upon untrustworthy Roman annalists. The Third War is described in Appian's *Res Libycae,* ch. 67 *sqq.*, and the fragments of Polybius, bk. 36–39.

The subsidiary authorities are: Diodorus, bk. 20–27, 32; Appian, *Res libycae, hispanicae, hannibalicae;* Zonaras' epitome of Dio Cassius, fr. 43, 54, 57; Plutarch's *Lives of Fabius and Marcellus;* Cornelius Nepos's *Lives of Hainilcar and Hannibal,* and short references in Justin, Eutropius, Aurelius Victor and Orosius. The sources and methods of composition of these authors hare been discussed in numerous articles and dissertations, mostly German, of which the most important are mentioned in Niese's work (quoted below). These essays have brought out few certain results. but they trend to show that the narratives, so far as they are not based on Polybius or earlier authorities, are of little value.

2. *Modern Works. a.* For general accounts *see* the respective passages in the general histories of Rome, especially Mommsen (Eng. trans., 1894, vol. ii), Ihne (Eng. trans., vol. ii) and de Sancti's; also C. Neumann, *Das Zeitalter der punischen Kriege* (Breslau, 1883), and R. B. Smith, *Rome and Cartlzage* (1881).

The battles are methodically examined in J. Kromager, *Antike Schlachtfelder* (1912 *et srq.),* and in Kromager-Veith, *Schlachten-Atlas zur antiken Kriegsgeschichte* (Leipzig, 1922). *See* also H. Delbrück, *Gesch. der Kriegskunst* (1901–07).

b. For the First \Tar.—0. Meltzer, *Geschichte der Karthager,* ii. 252–356 (1879–86) ; J. Beloch, *Griechische Geschichte,* vol. iii, pt. i, pp. 664–684 (Strasbourg, 1893–1904) ; B. Niese, *Gcschichte der griechisckrn und makedonischen Staaten,* ii, 174–199 (Gotha, 1893–1903) ; W. W. Tarn, "The Fleets of the First Punic War," in *Journal of Hellenic Studies* (1907), pp. 48–60. For the chronology, *see* F. Reuss, in *Philologus* (1901), pp. 102–148, and especially P. Varese, in *Studi di storia antica,* rol. iii (1902).

c. For the period 241–238.—O. Gilbert, *Rom und Kavthago 513–536 A.U.C.* (Leipzig, 1876) ; Meltzer. *op. cit.* ii. 357–456.

d. For the Second War.—Thomas Arnold, *The Second Punic War* (ed. William Thomas Arnold, 1886); T. A. Dodge, *Great Captains, Hannibal* (1889); *G.* Bossi, in *Studi di storia e diritto,* vol. x–xiii; *P.* Cantalupi, "Le Legioni romane nella guerra d'Annibale" *Studi di storia antica,* i, 3–48 (1891); Th. Zielinski, *Die letzten Jahre des* *zweiten punischen Krieges* (Leipzig, 1880); B. H. Liddell Hart, *A* Greater than *Napoleon—Scipio* Africanus (1926).

e. Special articles.—On Sicily: Niese, *op. cit.* ii, 505–561. On Spain: J. Frantz, Die Kriege der *Scipionen* in *Spanien* (Munich, 1883).

For further bibliographical references consult B. Niese, Grundriss der romischen Geschichte, pp. 81–88, 94–108, 138–142 (Munich, 1906). See also the articles on chief personages (especially HANNIBAL and SCIPIO AFRICANUS, PUBLIUS CORNELIUS), and under ROME: Ancient History; ROMAN ARMY; CARTHAGE; SICILY. (M. C.)

PUNISHMENT, the infliction of some kind of pain or loss upon a person for a misdeed. *i.e.,* the transgression of a law or command. See CRIMINAL LAW; CRIMINOLOGY; CAPITAL PUNISHMENT; PRISON, etc.

PUNJAB (land of the "five rivers"; viz., the Jhelum, Chenab. Ravi. Beas and Sutlej, all tributaries of the Indus), in the Indo-Pakistan subcontinent, is the name given primarily to the triangle of country of which the Indus and the 'Sutlej form the two sides and of which the base is the lower Himalayan hills between those two rivers. From 1848 to Aug. 1947, when British responsibilities were transferred to India and Pakistan, the Punjab formed a British province, with changing boundaries. Until 1901 it included the whole area stretching from the Jumna in the east to the Sulaimans (Suliman) in the west and the Himalayan region lying on either side of the state of Jammu and Kashmir. From its territories the North-West Frontier province was created to the west of the Indus in 1901 and the Delhi enclave in the southeast in 1912. The remaining territory of the province was divided in 1947 into two parts. the East Punjab and the West Punjab, occupied by India and Pakistan respectively. Later both India and Pakistan changed the names of their provinces to Punjab. At the time of the 1951 census the area of the Pakistani Punjab (excluding Bahawalpur) was 62,245 sq.mi. Pop. 18,828,015. The area of the Bharati Punjab was 37,378 sq.mi. Pop. 12,641,205. The Pakistani Punjab province was merged in West Pakistan in Oct. 1955. The Bharati Punjab forms the Indian-state of Punjab, and is the only remaining political entity bearing this name. (*See* also below.)

The geographical area of the Punjab, in addition to the British province in its final form, comprised 43 states under the personal government of rulers who had treaty relations with the Punjab government or the government of India. The largest of these was Bahawalpur (pop. [1951] 1,823,125; area 17,471 sq.mi.), which at the time of the partition acceded to Pakistan. The remainder which all lay in the East Punjab joined India. These were formed into two groups: the Patiala and East Punjab States Union (PEPSC) (pop. [1951] 3,493,685; area 10,078 sq.mi.), a "B" state under the constitution of the republic of India; and the Himachal Pradesh (pop. [1951] 1,109,466; area 10,904 sq.mi.), a part "C" state under that constitution. administered by a lieutenant governor appointed by the government of India. As a result of the reorganization of Nov. 1, 1956, PEPSU was incorporated in Punjab, which was grouped with the northern zone.

The total population of the two Punjab areas (including states) according to the census of 1951 was about 39,000,000. The Jats form the backbone of the cultivating community, though large numbers of them have become Sikhs or Mohammedans in the tracts where those religions predominate. The Rajputs comprising tribes of different religions and social systems are also an important element in the population. By religion they are about 40% Mohammedans, about 40% Hindus and 20% Sikhs. The Gujars are an important agricultural and pastoral tribe. Baluchis and Pathans are strongly represented in the southwest and west.

Physical Features.—The mountain regions of the Punjab fall into four separate groups. To the northeast of the country lies the Himalayan system, with the fringing range of the Siwaliks at its foot. In the southeastern corner the Aravalli system sends out insignificant outliers, which run across Gurgaon and Delhi districts. The southern portion of the western frontier is constituted by the Sulaiman chain; while the northwestern districts of the old province are traversed by the Salt range which cuts off the Potwar plateau from the plains.

The "five rivers" of the Punjab are each of large volume but their wide sandy channels and shifting shoals make them worthless for steam navigation, though they all support a considerable boat traffic. They have been much utilized for irrigation purposes and many canals have been cut from them.

South of the Himalayas lies the great alluvial plain stretching from the Jumna in the east to the Sulaimans in the west. This is one vast level, unbroken save by the wide eroded channels within which the great rivers ever shift their beds, by the insignificant spurs of the Aravalli range in the southeastern corner and by the low hills of Chiniot and Kirana in Jhang. The land between two rivers is known as doab. Between the Sutlej and the Beas lies the Bist-Jullundur doab, between the Beas and the Ravi, the Bari doab, between the Ravi and the Chenab, the Rechna doab, between the Chenab and the Jhelum, the Chaj or Jech doab and between the Jhelum and the Indus, the Sind Sagar doab. The land between the Jumna and the Sutlej is known as the Ghaggar or Sirhind plain. Large areas of the doabs between the Sutlej and the Jhelum were formerly desert wastes which, with the help of irrigation, have now been turned into prosperous agricultural settlements with wheat and cotton as the principal crops. Several canal colonies have sprung up including those of Nilibar, Montgomery, Lyallpur and Shahpur. The area between the Jhelum-Chenab and the Indus known as Thal was also a sandy waste but in the 1950s was being reclaimed by the construction of canals and tube-wells under the guidance of the Thal Development authority.

Geology.—By far the greater part of the Punjab is covered by alluvial and wind-blown deposits which constitute the Indus and the Ghaggar plains. The Salt range area forms a plateau with a steeply scarped face to the south, along which there is an axis of abrupt folding. accompanied by faulting. The rocks found in the Salt range belong to the Cambrian, Carboniferous, Permian, Triassic and Jurassic systems, while Tertiary beds cover the plateau behind. The extensive and valuable deposits of salt, from which the range takes its name, occur near the base of the Cambrian beds. Gypsum, kieserite and other salts are found. Between the Cambrian and the Carboniferous beds there is an unconformity, which, however, is not very strongly marked. in spite of the lapse of time which it indicates. At the bottom of the Carboniferous series there is usually a boulder bed, the boulders of which have been brought from a distance and scratched and striated as if by ice. It is generally admitted that this deposit indicates a southern glacial period in late Carboniferous times. Above the sandstone series at the base of which the boulder bed lies come the *Productus* and Ceratites limestones. The former is believed to belong to the Upper Carboniferous and Permian, the latter to the Trias. Jurassic beds are found only in the western portion of the range. Coal occurs both in the cis-Indus (eastern) and trans-Indus extensions of the Salt range. There are two workable seams, both in the Ranikot stage of the lower Eocene.

Climate.—Because of its subtropical position, scanty rainfall and cloudless skies and the wide expanse of untilled plains, the climate of the Punjab presents great extremes of both heat and cold. From April to September is the hot season with hot dusty winds blowing during the day, while from the begmning of October to the end of March there is a magnificent cool season, with warm bright days and cold nights. Frosts are frequent in January. In the early months of the hot season, till the end of June, a dry heat is experienced, with temperatures rising in places to 120° F. in the shade. At the end of June the monsoon arrives, the rains break in the east of the Punjab and though the heat is less intense the air is moist; and from the middle of August the temperature gradually falls. This is the most unhealthful period of the year, being exceedingly malarious. The Punjab enjoys two well-marked seasons of rainfall: the monsoon period, lasting from the end of June till the third week of September, on which the autumn crops and the sowings for the spring crops depend; and the winter rains from January to March which, though often insignificant in amount, materially affect the yield of the spring harvest. The greatest rainfall is in the outer ranges of the Himalayas, averaging about 50 in. The submontane area has about 30 in.; the central plain 20 in. to 24 in., while in the western plain Multan has only 7 in. The rainfall is heavier in the east than in the west because it is derived mainly from the Bay of Bengal monsoon current. The Arabian sea monsoon is practically exhausted over Sind and Rajasthan before it reaches the Punjab. (K. S. AD.)

History. — The history of the Punjab has been profoundly influenced by the fact that between Peshawar and Dera Ismail Khan the four frontier passes of the Khyber, Kurram. Tochi and Gomal serve as gateways from Afghanistan to the Punjab plains. For this reason it is ethnologically more closely related to central Asia than to India. Until 1922 no structural remains in India could be assigned with certainty to a period earlier than the 3rd century B.C.; later, excavations at Harappa and Mohenjo-Daro unearthed the remains of a civilization 5,000 years old bearing a general resemblance to that of Elam and Mesopotamia *(see* INDIA: *History)*. The first migration of which there is any evidence, however. is that of the Indo-European (Aryan) peoples who entered the Punjab in prehistoric times. Centuries later, within historical times. successive waves of other invaders swept through the frontier passes; and all these migrations and invasions added to the heterogeneity of the population.

The exact limits of the Achaemenian empire of Darius I cannot be determined, but probably included the Indus valley and parts of the Punjab. The earliest date known for certain in Indian history is Alexander the Great's invasion of the Punjab in 326 B.C. *(see* ALEXANDER III THE GREAT). His invasion was merely a large-scale raid and his death in 323 prevented consolidation of his power in the Punjab and the Indus valley. The history of northern India proves that the mountain barrier of the northwestern frontier seldom formed a political boundary, for the kingdoms of the Persians! Mauryas, Graeco-Bactrians, Sakas, Parthians. Kushans and Ephthalites extended from Afghanistan to the Punjab plains.

The first Moslems to penetrate into northern India were the Arabs who, in A.D. 713, extended their power to the lower Punjab; but the Moslem conquest of the Punjab was the work of Mahmud of Ghazni (971–1030), who overthrew the Hindushahiya dynasty ruling between Lamaghan and the Chenah and annexed their territories to his extensive central Asian empire. The Punjab remained in Ghaznevid hands until Mahmud's descendants were expelled by Mohammed of Ghur in 1186. It formed part of the sultanate of Delhi from 1206 until Baber's defeat of Ibrahim Lodi at Panipat in 1526 paved the way for the foundation of the Mogul empire, of which it remained a part until disintegration set in during the first half of the 18th century.

The religious intolerance of the Mogul emperors after the death of Xkbar in 1605 led to the growth of Sikh political power in the Punjab and transformed a religious sect, founded by Guru Nanak in the second half of the 15th century, into a military organization animated with undying hatred toward Moslems. The weakness of the emperors who succeeded Aurangzeb facilitated the growth of Maratha power. From 1720 onward the Maratha princes adopted a policy of territorial aggrandizement and, by 1758, had overrun almost the whole of northern India as far as Peshawar. They were gradually driven southward by the Afghans under Ahmad Shah Durrani to Panipat, where they were routed with enormous losses on Jan. 14, 1761. After the death of Ahmad Shah the various Sikh groups or *misls* began to consolidate their power in the Punjab. The most important of these *misls* were the Bhangis of Gujrat, Sialkot, Lahore and Amritsar; the Ahluwalias of Kapurthala, Jullundur and Hoshiarpur; and the Kanhyas of Gurdaspur. From 1790 onward. Ranjit Singh, the head of the Sukarchakia *misl,* rose to prominence as leader of the Sikh resistance to the Afghan ruler Zaman Shah. His attempt to establish his authority over his coreligionists, the cis-Sutlejian Sikhs, brought him into contact with the British, who had extended their power to the Jumna; and an agreement mas formed in 1809 by which the Sikh ruler accepted the Sutlej as his frontier. From this date his power increased rapidly. Between 1813 and 1821 he annexed Attock, Kashmir, Dera Ghazi Khan and Dera Ismail Khan. It was not until 1834, however, that Peshawar came under Sikh control.

After the death of Ranjit Singh in 1839 the Punjab became the scene of widespread lawlessness, and power passed to the army of the Sikh Khalsa. Suspecting the British of contemplating annexation and eager for war, the Sikhs in 1845 invaded British territory but were defeated in desperate struggles at Moodkee, Ferozeshah, Aliwal and Sobraon. By a treaty in 1846 they were compelled to surrender all lands on the British side of the Sutlej together with the Bist-Jullundur doab, to pay an indemnity and to limit the strength of their armed forces. The young maharaja, Dalip Singh, was to be guided by a council of regency presided over by Sir Henry Lawrence. The new arrangements did not prove acceptable to the Sikhs. and war broke out once more in 1848. After the battles of Chillianwalla and Gujrat the Punjab was annexed to British India on April 2, 1849. (*See* SIKH WARS.)

The newly conquered territories were placed under a board of administration until 1853, when the board's powers and functions were vested in a chief commissioner. Six years later the Punjab and its dependencies were formed into a lieutenant governorship. The annexation of the Punjab, by advancing the British administrative boundary across the Indus. brought the government of India into closer contact with the Pathan tribes of the northwestern frontier. Until 1876 relations with the tribesmen were conducted by the deputy commissioners of Hazara, Peshawar. Kohat, Bannu, Dera Ismail Khan and Dera Ghazi Khan. The system of political agencies was not adopted until 1878, when a special officer was appointed for the Rhyber. The Kurram, Malakand, Tochi and Wana agencies were created between 1892 and 1896. The tribes remained under the control of the Punjab government until the creation of the North-West Frontier province in 1901.

The response of the Punjab during World War I was magnificent: of the 1,302,000 combatants recruited throughout British India, 300,000 were provided by the Punjab, of whom more than one-half were Moslems. Between World Wars I and II communal relations in the province were embittered by the activities of the *tanzim* (orthodox) and *tabligh* movements organized by Moslems to combat the proselytizing of the Hindu *shuddi* (members of lowest caste). Far more serious than this communal strife were the political disturbances culminating in the Jallianwalla Bagh incident of 1919. (For the Punjab rebellion of 1919 *see* INDIA: *History.)*

In 1921 the Punjab was raised to the status of a governor's province. From 1922 until the passing of the Sikh Shrines act, 1925, the peace mas disturbed by the Akali Sikhs who wished to devote the revenues of certain shrines and temples to the spiritual benefit of the Sikh community. The Punjab became an autonomous province in 1937 and in World War II Punjabi troops again greatly distinguished themselves. The separation of Pakistan from India in 1947 was followed by the division of the Punjab into the state and province of East and West Punjab with Hindu and Moslem majorities respectively. (C. C. D.)

Partition set the boundary in the Punjab between India and Pakistan roughly along the line of the Sutlej up to beyond Ferozepur, and then due north between Lahore and Amritsar to the boundary of Kashmir along the line of the Ravi and the Ujh. Under British rule the Punjab was divided into the five divisions of Ambala (Umballa), Jullundur. Lahore. Rawalpindi and Multan. At the partition India received the Xmbala and Jullundur divisions and part of the Lahore division (including Amritsar district with Amritsar city, the holy city of the Sikhs). Pakistan was granted the Ramalpindi and Multan divisions and the districts of Sialkot, Gujranwala and Sheikhupura from the Lahore division in addition to part of Lahore district, including the important capital city of Lahore (pop. [1951] 849.476). The district of Gurdaspur was partitioned, and in the extreme south of the province Pakistan was allotted a small area on the east bank of the Sutlej with control of the Suleimanki headnorks on which the irrigation of the former Bahawalpur state depended.

The immediate result of partition was an outbreak of violence aith much loss of life followed by a great mass movement of population involving about 10,000,000 people. Practically all the Hindus migrated from the West to the East Punjab and practically all the Mohammedans from the East to the West Punjab.

(K. S. AD.)

BIBLIOGRAPHY.—G. L. Chopra, *The Panjab as a Sovereign State* (Lahore. 1928); J D. Cunningham. *History of the Sikhs* (London, 1919); M L Darling, The *Punjab Peasant in Prosperity and Debt* (Oxford. 1925); C. C Davies, *The Problem of the North-West Frontier* (Cambridge, 1932); H. R. Gupta, *Studies in Later Mughal History*

of the Panjab, 1707–1793 (Simla, 1944); H. A. Rose, *A Glossary of the Tribes and Castes of the Punjab and North-West Frontier*, 3 vol. (Lahore, 1911–19). (K. S. AD.; C. C. D.)

PUNJAB (India), a state of India created out of the eastern part of the former province of the Punjab at the partition of the subcontinent between India and Pakistan in 1947. On Nov. 1, 1956. PEPSU was merged with it. (For geography and earlier history *see* the article on the former province PUNJAB above.) Partition dislocated the economy and administration of the state. Priority was given to agricultural development. The multipurpose Bhakra-Nangal project was designed to irrigate 370,000 ac., and the Nangal dam was completed. Concreting of the Bhakra dam was started in Nov. 1955, and 677 m i of main canals and 3,958 mi. of distributary canals had been constructed by 1956. One million acres had then received irrigation facilities, and on completion of the project 6,500,000 ac. would for the first time be irrigated and 3,500,000 ac. already under irrigation would receive more water. One hydroelectric powerhouse had begun to supply 34,000 kw. to the Punjab state and Delhi, and a second was expected to be ready shortly afterward. Holdings were consolidated, erosion in the southeast portion of the state was being checked, and five community projects, nine community development blocks and sixteen national extension service schemes, covering in all a quarter of the state, were formed. The result was an enormous increase in the production of food grains, cotton, raw sugar and oilseeds.

In 1951 work was begun on the construction, on modern principles of architecture, of a new capital at Chandigarh; and in Sept. 1953 government offices began to move to their new headquarters. A few cotton ginning and textile mills were constructed and the manufacture of sports goods was established at Jullundur. Oilseed crushing was undertaken on a minor scale, and a few foundries for the manufacture of agricultural implements were built. The state is served by the Northern railway line with headquarters at Delhi, uhence it is connected with the other lines of the Indian railway system. Within the state one section of the line runs north and northwest through Panipat, Ambala (Umballa), Ludhiana and Amritsar, and then links up with the North Western railway of West Pakistan. The southern section runs through Rohtak to Ferozepur and thence via Pakistan's North Western line to Lahore.

In the mid-1950s there were 8,647 primary schools, 845 middle schools, 654 high schools for boys and 86 for girls, and 63 colleges for men and 11 for women. About 40% of the children aged 6 to 11 and 25% of children aged 11 to 14 were in schools. The East Punjab university had its headquarters at Hoshiarpur.

The state comprises 19 districts and has an area of 47,062 sq.mi. Pop. 16,134,890. In the years after partition, politics in the state were confused and there was need for a time (June 1951–April 1952) of governor's rule. In the 1952 elections the Congress party gained a decisive majority; and in 1957 they secured 118 out of 152 seats, and continued in office. (S. GL.)

PUNJAB (Pakistan). With the partition of India in Aug. 1947, the old province of Punjab (*q.v.*) was divided between Pakistan and India according to the Radcliffe award. The western major portion became a province of Pakistan under the name of West Punjab which was subsequently changed to Punjab. In 1955 the province was abolished under a reorganization act. The boundary between the two Punjabs followed the Ujh and Ravi rivers to a point about 14 mi. N.E. of Lahore and then cut across the Bari doab to the Sutlej about 12 mi. N.E. of Ferozepore; thereafter it followed the Sutlej. At the extreme south a small area on the east bank of the Sutlej had been allotted to Punjab (Pakistan) to give control of the Suleimanki headworks on which the irrigation of the former Bahawalpur state depended. The boundary allotted one of the four tehsils of the Gurdaspur district, named Shakargarh, to Pakistan and half of the Kasur tehsil of Lahore district to India. The Shakargarh tehsil was incorporated in the adjoining district of Sialkot.

The Punjab province of Pakistan comprised 16 districts, grouped into three divisions, Lahore, Rawalpindi and Multan, and had an area of 62,245 sq.mi. Pop. (1951 census) 18,828,015. At the time of the 1951 census 98% of the population was Mohammedan as compared with a Mohammedan population of about 75% for the same area in 1947). When the province was merged in West Pakistan province in Oct. 1955, its capital, Lahore, became the capital of the new and much larger province.

The Punjab has an extensive system of canals which has converted large areas that were formerly desert wastes into prosperous agricultural settlements. Wheat and cotton are the principal crops where rainfall or irrigation are sufficient. Millet and gram are the chief crops in the drier western part of the province. The Salt range contains many minerals, especially salt and coal. A number of mills, especially for cotton textiles, were established after the partition, and in the Attock district the oil industry was of considerable importance.

Lahore is a great centre of trade and industry and the site of the Panjab university. The entire area is served by the North Western railway which also has its headquarters at Lahore. It connects that city with Karachi to the southwest and with Peshawar and other frontier cities to the northwest, and links up with the Northern railway in the Punjab state of India. (K. S. AD.)

PUNO, a southern sierra department of Peru, bounded north by Madre de Dios, west by Cuzco, Arequipa and Moquegua, south by Tacna and east by Bolivia. Pop. (1958 est.) 896.510. Area 27,947 sq.mi. The northern portion of the department was removed in 1912 to form a section of the department of Madre de Dios. Puno includes most of the shore of Lake Titicaca, the high plateau on which the lake stands and the mountains surrounding it on the north, east and west. Vilcanota Knot, on the border of Puno and Cuzco, constitutes the watershed dividing the enclosed lacustrine basin of Titicaca from the Amazon basin. The department is the source of the headwaters of the Amazon, notably the Tambopata and Inambari, affluents of the Madre de Dios.

Crops cultivated in the region are limited to those that mature in the cold climate; chiefly potatoes, barley and other hardy cereals. Cattle and sheep are bred there; wool, both from sheep and alpaca, is exported. The department contains one of the most important auriferous regions of the world. In addition to silver and gold which have been worked extensively, coal, salt, copper, antimony, cinnabar, arsenic, quicksilver, tin, marble, zinc, cobalt and petroleum are found. The manufacture of pottery and woolen textiles are also important industries.

The city of Puno. pop. (1958 est.) 23,227, capital of the department and province of Puno, lies at an elevation of more than 12,600 ft. above sea level, on the northwest shore of Lake Titicaca: it is the seat of a bishopric and a superior court. Puno is connected by the Southern railway with both Cuzco and the Pacific port of Mollendo and with La Paz, Bolivia by steamer across Titicaca and railway. Motor roads connect with Cuzco, Arequipa and Guaqui and northeastward to Sandia and Ollachea. Puno is 171 mi. from La Paz, 218 mi. from Arequipa and 820 mi. from Lima. (J. L. TR.)

PUNTA ARENAS, southernmost city of the world, capital of Magallanes province and department, Chile. Pop. (1952) 34,263. The city, located on the Straits of Magellan, was founded in 1849 by Col. José de los Santos Mardones. Punta Arenas' role as a port-of-call and coaling station waned after the opening of the Panama canal and fuel oil became significant in maritime movement; nevertheless, a flourishing export trade in wool and mutton, primarily with the British Isles, continues. Punta Arenas supports slaughterhouses, tallow works and wool exporting houses. The administrative and supply activities of the national petroleum company that operates in oil fields on Tierra del Fuego, the recreation requirements of its employees, the attractions of the free port to Chilean consumers and the maintenance of naval, air and army garrisons are contributing factors to the city's growth in the 20th century. Frame and corrugated metal construction predominates among the city's buildings. Surface and air communication with the north and Tierra del Fuego is good. Some lignite and placer gold are mined nearby. From 1927 to 1937 the city was called Magallanes. The name Punta Arenas means "sandy point." (J. T.)

PUNTARENAS or PUNTA ARENAS ("sandy point") a seaport on the Gulf of Nicoya on the Pacific coast of Costa Rica.

Pop. (1950) 13.272. In colonial times the city's chief function was to link Costa Rican commerce nith Panama and South America. A royal order of 1814 brought the first attempt to improve the harbour facilities: a cart road from San José was opened in the 1840s. Most Costa Rican coffee went to Europe around Cape Horn and Puntarenas was the shipping centre.

Now connected with San José by the Pacific railway, it is an increasingly important port for exporting bananas as well as coffee. There is a considerable coastal trade in rice, corn and beans. Canning and freezing fish and ship repairing are relatively new industries in Puntarenas. Most imports to Costa Rica from the west coast of the United States pass through this city. It is the capital of Puntarenas province (area 4,367 sq.mi.; pop. [1950] 88,168), a long narrow district that skirts the Pacific to the Republic of Panama. The province was the fastest growing in Costa Rica by the 1960s. Much of this was due to greatly increased activity in the banana industry as new areas opened on the Pacific coast.

(T. L. K.)

PUPIN, MICHAEL IDVORSKY (1858–1935), U.S. physicist and inventor, particularly of electrical devices, was born in Idvor, Hung. (Yugoslavia), Oct. 4, 1858. He went to the U.S. in 1874, graduating from Columbia university, 1883. The first to hold the John Tyndall fellowship (1886–88), he later studied physics and mathematics at Cambridge university and under H. von Helmholtz at the University of Berlin (Ph.D., 1889). He was instructor in mathematical physics at Columbia, 1890; and was appointed adjunct professor of mechanics, 1892, becoming professor of electromechanics there in 1901 and later director of the Phoenix research laboratories. By means of inductance coils placed at predetermined intervals of·the transmitting wire, he greatly extended the range of long-distance telephony, particularly over telephone cables. The patent for this invention was acquired in 1901 by the Bell Telephone company and by German telephone interests. He made several other inventions in electrical wave propagation, electrical resonance and multiplex telegraphy. He discovered secondary X-ray radiation in 1896 and invented in the same year means for short exposure X-ray photography by the interposition of a fluorescent screen. He wrote *From Immigrant to Inventor* (1923). He died in New York city, March 12, 1935.

PUPPETS AND MARIONETTES, jointed figures which, by various devices, are made to move in mimicry of persons or animals — usually for dramatic performances. The closely related shadows are flat cutout figures which are exhibited in silhouette against a lighted screen. The following are commonly accepted methods of producing simple types of hand puppets, rod puppets, string puppets (marionettes) and shadow figures.

Hand Puppets can be of wood, plaster, plastic wood, papier-mâché or stuffed cloth. Head and neck are in one piece with a hole running up the neck for the first finger of the operator. The arms consist of cylindrical cuffs (cardboard strengthened with cloth) which are glued or tacked to wooden hands. The operator's second finger and thumb each fit into a cuff. A small stuffed bag is suspended by tapes from a ledge at the base of the neck. Grasping this bag in the palm with the two last fingers gives a firmer control. The cuffs also are attached to the bag with tapes. This framework of the hand puppet is then concealed — the head by a mask and wig (unless the face and hair are already carved and painted on), the rest by clothing firmly attached to the ledge at the base of the neck. If desired, legs and feet can be attached.

To operate, put the doll on the hand like a glove, always keeping the forearm upright so that the puppet will stand straight. Arm and head movements are made with the fingers. The stage has no floor; a curtain or three-sided screen with an opening for the proscenium arch is required. The little roll or draw curtain is suspended from a frame or from wooden strips across the top of the screen. Painted or dyed scenery behind the dolls is similarly suspended. Puppets must be held high so that the operator's head is invisible. A ledge along the base of the proscenium arch offers a place on which to rest "properties." The stage lighting (floods or strips) should shine upon the puppets' faces, as well as upon the scenery. Humorous, lively plays are best for this grotesque, intimate type of puppet show.

String Puppets (Marionettes) are made of the same materials as hand puppets. If the head is of plaster or stuffed cloth put a wire from ear to ear with a loop at either end and another wire, twisted on to this, running down through the neck with a loop at the end. If the head is wooden, scre eyes at the sides and at the bottom of the neck are used. The torso can be one piece; but separate shoulders and hip pieces of wood with a centre section of loosely stuffed cloth give flexibility to the body. Limbs can be wooden loosely jointed,. or a wire skeleton padded or firmly stuffed cloth. The joints must be flexible: brass hinges, double screw eyes, leather or cloth straps or carved wooden joints. Hands can be of wood, plaster or wire mound with narrow tape. If the doll is of stuffed cloth the feet, lower arms and hips should be weighted with lead. Faces and hands should be painted, like theatrical make-up to carry at a distance with either oil or water-colour paints. When dressing the doll freedom must be allowed for movement of neck, elbow, shoulder, etc.

The marionette is suspended by strings from a controller held in the hand of an operator above. This controller can be a flat strip of wood about 10 in. long with a shorter crossbar. A leather strip tacked to the crossbar slips over the back of the operator's hand. The head strings are tied (from loops at the ears) to ends of the crossbar and to hold the weight of the doll. The hand strings are attached to the front end of the controller. The back string from the back waistline of the doll is attached to the rear end of the controller. A separate bar is generally used for the foot controller, and a hole in the centre of this bar allows it to be hung up, when not in use, upon a peg at the front of the main controller. The strings are attached at the knee, not foot, of the doll. Shoulder strings or extra strings for special gestures can always be added.

Practice is required for operating string puppets smoothly. To turn or bend the head, tip the controller sidewise (or pull on the shoulder strings). To seat or bow the doll, tip the controller forward or pull on the back string. To walk the puppet take the foot control in the free hand and tilt it from side to side, moving the figure on with the main controller at desired speed.

A marionette stage is a miniature replica of any stage except that the wings are left open to allow passage of dolls, strings and controllers. Operators stand on a platform directly behind and higher than the puppet stage. A strong rail, waist high, in front of this "bridge" supports the weight of the operators leaning against it. A rail at the back of the bridge is used to hang dolls upon. The bridge, the wings and the space below the puppet stage are concealed from the audience, usually by draperies. Behind these a framework forms the proscenium arch; it supports the little curtain and the front lights of the stage. Lighting and scenery must be planned not to catch the marionette's strings.

Rod Puppets are worked from below by rods. The head (of material similar to other puppets') can be made with a hole bored up the neck. A thin dowel fastened in this hole extends down below the feet and serves to hold and walk the puppet. The body usually consists of wooden shoulder and hip pieces attached horizontally at proper points to the upright dowel. Wire, or cloth stiffly stuffed with cotton, can be made to give a shape to the torso. Arms and legs are constructed as are the limbs for string puppets but the legs are generally allowed to hang without control. The arms are moved from below by thin rods of wood or mire attached to the palms. To articulate the neck of a rod puppet a more complicated construction is required. The head must be hollow and pivoted over the neck which is modeled (hollow) in one piece with the shoulders. A slender hollow metal tube is used instead of the upright dowel to allow strings attached at very precise points inside the head to drop down below the feet. By pulling these strings the operator can nod the figure's head. A convenient method of standing the puppet when not being held is to have two round disks about an inch apart fastened to the dowel just below the feet. Wooden strips must be built in just below the stage floor level at required places. These strips have slots cut into them at intervals into which the rod can be firmly set. Otherwise the stage, lighting, decor, etc., for rod puppets are similar to those for hand puppets. Rod puppets move slowly and gesture gracefully, hence are well suited for religious plays or dramas of fantasy.

Shadow Plays.—Somewhat like rod puppets, shadow plays are usually worked from below, at an opening in a screen or curtain; but this opening is covered with white cloth, drawn tight. The figures are cut in silhouette out of cardboard or tin and attached to slender staves by which they are held and moved, directly behind or in front of the cloth. Movable arms or jaws can be cut out separately, joined with brass clips and moved from below by wires or threads concealed behind the figure. Faces must be in profile. A light from behind throws the shadows plainly into view. Some suggestion of scenery can be painted upon the cloth or hung close against it. *See* DOLLS; MASK; SHADOW PLAY.

BIBLIOGRAPHY.—C. Magnin, *Histoire des Marionettes en Europe; E.* Gordon Craig in *The Marionette* (1918); Helen H. Joseph, *A Book of Marionettes* (1929); Paul McPharlin (ed.) in *Puppetry,* international yearbook (1929); Cyril William Beaumont, *Puppets and the Puppet Stage* (1938); Remo Bufano, *Be a Puppet Showman* (1933); *R.* B. Inverarity, *Manual of Puppetry* (1938); Mills and Dunn. *Marionettes, Masks and Shadows* (1927). (H. H. Jo.)

PUPPIS, one of the three southern constellations into which the large Ptolemaic constellation Argo (*q.v.*) was subdivided (*puppis,* "poop"). The bright new star Nova Puppis was visible during the winter of 1942.

PUQUINAN, a group of tribes of South American Indians, doubtfully constituting an independent linguistic stock. Their identity with the modern Uros has been much discussed. The area occupied (if this identity be accepted) would include the whole basin of lakes Titicaca and Poopo, and the Salar de Uyuni in the Bolivian plateau, together with the Peruvian-Chilean coast from about 16° to 22° S. lat. Within this area they lived in scattered small groups among the Aymaran (*q.v.*) tribes. Rivet thought that the Puquinan language (together with the Uro) is in reality a member of the Arawakan (*q.v.*) stock and that this whole group of Puquinan and Uran tribes represents a very ancient intrusion westward of the Arawakan peoples.

PURCELL, EDWARD MILLS (1912–), U.S. physicist, noted especially for his research on magnetic resonance, was born in Taylorville, Ill., Aug. 30, 1912. He received his B.S. from Purdue in 1933, and his Ph.D. from Harvard in 1938. During the war he was head of the Advanced Development group on radar problems at the radiation laboratory of the Massachusetts Institute of Technology. He became professor of physics at Harvard university in 1949. He was awarded the Nobel prize in 1952 jointly with Felix Bloch (*q.v.*) for the discovery of nuclear magnetic resonance in solids, a phenomenon observed independently for the first time at Harvard and Stanford. These investigators showed that by the absorption of radio-frequency waves in solids it is possible to detect nuclear magnetic moments. This research opened up a whole new field of physics: magnetic resonance spectroscopy. It yielded information not only on nuclear moments, but also on chemical bonds and atomic binding in liquids and solids, even supplying data on the structure of hydrocarbons useful for the oil industry. Another notable achievement of Purcell was the detection jointly uith Harold I. Ewen in 1952 of the 21 cm. line of neutral atomic hydrogen in extraterrestrial radiation. This discovery added a new dimension to radio astronomy by revealing the distribution of hydrogen in galaxies. (J. H. V. V.)

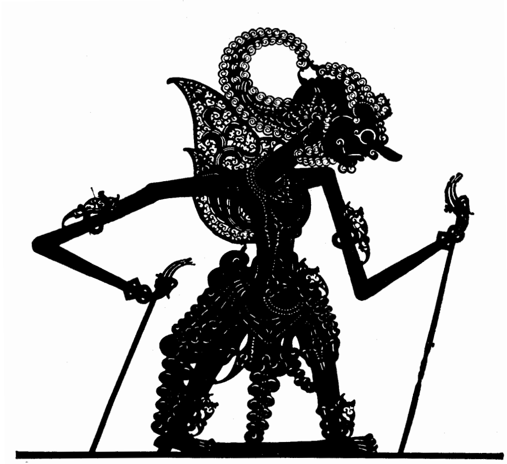
PURCELL, HENRY (*c.* 1659–1695), English composer, whose date of birth and birthplace are uncertain, is said to have been born in Westminster. His father, according to his biographer W. Cummings, was Henry Purcell, or Pursell, a gentleman of the chapel royal, whose eldest son Edward (1653–1717), became gentleman usher to Charles II, and afterward distinguished himself in the army, while Henry and Daniel, the tuo younger sons, became musicians. On his father's death in 1664, Henry Purcell was placed under the guardianship of his uncle Thomas Purcell (d. 1682), also a gentleman of the chapel and a man of extraordinary probity and kindness. (According to J. A. Westrup, Thomas was the composer's father, not his uncle.) Both he and Henry Purcell the elder sang at the coronation of Charles II. Through Thomas's interest Purcell was admitted as a chorister of the chapel and was placed under Capt. Henry Cooke (d. 1672), master of the children, an excellent teacher and a composer of anthems, to whom Samuel Pepys makes a number of references in his *Diary.* On Cooke's death Pelham Humfrey (1647–74) became master, and mas an excellent teacher as well as a musician of genius; but as a pupil of Lully he naturally stood for the French school, and in this respect failed to influence Purcell, who admired the Italian masters.

Purcell's third and last master was the distinguished composer and organist John Blow (1648–1708), to whom Purcell's great indebtedness is not always sufficiently realized. In 1673, when his voice broke, Purcell was dismissed with an ex-chorister's salary of £30 a year and presented with certain articles of dress. He was also given the appointment of (unpaid) assistant to John Kingston, keeper of the king's instruments, together with a promise to succeed him. In 1677 he was appointed "composer in ordinary for the violin" in succession to Matthew Lock. Purcell had been copyist at Westminster abbey since 1677, and in 1679 he succeeded Dr. Blow as organist.

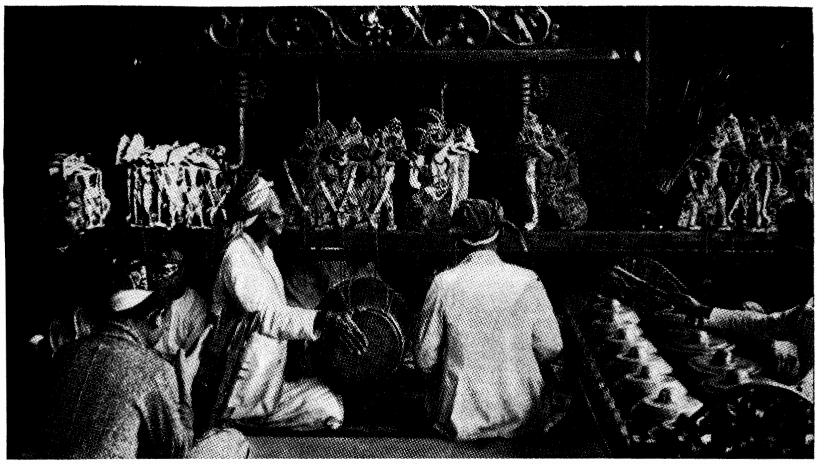
The year 1680 was the beginning of a period of great productivity. In it he wrote the music to Nathaniel Lee's *Theodosius,* the first of a long series of dramas for which he provided incidental music, and one in which an introductory ritual scene gave him unusual scope; this was followed by Thomas D'Urfey's *Virtuous Wife.* He also produced the first of his court odes or "Welcome Songs" at this date and wrote several anthems, many of which were composed especially for the prodigious basso profundo of the Rev. John Gostling (or Gosling). a singer at Canterbury and later at the chapel royal, to whom John Evelyn alludes as "that stupendous bass." Either in 1680 or the following year he married Frances Peters, and in 1682 his eldest son was born. From 1682 he held the post of organist to the chapel conjointly with his appointment at the abbey. His first printed composition was the 12 *Sonnatas of III Parts: two violins and basse: to the organ or harpsichord.* These, though avowedly based on Italian models, show great power and originality. Purcell had now become "composer in ordinary to the king" and his official life was a very full one. For each public event he composed an ode or an anthem: some of the finest of these are the ode "Swifter. Isis, Swifter Flow" (1681); the "St. Cecilia" odes; the "Fly, Bold Rebellion" (in celebration of the suppression of the Rye House Plot, 1683); two anthems written for James II's coronation: "O I Was Glad" and "My Heart is Inditing." The *Te Deum and Jubilate,* written for St. Cecilia's Day 1694. was notable as being the first English anthem with orchestral accompaniment. It was performed annually at St. Paul's cathedral until 1712 and in alternate years with G. F. Handel's Utrecht *Te Deum* until 1743. In all his anthems there is a large proportion of instrumental music.

The opera *Dido and Aeneas,* which above all Purcell's works inspires admiration and affection in an equal degree, was written to a libretto furnished by Nahum Tate at the request of Josiah Priest, a dancing master who also kept a boarding school for young gentlewomen, first in Leicester Fields and afterward at Chelsea. The date of its composition and original performance at the school was fixed by W. Barclay Squire of the British museum as about the year 1689. In this work there is no spoken dialogue, but only recitative, and it is characterized from beginning to end by the dramatic directness which Purcell possessed in so high a degree. Dido's exquisite song of farewell is one of the flawless things in music, classical in form and in its dignified restraint, and yet of rare emotional quality. As is so often the case when he has some poignant emotion to express, Purcell chooses here to build up the song on a "ground," and the relentless reiteration of the bass contributes greatly to the dramatic effect. Graceful dance choruses, lumbering sailor dances and witches' incantations relieve the tragedy, and, avoiding an anticlimax after Dido's farewell, the composer ends with a soft and tenderly expressive chorus, "With drooping wings, ye Cupids, come," in which music and words achieve perfect union.

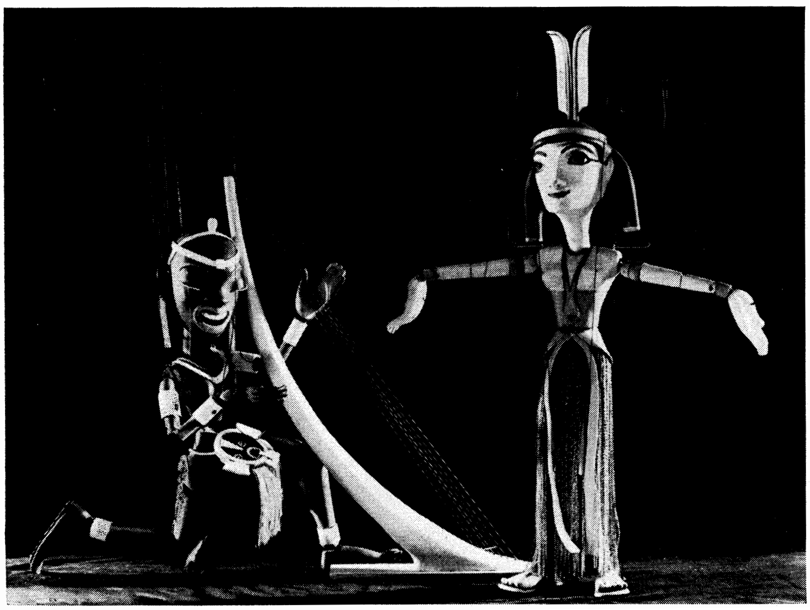
Although *Dido and Aeneas* stands out today as an isolated phenomenon in the age in which it is written. it was rather the peak of a movement in which Purcell's predecessors did valuable experimental work; and here, again, Blow's influence is seen, for in his only known dramatic work, *Venus and Adonis,* he sets the



Javanese shadow puppet

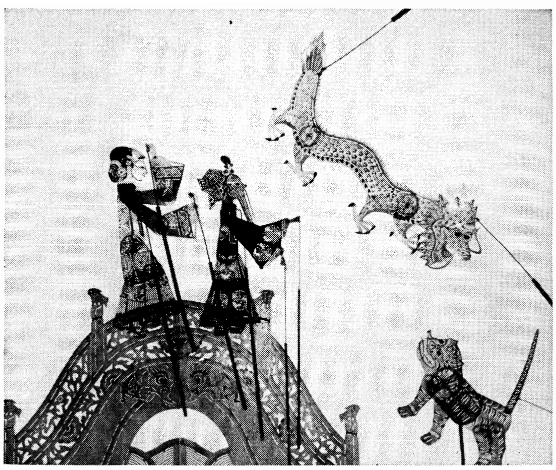


Javanese puppet theatre with operator, orchestra and fiat, wooden puppets



Production of "Tea and Hashish" by the Braunschweig Marionette theatre; Harro Siegel, director

"The Glowing Bird" by Tatterman Marionettes; puppets by Roy Patton



Chinese shadow puppets

A four-foot Japanese Bunraku puppet operated by Yoshida Bungoro

TRADITIONAL ORIENTAL PUPPETS AND MODERN MARIONETTE PRODUCTIONS

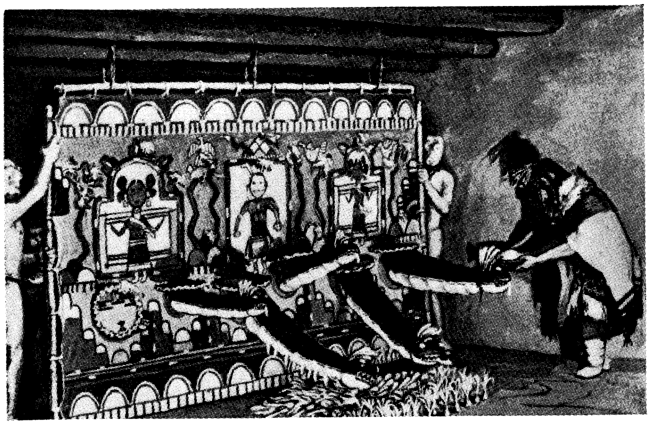
BY COURTESY OF (TOP LEFT TOP RIGHT, BOTTOM LEFT) MARJORIE B MCPHARLIN, (CENTRE LEFT) DETROIT INSTITUTE OF ARTS, (CENTRE RIGHT) WILLIAM I. DUNCAN, (BOTTOM RIGHT) KINGSLAND MARIONETTE COLLECTION PHOTOGRAPHS, (TOP LEFT, BOTTOM LEFT) LAURA GILPIN

PUPPETS AND MARIONETTES

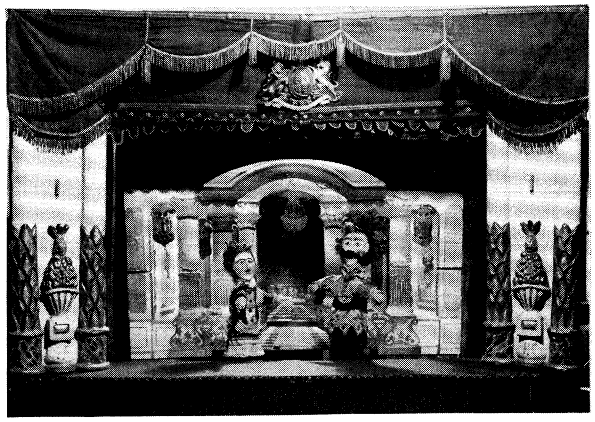
Harlequin and Columbine by Richard Teschner, Vienna, Aus

Pathelin from "Pierre Pathelin." Teatro del Nahual, Mexico city: Roberto Lago, director

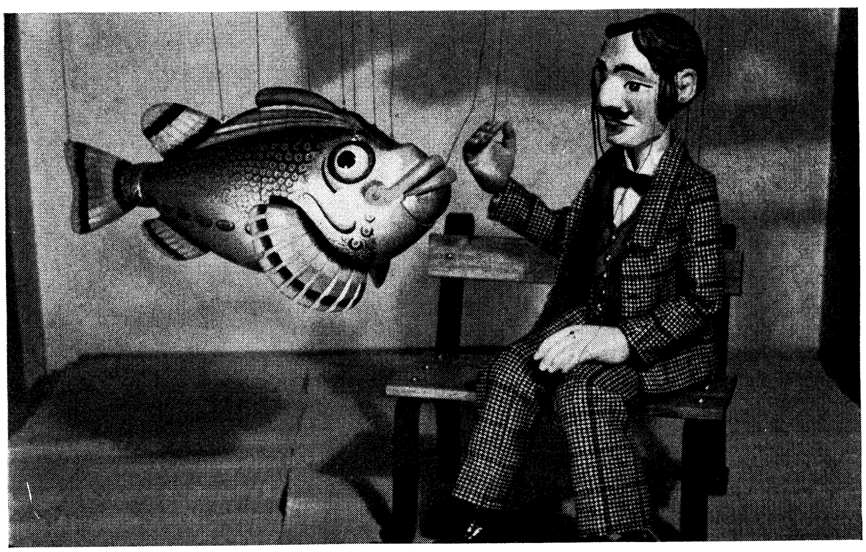
Sicilian knight in armour from Papa Manteo's company, New York city



Rod puppet serpents from a Hopi Indian snake dance



Victorian English hand puppet theatre of about 1870, with seven characters and many scenes



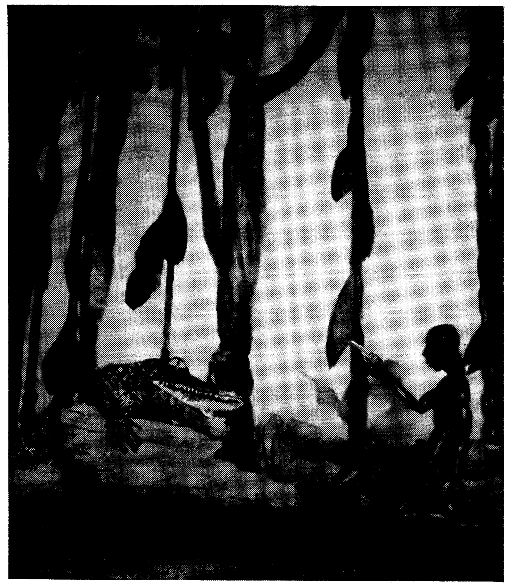
Scene from "The Man, The Fish and The Spirit" by the Lanchester Marionettes. Carving by Frank Rose

Robinson Crusoe by Tony Sarg

PUPPETS OF EUROPE AND AMERICA

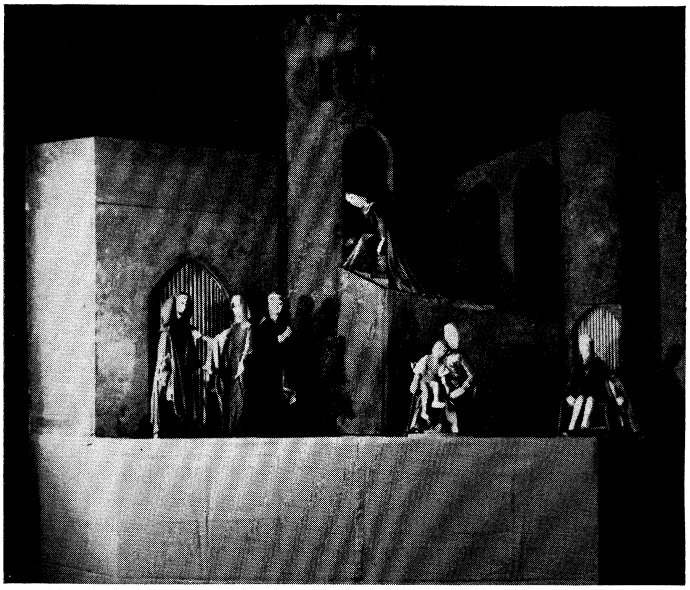
BY COURTESY OF (TOP LEFT CENTRE RIGHT) DETROIT INSTITUTE OF ARTS (TOP CENTRE) TEATRO DEL NAHUAL, PHOTO BY RICARDO RAZETTI, (TOP RIGHT) MARJORIE B MCPHARLIN, (BOTTOM LEFT) LANCHESTER MARIONETTES, (BOTTOM RIGHT) KINGSLAND MARIONETTE COLLECTION

Indian puppet operated by Frank Paris, night club entertainer

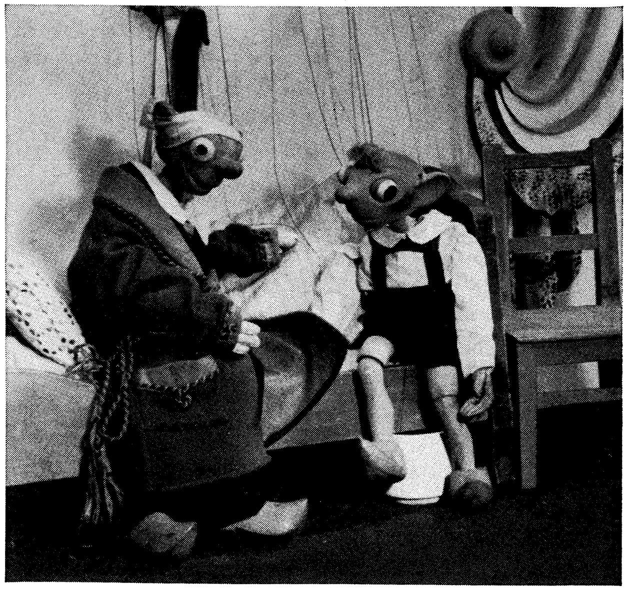


Scene from Ralph Chessé's production of "The Emperor Jones." Scenery by Blanding Sloan

Kukla and Ollie from Burr Tillstrom's "Kukla, Fran and Ollie"



Architectural stage used by Marjorie Batchelder in her production of Maeterlinck's "The Death of Tintagiles"



Puppets of Josef Skupa's marionette theatre, Prague, Czech.

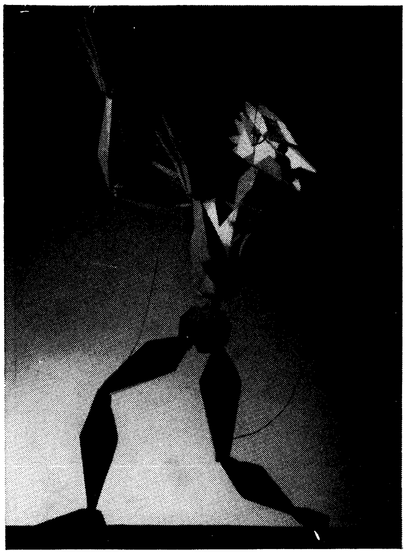
"La Misère" by S. Walleshausen. G. Blattner's theatre, Arc-en-Ciel, Paris

Scene from a play by Karei Čapek. Puppets and scenery by Jan Malik, Prague

20TH CENTURY PUPPETS AND PUPPET DRAMAS

BY COURTESY OF (TOP LEFT) FRANK PARIS, PHOTO BY BRUNO OF HOLLYWOOD, (TOP CENTRE) RALPH CHESSÉ, (TOP RIGHT) BURR TILLSTROM, (CENTRE LEFT) MARJORIE B. MCPHARLIN, (CENTRE RIGHT, BOTTOM LEFT, BOTTOM RIGHT) DETROIT INSTITUTE OF ARTS; PHOTOGRAPH (BOTTOM RIGHT) SCHOLZ

PUPPETS AND MARIONETTES



Jack Frost from "The Flower Ballet." Hogarth puppets, Eng.

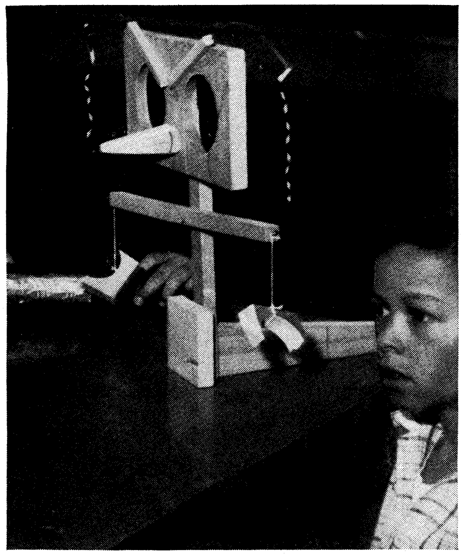
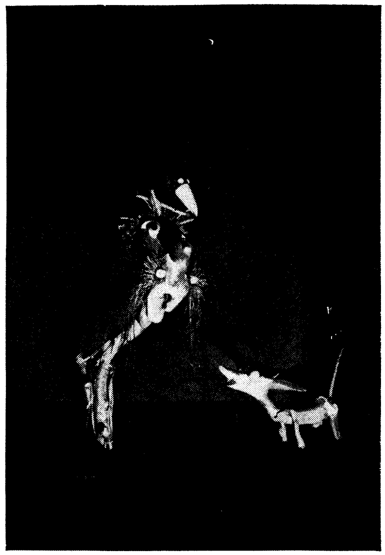
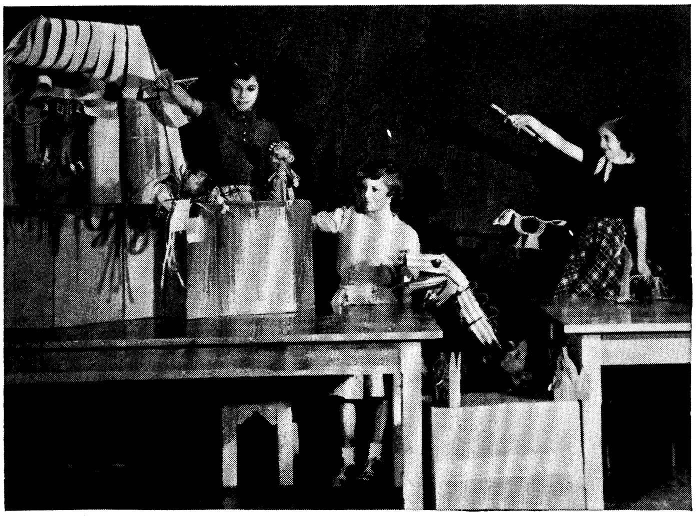


Table puppet made by an 11-year-old boy from wood scraps



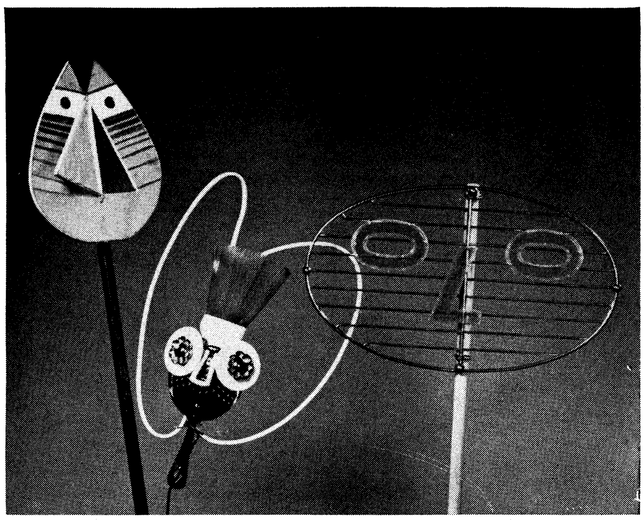
Puppets made of roots by Basil Milovsoroff



Children working puppets on a table stage

Ball puppets by Sergei Obraztsov. State Central Puppet theatre, Moscow, U.S.S.R.

Scene from "The Tale of Timothy T." Shadows by David Orcutt, Vancouver, B.C.



Space creatures from "The Runaway Rocket." By George Latshaw, Akron, O.

UNUSUAL PUPPETS OF VARIOUS MATERIALS

BY COURTESY OF (TOP LEFT) HOGARTH PUPPETS, (TOP CENTRE) HANK SCHRIEBER, (TOP RIGHT) BASIL MILOVSOROFF, PHOTO BY JOHN A. CLARK, (CENTRE LEFT) HARPER AND BROTHERS; FROM BATCHELDER AND COMER, PUPPETS AND PLAYS," PHOTO BY LAURA GILPIN (CENTRE RIGHT) DETROIT INSTITUTE OF ARTS, (BOTTOM LEFT) DAVID ORCUTT, (BOTTOM RIGHT) GEORGE LATSHAW example of having every word sung and none spoken. He is no doubt also partly responsible for Purcell's skill in the use of a ground, and he probably encouraged, rather than discouraged, his pupil's audacities of harmony, since he himself was a notorious offender. Among the peculiarities of Purcell's idiom are the constant false relations and the use of the descending melodic minor in ascending passages, and vice versa. He had a marked preference for the flat minor keys. His fine feeling for rhythm, form and climax invests even his smaller pieces with a quality that is unmistakable.

In judging Purcell's scores it should be remembered that he was practically restricted to oboes and trumpets as regards wind instruments, since even the modern flute had not come into use in his time.

In 1690 Purcell wrote the music to Betterton's *Dioclesian*, which includes a masque. He was associated with Dryden in *Tyrannic Love* (1687), *Amphitryon* (1690) and *King Arthur* (1691), in all of which the music consists of separate numbers which form no integral part of the drama. In *King Arthur*, Josiah Priest was responsible for the dances. This play, which contains the famous song "Fairest Isle," had a great success and was revived on various occasions up to 1803, and once in 1842. It was first published in 1843 by the Musical Antiquarian society. The score of Purcell's songs and music to *The Fairy Queen* (an adaptation of William Shakespeare's *A Midsummer Night's Dream)* written in 1693 was discovered in 1901 and edited for the Purcell society by J. S. Shedlock in 1903.

Purcell suffered much at the hands of his editors until, in 1876, the Purcell society was founded for the purpose of bringing out a complete and authoritative edition of his works, the majority of which were still in manuscript.

Purcell died at his house in Dean's Yard, Westminster, on Nov. 21, 1695, and was buried in Westminster abbey on Nov. 26. He left a widow and three children, three others having died before him. In 1682 and 1702 she published *Orpheus Britannicus*, a collection of his works, in two parts. A famous portrait of the composer is that by Sir Godfrey Kneller, bequeathed to the National Portrait gallery, London, by Barclay Squire.

Other dramatic works by Purcell were *Don Quixote, The Indian Queen* and *Bolt duca* (all in *1695)* and many earlier works. Smaller works are the fantasias and sonatas for three or more parts, the suites and many miscellaneous pieces for harpsichord, and songs. For a detailed list, see *Grove's Dictionary* (5th ed., *1955)* and the publications of the Purcell society. Other publications include the *Chacony* for string quartet *(1926)*; *Dido and Aeneas* with English and German text, ed. by E. J. Dent, and Dennis Arundell's life, *Henry Purcell* (both by the Oxford University Press, 1928); Henri Dupré, *Purcell* (Eng. trans., 1929); the life by W. Cummings in the "Great Musicians" series *(1903)* is a standard work. *See* also J. A. Westrup, *Purcell*, "Master Musicians" series *(1937)*.

PURCHAS, SAMUEL (c. 1577–1626), English compiler of works on travel and discovery, was born at Thaxted, Essex, and studied at St. John's college, Cambridge, and at Oxford. He was vicar first of a Thames-side parish in Essex and later in London (where he was also chaplain to Archbishop G. Abbot) and met many seafarers. As an editor and compiler he sought to interest the general public of his day. In this he was very successful though his works have been severely criticized by scholars. They are however an indispensable source of information and contain many references to original accounts of voyages. His writings include; *Purchas, His Pilgrimage; or, Relations of the World and the Religion observed in all ages* (1613; other editions 1614, 1617, 1626); *Purchas, His Pilgrim. Microcosmus, or the Historie of Man* (1619); and *Hakluytus Posthumus or Purchas His Pilgrimes*, 4 vol. (1625; 20 vol., 1905–07).

See E. G. R. Taylor, "Samuel Purchas," *Geogr. J.*, vol. lxxv, pp. 536–539 (1930). (A. M. F.)

PURE LINE. A pure line consists of a self-fertilized individual and its progeny; it is a group of individuals all possessing the same hereditary constitution; in which all the factors are present in duplicate. Until W. L. Johannsen studied the effects of selection on the weights of individual seeds of the Princess bean there was no general explanation of the manner in which this process operates (*see* ANIMAL BREEDING; GENETICS; HEREDITY; INBREEDING; MENDEL, GREGOR JOHANN).

PURGATORY, according to Roman Catholic faith, a state of suffering after death in which the souls of those who die in venial sin, and of those who still owe some debt of temporal punishment for mortal sin, are rendered fit to enter heaven. It is believed that such souls continue to be members of the church of Christ; that they are helped by the suffrages of the living — that is, by prayers, alms and other good works, and more especially by the sacrifice of the mass; and that, although delayed until "the last farthing is paid," their salvation is assured. Catholics support this doctrine chiefly by reference to the Jewish belief in the efficacy of prayer for the dead (2 Macc., xii, 42 *seq.)*, the tradition of the early Christians and the authority of the church.

The state of purgatory is usually thought of as having some position in space, and as being distinct from heaven and hell; but any theory as to its exact latitude and longitude, such as underlies Dante Alighieri's description, must be regarded as imaginative.

Most theologians since Thomas Aquinas and Bonaventura have taught that the souls in purgatory are tormented by material fire, but the Greeks have never accepted this opinion. It must be inferred from the whole practice of indulgences as at present authorized that the pains of purgatory are measurable by years and days; but here also everything is indefinite. The council of Trent, while it commands all bishops to teach "the sound doctrine of purgatory handed down by the venerable fathers and sacred councils," bids them exclude from popular addresses all the "more difficult and subtle questions relating to the subject which do not tend to edification."

The Eastern Church affirms belief in an intermediate state after death, but the belief is otherwise as vague as the expressions of the pre-Nicene fathers on the subject. The Longer Catechism of the Orthodox Church (Q. 376) states:

"Such souls as have departed with faith but without having had time to bring forth fruits meet for repentance may be aided towards the attainment of a blessed resurrection by prayers offered in their behalf, especially such as are offered in union with the oblation of the bloodless sacrifice of the Body and Blood of Christ, and by works of mercy done in faith for their memory."

The efficacy of prayers for the dead, and indirectly the doctrine of purgatory, were denied by early Gnostic, sects, by Aetius in the 4th century and by the Waldenses, Cathari, Albigenses and Lollards in the middle ages. Protestants, with the exception of a small minority in the Anglican communion, unanimously reject the doctrine of purgatory and affirm that "the souls of believers are at their death made perfect in holiness and do immediately pass into glory."

Rejection of an intermediate state after death follows the Protestant idea of justification by faith as logically as the doctrine of purgatory results from the Catholic idea of justification by works.

An analogy to purgatory can be traced in most religions. Zoroaster conducts souls through 12 stages before they are sufficiently purified to enter heaven; and the Stoics conceived of a middle place of enlightenment which they called *empurosis*.

BIBLIOGRAPHY. — The principal authoritative statements of the Catholic Church on the doctrine of purgatory were made at the council of Florence *(Decret. unionis)*, and at that of Trent (Sess. vi. can. *30;* Sess. xxii, c. 2, can. 3; Sess. xxv). *See* H. J. D. Denziger's *Enchiridion;* J. Bautz, *Das Fegfeuer* (1883) and L. Redner, *Das Fegfeuer* (1856). An elaborate treatise from the Catholic standpoint is that of Cardinal Bellarmine, *De purgatorio*. The subject is discussed, moreover, in all major works on dogmatic theology. There is a representative Catholic statement in the *Catholic Encyclopaedia*, and a Protestant presentation by Rud. Hoffmann in Herzog-Hauck's *Realencyklopädie*, 3rd ed., vol. v, pp. 788–792.

PURI, a town and administrative centre of a district of Orissa state: India. is situated on the shore of the Bay of Bengal. 311 mi. S.W. of Calcutta and 776 mi. N.E. of Madras. Pop. (1951) 49,057. The old name of the town was Purushottam Puri (the city of the Greatest Being), abbreviated to Puri in common usage. William Bruton. the first European to visit the town (1633). called it "the great city of Jaggarnat." As the seat of the well-known shrine of Jagannath (see JUGGERNAUT), Puri is one of the most sacred places of pilgrimage for Hindus. The temple of Jagannath was built in the 12th century by Choda Ganga (the greatest of the eastern Ganga kings) and consists of a suite of three chambers, the dancing hall, the audience hall and the sanctuary with its images. About two miles from the temple is the Garden house (Gundicha ghara), the retreat of Jagannath to which his image, mounted on a huge car or *rath* (followed by smaller cars of his brother and sister), is pulled by enthusiastic pilgrims during the car festival each summer. The rajas of Khurda, titular descendants of the ancient Hindu monarchs of Orissa, have been in charge of the temple since 1590. The town contains the summer castle of the state governor, the palace of the raja of Khurda, a college, an observatory and many hotels and hospices (*dharamsalas*). The beach of Puri attracts many tourists.

PURI DISTRICT is a country of alluvial plains with hills and woods in the north and northeast. Pop. (1951) 1,572,262; (1961) 1,865,834. Area 4,002 sq.mi. The main river is the Kuakhai (a branch of the Katjori) which itself divides into two branches, the Daya and the Bhargavi, both flowing into Chilka lake. Chilka is one of the largest lakes in India (length 44 mi.; breadth 13 mi. in the north and 5 mi. in the south). Dotted with islands, it is saline and shallow and most suitable for fish breeding. A large quantity of fish is exported. The district is rich in antiquities. At Dhauli hill are the rock edicts of Asoka (3rd century B.C.). Sisupalgarh is a fort of 2nd–1st century B.C. and Khandagiri contains the caves and inscriptions of Kharavela (1st century B.C.). Bhubaneswar (*q.v.*) is a city of temples and at Chandrabhaga is the Konarak (*q.v.*).

Khurda is the divisional headquarters of Eastern railway, and has an arts college. There is a science college at Nirakarpur, and Satyabadi (a Brahmin village) is famous for Krishna worship (*sakhigopal*). This village in modern times was associated with the experiment of an open-air school initiated by Gopabandhu Das. At Atri is a hot sulfur spring around which a big annual fair takes place.

Puri first came under the British in 1803. Later events were the rebellion of the raja of Khurda (1804) and the rising of the *paiks* (peasant militia) in 1817–18. More than one-third of the population is said to have perished in the Orissa famine of 1866.

(MA. M.; N. K. S.)

PURIFICATION. As used in anthropology, purification denotes the preparation of individuals or communities for contact with persons or things otherwise dangerous, or to prevent the consequences of such contact. A man may unwittingly violate a tabu and such is the sense of social solidarity that the whole community feels itself menaced until he is purified. Thus. "among most or all African tribes a sin, wrong doing or breach of custom is not merely a matter demanding punishment or redress but it imparts a bane or evil influence which remains unless the necessary purification follows. The point to be emphasized is that this mysterious force affects not the evildoer but the person injured. so that it is he who must be purified. For instance, a man who is wounded is purified by the one who wounded him." (C. Dundas, *Kilimanjaro* and *Its* People, 1924, p. 155.) In primitive societies women, and sometimes their husbands, may observe ritual cleansing after childbirth—a custom with modern parallels (see CHURCHING OF WOMEN). Puberty, marriage, warfare or bloodshed, and death are other common events often marked by purifying rites, which may entail the use of water (as in baptism), mutilation (as in circumcision), fasting. prayer and confession. Food often is surrounded by tabu'and ritual in modern, folk and primitive societies. Members of totemic clans commonly abstain from the flesh of the totem animal: foods freelv eaten bv one group may be avoided by others as contaminating. The persons, objects and situations requiring purification may be regarded as sacred or as profane.

See also CIRCUMCISION; LEVITICUS; PASSAGE RITES; RELIGION; RITUAL; TABU.

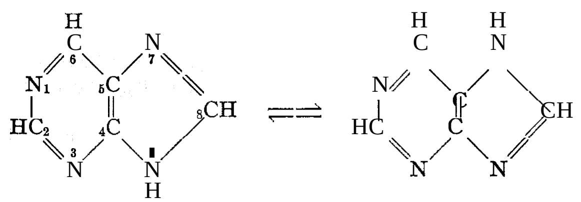
See Robert H. Lowie, *Primitive Religion* (1948); Paul Radin, *Primitive Religion* (1937).

PURIM, or the Feast of Lots, a Jenish festival celebrated on 14 Adar (February or March) and commemorating the deliverance of the Jews from the wrath of Haman, minister and favourite of the Persian king Ahasuerus. The events are related in the Book of Esther. she having been the heroine of the story. The 13th of Adar determined by lot, was set as the day on which all the Jews of Persia were to be destroyed. On that day the Jews defeated the Persians, and on the 14th they celebrated their victory and their deliverance. The Jews of Susa, who were attacked on the 14th, celebrated their triumph on the 15th; hence 15 Adar is called the Purim of Susa.

The festival is predominantly secular, having few of the religious and ethical elements of other Jewish feasts. It is celebrated with feasting, games and merriment, and since the middle ages has had a strongly carnival flavour. Purim plays, dealing often but not always with the Esther story, date from the 17th century.

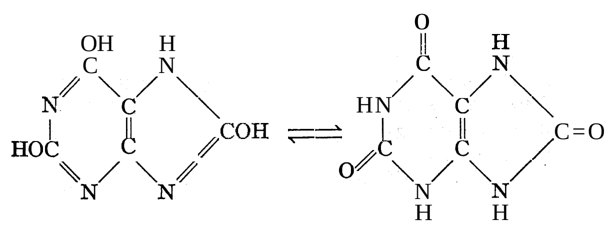
PURINES. The purines comprise a group of nitrogenous compounds, a few of which are of great importance in living cells. The first purine known was uric acid, which was discovered in human urinary calculi by the Swedish chemist, K. Scheele, in 1776. The naturally occurring purines include adenine and guanine, two essential building blocks of nucleic acids (*q* v.), a group of compounds regarded as carriers of hereditary characteristics. Another well-known purine is caffeine which, along with theobromine and theophylline, gives the stimulating effect to drinks made from coffee beans, tea leaves and cocoa beans.

Chemically, purines are structurally related to the pyrimidines. They are bases because of their nitrogen content. All purines are derived from purine itself, a substance with the empirical formula $C_5H_4N_4$. The structural formula of purine is shown in the following diagram.



Each atom is given a number, as indicated. The molecule can exist in two forms which are very readily interconvertible, a phenomenon known as tautomerization (see TAUTOMERISM). The change of structure in the tautomerization of purine consists of the migration of a labile hydrogen atom between the nitrogen atoms at position 7 and position 9.

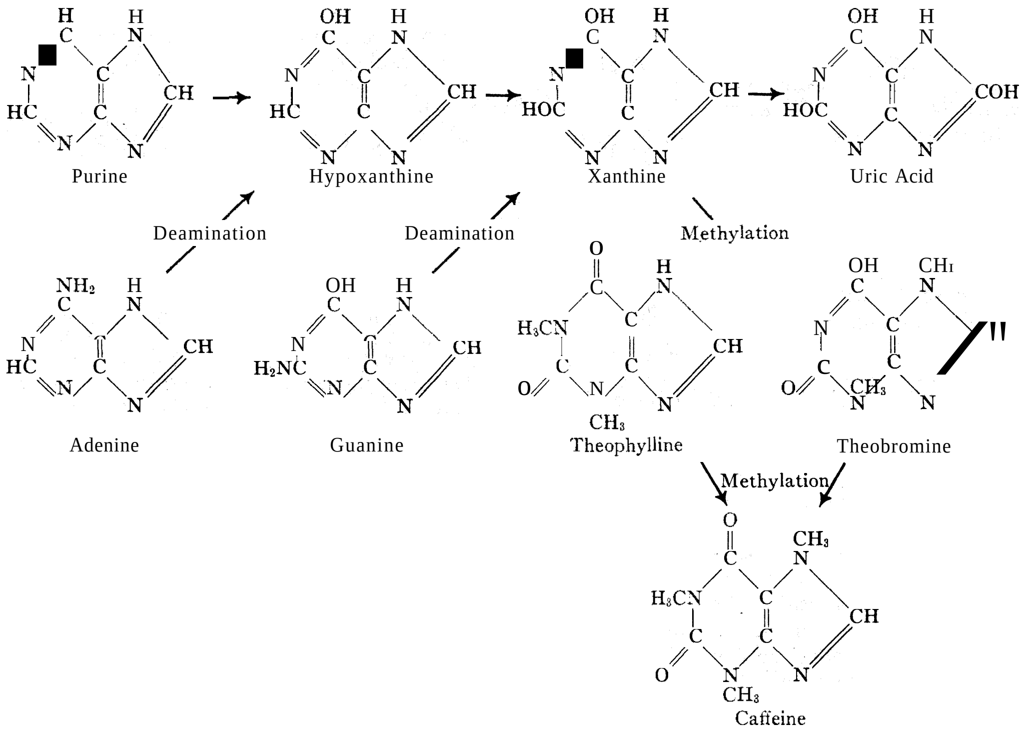
The four hydrogen atoms in purine (at positions 2, 6, 8 and either 7 or 9) may be substituted by other groups, such as hydroxyl (OH), amino-(NH_2) or methyl (CH_3) groups. When a hydroxyl group is introduced at position 2, 6 or 8, another type of tautomerization is possible, since the H of the OH group may migrate to a neighbouring nitrogen atom. For instance, uric acid, which is 2:6:8-trihydroxypurine, exists in two tautomeric forms, A and B as shown below.



A B

In form A, uric acid yields salts with metal ions, the hydrogen on oxygen being replaceable and thus making the substance an acid. Form B explains why substitution may occur on the 1 and 3 nitrogen atoms as in the methylated purines such as caffeine.

The following diagram outlines the relationships between the various naturally occurring purines. Starting with purine, and successively substituting hydroxyl groups for the hydrogen atoms attached to carbon. hypoxanthine, xanthine and uric acid are ob-



tained. Most living cells can synthesize the important purines adenine and guanine from simpler precursors *(see* NUCLEIC ACIDS). Ingested purines, as well as those formed within the cell, are eventually oxidized to uric acid.

In man, this substance is excreted in the urine as the main end-product of purine metabolism. Other mammals excrete allantoin, a degradation product of uric acid. In reptiles and birds, however, uric acid is the main nitrogenous end product of protein as well as of purine metabolism. The excrement of birds and snakes, therefore, consists mainly of uric acid.

A rich source of uric acid, guano, the excrement of certain South American sea birds, has been accumulating, with the help of a dry climate, for untold years.

Because uric acid and its monosodium salt are relatively insoluble, they are readily precipitated. Such precipitates constitute the painful nodules characteristic of the disease gout in human beings.

The pig is deficient in enzymes which convert guanine to allantoin, and consequently the pig frequently suffers from a form of gout similar in all respects to that in humans, except that the deposit in the joints consists of crystalline guanine instead of acid sodium urate.

Much of the fundamental work on purine chemistry was done by the German chemist, Emil Fischer, who coined the name purine from the Latin words *purum* and *uricum,* the latter being chosen because the best-known purine at that time, uric acid, occurs in the urine.

Any modern text book of biochemistry will give further information on this subject. (B. V.)

PURITANISM, the most dynamic form of Protestantism among English-speaking peoples during the 16th and 17th centuries. The age of Puritanism in England may be roughly defined as the century following the Reformation (*q.v.*). It extended from the first years of the reign of Elizabeth I to 1660, when the restoration of the Stuarts brought to an end the attempt to fashion a Puritan state. The Puritan age in New England dated from the first settlement in 1620 to Massachusetts' loss of the old charter and the issuance of a new one in 1691, although there was to be a brief attempt to reconstitute the old order upon a new basis during the 1730s under the leadership of Jonathan Edwards.

The term Puritan was coined as an epithet of contempt during the 1560s, and it was applied to all those persons within the Church of England who sought a more thoroughgoing reformation of the church than had been provided by the Elizabethan religious settlement. It also came to be applied to those who broke away from the Church of England in order to carry out the desired reforms without further delay. The major body of Puritans were Anglicans and remained so until the outbreak of the English Civil War in 1642 *(see* CIVIL WAR, ENGLISH). Most of them were moderate episcopalians in sympathy, although presbyterian and congregationalist sentiment was to be found among them. Even the early Congregationalists of the Massachusetts Bay colony in North America professed themselves to be loyal members of the Church of England. The small non-Anglican wing of Puritanism was composed initially of "separatist" Congregationalists and Baptists, but during the regime of Oliver Cromwell, when religious groups multiplied in a vast profusion, the Society of Friends (Quakers), constituted the extreme left of the Puritan movement.

In North America there was a varying degree of Puritan influence in all the English colonies, but the term tended to be reserved to designate the "separatist" and "nonseparatist" Congregationalists who established the Plymouth and Massachusetts Bay colonies and spread out into the rest of what was to become known as New England.

Nature of Puritanism. — Puritanism arose put of a desire for liturgical reform, being given classic definition at its earliest stage by G. M. Trevelyan: "the religion of all those who wished either to 'purify' the usage of the established church from taint of popery or to worship separately by forms so 'purified' " *(England under the Stuarts,* 16th ed., London, 1933). Questions of polity and theology later mere brought into the area of controversy, but the underlying spirit of religious and moral earnestness that had given rise to the initial demand for reform remained the most constant feature of Puritanism. As a consequence, a Puritan became identified quite correctly in the popular mind as one who followed a strict and closely regulated habit of life. Edwards gave expression to this aspect of Puritanism when he described the Christian's "practice of religion" in these words: "It may be said, not only to be his business at certain seasons, the business of Sabbath-days, or certain extraordinary times, or the business of a month, or a year, or of seven years, or his business under certain circumstances; but *the busines of his life" (The Works of Jonathan Edwards,* vol. i, p. 314, 10th ed., London, 1865). The Puritan was a spiritual athlete, characterized by an intense zeal for reform, a zeal to order everything — personal life, family life, worship, church, business affairs, political views, even recreation — in the light of God's demand upon him.

The daily routine of the Puritan usually involved private devotions at the hour of rising; family prayers with the reading of Scripture and the catechizing of children and servants; and the keeping of a spiritual diary in which the events of the day were closely scrutinized and an accounting made of moral successes and failures as well as note being taken of the signal evidences of divine grace or displeasure that had been disclosed during the course of the day. The whole thrust of Puritan preaching was designed to reinforce this systematic and carefully controlled pattern of life by sensitizing the conscience to the issues that must be faced from day to day by earnest Christians. A non-Puritan clergyman, Anthony Gilbert, in 1566 put this aspect of Puritanism vividly when he reported that his patron had said that "he could never go to any of these Genevan sermons that he came quiet home, ... there was ever something that pricked his conscience; he always thought that they made their whole sermon against him. But in the reading of Mattins and Evensong at [St.] Paul's, or in my reading of my service in his chapel, he sayeth, he feeleth no such thing, for he is never touched, but goeth merrily to his dinner."

These differing facets of the Puritan's concern make it evident that Puritanism was rooted in a vast sense of dissatisfaction with mediocre and halfhearted endeavour. This dissatisfaction, in turn, was rooted in a deep religious experience of dramatic intensity. The whole object of the Puritan mas to experience the miracle of grace himself and to produce it in others. Thus Puritanism falls within the category of a religious revival, and it is analogous in many ways to earlier revivals that sprang from the preaching of the friars and to the later revivals associated with the names of John Wesley, George Whitefield and Gilbert Tennent.

Tudor Puritanism. — Under Henry VIII the authority of the Roman papacy had been formally abolished by a series of parliamentary acts, culminating in the Act of Supremacy of 1534, which declared the king to be "the only supreme head in earth of the Church of England." The few limited reforms of the Henrician period were followed by a rapid Protestant advance under the boy king Edward VI (1547–53). This was followed, in turn, by a restoration of Roman Catholicism under Queen Mary (1553–58). Many of the more prominent Protestant leaders, including the archbishop of Canterbury, were burned at the stake during the Marian regime; the revulsion occasioned by these executions, it has been said, guaranteed that England was to be a Protestant nation in the future. Of greater importance was the fact that the exile on the continent, into which many younger men were forced, proved to be a school for training of men upon whom Elizabeth of necessity was to depend for leadership in the English Church. When Elizabeth I came to the throne late in 1558, she was hailed by the returning exiles as the English Deborah who would restore the Church of England to what they regarded as its pristine purity. She was to frustrate rather than fulfill their hopes.

Elizabeth was committed to the Protestant cause for a variety of reasons, but she detested anything that smacked of Geneva, having been alienated by John Knox's attack upon the right of women to rule and being convinced that the Genevans were "overbold with God Almighty, making too many subtle scannings of his blessed will, as lawyers do with human testaments." It was, she believed, dangerous to royal power to have private men citing Scripture against the government. Elizabeth was determined to exercise power in both state and church as her royal prerogative, and she was especially determined that the religious settlement should follow a middle course. Under pressure from the crown parliament passed an Act of Uniformity which required several observances that most Protestants regarded as popish superstitions. It was at this point, hoxever, that a division occurred. Some remembered Peter's word that one must obey God rather than men; these were to be the Puritans. Others remembered Paul's counsel that due regard must be given to constituted authority; these were to be the apologists for the Elizabethan settlement who insisted that a godly prince, after the pattern of Israel, must be obeyed in all matters not clearly proscribed in Scripture.

The initial controversy had been foreshadowed in the reign of Edward VI when Knox objected to kneeling as a practice associated with the adoration of the host and indicating a belief in transubstantiation, and when John Hooper objected to a distinctive clerical garb as representing in symbolic form a denial of the priesthood of believers. It was this latter issue that came to the front with the publication of Matthew Parker's *Advertisements* in 1566 as part of the effort to secure uniformity of clerical dress, and resulted in the label of "Puritan" being attached to the dissident party. The Puritans, of course, were seeking to reform the whole liturgy of the church that it might have greater theological integrity; and a rightly ordered worship, they believed, also involved the recovery of gospel discipline within the church. Their program was made explicit in 1572 in *An Admonition to Parliament,* which declared that "we in England are so far off from having a church rightly reformed according to the prescript of God's Word, that as yet we are not come to the outward face of the same." The "outward marks whereby a true Christian church is known," it continued, "are preaching of the Word purely, ministering of the sacraments sincerely, and ecclesiastical discipline which consisteth in admonition and correction of faults severely"; on all three counts the provisions of the Elizabethan settlement were deemed defective.

Puritan sentiment was strong enough in 1563 to come within one vote of adopting a sweeping program of reform in the Convocation of Canterbury, the legislative body for most of the Church of England. Defeated there, the Puritans turned to parliament where they were able to command majority support throughout Elizabeth's reign, but Elizabeth always claimed her prerogative and prevented parliament from dealing with the religious question. Edmund Grindal, archbishop of Canterbury, encouraged the voluntary implementation of a portion of the Puritan program, and this led to his being sequestered from office. While official efforts at reform were rebuffed by the queen, and while she was careful to prevent any widespread organization from being developed, a great deal of latitude and freedom was permitted within the parishes; and it was within the parishes, by virtue of effective preaching and pastoral example, that Puritanism continued to gain strength throughout the Elizabethan period. During this period also there were a few ardent and impetuous spirits who had become impatient with delay and who, adopting as their slogan "reformation without tarrying for any," proceeded to organize "separate" congregations. Ultimately most of these separatists were forced to take refuge in the Netherlands.

Stuart Puritanism. — Puritan confidence in the rightness of their cause may well have been the source of the optimism with which they greeted each new monarch. They were especially hopeful when after Elizabeth's death James I came to the throne in 1603. A dozen years earlier, as James VI of Scotland, he had consented to the establishment of Presbyterianism in his native land. The Puritans believed, therefore, that he might be expected to show some favour to Puritanism in England. With high expectations the Puritans presented the new king with a moderate plea for church reform known as the Millenary petition because it purported to represent the desires of more than 1.000 clergymen. The king promised a conference at Hampton court on the matter. When he met with them in Jan. 1604, he rejected the Puritan plea with scorn. James was an ardent Calvinist, but he was no presbyterian; far from restricting the power of the bishops, his dictum was "No bishop, no king."

One consequence of James's attempted repression of Puritanism was to drive additional Puritans into separatism and exile. Among these groups of exiles was the Gainsborough-Scrooby congregation, one portion of which went to Amsterdam under the leadership of John Smyth, where they became the earliest group of English Baptists. The Scrooby portion under the leadership of John Robinson went to Leiden, from which in 1620 some of their number departed to establish the colony of Plymouth in the new world. Other Puritans, unwilling to renounce all bonds of fellowship with the Church of England, adopted a middle position which has been called nonseparatist congregationalism. Chiefly under the guidance of Henry Jacob and William Ames, they developed the theory that the Church of England was in essence composed of congregational churches; this fact had been obscured but it had not been obliterated. Thus they were justified in forming independent congregations when necessary and at the same time professing themselves to be loyal members of the Church of England. Nonseparatists of this type established the Massachusetts Bay colony in 1629.

James I, however, was not an effective persecutor, and his policy was moderated by the influence of Archbishop George Abbot, who was sympathetic to the Puritan cause. By virtue of various expedients, many of the clergy were able to retain a measure of freedom in their parishes, and a system of lectureships was developed to provide for those who could not. The lectureships were preaching stations set up voluntarily, and they permitted the occupants to escape from the necessity of reading the required service. Serious trouble developed only after the accession of Charles I in 1625. Under the aegis of William Laud (*q.v.*), archbishop of Canterbury, rigorous measures were adopted to enforce conformity, lectureships were suppressed and when parliament proved to be refractory Charles embarked upon a period of personal rule that lasted through the 1630s.

Puritan Revolution. — As the result of an attempt to impose "Laud's liturgy" on the Scottish Church, Scotland rose in revolt and in 1639 invaded England. Charles was without adequate financial resources to carry on a war and was forced to summon parliament in 1640. Parliament immediately took command of the situation, refusing to grant necessary subsidies until the abuses of Charles's personal rule had been remedied. There was general agreement that the evils of prelacy should be eliminated, but when parliament abolished episcopacy the king was able to rally support; civil war broke out in 1642 (*see* CIVIL WAR, ENGLISH). The Westminster assembly of divines was summoned in 1643 to draft a new religious settlement for the nation, but its essentially presbyterian proposals were unsatisfactory for a variety of reasons to a majority of the people. The more erastian members of parliament did not look with favour upon the establishment of an independent ecclesiastical system. Large segments of the population remained strongly episcopalian in their sympathies. There had also been a vast proliferation of smaller religious groups since the lifting of the restraints of the Laudien regime. Furthermore, the Puritan preachers, who for three generations had been insisting upon the necessity for the Word of God to be freely preached, had cultivated a climate of opinion among many of their followers that was hostile to the placing of new restrictions upon the freedom to preach. Most important of all, widespread sentiment for religious toleration had developed in the parliamentary army. This was "the good old cause" that held the army together in its struggle with the king, and to the army the proposals of the assembly represented the substitution of one repressive ecclesiastical system for another. John Milton spoke for the army when he said: "New presbyter is but old priest writ large."

With parliament becoming increasingly divided and impotent, effective rule shifted to the army under the leadership of Cromwell. The royalists were brought under control in a series of battles, the king was executed and the religious problem was resolved in terms of a voluntary national establishment. Cromwell was less successful in his efforts to shift authority from the army to a stable parliamentary regime. The nation was too divided for any of the expedients he devised to succeed. After his death and the removal of his strong hand, the political situation rapidly deteriorated, and in 1660 the Puritan attempt to fashion a holy commonwealth was brought to an end with the restoration of the monarchy. The religious issue remained troublesome, however, until the adoption of the Act of Toleration in 1689.

American Puritanism. — The term Puritan has been given a much narrower definition in the United States. There was a conspicuous Puritan influence in early Virginia, and the blue laws of that colony have been said to have been even more repressive than those of New England. Moreover a Puritan influence was represented to varying degrees in all the English colonies by Baptists, Quakers and English Presbyterians. Puritanism in America, however, is generally understood to mean the early Congregationalism of New England.

Massachusetts Bay, the strongest of the New England colonies, was founded by a group of nonseparatist Congregationalists who had become convinced — as a result of the dissolution of parliament in 1629 by Charles I and the adoption of the rigorous repressive measures of Laud — that it was no longer possible to reform the Anglican Churc'n in England. Through a defect in the charter they were able to transfer the government of the colony to the new world, and throughout the Laudian decade of the 1630s a large and well-organized migration into the new colony proceeded. No colony in the history of European colonization ranked above Massachusetts Bay in wealth, station, education or capacity. The colonists were a selected people ("sifted grain") with strong clerical leadership, and their purpose was to accomplish in the new world that which they had been prevented from accomplishing at home. Their intention was to create in the American wilderness a new Zion that would become "a city set on a hill" and force by the power of its example the desired reformation in England.

The Massachusetts Bay Puritans established what they believed to be a biblical church order and with it a community that was regulated throughout by divine and natural law. The whole program was outlined in the *Cambridge Platform* of 1648. Church membership was restricted to the regenerate and their children who should "own the covenant," and only church members enjoyed political rights. Religious uniformity was enforced, and dissenters were informed that they had the right to stay away or to cross the river and take up land of their own beyond the boundary of Massachusetts. The restrictions were difficult to maintain; there were demands that the franchise be broadened and religious dissent kept appearing. When Roger Williams was banished, the settlement he established at Providence became a new source of dissidence. The second generation saw a diminution of zeal. The clergy interpreted recurrent misfortunes as signs of God's wrath with the growing laxity, but the adoption of the "halfway covenant" was evidence of clerical inability to halt the trend. The replacement of the charter in 1691 put an end to any real hope they still entertained of maintaining their holy commonwealth in its purity. The story was much the same in the other Puritan colonies of New England. Edwards briefly rallied the waning forces of Puritan zeal, and attenuated Congregational establishments lingered on in Massachusetts, Connecticut and New Hampshire until the 19th century. The Puritan heritage, however, was stamped deep in the character of the New Englanders, and with the great migration westward it became a major factor in the shaping of the American spirit.

Puritan Contributions. — One of the most conspicuous contributions of Puritanism was the sturdiness of character it produced. "The Puritan mind was one of the toughest the world has ever had to deal with. It is inconceivable to conceive of a disillusioned Puritan; no matter what misfortune befell him, no matter how often or how tragically his fellowmen failed him, he would have been prepared for the worst, and would have expected no better" (Perry Miller and T. H. Johnson, *The Puritans*, pp. 59–60, New York, 1938). The Puritan knew that the life of faith is an arduous struggle, that sin is a stubborn fact of human existence and that affliction is frequently the lot of the saints; but he was nerved and strengthened by a great devotion to God and by a great confidence in God's overruling Providence. Later generations were fed again and again from the devotional works the Puritans produced.

Curiously, the Puritans, who began as firm believers in the necessity for religious uniformity, became the architects who fashioned the principles of religious freedom. This was partly the result of the fact that the religious diversity they generated bred of necessity a spirit of toleration, but the necessity was supported by theological convictions whose implications only gradually became fully apparent. They had emphasized the necessity for the Word of God to be freely preached, and they recognized that even the best of men and churches were fallible. Who was to decide who might preach, when God might speak through the humblest of the brethern? Thus the New England Puritans could pursue measures of repression only with a lurking sense of guilt, elaborate apologetics and a tendency to make increasing concessions to dissent. More typical of the logic of Puritanism was Williams' *Bloudy Tenent of Persecution*, which became one of the great Puritan manifestoes in the English civil wars.

Many scholars have noted the contribution of Puritanism to the development of democracy. The army debates, the gathered churches, the demand for liberty and the denunciations of arbitrary power all helped create a climate of opinion favourable to the development of self-government. Even more important was the insistence upon the necessity for checks and balances if the abuse of power was to be prevented. Said John Cotton: "Let all the world learn to give mortal man no greater power than they are content they shall use, for use it they will . . . . It is necessary that all power that is on earth be limited, church power or other. . . . It is counted a matter of danger to the state to limit prerogatives, but it is a further danger not to have them limited" *(An Exposition of the Thirteenth Chapter of Revelation,* p. 72). The relationship that has been suggested between Puritanism and the rise of modern capitalism is more debatable. *See* also Index references under "Puritanism" in the Index volume.

BIBLIOGRAPHY.—William Haller, *The Rise of Puritanism* (1938), and *Liberty and Reformation in the Puritan Revolution* (1955); I. D. Jones, *The English Revolution* (1931); M. M. Knappen, *Tudor Puritanism* (1939); Perry Miller, *Orthodoxy in Massachusetts* (1933), *The New England Mind: The Seventeenth Century* rev. ed. (1954) and *The New England Mind: From Colony to Province* (1953); Alan Simpson, *Puritanism in Old and New England* (1955). (W. S. H.)

PURITY, BRETHREN OF, the usual English designation of the IKHWAN AS-SAFA' (*i.e.,* "Sincere Brethren"), an Arabic secret confraternity who produced, probably in the second half of the 10th century A.D., a philosophical and religious encyclopaedia consisting of 52 "writings" (Arabic *rasa'il;* sing. *risala)* by different authors. The contents of this encyclopaedia appealed to the Ismailian movement, but its authors were not Ismaili themselves. As all other Islamic philosophers, they attempted to naturalize Greek philosophy in a way of their own, but they differ from other Islamic philosophers in following a more orthodox Neoplatonic line and in admitting Hermetic, Gnostic, astrological and occult sciences on a large scale. According to them, the individual human souls emanate from the universal soul and rejoin it after death; and the universal soul in its turn will be united with God on the day of the Last Judgment.

Rasa'il 1–14 deal with the preparatory sciences such as mathematics, astronomy and astrology, music, geography and the different parts of Aristotelian logic *(risala* 13 was translated into Latin in the middle ages); *rasa'il* 15–31 with the natural sciences in the order established by the later Greek commentators of Aristotle and also with man as a microcosm, with the human soul, with the influence of the stars and with the difference of languages *(see* below for *risala* 22); *rasa'il* 32–41 with the spiritual world on Neoplatonic lines, with the final destruction of the world, with the longing of the soul for God and its spiritual resurrection, etc.; and *rasa'il* 42–52 with various aspects of the revealed divine law, with the mutual duties of the brethren, with prophetic revelation and with miracles, magic, etc. There is also an important summary of the whole encyclopaedia, *Ar-Risala al-Jami'a. Risala* 22 tells the story of a dispute between animals and men before the king of the genii (in which the animals eventually lose). This story was translated into Catalan by a Franciscan friar, Anselmo de Turmeda, in 1417 (he represented it as his own original work) and into English by way of a Hindustani version, by J. Wall (1863).

Apart from Arabic editions of the whole encyclopaedia, 4 vol. (1888–89), and of the summary, critical ed., 2 vol. (1949–51), there are German translations of several of the *rasa'il* by F. Dieterici *(Die Naturanschauung und Naturphilosophie der Araber . . . ,* 2 parts, 1876–79; and *Die Abhandlungen der Ichwan es-Safa im Auswahl,* 3 parts, 1883–86). Dieterici, however, was unaware of certain Islamic aspects of the work and overrated its philosophical importance.

BIBLIOGRAPHY.—Adel Arva, *L'Esprit critique des "Frères de la Pureté"* (1948); F. Goldziher, *Richtungen der islamischen Koranauslegung* (1920); C. Brockelmann, *Geschichte der arabischen Litteratur,* i, 2nd ed., pp. 236–237 (1943). (R. R. WR.)

PURKINJE, JOHANNES EVANGELISTA (JAN EVANGELISTA PUPKYNE) (1787–1869), Czech physiologist, a pioneer in experimental physiology, histology and embryology, was born in Libochovice, near Prague, Dec. 17, 1787. In 1823 he became professor of physiology and pathology at Breslau university, where he began a course of experimental physiology, established a small laboratory and created an independent department of physiology (1839), the first of its kind. He established another after becoming professor at Prague university (1850). He died in Prague, July 28, 1869.

Purkinje's scientific work was extremely varied, the most important concerning vision and microscopy. He noticed similar granular formations in different animal tissues and drew attention to the analogy of these animal granules (Ger. *Kornchen)* with the vegetal cells (1837), and introduced the term protoplasm. Some of his discoveries bear his name: Purkinje's cells in the cerebellar cortex; Purkinje's fibres; the large heart muscle cells beneath the endocardium, forming Purkinje's network; Purkinje's germinal vesicle, the nucleus of the ovum; Purkinje's figure, the shadows of the retinal vessels; Purkinje's images, the reflections on the surfaces of cornea and lens of the eye; Purkinje's phenomenon, the change in the brightness of blue and red in the dark.

Publication of Purkinje's *Omnia Opera* began in 1918, and by 1960 eight volumes had appeared.

BIBLIOGRAPHY.—R. Heidenhain in *Allgemeine Deutsche Biographie,* 26:717 (1888); V. Robinson, *Pathfinders in Medicine* (1929); H. J. John, *Proc. Roy. Soc. Med.,* 46:933 (1953). (V. O. KR.)

PURNEA, a town and district in the Bhagalpur division of Bihar state, India. The town, with a railway station, is on the little Saura river. Pop. (1951) 25,060.

PURNEA DISTRICT has an area of 4,299 sq.mi. and a population (1951) of 2,252,159. It extends from the Ganges northward to the frontier of Nepal. It is a level tract of country, traversed by several rivers flowing from the Himalayas, the greatest of which is the Kosi, which has been known to move 20 mi. in 25 years, leaving behind it a trail of sterile sand. A scheme to control its water was planned in the late 1950s. The principal crops are rice, pulses and oilseeds. Although the cultivation of indigo has declined. that of jute has greatly increased.

The district is served by the North-Eastern railway. Kishanganj (pop. [1951] 15,903) is a centre of the jute trade and a branch terminus on that railway.

PURNELL, THOMAS (1834–1889), English author, was born in Tenby, Pembrokeshire, in 1834. He studied at Trinity college, Dublin, and was assistant secretary and librarian of the Archaeological Institute of Great Britain and Ireland, 1862–66. In 1871 he published *Dramatists of the Present Day,* a reprint of his series of articles which first appeared in 1870–71 in the *Athenaeum* under the pseudonym "Q." He also edited Charles Lamb's *Correspondence and Works* (1871).

PURPLE, a shade varying between crimson and violet. Formerly it was the deep crimson colour called in Latin *purpura,* from the name of the shellfish *(Purpura)* which yielded the famous Tyrian dye. Tyrian purple during many ages was the most celebrated of all dyed colours, and possibly the first to be permanently fixed on wool or linen. Being extremely costly, robes of this colour were worn as a mark of imperial or royal rank, whence the phrase "born in the purple." In the Roman Catholic church "promotion to the purple" is promotion to the rank of cardinal.

The ancients derived their purple from the molluscs, *Purpura haemastoma,* and *Murex brandaris,* the shells of which have been found adjacent to ancient dyeworks at Athens and Pompeii. The colour-producing secretion is contained in a small cyst adjacent to the head of the animal, and this pus-like matter when spread on textile material in presence of sunlight develops a purple-red colour. P. Friedlander has shown that the dye developed from the molluscs is 6:6'-dibromoindigotin. (A. G. P.; X.)

PURPURA is the presence of large (ecchyrnoses) and small (petechiae) hemorrhages in the skin, often associated with bleeding from natural cavities and in tissues. It occurs as a result of failure of hemostasis which, in turn, has five major causes:

1. Damage to the wall of small arterial vessels (vascular purpura), due to vitamin deficiency (scurvy), bacteria, viruses, allergic reactions, etc. A hereditary disease in which the vessels appear normal but cannot contract after injury is known as pseudohemophilia.

2. Deficiency of platelets, small bodies that not only plug leakages in the vessel wall mechanically but also contain many chemicals active in the coagulation of blood. Bleeding occurs when platelets are insufficient in number (thrombocytopenia) either because they are not produced (as a result of destruction of

the precursor megakaryocytes in the bone marrow, due to invasion by leukemia or to aplasia induced by drugs or by radiation injury) or because they are too quickly destroyed by an overactive spleen or by antibodies (immunothrombocytopenia). Platelet antibodies develop in the course of other diseases (such as lupus erythematosus; *see* Lupus) or may be evoked by allergy to viruses, bacteria or certain drugs. Spleen and antibodies are usually associated in destroying platelets. In one variety of the disease (thrombocytoasthenia) the platelets are normal in number but abnormal in function.

3. Deficiency of clotting factors, either congenital as in hemophilia, Christmas disease, hypoprothrombinemia. afibrinogenemia, etc.) or acquired in the course of disease (especially of liver), administration of drugs (anticoagulants, etc.).

4. Development of circulating anticoagulants of various types (abnormal proteins, antibodies, etc.) that prevent normal interaction of the various clotting factors and are found in some blood disorders (multiple myeloma, leukemias, etc.), following reactions to drugs, in diseases of the connective tissue and in radiation injury.

5. Fibrinolysis. due to the activation of a usually dormant system that is able to destroy the blood fibrin clot; this may occur during accidents of pregnancy, delivery and surgery. A paradoxical type of bleeding is found when tissue materials (as in shock, trauma, burns, etc.) enter the blood stream and cause clotting within the vessels. As the patient is depleted of clotting factors, he becomes a bleeder. This mechanism is often found behind severe hemorrhage at delivery.

Treatment of purpura depends on the causative mechanism. ACTH and steroid hormones are effective in controlling vascular purpura and the bleeding of thrombocytopenia. Transfusion of platelets may be a useful technique for bleeding emergency, and surgical removal of the spleen is resorted to in thrombocytopenic purpura when other therapy has failed. The administration of either blood or plasma or of the fractions specifically absent (fibrinogen, antihemophilic globulin, etc.) is the basis of the treatment of acute bleeding in disorders of blood coagulation. *See* also Blood; Haemorrhage.

See M. Stefanini and W. Dameshek, *Henzorrhagic Disorders* (1955). (M. St.)

PURRAH, Purroh or Poro, a secret society of Sierra Leone, Africa. Only males are admitted to its ranks while the Bundu is strictly reserved to women.

The Purrah had its special ritual and language, markings and symbols and exercised authority by the imposition of tabus which mere enforced by various methods. In 1897 the British local government was compelled to pass a special ordinance absolutely forbidding the imposition of the tabu on all indigenous products.

See T. J. Alldridge, *The Sherbro and its Hinterland* (1901); *N.* W. Thomas, *Anthropological Report on Sierra Leone,* Part *I. (Law and Custom of the Timne and other bribes).*

PURSH, FREDERICK (1774–1820), American botanist, was born at Tobolsk, Siberia, in 1774. He received his education in Dresden. Germany. In 1799 he went to the United States where he devoted 12 years to botanical exploration and the scientific study of North American plants. In 1811 he visited England and in 1814 he brought out in London his important *Flora Americae Septentrionalis.* He then returned to the U.S. and resumed his botanical investigations. On one of his solitary tours afoot he discovered the hart's-tongue (*q.v.*), one of the rarest of the ferns in North America.

Pursh died at Montreal, Que., June 11, 1820.

PURSLANE, the common name for a small fleshy annual with prostrate stems, entire leaves and small yellow flowers, known botanically as *Portulaca oleracea,* family Portulacaceae (*q.v.*). It is a native of India, which was introduced into Europe as a salad plant, and in some countries has spread so as to become a noxious weed. Besides the common purslane, about ten other species occur in North America, chiefly in the southern United States. Some of the species of the same genus, such as P. *grandiflora* and its varieties, are grown in gardens on rockwork. The purslane is found in England but is rare.

The persistence of purslane plants is due to their ability to retain moisture and thus blossom and ripen seeds long after they have been removed from the soil. The capsules opening by a lid produce many small seeds of great longevity.

PURSUIVANT, a member of the third and lowest rank of heraldic officers, formerly an attendant on the heralds.

PURVA MIMAMSA, one of the six schools of thought to which Indian philosophers adhered in the centuries following the Epic period. *See* Indian Philosophy: *Six Systems.*

PURVEYANCE was a prerogative of purchasing goods for the royal household enjoyed by all English kings up to Charles II. Certain officers attached to the king's court were charged with the duties of buying and arranging for the cartage of goods where necessary, the ancient prerogative of the king entitling him to demand carriage services from his subjects. The possibilities of abuse were obvious. Magna Carta (*q.v.*) ordered that goods should be paid for at once and that horses and carts should not be taken for carriage duty nor timber taken for castles without the consent of the oaner. These stringent regulations were considerably modified to the king's advantage in later issues of the charter.

Many early statutes were passed against purveyance. People particularly resented the exercise of this right by royal officials and ministers for their own benefit. Statutes therefore limited its use to the immediate households of the king and queen. The name purveyor was so much hated that it was provided by statute that it should be changed to *achatour* (buyer). But statutes had little effect. In Elizabeth's reign complaints against purveyance were particularly bitter. In her early years the queen seems to have made use of her rights of purveyance to victual her navy. Later an arrangement was made by which some, if not all, counties agreed to furnish definite provisions at a fixed rate in order to get rid of the uncertainty which made the burden so much heavier. These compositions were arranged between the officers of the Board of Green Cloth and the Justices of Peace for each county at fixed prices. These fixed prices were very much lower than the market value of the goods and the difference was met by an assessment on the county. Cattle supplied in this way were kept in certain royal pastures. The parliaments of James I determined to get rid of the abuses of purveyance, and Sir Francis Bacon made a famous speech against the purveyors in the first parliament of the reign. It was held that only the abolition of the right would put an end to its abuse. The purveyors made a practice of demanding far more goods than were necessary and sold the surplus for their own advantage. They ordered goods to be taken to remote places that people might buy from them exemption from coming with their portions. There were innumerable ways in which purveyors could make dishonest profit. Despite complaints, the right of purveyance went on until it fell into disuse during the Commonwealth. Its abolition was part of the Restoration settlement, though until the end of the century it was sometimes partially revived during royal progresses. (D. M. S.)

PURVITS, VILHELMS KARLIS (1872–1945), Latvian landscape painter who introduced Impressionism into northeastern Europe, was born in Zaube rural district on March 3, 1872, and attended a secondary school in Latgale province. He later abandoned his father's milling business for painting, graduating from St. Petersburg academy in 1897; awarded a Rome prize, he traveled widely in western Europe. After teaching at Tallinn cathedral school (1906–09) he directed the Riga state art school until it was closed in 1916; from 1913, when he was elected academician of St. Petersburg academy, he was also director of the state museum and professor at Riga university.

Purvits organized the independent Latvian Academy of Arts in 1919 and was its rector and professor until 1934. In 1934–36 he edited a history of art. From Impressionism he developed the Baltic landscape style; later, his methodical compositions became more colourful and expressionistic.

Many of his pictures were destroyed by military action at Jelgava, Latvia, in July 1944; others, evacuated to Bavaria, disappeared. A refugee, Purvits died at Nauheim, Hesse, Ger., on Jan. 18, 1945.

PUSA, a village in Bihar, India, about 40 mi. N.E. of Patna. The government acquired an estate there in 1796 which was long used as a stud depot and afterward as a tobacco farm. The estate, which covered 1,280 ac., was made over in 1904 to the imperial agricultural department of the government of India, of which department it was the headquarters. In 1905 a research institute was founded with an experimental farm and an agricultural college at which officers were trained for higher posts in the agricultural departments.

The institute owed its inception to Lord Curzon, then viceroy; it rendered very useful service to Indian agriculture. A. and G. L. C. Howard produced strains of wheat which gave high yield and were of good milling quality; they had power of resistance to rust and gave good results under diverse conditions of soil and climate.

The Pusa varieties were in their day grown over large tracts of the United Provinces, the Punjab and the North-West Frontier province. E. J. Butler carried out masterly researches there on fungus pests, as did H. M. Lefroy on insect pests troublesome in India. B. P. Pal and other Indian agricultural scientists also did good work. The advantages of selective breeding of cattle were demonstrated; the milk yield of a pure herd was by this method doubled in ten years.

The institute always suffered from its isolated position, and when in 1934 an earthquake destroyed the main block of laboratories it was decided to transfer the work to New Delhi and to found a great central research institute there. This plan was duly executed, and the new Indian Agricultural Research institute was opened on Nov. 7, 1936, by the viceroy, Lord Linlithgow. The associated Central College of Agriculture is connected with Delhi university.

The road on which the institute buildings stand is called Pusa road. (E. J. R.)

PUSAN (Japanese FUSAN), a city located along a deep, well-sheltered bay at the southeast tip of Korea, facing the Korean strait. During Japanese control (1910–1945) Pusan became the major Korean port. Ferry services connected it to Shimonoseki, Japan. Rail lines through Korea to Manchuria and China terminated in Pusan. Industries, including shipbuilding, iron and steel, railroad shops and textile manufacturing were developed. Rice milling and salt refining were also carried on.

The beachhead area around Pusan was held by the United Nation forces in 1950 and the city became the temporary capital of the Republic of Korea and a port of supply and disembarkation during the first years of the Korean war. The city was swollen by refugees, whose many temporary shacks covered the hills. Disastrous fires occurred in these areas but the city was rebuilt and more permanent structures established. Industries were redeveloped and the population grew to 1,049,363 (1955 census.) (S. McC.)

PUSEY, EDWARD BOUVERIE (1800–1882), English leader of the Oxford movement, who, though remaining firm in his Anglican beliefs, headed the Catholic revival in the Church of England. mas born at Pusey on Aug. 22, 1800. His father was Philip Bouverie, whose ancestor was a Protestant refugee from the Low Countries who reached England in the 16th century. Philip Bouverie took the name of Pusey upon succeeding to the estate of that name in Berkshire. Edward was educated at Eton and Christ Church, Oxford. In 1823 he stood for a fellowship by examination at Oriel college and was elected, thus entering the brilliant common room of which John Keble and J. H. Newman (*qq.v.*) were already members.

From 1825 to 1827 he studied oriental languages and theology in Germany, where the state of German Protestantism, driven to skepticism by the rationalism of the Enlightenment, made a permanent impression upon him by way of reaction.

In 1828 Pusey's reputation as an orientalist caused the duke of Wellington to nominate him to the regius chair of Hebrew in Oxford, which carried with it a canonry of Christ Church. From the year 1833 began his association with the Oxford movement, to which he brought a decisive reinforcement. "He," wrote Newman, "at once gave us a position and a name." He contributed a tract on fasting to the Tracts for the Times in 1834 and his most noteworthy work in that series was the extensive tract upon baptism of 1835.

In 1843 Pusey preached his university sermon on "The Holy Eucharist, a Comfort to the Penitent," which asserted the doctrine of the Real Presence. For this he was suspended by the vice-chancellor (without being allowed to speak publicly in his own defense) from preaching before the university for t o years, an arbitrary act which, in H. P. Liddon's words, "sealed the doom of the old *régime*—the authority of the Heads and the old ecclesiastical polity of Oxford" and was a factor leading to university reform. Yet, after the ending of the sentence, Pusey preached in 1846 another sermon asserting another principle of the Oxford movement, the right of private confession and the existence of priestly absolution in the Church of England. Newman's secession to the Roman Catholic Church in 1845 was a crushing blow to Pusey.

Pusey's intense industry was devoted to the work of his professorial chair, to learned theological writing, to preaching and to individual spiritual direction. Nor were his activities confined to Oxford. In the cholera epidemic of 1866 he tended the sick in Bethnal Green; he preached in many parts of the country and contributed generously to church purposes, such as building St. Saviour's church, Leeds, at his own expense in 1842–45; and in addition, he was responsible for the revival of the monastic life in the Church of England, encouraging Marian Hughes to take religious vows (the first Anglican to do so since the Reformation) in 1841 and helping, in 1845, to found in London the first Anglican sisterhood,

In matters of biblical criticism Pusey was strictly conservative and to the end of his life combated the newer ideas which were becoming fashionable; his works on The Minor Prophets, with Commentary (1860) and Daniel the Prophet (1864) show a deep but old-fashioned Hebrew scholarship. Averse to the use of philosophy in theological construction, his doctrinal outlook was marked by a strong attachment to the principle of revelation interpreted by the historic authority of the church. He lacked Newman's speculative brilliance but had the intellectual strength of a well-stored and balanced mind and of a deep reverence for historic truth; he tested all current teaching by its consonance with the Bible and the mind of the early church.

Pusey's private life was marked by severe asceticism, intense personal religion, a capacity for lasting friendship and deep family affection. The death of his wife in 1839, of a daughter in 1844 and of his only son in 1880 were irreparable blows. He died on Sept. 16, 1882, at Ascot priory, the home of a sisterhood with which he was associated; he was buried in Christ Church cathedral.

Two years later his friends founded Pusey house, Oxford, as an institution for theological study and pastoral care in the university. There his library and many personal letters, papers and relics are preserved.

See H. P. Liddon, *Life of Edward* Bouverie *Pusey,* 4 vol. (1893–94), with a list of Pusey's works; and shorter biographies by G. W. E. Russell (1907) and G. L. Prestige (1933). (T. M. P.)

PUSHBALL, a game invented by M. G. Crane of Newton, Mass., in 1894. It was taken up by Harvard the next year, but never attained any considerable vogue in the U.S. In Great Britain the first regular game was played at the Crystal palace in 1902 by teams of eight. The game still is played in English preparatory and public schools, but the rules are somewhat different from those originally devised.

Pushball is played by two sides on a field usually 140 yd. long and 50 yd. wide. with a heavy, 50-lb. ball, 6 ft. in diameter. The goal consists of two uprights 18 ft. high and 20 ft. apart, separated by a crossbar 7 ft. from the ground. Scoring occurs when the ball passes the goal: 5 points for a push below the bar, 8 for heaving the ball over it. A touchdown behind the goal counts 2 for the attacking side. The sides usually number 11 each: five forwards, two goalkeepers, two right and two left wings. There are two periods of play with an intermission.

Often pushball is one of the events featured in circus performances, especially when played by teams of Indians and cowboys on horseback, perhaps representing the traditional play rivalry between these two groups. Mounted organizations seem to play the game more often than do small boys, and it seems likely to survive in countries where there are considerable numbers of horseback riders. (N. F. J.)

PUSHKIN, ALEXANDER (1799–1837), Russian poet, was born at Moscow on June 6, 1799. He belonged to an ancient family of boyars; his maternal great-grandfather was an Abyssinian general in the Russian service, ennobled by Peter the Great. In 1811 the future poet entered the newly founded lyceum of Tsarkoe Selo, situated near St. Petersburg. On quitting the lyceum in 1817 he was attached to the ministry of foreign affairs. and in this year he began to write his *Ruslan and Ly'udmila,* a romantic epic in six cantos, ahich was completed in 1820.

Meanwhile Pushkin mixed in all the gayest society of the capital, and it seemed as if he would turn out a mere man of fashion instead of a poet. But a very daring *Ode to Liberty* written by him and circulated in manuscript in St. Petersburg came to the notice of the governor, and the young author was exiled to the south of Russia where he held official positions at Ekaterinoslav and at Kishinev.

In company with General Rayevsky he visited the baths of the Caucasus for the re-establishment of his health in 1820. The Rayevskys introduced him to the poetry of Lord Byron. and the magnificent scenery of the Caucasus kindled his own poetic genius. The first fruit of the Caucasian visit was *The Captive of the Caucasus* (1822), narrating the story of the love of a Circassian girl for a Russian officer. This was followed by the *Fountain of Baklzchisarai* (1827) which tells of the detention of a young Polish captive in the palace of the khans of the Crimea. About the same time he composed the lines on Ovid, whose place of banishment. Tomi. was not far distant, and the *Ode to Napoleon.* The next long poem was the *Gipsies* (Tsygany) (1827). During his stay in southern Russia he mixed with the secret societies then rife throughout the country. In 1823 he was allowed to leave Kishinev, where the life was hateful to him, and was transferred to Odessa where he was once more on real Russian soil, and on the coast of the sea which delighted him. But he came into conflict with his official superior, and was dismissed from the service, because of an intercepted letter in which he spoke favourably of atheism. He was ordered to reside at Mikhailovskoe, near Pskov, where he soon involved himself in trouble on all sides.

In his retirement he studied old Russian popular poetry. Recollections of Byron and André Chenier gave the inspiration to some fine lines consecrated to the latter, in which Pushkin appeared more conservative than was his wont. In 1825 he wrote his tragedy *Boris Godunov,* not published till 1831, a bold effort to imitate the style of Shakespeare, thus breaking with the French traditions.

In 1825 the conspiracy of the Dekabrists broke out. Many of the conspirators were personal friends of Pushkin, especially Kuchelbecker and Pustchin. The poet himself was to a certain extent compromised, but he succeeded in getting to his house at Mikhailovskoe and burning all the papers which might have been prejudicial to him. The emperor, to whom he was presented at Moscow soon after his coronation, summoned him to Moscow and assured him of pardon and "protection." The story goes that Nicholas said to Count Bludov on the same evening. "I have just been conversing with the most intelligent man in Russia." In 1829 appeared *Poltava,* a spirited narrative poem, in which the expedition of Charles XII against Peter and the treachery of the hetman Mazeppa were described. In 1829 Pushkin again visited the Caucasus on this occasion accompanying the expedition of General Paskevich, ahich is described in *A Voyage to Arzrum* (pr. 1836). The lyrics are delightful.

In 1831 Pushkin married Natalia Goncharov, and in the following year was again attached to the ministry of foreign affairs, with a salary of 5,000 roubles. He now began his *History of the Revolt of Pugachev of 1773* (pr. 1834), an admirable piece of historical writing. While engaged upon this he wrote *The Captain's Daughter* (1836), one of the best of his prose works. In 1832 was completed the poem *Evgeni Onegin* (1825–33), again influenced by Byron.

In 1837 the poet, who had been long growing in literary reputation, fell mortally wounded in a duel (Feb. 8) with Baron George Heckeren d'Anthès, the adopted son of the Dutch minister who had married a sister of the poet's wife. Pushkin died on Feb. 10. D'Anthès was tried by court-martial and expelled from the country. In 1880 a statue of the poet was erected at the Tver Barrier at Moscow. He left four children; his widow married an officer named Lanskoi: she died in 1863.

Pushkin's poetical tales are full of drama. *Boris Godunov* and *Evgeni Onegin* are the basis of operas by Mussorgsky and Tschaikowsky respectively. Pushkin's lyrical pieces are the finest in the language Interspersed among his minor works will be found many epigrams. He was one of the earliest Russian novelists. Indeed most of his work after 1831 was done in prose. In 1831 he published a small volume of tales under the pen name of Ivan Belkin. These all show great narrative powers. The one long novel finished is *The Captain's Daughter,* a tale of the times of Catherine II, which exercised a great influence on later Russian novelists. The most famous of all his short stories is *The Queen of Spades* (1834). In the posthumous *History of the Manor of Goryukhino* Pushkin parodied Polevoy's *History of the Russian People,* and presented an amusing picture of the fictitious author of his own Tales. Ivan Petrovich Belkin.

See Prince D. S Mirsky, *Pushkin* (1926), which contains a bibliography; and the bibliography in the editions of Gennadi (7 vols, 1861), and Annenkov (6 vols. 1855).

PUSHTU, PAKHSTO, PAKKHTO (PASHTO), the language of the Afghans, belongs to the Eastern Iranian group, the oldest form of which is probably found in the Zend. Numerous terms are traceable to the Avesta. *(See* Paul Horn's *Grundriss der Neupersischen Etymologie*). The remainder of its vocabulary comes from Arabic. Persian and from the Indian Prakrits. Among the last, Sindhi takes first place. It has thus considerable claims to antiquity.

About 10% of the Afghans are able to read and write, and education is making rapid progress.

Structure. — There are nine declensions. The accusative is the same as the nominative. The agent and oblique forms are identical. The genitive, dative and locative are formed by adding suffixes to the oblique form. Most adjectives form the feminine by adding *a.* Pronominal suffixes are used as well as definite, personal, demonstrative and reflexive pronouns. The regular verb has two main tenses, the imperfect and the present. There are 37 classes of verbs, 13 intransitive and 24 transitive.

BIBLIOGRAPHY.—*Linguistic Survey of India,* vol x (1924), full bibliography; also vol. i (1927); T. P. Hughes, *Kalīd-Afghānī* (English trans., 1893) Manual. G. W. Gilbertson, *The Pakkhto Language* (1929) Dictionary: G. W. Gilbertson, *English-Pakkhto Colloquial Dictionary* (1929)

PUT AND CALL: *see* OPTIONS.

PUTEOLI, an ancient tonn of Campania (mod. *Pozzuoli, q v.).* Italy, on the northern shore of the Bay of Puteoli, a portion of the Bay of Naples. from nhich it is 6 m. W. The city was probably founded under the name of Dicaearchia by a colony of Samians from Cumae about 520 B.C., before which Misenum was the original port. In 215 the Romans introduced a garrison of 6.000 men and Hannibal besieged it in vain in 214. In 194 a Roman colony of 300 men was established. Puteoli belonged to the tribus Palatina, thus breaking the rule (the only other exception is Turris Libisonis nhich belonged to the Colluia) that *municipia* and *coloniae* were not enrolled in the four urban tribes.

The *lex parieti faciundo,* 105 B.C., relating to building works in front of the temple of Serapis, shows that Puteoli had considerable administrative independence. Sulla retired to Puteoli after his resignation of the dictatorship in 79. Cicero had a house in Puteoli itself, and a villa on the edge of the Lucrine lake (*q.v.*), and many other prominent men of the republic possessed country houses near by. *(See* AVERNO; BAIAE; LUCRINUS LACUS; and MISENUM.) In AD. 61 St. Paul landed here, and spent seven days before leaving for Rome (Acts xxviii. 13). Vespasian gave the town part of the territory of Capua, and installed more colonists

—whence it took the title Colonia Flavia.

The remains of Hadrian, who died at the neighbouring town of Baiae, were at first deposited at Puteoli, and Antoninus Pius erected a temple to his memory on the site of Cicero's villa. It was mainly, however, as a great commercial port that Puteoli was famous in ancient times. It exported iron from Elba, mosaics, pottery, perfumes, pozzolana earth (taking its name from the place), glass cups engraved with views of Puteoli, mineral dyes, etc , but its imports were considerably greater, During the Punic Wars it was a naval port, bur, in the latter part of the 2nd century B.C. it became the greatest commercial harbour of Italy and we find Lucilius about *12j* B.C. placing it next in importance to Delos, then the greatest harbour of the ancient world.

The corn supply of Rome came partly through Puteoli, partly through Ostia. Seneca (*Epist. 77*) describes the joy of the inhabitants in the spring when the fleet of corn vessels from Alexandria was seen approaching, and Statius tells us that the crew of the ship which arrived first made libations to Minerva when passing the promontory which bore her name (the Punta Campanella at Sorrento). ,

Claudius established here, as at Ostia, a cohort of *vigiles* as a fire-brigade. Brundisium was similarly protected. There was also a station of the imperial post, sailors of the imperial fleet at Misenum being apparently employed as couriers. The artificial mole was probably of earlier date than the reign of Augustus; and by that time at any rate there were docks large enough to contain the vessels employed in bringing the obelisks from Egypt. Alaric (410), Genseric *(455)* and Totila *(545)* devastated Puteoli.

The original town of Puteoli stood on the narrow hill of the Castello. The streets of the old town preserve the ancient alinement. There are also traces of the division of lands near the town into squares by parallel paths (*decumani* and *cardines*) at regular intervals of $1{,}111\frac{1}{9}$ Roman feet, postulating as the basis of the division a square with a side of 10,000 Roman feet, divided into *81* smaller squares. The market hall (*macellum*), generally known as the temple of Serapis, from a statue of that deity found there, was excavated in 1750. In the centre of the ancient city was a round colonnade with sixteen columns of Numidian marble (*giallo antico)* now in the theatre of the palace at Caserta. In the amphitheatre there were exceedingly interesting arrangements for flooding the arena, but these can only have been in use before the construction of the greater part of the subterranean portion with its cages, etc. The whole amphitheatre is 489×381 ft.; the arena 245×138 ft. Inscriptions record that it was built by the *Colonia Flavia,* i *e.,* not before Vespasian. In the older amphitheatre (426×312 feet), which was found in excavations for the new railway to Naples, Nero fought in games given in honour of Tiridates, king of Armenia. Remains of thermae also exist in various places. The cathedral of S. Proculus (containing the tomb of the musician Pergolesi, d. 1736) is built into a temple of Augustus, 6 columns of which, with their Corinthian capitals, still exist. Other ruins—of a circus, of tombs, villas. etc., exist.

Puteoli was supplied with water by two aqueducts, both subterranean, one of which, bringing water from springs in the immediate neighbourhood, is still in constant use. Puteoli was reached direct by a road from Capua traversing the hills to the north by a cutting (the Montagna Spaccata), which went on to Neapolis, and by the Via Domitiana from Rome and Cumae. There was also a short cut from Puteoli to Neapolis by the tunnel of Pausilipon, made under Augustus. In *305,* S Januaris (S. Gennaro, the patron saint of Naples). bishop of Beneventum, S Proculus, patron of Puteoli. and others, were martyrs at Puteoli,

See the study of C. Dubois, *Pouzzoles antique* (Paris, 1907) (Bibliothèque des écoles françaises d'Athènes et de Rome, fasc. 98). (T. A)

PUTNAM, FREDERIC WARD (1839–1915), U.S. anthropologist, educator and museum administrator, was born in Salem, Mass.. on April *16, 1839,* the son of a horticulturist. After studying at Harvard college under Louis Agassiz, Putnam held various museum posts in Salem and Boston; from *1869* to *1873* he was director of the Peabody Academy of Science in Salem

Putnam was curator of the Peabody Museum of American Archaeology and Ethnology at Harvard from *1874* to 1909, and he also served as curator of anthropology at the American Museum of Natural History. New York city. 1894–1903. Putnam was Peabody professor of American archaeology and ethnology at Harvard. and played an important part in establishing a department of anthropology at the University of California in the early 1900s.

Head of the department of ethnology at the World's Columbian exposition in Chicago, Ill., 1891–94, he organized various expeditions and prepared collections and exhibits that later were preserved in the Chicago Natural History museum. Putnam has been credited with increasing popular interest in anthropology and with making important contributions to museum administration. He was secretary of the American Association for the Advancement of Science for 25 years and a founder and editor of the *American Naturalist.* He died in Cambridge, Mass.. Aug 14, 191*j*.

PUTNAM, GEORGE HAVEN (1844–1930), U.S. publisher, whose chief contribution was his championship of international copyright, was born in London, Eng , on April 2, 1844, the son of the U S. publisher George Palmer Putnam (1814–1872). He attended grammar school in New York city and later studied at the Sorbonne and the University of Gottingen. Upon the outbreak of the Civil War. he returned to the United States from Germany and enlisted in the Union army. He was taken prisoner at Cedar Creek, and sent first to Libby prison and later to Danville. He later described his war experiences in several volumes. In 1872 he succeeded his father as head of one of the oldest publishing concerns in the country, the house that had introduced to American readers such authors as Washington Irving and James Fenimore Cooper.

Putnam was active throughout his long life in political organizations and civic groups, but his chief interest lay in the practical problems of authorship. He continued his father's efforts in behalf of an international copyright law and was in great measure responsible for the passage of the Copyright act of 1909, establishing more equitable copyright relations between the U.S. and Europe. He also vigorously opposed all attempts at literary censorship. His own writings deal mainly with copyright and publishing, and include *The Question of Copyright* (1891), *Authors and Their Public in Ancient Times* (1894), *A Memoir of George Palmer Putnam* (1903), *Memories of My Youth* (1914), and *Memories of a Publisher* (1915). He died in New York city, Feb. 27, 1930.

PUTNAM, GEORGE PALMER (1814–1872), U.S. publisher. was born at Brunswick, Me., on Feb. 7, 1814, and at an early age went to work in a New York city bookstore From 1841 to *1848* he sold American books in London. He also wrote articles for New York newspapers while he was in England and published a book entitled *American Facts* (1845). After his return to New York in 1848, Putnam became a book publisher and founded *Putnam's Monthly Magazine*. issued from *1853* to 1857, when he suffered financial difficulties, and again from 1868 to 1870.

After the American Civil War Putnam established the publishing house that bore his name thereafter. His son George H. Putnam (*q.v.*) succeeded him as head of the firm after his death on Dec. *20,* 1872, and continued the campaign for international copyright protection that his father had begun in the latter 1830s.

George Palmer Putnam's other children included Ruth Putnam (1856–1931), who wrote a number of books on the Netherlands, and the pioneer woman physician Mary Putnam Jacobi (*q.v.*).

PUTNAM, GEORGE PALMER (1887–1950), U.S. publisher, author and explorer, was born at Rye, N.Y., on Sept. *7, 1887,* the grandson of the publisher George Palmer Putnam (*q.v.*). He studied at Harvard university and the University of California, Berkeley, and entered newspaper work in Bend, Ore, in 1910. After serving as a lieutenant of field artillery during World War I, he became treasurer of his father's publishing firm of G. P. Putnam's Sons. Between 1930 and 1932 he was vice-president of the publishing house of Brewer, Warren and Putnam, and from 1932 to 1935 was chairman of the editorial board of Paramount Productions. During World War II he served as an officer with the U.S. army air forces in India and China. Putnam led expeditions to Greenland in *1926* and to Baflin Island the following year. In 1931 he was married to Amelia Earhart, who was the first woman to fly the Atlantic and who held women's speed and distance flight records. She was lost in the mid-Pacific during a flight around the world in 1937. He wrote her biography. *Soaring Wings* in 1939. Putnam's 12 books include his autobiography, *Wide Margins* (New York, 1941), and three volumes on Death valley. He died at Trona. Calif., Jan. 4, 1950.

PUTNAM, HERBERT (1861–1955), U.S. librarian. was born in New Tork city on Sept. 20, 1861. He graduated from Harvard college in 1883 and thereafter studied law at Columbia university, being admitted to the bar in 1886. His calling, however, proved to be that of librarian. He was librarian of the Minneapolis Athenaeum in 1884–87, of the Minneapolis Public library in 1887–91 and, after a fen years in the practice of law in Boston (1892–95), of the Boston Public library in 1895–99. He was librarian of the Library of Congress. Washington D.C.. 1899–1939, and president of the American Library association in 1898 and 1904. Putnam died Aug. 14.19jj, in Quissett. Mass.

PUTNAM, ISRAEL (1718–1790), American soldier, was born in Salem Village (now Danvers), Mass. on Jan. 7, 1718, and in 1740 removed to a farm in the vicinity of Pomfret, Conn. He was active in the French and Indian War, rising to the rank of major in 1758 News of the fighting at Lexington and Concord reached him while he was ploughing on his farm; he instantly left the plough in the furrow and hastened to Cambridge; and he was later made second brigadier of the Connecticut forces. He was with the force, commanded by Col. William Prescott, which on the night of June 16, 1775, fortified Breed's Hill, and on the next day he took a conspicuous part in resisting the British attack (*see* BUNKER HILL). After the evacuation of Boston he was in command of New York city till Washington's arrival (April 13, 1776), and then was put in general charge of the city's fortifications. Immediately before the battle of Long Island he succeeded Gen. John Sullivan in command of the troops on Brooklyn Heights, and in the battle of Long Island (of Aug. 27) he was in immediate command of the American side. In the retreat from New York city he took part in the battle of Harlem Heights (Sept. 16). In May, 1777, he took command of the Hudson highlands at Peekskill, which with Forts Montgomery and Clinton he abandoned in October, being out-manoeuvred by the British. After a few months' recruiting service in Connecticut he returned to the main army at White Plains. In the winter of 1778–79 he commanded the troops quartered near Redding, Conn. In May, 1779, he took command of the right wing on the west side of the Hudson. An attack of paralysis in Dec. 1779 terminated his active service in the war. He spent his last years on his farm in Brooklyn, Conn , where he died May 29. 1790. A bronze equestrian statue by Karl Gerhardt, over a sarcophagus, was erected at Brooklyn, Conn., by the State in 1888, and there is another statue (1874) in Bushnell park, Hartford, by J. Q. A. Ward.

Putnam was a brave, intrepid and very industrious soldier rather than a great general. His bluff heartiness has made him one of the popular heroes in American history.

See W. F. Livingston, *Israel Putnam, Pioneer, Ranger and Major-General* (1901) in the "American Men of Energy" series; I. N. Tarbox, *Life of Israel Putnam* (Boston, 1876); and *Essay on the Life of the Honorable Major-General Israel Putnam* (Hartford, 1788; enlarged ed., Boston, 1818), by David Humphreys, for a time Putnam's aide-de-camp.

PUTNAM, RUFUS (1738–1824), American soldier and pioneer, was born in Sutton, Mass., on April 9, 1738 (O.S.). He served in the French and Indian War in 1757–60; was a millwright in New Braintree in 1761–68, during which time he studied surveying; and from 1769 until the American Revolution was a farmer and surveyor. He became lieutenant colonel in one of the first regiments raised after the battle of Lexington, and served before Boston. In 1777 he served in the Northern army under Gen. Horatio Gates, commanding two regiments in the second battle of Saratoga. In 1778 he laid out fortifications, including Ft. Putnam, at West Point, and in 1779 he served under Gen. Anthony Wayne after the capture of Stony Point. After the war he returned to Rutland, Mass., where he had bought a confiscated farm in 1780. In March, 1786, he founded, with other officers of the American Revolution, the Ohio Company of Associates for the purchase and settlement of Western lands. In Nov. 1787, he was appointed by the company superintendent of its proposed settlement on the Ohio, and in 1788 he led the small party which founded Marietta, Ohio. He was a brigadier-general in the army and a commissioner to treat with the Indians in 1792–93; was surveyor general of the United States in 1796–1803; and in 1802 was a member of the Ohio State Constitutional convention. He died, in Marietta, May 4, 1824. He has been called "the father of Ohio," and greatly contributed to its development.

BIBLIOGRAPHY.—John W. Campbell, *Biographical Sketches* (1838); Sidney Crawford, "Rufus Putnam, and his Pioneer Life in the North-West," vol. xii, new series, pp. 431–454, *Proceedings of the American Antiquarian Society* (1899), and Rowena Buell (ed), *The Memoirs of Rufus Putnam* (1903), in which his autobiography, journal and other papers, in the library of Marietta college, are reprinted. His *Journal, 1757–1760*, dealing with his experiences in the French and Indian War, was edited with notes by E. C. Dawes (1886).

PUTNIK, RADOMIR (1847–1917), Serbian general, was born on Jan. 25, 1847, at Kraguyevats. After serving against Turkey in 1876 and 1877, and against Bulgaria in 1889, he was made deputy-chief of the general staff, and professor at the military academy in Belgrade. The intrigues and favouritism introduced by the kings, Milan and Alexander, caused him to be placed on the retired list, but in the autumn following the military revolution of 1903 he was appointed general and chief of the general staff. In 1906 he succeeded General Gruič as minister of war, and again held that office in 1912, during the period when the military convention with Bulgaria was negotiated.

Op the outbreak of war with Turkey Putnik was made *voivode* or marshal (being the first holder of that title) and commander-in-chief, and was responsible for the rapid success of the Serbian arms at Kumanovo, Prilep and Monastir. It was largely owing to his vigilance and foresight that the treacherous night attack by which the Bulgarians opened the second Balkan War (June 29, 1913) failed as it did. When World War I broke out, he was undergoing a cure at an Austrian watering place, and was at first placed under arrest, being later released by special order of the emperor Francis Joseph and conveyed to the Rumanian frontier. Despite impaired health he resumed the position of Serbian generalissimo and inflicted upon the forces of General Potiorek three successive defeats — on the Yadar (Aug. 16-20), the Drina (Sept. 8–19) and at Rudnik, which ended on Dec. 14, 1914 with an Austrian rout and the complete evacuation of Serbia. Putnik retained the supreme command during the triple invasion of Serbia in Nov. 1915, and shared the retreat of the Serbs through Albania. When, however, the exiled government established itself at Corfu, he and most of his staff were placed on the retired list. He himself withdrew to France. He died on May 17, 1917, at Nice.

PUTTEE or **PUTTIE.** The name adapted from the Hindu *patti*, bandage (Skr. *patta*, strip of cloth), for a covering from the ankle to the knee, consisting of a long narrow piece of cloth wound spirally, and fastened by a tape, though straps may be used. For infantrymen, the winding commenced at the ankle, but mounted men reversed the process as the rubbing against the horse caused the tape to come undone. Their advantages over leggings were said to be that they were not hard on the legs, could be used as bandages or slings in case of need and occupied less space when not in wear. Worn by most armies except the German in World War I, they gradually disappeared thereafter in favour of short leggings.

PUTTENHAM, GEORGE (d. 1590), the reputed author of *The Arte of English Poesie* (1589). The book was entered at Stationers' Hall in 1588, and published in the following year. The writer of *The Arte of English Poesie* was educated at Oxford, and at the age of 18 he addressed an eclogue entitled *Elpine* to Edward VI. In his youth he had visited Spain, France and Italy, and was better acquainted with foreign courts than with his own. In 1579 he presented to Queen Elizabeth I his *Partheniades* (printed in a collection of manuscript *Ballads* by F. J. Furnivall), and he wrote the treatise in question especially for the delectation of the queen and her ladies. He mentions nine other works of his, none of which are extant. There is no direct evidence beyond Bolton's ascription to identify the author with George or Richard

Puttenham, the sons of Robert Puttenham and his wife Margaret, the sister of Sir Thomas Elyot, who dedicated his treatise on the *Education or Bringing up* of *Children* to her for the benefit of her sons.

Many later "poetics" are indebted to this book. The original edition is very rare. Edward Arber's reprint (1869) contains a clear summary of the various documents nith regard to the authorship of this treatise. The history of the Puttenhams is discussed in H. H. S. Croft's edition of Elyot's *Boke called the Governour*. There are other modern editions of the book, notably one in J. Haslewood's *Ancient Critical Essays* (1811–15).

PUTTING THE SHOT: *see* SHOT-PUT.

PUTTKAMER, ROBERT VON (1828–1900), Prussian statesman, was born at Frankfurt an der Oder on May 5, 1828. Puttkamer was the chosen instrument of the clerical conservative policy initiated by Bismarck when the growth of the Socialist movement made it expedient to conciliate the Catholic centre. As *Oberprasident* of Silesia he had mitigated the rigour of the application of the "May laws," and as minister of public worship and of the interior he continued this policy. He was also the author of the ordinance of Jan. 2, 1880, on the simplification of German orthography.

As minister of the interior, Puttkamer's temper was in harmony with the view of Bismarck and the emperor William, and with their support he tried to re-establish the old Prussian system of rigid discipline from above.

On his initiative, on Jan. 4, 1882, a royal ordinance required all officials to give the government their unconditional support at political elections. He also interfered with the liberty of public meetings and attempted to suppress strike movements by force. This "Puttkamer regime" was intensely unpopular. and when the emperor Frederick III succeeded to the throne Puttkamer was forced to resign (June 8, 1888). He was largely rehabilitated under William.

Puttkamer died at Karzin, in Pomerania, on March 15, 1900.

PUTTY, a term that generally means a cement of one of two types: whiting putty or white-lead whiting putty.

A high-grade whiting putty consists of 85% to 90% whiting (finely powdered calcium carbonate) blended with 10% to 15% boiled linseed oil. White-lead whiting putty has an admixture of 10% white lead, reducing the amount of whiting proportionately.

Prepared putty should roll freely in the hands without exuding oil. It is commonly used to secure sheets of glass in place, to fill nail holes, etc.

The term is also applied to substances resembling putty, for example, iron putty, which is a mixture of ferric oxide and linseed oil, and red-lead putty, which is composed of red and white lead and linseed oil. The term putty is also applied to certain dough-like plastic compounds. Putty is also a shortened name for putty powder (tin oxide), which is used in polishing glass, granite, metal, etc. (E. L. Y.)

PUTUMAYO RIVER, a 980 mi.-long tributary of the Amazon which rises in the Andes mountains of southern Colombia, forms the southern boundary of Colombia with Ecuador and Brazil for almost 800 mi., but for its last 100 mi. before it enters the Solimões or Amazon at Santo Antonio de Icá it flows through Brazilian territory. In Brazil it is known as the Icá river.

The area drained by the Putumayo is a vast zone of tropical rain forest where rainfall ranges upward to 140 in. a year. Except near its headwaters, in the foothills of the Andes, the population along its banks is composed largely of small groups of forest Indians.

A highway built by the Colombian government from Pasto through the Sibundoy valley to Puerto Asís on the upper Putumayo was opening the eastern flanks of the Andes to settlement in the second half of the 20th century. Another road was under construction from Ipiales toward the valley of the Rio San Miguel, which is a main affluent of the Putumayo and itself forms the Ecuador-Colombian border near its headwaters. Navigation on the Putumayo is unobstructed by rapids below Puerto Ospina, 80 mi. downstream from Puerto Asís. The only settlement of any size on the Putumayo below Puerto Ospina is Puerto Leguizamo (formerly Caucayá), from which there is a 25 mi. portage road northward to La Tagua on the Caquetá river.

The Putumayo region was the scene of the famous Putumayo rubber scandal during the height of the rubber boom which saw many Indians enslaved and killed by unscrupulous rubber operators. In 1932 there was fighting there between Colombian and Peruvian forces prior to the settlement of the so-called Leticia affair, which gave Colombia a wedge-shaped salient that extends 90 mi. south of the Putumayo to the Amazon port of Leticia. (Js. J. P.)

PUVIS DE CHAVANNES, PIERRE CÉCILE (1824–1898), French painter. was born at Lyons on Dec. 14, 1824. He occupied a rather unique position in 19th-century painting, for his work was largely independent of the major artistic currents and, perhaps for that very reason, it was approved by representatives of almost all shades of critical opinion. The son of a mining engineer, Pierre Puvis was educated at Lyons and at the Lycée Henri IV in Paris and was intended to follow his father's profession.

Puvis first studied painting under Henri Scheffer, spent some time in Italy and then frequented for a short period the studios of Thomas Couture and Eugène Delacroix. He first exhibited at the Salon in 1850 (a Pietà), but was then consistently rejected until 1858. His work was, however, esteemed by such critics as Théodore de Banville, Théophile Gautier, Charles Baudelaire and Paul de St. Victor. In 1859 he reappeared at the Salon with the "Return from Hunting" (Marseilles), an adaptation of a "Return of the Prodigal Son" executed in 1854 as part of a decorative scheme for his brother's dining room. In 1861, with the production of "War" and "Peace." he began an important series of paintings which were destined to become part of the decorative scheme for the museum at Amiens. The scheme was augmented by various gifts from the artist and finally completed with "Ave Picardia Nutrix" (1865) and the state commission for "Pro Patria Ludus" (1882).

During these years Puvis de Chavannes undertook other decorative work at Lyons, Marseilles, Poitiers and Paris, as well as exhibiting a number of important pictures such as the "Beheading of St. John" (1869), "Hope" (1872), "Family of Fisher-folk" (1875), "Women on the Seashore" (1879) and "The Poor Fisherman" (1881). The work at Lyons includes "Autumn" (Salon of 1864) and the major decorative works "The Sacred Grove." "Vision of the Antique," "The Rhône" and "The Saône" (1884–87).

In the Palais Longchamp at Marseilles are two panels representing "Marseilles as a Greek Colony" and "Marseilles, Gateway to the East" (1868–69) and in the Hôtel de Ville, Poitiers, are two decorative panels of historical subjects, "Radegund" and "Charles Martel" (1872–74). In 1876 Puvis de Chavannes was commissioned to paint a series of panels illustrating the life of St. Geneviève, for the Panthéon; although part of this task was finished and exhibited by 1880, the total scheme was completed only after the death of Puvis in Paris (Oct. 24, 1898) by pupils, under the direction of J. C. Cazin, working from the completed cartoons. Other mural decorations in Paris are those for the Sorbonne (1887–89) and for the Hôtel de Ville, which were completed in 1893. Two other important decorative commissions were those for the museum at Rouen (1890–92) and for the staircase of the public library, Boston (1894–98).

BIBLIOGRAPHY.—M. Vachon, *Puvis de Chavannes* (1895); J. Buisson, *Gazette des Beaux-Arts* (1899); M. Lagaisse, *Puvis de Chavannes et la peinture lyonnaise du XIXe siècle* (exhibition catalogue, 1937); R. Goldwater, *Art Bulletin* (1946). (R. A. DY.)

PUY, a geological term used locally in Auvergne for a volcanic hill. Most of the puys of central France are small cinder cones, with or without associated lava, while others are domes of trachytic rock, like the domite of the Puy-de-DBme. The puys may be scattered as isolated hills, or, as is more usual, clustered together, sometimes in lines. They probably became extinct in late prehistoric time. Puys are also found in the Eifel, on the Bay of Naples, in the Swabian Alps of Wiirttemberg, and, as Sir A. Geikie has shown, in Scotland.

PUY-DE-DÔME, a *département* of central France, four-fifths of which belonged to Basse-Auvergne, one-sixth to Bourbonnais, and the remainder to Forez (Lyonnais). Area, 3,095 sq.mi. Pop. (1954) 481,380. It is bounded north by Allier, east by Loire, south by Haute-Loire and Cantal, and west by Corrkze and Creuse.

The famous plain of the Limagne, watered by the Allier and its tributary, the Dore, has on its western flank the volcanic Puys and Monts Dore, while on its eastern side rises the largely granitic heights of the Forez (5,381 ft.). The Puys include a number of craters, now dead and often filled by lakes, which also occur behind lava dams in the valleys. The Puy de Sancy (6,188 ft.) is the highest crater, but the Puy de Dôme (4,806 ft.) gives its name to the de'partement and has a meteorological observatory on its summit, once crowned by a Roman temple, the ruins of which still exist.

The climate of Puy-de-Dbme is usually very severe, owing to its high level and its distance from the sea; the mildest air is found in the northern valleys, where the elevation is least. During summer the hills about Clermont-Ferrand, exposed to the sun, become all the hotter because their black volcanic soil absorbs its rays. The rainfall averages 2j to 26 in. annually; in the Limagne, around which the mountains arrest the clouds, rainfall is less. Nevertheless the soil of this plain, consisting of alluvial deposits of volcanic origin, and watered by torrents and streams from the mountains, makes it one of the richest regions of France. In the highest altitudes the rainfall attains 64 inches.

About two-thirds of the inhabitants of the Puy-de-Dôme are engaged in agriculture. The Limagne yields a variety of products and the vine flourishes on its hillsides. The high mountains provide pasture for large flocks of cows and sheep, and cheese-making is an important industry. The intermediate region is cultivated mainly for cereals, the chief of which are wheat, rye, oats and barley. Potatoes are largely grown, and peas, beans, beetroot, colza and tobacco. The Limagne produces fruit of all kinds—apricots, cherries, pears, walnuts and apples, yielding considerable quantities of cider.

The *département* possesses considerable mineral wealth. There are important coal mines at Brassac on the Allier, on the borders of Haute-Loire, at St. Elroy near the *département* of Allier, and at Bourg-Lastic on the borders of Correze. Peat, asphalt, bituminocs schists, antimony, mispickel and argentiferous lead are also worked. Of the last named there are mines and foundries at Pontgibaud on the Sioule. Amethysts and other rare minerals are found, and there are numerous stone quarries. Mont Dore, Royat and La Bourboule are watering places. The springs of St. Nectaire contain sodium and iron chlorides and bicarbonates. The waters of Châteauneuf (on the Sioule), also known to the Romans, contain iron bicarbonates; those of Châtelguyon, like the waters of Carlsbad and Marienbad, are also widely known, and there are many other mineral springs of varied character. Manufactures are grouped around Thiers, which produces a large amount of cheap cutlery, and Clermont-Ferrand, the capital. The textile industry includes wool carding and making of linen cloths, bunting, clothing, manufactories for lace and for rubber (Clermont-Ferrand), sugar-works, manufactures of edible pastes and of fruit preserves. The de'partement exports grain, fruits, cattle, wines, cheese, wood, mineral waters, cutlery, etc.

Puy-de-Dôme is served by the Orléans and P.L.M. railway companies. Many thousands of the inhabitants, chiefly of the district of Ambert, leave it during winter and find work elsewhere. The de'partement comprises 5 *arrondissements*—Ambert, Clermont-Ferrand, Issoire, Riom, Thiers — jo cantons and 473 communes. The chief towns are Clermont-Ferrand, Issoire, Thiers, Riom, Ambert, Mont-Dore-les-Bains, La Bourboule and Royat. Near Clermont-Ferrand is Mt. Gergovie (see GERGOVIA), the scene of the victory of Vercingetorix over Julius Caesar. Billom, Chamalières, Courpière, Orcival, St. Nectaire and St. Saturnin possess churches in the Romanesque style of Auvergne. 'There are interesting ruined feudal strongholds at Murols and Tournoël (near Volvic). Vic-le-Comte has a *sainte-chapelle* which is a beautiful example of the transition from Gothic to Renaissance architecture, and Aigueperse has a Gothic church of the 13th to the 15th century. Near Pontgibaud are the ruins (13th century) of the Carthusian abbey of Port St. Marie. There are a few megalithic remains in the *département.*

PUZZLE, a mechanical toy or other device involving some constructional problem. to be solved by the exercise of patience or ingenuity. Some of the oldest mechanical puzzles are said to be of Chinese origin, one of the most familiar being known as the "Chinese puzzle," or tangram (chi *ch'iao* t'ue), which consists of a square of wood or other material cut into five triangles, of different sizes, a small square and a lozenge, which can be so placed as to form over 300 figures. Another puzzle attributed to the Chinese consists of a series of rings running linked together on a bar, the problem being to take them off the bar and replace them. A common type of puzzle, the jigsaw puzzle, consists of coloured pictures cut into a number of variously shaped pieces to be fitted together.

For other forms of puzzles see LABYRINTH; REBUS; CROSS-WORD; etc.

PWLLHELI ("salt pool"), a municipal borough, seaport and market town in the Caernarvon parliamentary division of Caernarvonshire, north Wales, 20 mi. S.S.W. of Caernarvon by road. Pop. (1961) 3,642. Area 1.9 sq.mi. It has a sandy beach on the north side of Cardigan bay. The town was incorporated in 1355 by Edward the Black Prince.

The chief industries are agriculture, boatbuilding and the making of machine tools.

PYANOPSIA, an ancient festival in honour of Apollo, held at Athens on the 7th of the month Pyanopsion (October). A hodgepodge of pulse was offered to Apollo. Another offering was a branch of olive or laurel, bound with purple or white wool, round which were hung fruits of the season, pastries and small jars of honey, oil and wine. Both are old pieces of rustic magic, for which many analogies can be found elsewhere. It was carried in procession to the temple of Apollo where it was suspended on the gate by a boy whose parents were both alive. The doors of private houses were similarly adorned. The branch was allowed to hang for a year, when it was replaced by a new one, since by that time it was supposed to have lost its virtue. During the procession a chant was sung, the text of which has been preserved in Plutarch's *Theseus.*

Both offerings have been connected with the Cretan expedition of Theseus, who, when driven ashore at Delos, vowed a thank offering to Apollo if he slew the Minotaur; the offering afterward took the form of the olive or laurel branch and Pyanopsia. His comrades on landing in Attica gathered up the scraps of their provisions which explains the origin of the hodgepodge.

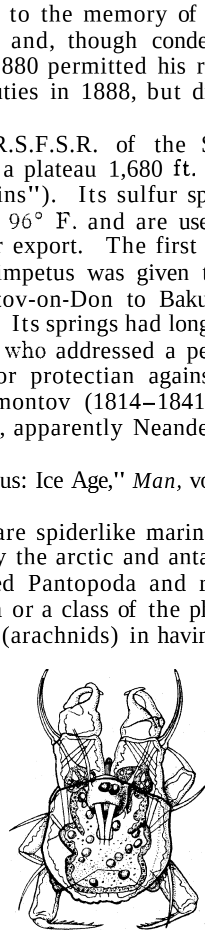
PYAPON, a town and district in Burma, on the Pyapon river. Pop. (1953) 19,174. The district, formed in 1903, lies within the delta of the Irrawaddy. It is intersected by creeks and liable to inundation at high spring tides. The jungle is being reclaimed for rice, which is the sole crop. Area, 2,076 sq.mi.; pop. (1941) 385,008, showing an increase of 50,058 in the decade. The district has no railways and few roads, communication being by water. Other urban centres, which ship the rice to Rangoon, are Kyaiklat (15,781 in 1953), and Dedayè (7,899 in 1953).

PYAT, FELIX (1810–1889), French communard, was born at Vierzon (Cher) on Oct. 4, 1810, the son of a Legitimist lawyer. Called to the bar in Paris in 1831, he threw his whole energies into journalism. The violent personalities of a pamphlet entitled *Marie Joseph Chénier et le prince des* critiques (1844), in reply to Jules Janin, brought him a six months' sojourn in La Pélagie, in the cell quitted by Lamennais. In 1848 George Sand, whom he had introduced in 1830 to the staff of the *Figaro*, now asked Ledru-Rollin to make him commissary-general of the Cher. After three months' tenure of this office he was returned by the *département* to the Constituent assembly, where he voted with the Mountain, and brought forward a motion for the abolition of the presidential office. About this time he fought a duel with Proudhon, who had called him the "aristocrat of the democracy." He joined Ledru-Rollin in the attempt of June 13, 1849, after which he sought refuge in Switzerland, Belgium, and finally in England. For a glorification of regicide at the time the Orsini attempt against Napoleon III he was brought before an English court; but acquitted, and the general amnesty of 1869 permitted his return to France, but further outbursts against the authorities compelled his return to England. The revolution of Sept. 4 brought him back to Paris, and it was he who in his paper Le *Combat* displayed a black-edged announcement of the *pourparlers* for the surrender of Metz. After the insurrection of Oct. 31, he was imprisoned for a short time. In Jan. 1871, *Le Combat* was suppressed, only to be followed by an equally virulent *Vengeur*. Elected to the National assembly, he retired from Bordeaux with Henri Rochefort and others until such time as the "parricidal" vote for peace should be annulled. He returned to Paris to join the committee of public safety, and, in Hanotaux's words, was the *âme ulcérée* of the Commune, but was blamed for the loss of the fort of Issy. He was superseded there by Delescluze, but he continued to direct the violent acts of the Commune, the overthro of the Vendôme column, the destruction of Thiers's residence and of the expiatory chapel built to the memory of Louis XVI. He escaped across the frontier, and, though condemned to death in 1873, the amnesty of July 1880 permitted his return. He was elected to the chamber of deputies in 1888, but died at Saint-Gratien on Aug. 3, 1889.

PYATIGORSK, a town in the R.S.F.S.R. of the Soviet Union, on the Podkoumok river and on a plateau 1,680 ft. above sea level, hence its name ("five mountains"). Its sulfur springs, about 15 in number, vary from 75° to 96° F. and are used for drinking and bathing and are bottled for export. The first buildings were erected in 1812 and a great impetus was given to the town when it was linked with the Rostov-on-Don to Baku railway. Its population in 1959 was 69,000. Its springs had long been known to the Circassians of the district who addressed a petition to Ivan the Terrible in 1551 asking for protectian against the Crimean Tatars. The poet M. Y. Lermontov (1814–1841) was killed here in a duel. In 1918 a skeleton, apparently Neanderthal, was reported.

See **Russ.** *Anthr. Journ.* (1922); "Caucasus: Ice Age," *Man*, vol. xxv (1926).

PYCNOGONIDA (SEA SPIDERS) are spiderlike marine animals which occur in all oceans, especially the arctic and antarctic, usually as bottom dwellers. Also called Pantopoda and rarely, Podosomata, they comprise a subphylum or a class of the phylum Arthropoda (*q.v.*) and resemble spiders (arachnids) in having the first pair of appendages characteristically arachnidlike or chelicerate. In most other respects pycnogonids are distinct from all other groups of arthropods. They are characterized by a relatively small body, excessively long legs with a patellar segment, and an additional pair of legs (ovigers) used by the male to carry the eggs about in a compact ball. The ovigers are present in all males except one New Zealand species but are lacking in the females of several genera. The sexes are usually separate, but one hermaphroditic species from Brazil has been described. Most species have eight walking legs, but species with ten legs are not uncommon in antarctic and Caribbean regions, and there is a 12-legged one in the antarctic. In addition to the walking legs and ovigers there may be a pair of pincerlike or chelate appendages (chelifores) and sensory palpi; the presence or absence of these appendages constitutes the basis of classification within the group, which includes about 50 genera divided into eight or nine families.



A PROTONYMPHON LARVA

The body of a pycnogonid consists of a cephalic segment or head region, followed by three to five trunk somites, which may be either distinctly segmented or coalesced into a compact disc, and a usually small, fingerlike abdomen with the anus at the tip. The mouth is a triangular opening at the end of an elaborate suctorial appendage (proboscis) which is often much longer and larger than the body. In such pycnogonids as *Nymphon* or *Achelia* the cephalic segment bears three pairs of appendages anterior to and in addition to the first pair of legs, the chelifores, which may or may not be chelate; the palpi, usually flanking the proboscis; and the ovigers, originating on the ventral surface. The extreme of reduction is found in *Pycnogonum,* which lacks both chelifores and palpi and has ovigers only in the males (except one species which has none). There are usually four simple eyes, located in a tubercle or elaborate process on the dorsal surface of the cephalic segment, but eyes are often lacking in deep-sea species. The digestive and reproductory systems have branches into the legs. The genital openings are usually on the ventral surface of the second joints of the last pair of legs but occur occasionally on all legs; the sexual products are stored in the fourth or femoral joints of the legs. The circulatory system is a simple dorsal heart with two or three pairs of lateral slits (ostia). The nervous system is composed of a supra-esophageal brain or ganglion and a chain of five or six ventral ganglia. There is no specialized excretory or respiratory system; secretory or cement glands occur in the males on the legs; and some species have a blood pigment of uncertain nature.

In all species of which the habits are known, the male attaches the eggs to his ovigers in masses or clusters as they are extruded from the female and carries them with him till they hatch into larvae. In some species the young larvae become attached to hydroids or polyps, in which they form galls or cysts; others are known to invade the medusa or jellyfish stage. The larval stages of a Japanese species, *Nymphonella tapetis,* are parasitic in the mantle cavity of clams; similar infestation of mussels by a California species has recently been observed. Others are associated with sea slugs (nudibranchs) and one may live within a sea cucumber (holothurian). Most species, however, are associated with coelenterates. The life cycle of deep sea forms, especially members of the genus *Colossendeis,* is unknown.

Pycnogonids occur in all oceans from the littoral zone to depths of more than 2,000 fathoms (12,000 ft.) but are especially abundant in arctic and antarctic waters. Most species are bottom dwellers, feeding on the soft parts and body juices of coelenterates and other defenseless animals? but some live on the floating or pelagic *Sargassum* in the mid-Atlantic; one, *Pallenopsis calcanea,* is bathypelagic, living at depths of 1,200–2,000 m. (about 4,000–6,500 ft.) in the Atlantic and Pacific oceans. Some species ascend to the surface to breed, swimming by treading water with their long legs. In size pycnogonids range from a spread of 3 to 4 mm. in such forms as the littoral *Tanystylum* to about 50 cm. in deep sea species of *Colossendeis.* While pycnogonids may sometimes occur in massive numbers, they are of no commercial significance and their study is untinged by economic motives.

One Devonian fossil, without discernible anterior appendages or proboscis, is considered to represent an extinct order, Paleopantopoda, while all the living species are included in the order Pantopoda. The Pycnogonida cannot be associated with the Arachnida because the sexual apertures are not restricted to the second abdominal somite (there being no such segment) as in Arachnida; the multiple gonopores are a condition not found in other living arthropods. Nor can they be considered as allied to Crustacea because they do not have antennae or biramous appendages at any stage. The patellar segment of the leg is an arachnid character, and the occurrence of both flexor and extensor muscles in the distal joint of the leg is a character of Crustacea as well as Arachnida. The musculature of the oviger is unique among arthropods: the distal division or tarsal segments are individually musculated. The chelate protonymphon larva is unique. The occurrence of supernumerary legs is not comparable with similar phenomena in other groups but seems instead to be a sort of polymorphism, possibly within a species, although the forms have been given generic names.

BIBLIOGRAPHY.—J. W. Hedgpeth, "On the Evolutionary Significance of the Pycnogonida," *Smithson. Misc. Coll.,* 106:18 (1947), "On the Phylogeny of the Pycnogonida," *Acta Zool., Stockh.,* 35:193–213 (1954); H. Helfer and E. Schlottke, "Pantopoda," *Bronn's Tierreich,* vol. 5, Abt. iv, bk. 2, i (1935). (J. W. HH.)

PYDNA, BATTLE OF (168 B.C.). The Roman operations in Greece having lingered on for some time, Lucius Aemilius

Paullus, "one of the few Romans of that age to whom one could not offer money," was sent to hasten a decision. Arriving at Heracleum he at once seized the pass of Pythium, which compelled Perseus king of Macedonia to fall back on Pydna.

The serried ranks of the Macedonian phalanx astonished and terrified Paullus, who, however, disguised his anxiety from his men, and advanced toward his enemy. The Roman vanguard was dispersed and one cohort almost annihilated. Once again the sarissa (pike) carried all before it, the Roman legions being forced back until they reached the hill upon which stood their camp. There, on account of the broken nature of the ground, the phalanx became somewhat disorganized. Paullus at once sizing up the situation "commanded his men, that wherever they should see the line of the enemy present openings, they should individually rush to these spots, and insinuating themselves like a wedge into such spaces, however narrow their extent, they should fight with impetuosity" (Livy). These tactics resulted in complete success, the phalanx being disjointed and broken up into a number of separated bodies. The 11 legion then charged the disorganized mass of pikemen and routed it. Perseus and his cavalry fled the field leaving the infantry to be slaughtered—20,000 were killed and 11,000 made prisoners. This battle was the last fought by the phalanx. The whole campaign was only 15 days. Thus perished the empire of Alexander the Great 144 years after his death.

See Livy xliv; T. Mommsen, *The History of Rome,* book iii, chap. x; H. G. Liddell, *A History of Rome* (1855). (J. F. C. F.)

PYE, HENRY JAMES (1745–1813), English poet laureate, was born in London on Feb. 20. 1745, and educated at Magdalen college, Oxford. Of all he wrote his prose *Summary of the Duties of a Justice of the Peace Out of Sessions* (1808) is most worthy of record; it is based on his own experience as a magistrate at Westminster.

Pye was made poet laureate in 1790, perhaps as a reward for his faithful support of Pitt in the house of commons. The appointment was looked on as ridiculous, and his birthday odes were a continual source of contempt. His most elaborate poem was an epic. *Alfred* (1801). He was the first poet laureate to receive a fixed salary of L27 instead of the historic tierce of Canary wine.

Pye died at Pinner, Middlesex, on Aug. 11, 1813.

PYGMALION, the name of two figures in classical literature and mythology.

1. In Greek mythology, Pygmalion was a king of Cyprus who fell in love with a statue of Aphrodite. Ovid, in the *Metamorphoses,* invents a more sophisticated version: Pygmalion, a sculptor, makes an ivory statue representing his ideal of womanhood, then falls in love with his own creation; Venus brings it to life in answer to his prayer.

Ovid's story was adapted by William S. Gilbert in *Pygmalion and Galatea* (1871), which appears to be the basis for the modern association of Galatea with Pygmalion's statue. George Bernard Shaw developed ironically the theme of the creative artist in *Pygmalion* (1912).

2. In the *Aeneid,* Pygmalion, king of Tyre, was the brother of Dido (*q.v.*) and the murderer of her husband. (Wm. S. A.)

PYGMY. Since Homer, the term has been applied specifically to a very small human race whose habitat was assumed to be the forest districts of the upper Nile; since then it has referred to a very short person (*see* Dwarfism and Gigantism). In modern anthropology the term is used as a category of size, applied to those human groups whose males do not pass 150 cm. or 59 in. in average bodily height; a slightly taller group is called pygmoid. Races of true pygmy size have not been discovered in human prehistory nor among American natives. The best known are the Twides, a generic term for three main subdivisions inhabiting the extended area of tropical Africa. (*See* also Bambute) They total probably 168,000 individuals. The Onge (Andaman Islands), the Aëta (Philippines), some portions of the Bushmen (Kalahari desert. South Africa), tribes in the mountains of New Guinea and in Indonesia also are of pygmy size. All Asiatic pygmies are known by the generic term "Negritos" (*q.v.*). Each of the tribes has its independent biological origin and enjoys a thoroughly normal development. The only characteristics they have in common are small bodily height and certain similarities in hair and face. Culturally, they still remain on the very low level of food gatherers, neglecting agriculture and stock farming. The men hunt, the women collect various kinds of small animals and roots, tubers, seeds, fruits and honey. These primitive nomads are obliged to roam around, changing their habitat every few days. Their huts are very simple, consisting of some sticks as scaffolding covered with leaves or skins. All adults wear short aprons of leaves, bark or leather, ornamentation is slightly practiced, mutilations not at all. The tribe is subdivided into many loose bands (sibs), each consisting of several families, without chief, priest or leader. The monogamic family (husband, wife, with their children) is the only form of social organization. Their principal weapon is the bow and arrow; they do not use stone or metal as raw materials. Through prayers and sacrifices they worship one Supreme Being. as the almighty ruler and author of all laws and morals. Pygmies more or less completely lack magic. animism and ancestor cult. Nearly all pygmy tribes maintain close symbiotic relations with culturally advanced tribes in their environment; consequently, they have lost their indigenous language and adopted that of their hosts.

Bibliography.—For the African Twides, M. Gusinde, "Pygmies and Pygmoids, Twides of Tropical Africa," *Anthropological Quarterly,* 28 3–61 (1955); for the Asiatic Negritos, P. Schebesta, *Die Negrito Asiens* (1952). (M. J. Gu.)

PYLE, ERNIE (Ernest Taylor Pyle) (1900–1945), U.S. newspaperman, was one of the most famous war correspondents of World War II. Born near Dana, Ind., on Aug. 3, 1900, he studied journalism at Indiana university and left school a few months before his graduation to become a reporter for a small-town newspaper. Later, after various editorial jobs, he acquired a roving assignment for the Scripps-Howard newspaper chain. His daily experiences furnished him material for a column that eventually appeared in as many as 200 newspapers. His coverage of the campaigns in North Africa. Sicily, Italy and France brought him a Pulitzer prize in 1944. as well as several other awards. He was with the U.S. forces in the Pacific on Iwo Jima and Okinawa, during which latter campaign he visited the nearby island of Ie Shima. There, on April 18. 1945, he was killed by Japanese machine-gun fire.

Compilations of his columns appeared in book form: *Ernie Pyle in England* (1941); *Here Is Your War* (1943); *Brave Men* (1944); *Last Chapter* (1946).

See Lee Graham Miller, *The Story of Ernie Pyle* (1950).

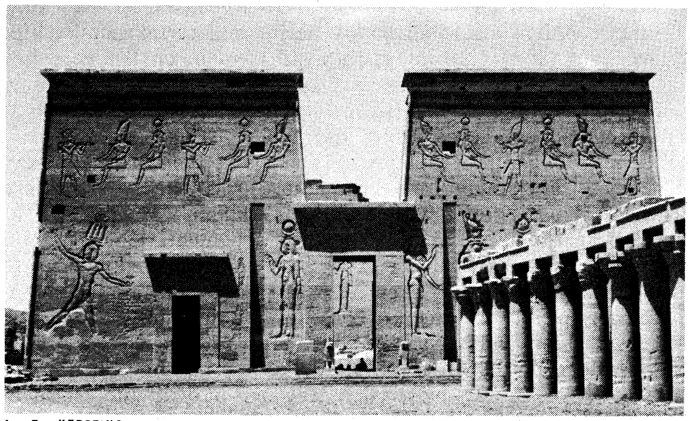
PYLE, HOWARD (1853–1911), U.S. artist and author, best known for his children's books, was born at Wilmington, Del., on March 5, 1853. He studied at the Art Students' league, New York city, and first attracted attention by his line drawings after the style of Albrecht Diirer. His magazine and book illustrations, particularly his drawings of scenes from American colonial life in New England and New Amsterdam. were of high quality. Some of Pyle's children's stories, illustrated by the author with vividness and historical accuracy, have become classics—most notably, *The Merry Adventures of Robin Hood* (1883); *Otto of the Silver Hand* (1888); and *Jack Ballister's Fortunes* (1894). Later he undertook mural paintings, executing. among others, "The Battle of Nashville" (1907) for the capitol at St. Paul, Minn.

Dissatisfied with his style in painting, he went to Italy for further study but died shortly afterward, on Nov. 9, 1911, in Florence. Pyle had established a free school of art in his home in Wilmington, where many successful American illustrators received their education.

PYLON, in architecture, originally a gate, but in modern usage applied to the huge truncated pyramidal forms, crowned with cornices, that flanked the entrances to Egyptian temples. The term is also applied to any similar large masses of masonry, often decorated with sculpture or architectural forms, used to flank the entrance to an avenue, a plaza or a bridge—especially a suspension bridge.

(*See* Bridges; Egyptian Architecture.)

A tower, usually of steel, to support a telegraph, telephone or



A. F. KERSTING

THE FIRST PYLON OF THE TEMPLE OF ISIS (PTOLEMAIC PERIOD, 332–30 B.C.), PHILAE, UPPER EGYPT

electric line over an extended span, is also called a pylon.

In aeronautics, a post or tower indicating a prescribed course of flight.

PYLOS (mod. NAVARINO), a town and bay on the west coast of Messenia, noted chiefly for the part it played in the Peloponnesian War. The bay, roughly semicircular, is protected by the island of Sphacteria (mod. Sphagia), more than 2½ mi. long. To the north lies the lagoon of Osman Aga. North of Sphagia is the rocky headland of Pylos or Coryphasium, called in modern times Palaea-Navarino or Palaeokastro, from the Venetian ruins on its summit. Most scholars have identified this with the Homeric Pylos, the home of Neleus and Nestor, and a cave on the north slope of Coryphasium is pointed out as that in which Hermes hid the stolen cattle of Apollo. But this view presents considerable difficulties, and Strabo (viii, 348 *et seq.*) argued that the Pylos of Nestor must be the place of that name in Triphylia, an important prehistoric site. After the Dorian migration Pylos declined. In 425 B.C. the Athenians sent an expedition to Sicily under command of Eurymedon and Sophocles. With them was the general, Demosthenes, who landed at Coryphasium with a body of Athenian troops and hastily fortified it. The Spartans, who were then invading Attica, withdrew their forces and attacked Pylos vigorously by sea and land, but were repulsed, and the Athenians were enabled by the arrival and victory of their fleet to blockade on the island of Sphacteria a body of 420 Spartiates with Helots. Their resistance was overcome by a rear attack directed by a Messenian, who led a body of men by a difficult path along the cliffs on the east, and the 292 Spartan survivors laid down their arms 72 days after the beginning of the blockade. Their surrender made a deep impression on the whole Greek world, which had learned to regard a Spartan surrender as inconceivable. Though Pylos should have been ceded to Sparta under the peace of Nicias (421 B.C.) it was retained by the Athenians until the Spartans recaptured it early in 409 B.C.

In the middle ages the name Pylos was replaced by that of Avarino or Navarino, derived from a body of Avars who settled there; the current derivation from the Navarrese company, who entered Greece in 1381 and built a castle at this spot, cannot now be maintained.

From 1498 to 1821 Navarino was in the hands of the Turks, save at two periods when it was held by the Venetians, who named it Zonklon. *See* NAVARINO, THE BATTLE OF.

BIBLIOGRAPHY.—W. M. Leake, *Travels in the Morea,* i. 398 *sqq.* (1830), and *Peloponnesiaca,* 190 *sqq.* (1846); E. Curtius, *Peloponnesos,* ii, 173 *sqq.* (Gotha, 1852); C. Bursian, *Geographie von Griechenland,* ii, 175 *sqq.* (Leipzig, 1868); Pausanias iv, 36, and the commentary in J. G. Frazer, *Pausanias's Description of Greece,* iii, 456 *sqq.*, v. 608 *sqq.* (1898); W. G. Clark, *Peloponnesus,* 214 *sqq.* (1858); W. Vischer, *Erinnerungen und Eindrücke aus Griechenland,* 431 *sqq.* (Basel, 1857); G. Grote, *History of Greece,* pt. ii, ch. 52; G. Busolt, *Griechische Geschichte,* iii, 1086 *sqq.;* F. M. Cornford, *Thucydides mythistoricus,* 82 *sqq.* (1907). The operations at Pylos described by Thucydides iv, 2–41, have been discussed on the basis of personal observation by G. B. Grundy (*Journal of Hellenic Studies,* xvi, 1 *sqq.; Classical Review,* x, 371 *sqq.,* xi, 155 *sqq.,* 448; *J.H.S.,* xviii, 232 *sqq.*) and R. M. Burrows (*J.H.S.,* xvi, 55 *sqq.; C.R.* xi, 1 *sqq.; J.H.S.* xviii, 147 *sqq.,* 345 *sqq.; C.R.* xix, 129 *sqq.*). Though differing on many points, they agree in thinking (1) that the island of Sphagia is the ancient Sphacteria, Palaeokastro the ancient Coryphasium or Pylos; (2) that in 425 B.C. the lagoon of Osman Aga was navigable and communicated by a navigable channel with the Bay of Navarino; (3) that Thucydides, if the manuscript reading is correct, underestimates the length of the island, which he gives as 15 stades instead of 24 (nearly 3 mi.), and also the breadth of the southern channel between it and the mainland. *Cf. J.H.S.,* xx, 14 *sqq.,* xxvii, 274 *sqq.,* and Frazer's summary (*op. cit.* v, 608 *sqq.*).

PYM, JOHN (1584–1643), English statesman, son and heir of Alexander Pym of Brymore, Somersetshire, a member of a family which had held this seat in direct male descent from the time of Henry III. Pym matriculated as a commoner at Broadgates hall (now Pembroke college), Oxford, in 1599, and entered the Middle Temple in 1602. Through the interest of the 3rd earl of Bedford—whose agent in the west country was Pym's stepfather, Sir Anthony Rous—Pym became receiver of the king's revenue for Hampshire, Wiltshire and Gloucestershire.

Growth of Leadership.—As a member for Calne in the 1621 parliament, Pym delivered a speech on Nov. 28 to "beseech the King that there may be a commission to see the Laws here of England duly executed against Papists." When King James tried to restrict the commons' freedom of speech, Pym was a promoter of the Protestation, which was entered in the commons' journals, asserting that parliament's privileges were "the ancient and undoubted birthright and inheritance of the subjects of England." This protest the king tore from the journal. After parliament's dissolution in Jan. 1622, Pym was ordered to be confined first to his London house and afterward to Brymore, an order which remained in force for three months. In the 1624 parliament Pym sat for Tavistock, which he continued to represent for the remainder of his life. There is no evidence that he took a prominent part in this parliament or in the first parliament (1625) of Charles I. In the 1626 parliament Pym was one of the managers of Buckingham's impeachment.

The outstanding event of the 1628–29 parliament was the Petition of Right of which Pym was a leading supporter. He also spoke at length against Roger Manwaring who had preached the doctrine of nonresistance to a king, deducing that a king could levy taxes without parliament's consent. Pym was the leader in impeaching Manwaring before the lords where he delivered a speech expounding the fundamental principles of government.

During the next 11 years, when no parliament met, Pym's energies were absorbed as treasurer of the Company of Adventurers for the Plantation of the Islands of Providence, and Henrietta, incorporated in Dec. 1630. After struggling for nearly 20 years the company finally failed. Its importance was that its members were mostly leading Puritans who had already been associated with Pym in the parliamentary struggle against Charles I and would be associated again when parliaments were resumed. Hence when the Short parliament met on April 13, 1640, it included a group of resolute men already accustomed to act together and to recognize Pym as leader. On April 17 Pym spoke for two hours denouncing grievances: "The first, are those which during these eleven years interval of Parliaments, are against the Liberties and Privileges of Parliament. The Second, are innovations in matters of Religion. The Third, Grievances against the property of our goods." "That which marked Pym from henceforth as a leader of men was the moderation combined with the firmness with which every sentence was stamped." (S. R. Gardiner, *History of England,* ix, 102.) Pym was concerned in an episode which led to the parliament's abrupt end: he and others prepared a petition that the king should make terms with the Scots. To forestall this, Charles dissolved parliament May 5.

Pym now aimed at compelling Charles to call another parliament. He drew up the petition which demanded redress of grievances, peace with the Scots and a new parliament, and which 12 peers presented to the king. When writs for another parliament were issued, Pym "rode about the country to promote elections of the Puritanical brethren to serve in Parliament"—the first election campaign in parliamentary history.

The Long Parliament.—Parliament assembled on Nov. 3,

1640. Pyrn was recognized at once as the leader of the opposition to the court and his dominance grew. Believing that the earl of Strafford was set upon impeaching the popular leaders for their dealings with the Scots, and that attack was the surest defense, on Nov. 11 Pym, behind closed doors, began his denunciation of him. That same afternoon Pym carried to the lords his impeachment and a summary of the charges on which the impeachment was based. Between this date and the opening of Strafford's trial, attempts were made to win Pyrn and others over to the king by offering to them ministerial posts. Twice the king interviewed Pyrn and twice the offer was refused, presumably because Charles demanded the dropping of Strafford's impeachment as the price of Pym's appointment. On April 13, 1641, the last day of the impeachment trial, Pyrn delivered one of his most eloquent speeches, basing his attack less upon Strafford's technical breach of the law of treason than upon his betrayal of trust as the king's adviser. "Shall it be treason," he declaimed, "to embase the King's coin, though but a piece of twelve-pence or sixpence? and must it not needs be the effect of a greater treason, to embase the spirits of his subjects, and to set a stamp and character of servitude upon them, whereby they shall be disabled to do anything for the service of the King and Commonwealth?" Meantime some of Pym's associates were doubting whether the lords would convict Strafford of treason on the available evidence. On April 10, therefore, they introduced a bill of attainder. Pym never agreed with this policy, believing that the impeachment should and could be carried. But it was the attainder process which was first completed and by which Strafford was executed on May 12.

Even more important than finance or Strafford to the opposition group was the subject of religion. In this matter Pym's position was different from that of most of his associates in that he was never a Puritan but was a staunch adherent of the orthodox, pre-Laudian church. In his maiden speech (Feb. 16, 1621) he had inveighed against a member named Shepherd because of his "exasperatinge one party by that odious and factious name of Puritans." Similarly in the 1628–29 parliament he condemned Archbishop Laud's Arminianism because it contravened "the 39 Articles set forth in Queen Elizabeth's time; and the Articles set forth at Lambeth as the doctrine of the Church of England." In Dec. 1640 Pyrn moved Laud's impeachment! and on Feb. 24, 1641, presented the impeachment articles to the lords. In February the Puritan members voted that a London petition against episcopacy should be sent to a committee for report, and the Anglican members voted against this; Pyrn voted with the Puritans, but a fellow member (Edward Bagshaw) wrote: "Mr. *John Pyrn* spoke to this purpose, 'That he thought it was not the intention of the House to abolish either Episcopacy or the Book of Common Prayer, but to reform both wherein offence was given to the people'." (E. Bagshaw, *A* Just *Vindication,* 1660.) When. however, Pyrn became convinced that the bishops were merely the king's nominees to make religious changes and to preach nonresistance, he supported the abolition of episcopacy and in May 1641 voted for the Root and Branch bill. That this attitude was not due to a change of conviction is shown by his "Declaration and Vindication" of March 1643 wherein he averred: "That I am, and ever was, and so will dye a faithfull son of the Protestant Religion. without having the least relation in my beliefe to those gross errours of Anabaptisme, Brownisme, and the like."

Pyrn was a leading supporter of the Grand Remonstrance, and his speech on Nov. 22, 1641. helped to secure its passing, though by only 11 votes. This small majority was evidence of a reaction in the king's iavour. Charles thought to take advantage of it by impeaching a member of the lords and five members of the commons, including Pym (Jan. 3. 1642). Next day, Charles went to the commons to arrest the five members, only to find that "the birds are flown." This breach of privilege turned the tide decisively against Charles and made war inevitable.

The **Civil** War. — Pym had a large part in the preparations for war. On July 4 he was appointed one of the 1j members of the Committee of Safety. of whom five had been members of the Providence company. After the outbreak of war in Aug. 1642 he was the organizer who kept the parliamentary forces in the field, raising taxes and maintaining supplies. He was, in effect, the head of the executive.

At first his aim was to prevent a general war. On Nov. 9, following the battle of Edgehill, at a conference between the two houses, he urged a petition to the king for negotiations. The king refused. to receive the petition, and Pym appealed to the city for its continued support. But a few days later he was urging that both sides should disband their armies so that negotiations should not be prejudiced by their existence. When hope of negotiations iailed, Pyrn gave himself entirely to organizing for victory. In March 1643 he proposed an excise on the sale of all goods: though then rejected. the excise was levied four months later. In May he opened negotiations with the Scots. In June he reintroduced the idea — rejected the previous October — of a covenant whose signatories should pledge themselves not to lay down arms until the Reformed religion was secure. Meanwhile, negotiations with the Scots were progressing. The final terms were that the Scots would send an army into England against the king on condition that they were paid £30,000 a month and that parliament would establish presbyterianism after the war. On Sept. 25 parliament accepted these terms.

The Scottish alliance was Pym's last notable contribution to the parliamentary cause. On Nov. 7 parliament made him master of the ordnance; *i.e.,* of arms stored in the Tower. On Dec. 8 he died of cancer at Derby house, Westminster, which had been granted to him as a residence. The commons accorded him a state funeral in Westminster abbey, where his body was buried. The commons further voted a sum of £10,000 to pay his debts.

Family.—Pym's wife had been Anne Hooke (or Hooker) who had died in 1620. Of their nine children, four were sons. The eldest, Alexander, died unmarried. Charles became a baronet; his title and Pym's male line became extinct in Charles's son (also Charles) in 1688. Anthony emigrated: probably to St. Kitts.

Character. — Moderation of views in both religious and political questions, consistency of principles and administrative efficiency were Pym's outstanding characteristics, and their combination explains his supremacy in parliament. His speeches showed a sound political philosophy and logical exposition rather than rousing oratory; but they were evidently impressive and persuasive. Pym's death left a gap in the parliamentary leadership that was never again filled.

BIBLIOGRAPHY.—S. R. Gardiner, "John Pym," in *Dict. Nat. Biog.* (London, 1917) supplemented by his *History of England 1603–42,* 10 vol. (London, 1883–84) and *History of the Great Civil War* (London, 1886); Anthony a Wood, *Athenae Oxonienses,* ed. by P. Bliss, 4 vol. (London, 1813–20); J. Forster on "Pyrn" in D. Lardner (ed.), *Cabinet Cyclopaedia,* 133 vol. (London, 1830–49) and in Sir J. Macintosh *et* al. (eds.), *Lives of Eminent British Statesmen,* 7 vol. (London, 1831–39); S. R. Brett, *John Pym, 1583–1643* (London, New York, 1940); J. H. Hexter, *The Reign of King Pyrn* (Cambridge, Mass., London, 1941). *See* also J. Forster, *The Debates on the Grand Remonstrance* (London, 1860), *Arrest of the Five Members by Charles I* (London, 1860) and "Life of Sir J. Eliot'! in *Eminent British Statesmen (see* above); A. P. Newton, *The Colonising Activities of the English Puritans* (New Haven, Conn., 1914); W. Notestein, F. H. Relf and Hartley Simpson (eds.), *Common Debates,* 1621, 7 vol. (New Haven, Conn., London, 1935); W. Notestein and F. H. Relf, *Commons Debates for 1629* (Minneapolis, 1921). (S. R. BT.)

PYNCHON, WILLIAM (1590?–1662), one of the original patentees of the Massachusetts Bay company and founder of Springfield. Mass., was born in Springfield. Essex, England. In 1630 he joined the party led by John Winthrop and emigrated to New England where he settled first at Dorchester. Mass., and later at Roxbury (*q.v.*). In the early days of the colony, Pynchon served as elected assistant (1630–36) and treasurer (1632–34). In 1636 he was put in charge of a group of colonists who wanted to settle along the Connecticut river. The settlement thus founded was named Springfield. after Pynchon's English home. He served as magistrate of Connecticut (1636–38), but, after a falling out with Thomas Hooker, he turned his allegiance back to the Massachusetts Bay colony and was re-elected to the board of assistants from 1642 to 1651. In 1652, Pynchon, who had been denounced as a heretic by the Massachusetts general court because of a tract he had written attacking orthodox Puritan views, returned to England and purchased an estate at Wraysbury, near Windsor, where he died on Oct. 29, 1662.

P'YŎNGYANG, capital city of the Democratic People's Republic of Korea. is located northwest along the Taedong river, 30 mi. from the Yellow sea. The reputed grave of the Chinese sage Kija (1122 B.C.), legendary founder of the city, is north of the city. Artifacts found in graves testify to the high cuitural level of the Chinese colony established near P'yŏngyang in 108 B.C. Walls were built to reinforce the natural protection afforded by the two rivers and hills that surround P'yŏngyang. In this well-fortified area. the Koguryo dynasty (*c.* 37 B.C.–A.D. 668) had its capital, until defeated by the combined forces of China and the Silla dynasty in south Korea. Thereafter P'yŏngyang, continued to be a political and educational centre for northwestern Korea.

Connected with other parts of Korea by rail, motor road and air, commercial activities in P'yŏngyang have been of paramount economic importance. Under Japanese control (1910–45) anthracite coal mines and modern industries were developed, mainly to the south of the city where rail lines converged and to the east across the Taedong river. Hydroelectric power was supplied from plants on the Yalu river and its tributaries and from a thermal plant in the city.

In surrounding areas, heavy industries, such as the iron and steel plant at Kyŏmip'o, cement plants to the east and chemical plants to the north. were developed. In the city an arsenal was established, also railroad workshops and many light industries, for example. textiles, rubber shoes, cigarettes and corn products.

During the Korean war numerous air raids devastated P'yŏngyang. It was captured by UN forces in 1950 but subsequently was lost when Chinese Communist forces entered the war. It was reported that postwar rehabilitation restored many of the industries and that many large new apartments were built.

Pop. (1944) 368.288; (19j6 est.) 500,000. (S. McC.)

PYORRHEA is an obsolete word in dental nomenclature meaning a discharge of pus. Pyorrhea alveolaris signifies pus discharge from the alveoli (tooth sockets), but it represents only the very late stages of the disease. It is a purulent inflammation of the tissue surrounding the roots of teeth with gradual loss of the supporting bone and eventual loosening of the teeth. See also PERIODONTAL DISEASES. (EK. D. C.)

PYRACANTHA, a genus of evergreen thorny shrubs of the rose family (Rosaceae), commonly known as fire thorn. There are six species native from southeastern Europe to central China. The leathery. alternate leaves are usually minutely toothed. The white flowers are in corymbs, followed by red orange or yellow berrylike fruits. P. *coccinea,* P. *crenato-serata* and P. *crenulata* are among the best-known kinds, widely used for foundation plantings and hedges where they are prized for their brilliant fruit in autumn. The plants are easily grown in subtropical and temperate regions (P. *coccinea Lalandii* is the most hardy form) in areas of full sun or partial shade and are not particular as to soil type. (G. H. M. L.)

PYRAMID, in architecture, a monumental structure of stone or brick with a rectangular base and four sloping triangular sides meeting at an apex. Structures of this type were built at various times in Egypt, the Sudan. Ethiopia, western Asia. Greece, Cyprus, Italy, India, Thailand. Mexico and on some islands of the Pacific ocean. The most famous and in many respects most remarkable of them all are the pyramids of ancient Egypt, with which the present article will deal exclusively.

The ancient Egyptian term for pyramid is *mer*. The English word "pyramid" comes from the Greek *pyramis,* pl. *pyramides,* a word of doubtful etymology that may have been derived from the ancient Egyptian *per-em-us,* a term used in a mathematical papyrus to denote the vertical height of a pyramid.

The' pyramids of ancient Egypt were all funerary edifices. Chronologically they cover a time span of 2,700 years ranging from the beginning of the Old Kingdom to the close of the Ptolemaic period; but the time at which pyramid building reached its acme, the pyramid age par excellence, was that commencing with the 3rd dynasty and ending with the 6th (*c.* 2700 to 2300 B.C.). During that 400 years the pyramid was the regular type of royal tomb. It was not, as such, an isolated structure, but was always part of an architectural complex.

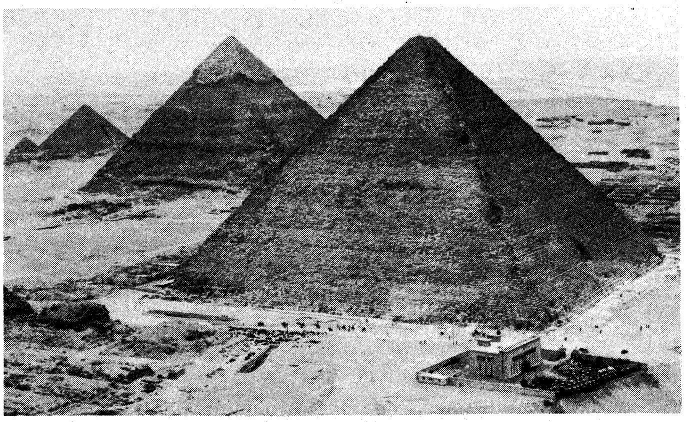
The essential components, during the Old Kingdom at any rate, were the pyramid itself. containing or surmounting the grave proper and standing within an enclosure on high desert ground; an adjacent mortuary temple; and a causeway leading down to a pavilion (usually called the valley temple), situated at the edge of the cultivation and probably connected with the Nile by a canal. About 80 royal pyramids have been found in Egypt, many of them, however. have been reduced to mere mounds of debris and were plundered of their treasures long ago.

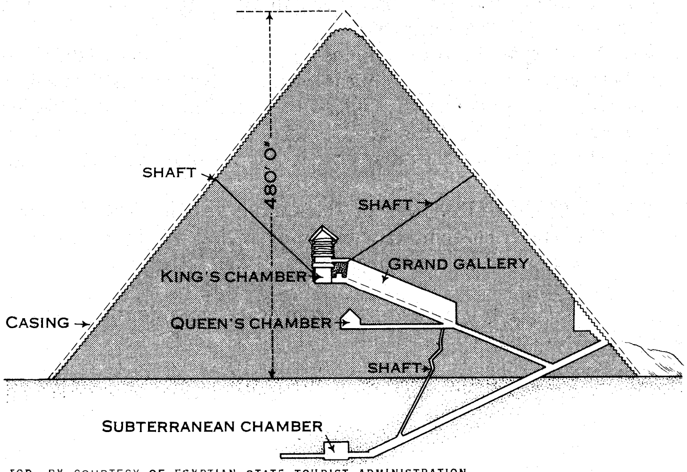
Early Forms. — The prototype of the pyramid was the mastaba, a form of tomb known in Egypt from the-beginning of the dynastic era. It was characterized by a flat-topped rectangular superstructure of mud brick or stone with a shaft descending to the burial chamber far below it. Zoser (Djoser), the first king of the 3rd dynasty, employing Imhotep (*q.v.*) as architect, undertook, for the first time. the construction of a mastaba entirely of stone. instead of brick; it was 8 m. high and had a square ground plan with sides about 63 m. each. Once completed it was extended on the ground on all four sides. and its height too was increased by building rectangular additions of diminishing size superimposed upon its top. Thus Zoser's original mastaba became a terraced structure rising in six unequal stages to a height of 60 m., its base measuring 120 m. by 108 m. This monument, which lies at Saqqara (Sakkara), is known as the Step pyramid and is probably the earliest stone building of importance erected in Egypt. The substructure has an intricate system of underground corridors and rooms, its main feature being a central shaft 2j m. deep and 8 m. wide, at the bottom of which is the sepulchral chamber built of granite from Aswan. Zoser's Step pyramid rises within a vast walled court j44 m. long and 277 m. wide, in which are the remnants of several other stone edifices built to supply the wants of the king in the hereafter.

A structure of peculiar shape called the Blunted. Bent. False or Rhomboidal pyramid. which stands at Dahshur a short distance south of Sakkara. marks an advance in the development toward the strictly pyramidal tomb. Built by Snefru (Snofru), the founder of the 4th dynasty, it is 188 m. square at the base and approximately 98 m. high. It is peculiar in that it has a double slope; it changes its angle of inclination about halfway up its sides. the lower portion of the monument being steeper than the upper portion. It comes nearer to being a true pyramid than Zoser's terraced tomb just described. A monumental structure at Medum, also ascribed to King Snefru, was a true pyramid. though not originally planned as such. It is uncertain whether it was begun as a mastaba, like Zoser's tomb, or as a small step pyramid. The initial structure was gradually enlarged until it became a gigantic eight-terraced mass of masonry; then the steps were filled in with a packing of stone so as to form a continuous slope. The entire structure was eventually covered with a smooth facing of limestone: a geometrically true pyramid was the final result. In its ruined condition. however, it has the appearance of a three-stepped pyramid rising to a height of about 70 m. The earliest tomb known to have been designed and executed throughout as a true pyramid is the North Stone pyramid at Dahshur, thought by some to have also been erected by Snefru. though the attribution is far from certain. It is about 220 rn. wide at the base and 104 m. high; thus it is nearly as large as the celebrated pyramids of Gizeh.

Pyramids of **Gizeh.**—The three great pyramids of Gizeh stand on a rocky plateau of the desert a few miles southwest of Cairo. They were built by the 4th dynasty Pharaohs Khufu (Cheopsj, Khafre (Khefren or Chephren) and Menkaure (Mycerinus), and came to be. numbered among the seven wonders of the ancient world.

Khufu or Cheeps.-The largest and oldest of them is that of Khufu. now known as the Great pyramid and called "Horizon of Khufu" by the ancient Egyptians. Perhaps the greatest single building ever erected by man, the Great pyramid's almost perfectly square base was, when intact, 230 m. long, thus covering





TOP: BY COURTESY OF EGYPTIAN STATE TOURIST ADMINISTRATION

PYRAMIDS OF GIZEH

Top: Aerial view of the three pyramids at Gizeh. Bottom: Section through the Great pyramid of Khufu, Gizeh, *c.* 2700 B.C.

an area of slightly over 13 ac.; it has been calculated that St. Peter's at Rome, the cathedrals of Florence and Milan, Westminster abbey and St. Paul's cathedral could all be grouped inside that area (E. B. Smith, Egyptian *Architecture* as a Cultural *Expression*). The original height was 146.59 m., reduced now to 137 m. The sides rise at an angle of 51° 52′ and are accurately oriented to the four cardinal points. The core is made of yellowish limestone blocks from the nearby Moqqatam hills, the outer casing (now mostly gone) and the inner passages are of finer limestone from Tura, while the burial chamber is built of huge blocks of granite from Aswan. Approximately 2,300,000 blocks of stone went into this stupendous structure, each weighing an average of 2½ tons.

The monument is a masterpiece of technical skill and engineering ability. The geometrical precision of its layout and the accuracy of the stonecutting are truly amazing, particularly when one considers the colossal proportions of the whole and the size and weight of the blocks employed in it. The internal walls as well as the casing stones that still remain *in situ*, some of which weigh as much as 16 tons, show finer joints than any other masonry in Egypt and possibly in the world. The question of how the pyramid was built has not received a wholly satisfactory answer. The most plausible answer is that the Egyptians. who lacked tackle and pulleys for lifting heavy weights. employed a sloping embankment of brick and earth, which was increased in height and in length as the pyramid rose, and on which the stone blocks were hauled by means of sledges. rollers and levers. According to Herodotus the road for the conveyance of building material from the river to the plateau on which the pyramid stands took 10 years to construct. while the pyramid itself took another 20 years and demanded the labour of 100.000 men. The theories that ascribe prophetic and esoteric meanings to the measurements, angles and proportions of the Great pyramid are wholly devoid of scientific foundation.

The entrance to the Great pyramid is on the north side, about 18 m. above ground level. A sloping corridor descends through the masonry, penetrates the rocky soil and ends in an unfinished underground chamber. From the descending corridor, at a point about 20 m. from the entrance! branches an ascending corridor that leads to a room known as the Queen's Chamber (a misnomer, for there is no evidence to suggest that it was designed for her) and to a great slanting gallery 8.50 m. high and 46.50 m. long. At the upper end of this gallery a low and narrow passage gives access to the burial room proper, usually termed the King's Chamber. Entirely lined and roofed with granite. the King's Chamber is 10.43 m. long. 5.21 m. wide and 5.82 m. high and stands at a perpendicular height of 42.28 m. from the ground. From the chamber two narrow shafts run obliquely through the masonry and reach the exterior of the pyramid; it is not known whether they served a religious purpose or were meant for ventilation. The King's Chamber contains nothing but an empty lidless sarcophagus of red granite without ornament or inscription. Above the room are five compartments separated by horizontal granite slabs, presumably built with a view to diverting the pressure from the ceiling of the burial chamber. There are scanty remains of the subsidiary buildings that once completed the architectural complex of the Great pyramid; they show, however, that the complex comprised the usual elements. The pyramid was surrounded by a temenos wall; attached to the east side of the wall was a temple for the mortuary service of the king, and from this a long causeway descended to the valley. It is highly probable that there was, at the lower end of the causeway. a portico or valley temple, remnants of which may still lie unearthed under the modern village of Kafr es-Sainman.

Khafre and Menkaure.—Next in size in the Gizeh group is Khafre's pyramid. which stands at a higher point of the plateau and thus appears to be taller than the larger and earlier pyramid of Khufu. It was originally 143.50 m. high, and the base 215.25 m. square. A substantial portion of its outer casing still clings round the top and consists of slabs of Tura limestone. whereas the casing blocks that remain at the bottom of the monument are of red granite. The third Gizeh pyramid, erected by Menkaure. formerly rose to a height of 66.50 m.; thus it is less than half as tall as its two towering neighbours.

Other Egyptian Pyramids.— Other noteworthy pyramids belonging to the Pyramid age are the three built at Abu Sir by kings of the 5th dynasty, of which the largest is that of Seferirkare, originally 106 m. square and 70 m. high. The other two are far smaller, but their adjoining mortuary temples appear to have been magnificent buildings decorated with excellent reliefs. some of a historical nature. The pyramids themselves were poorly constructed. and are now in a state of dilapidation.

Pyramid Texts.—The relatively small pyramids of Unas, the last monarch of the 5th dynasty, of four kings and three queens of the 6th and of an obscure 7th dynasty Pharaoh named Ibi. all of which are at Saqqara, are of particular interest because they contain. inscribed upon the walls of their inner chambers. collections of prayers. hymns and spells meant to ensure the welfare of the king or queen in the afterlife. These inscriptions, which are known as the Pyramid texts, form the world's oldest surviving corpus of religious and funerary writings.

Middle Kingdom.—The pyramids of the Middle Kingdom exhibit some structural innovations. A small pyramid mounted on a high podium surrounded by a terraced structure with a forest of columns was the dominant feature of King Nebhepetre Mentuhotep's tomb-temple at western Thebes. The pyramid was solid throughout, it had neither passages nor chambers and consisted of a rubble core cased with limestone. The core of Sesostris I's pyramid at Lisht consisted of a network of stone cross walls with the interspaces filled in with sand and loose blocks, the whole covered by a casing of dressed limestone blocks. This novel and labour-saving mode of construction was subsequently employed in other 12th dynasty pyramids at Dahshur. Illahun and Hawara, in which. however. mud brick was used for the cross walls of the core and as filling material as well. A further characteristic of the Middle Kingdom pyramids is the intricate design of the substructures.

No pyramid appears to have been constructed by any of the kings from the 18th dynasty to the 24th, with one exception: the pyramid-cenotaph erected at Xbydos for Queen Tetisheri by Ahmose I. the founder of the 18th dynasty. Royal tombs of pyramidal form were built once again by the thoroughly egyptianized Ethiopian rulers who held sway over Egypt as kings of the 25th dynasty in the 8th and 9th centuries B.C. They were buried in pyramids which they had erected for themselves in their homeland, at Nuri and Kurru, near the Fourth Cataract, in the north-' ern Sudan.

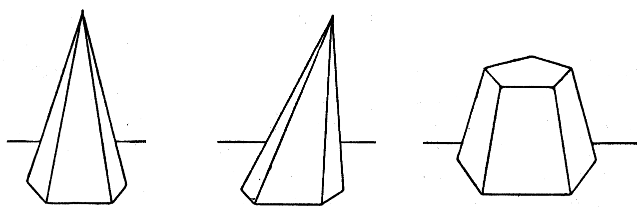
Tombs of pyramidal design were built for private persons from the Middle Kingdom onward. The earliest have been found at Abydos. They were made of coarse unbaked bricks, coated with mud plaster and whitewashed. The pyramid itself was from 3 to 4 m. high and rested on a shorter rectangular podium. The coffin was deposited in a vaulted chamber which took up most of the interior of the pyramid. In the Theban necropolis, during the New Kingdom, a rather small mud-brick pyramid, sometimes topped with an apex of limestone, was a conspicuous feature of many private tombs.

See also EGYPTIAN ARCHITECTURE.

BIBLIOGRAPHY.—I. E. S. Edwards, *The Pyranzids of Egypt* (1947); *L.* Grinsell, *Egyptian Pyranzids* (1947); *W.* M. Flinders Petrie, *Pyramids and Temples of Gizeh* (1883); J. H. Cole, *The Determination of the Exact Size and Orientation of the Great Pyramid of Giza*, Survey of Egypt, Paper No. 39 (1925); E. Baldwin Smith, *Egyptian Architecture as a Culturul Expression* (1938); J. H. Breasted, *The Development of Religion and Thought in Ancient Egypt* (1912).

(R. A. Cs.)

PYRAMID, in geometry, a polyhedron of which one face, called the base, is any polygon and the other faces (the lateral faces) are triangles with one vertex in common. The intersections of the lateral faces are called the lateral edges of the pyramid, and their common vertex is called the vertex of the pyramid. The perpendicular distance from the vertex to the plane of the base is called the height or altitude of the pyramid. If the base is a regular polygon the centre of which coincides with the foot of the perpendicular from the vertex to the base, the pyramid is called a regular pyramid. As in the case of prisms (*q.v.*), pyramids are classified according to their bases. The portion of a



REGULAR PYRAMID, OBLIQUE PYRAMID, AND FRUSTUM OF PYRAMID

pyramid and a plane cutting all the lateral edges is called a truncated pyramid; and if the cutting plane is parallel to the base, the truncated pyramid becomes a frustum of a pyramid. The volume of a pyramid with base B and altitude a is $\frac{1}{3}aB$. The volume of a frustum of a pyramid with bases B and B' and altitude a is $\frac{1}{3}a(B + B' + \sqrt{BB'})$.

See SOLIDS, GEOMETRIC.

PYRAMIDION (diminutive of "pyramid"), an architectural term for the copper-gilt casing covering the apex of an obelisk; also its upper termination of pyramidal form.

PYRAMUS AND THISBE, the hero and heroine of a Babylonian love story told by Ovid in his *Metamorphoses*. Their parents refused to consent to their union, and the lovers used to converse through a chink in the wall separating their houses. At last they resolved to flee together. and agreed to meet under a mulberry tree near the tomb of Ninus. Thisbe was the first to arrive. but, terrified by the roar of a lioness, took to flight. In her haste she dropped her veil, which the lioness tore to pieces with jaws stained with the blood of an ox. Pyramus, believing that she had been devoured by the lioness, stabbed himself. Thisbe returned to the rendezvous, and finding her lover mortally wounded, put an end to her own life. From that time the fruit of the mulberry, previously white, was always black.

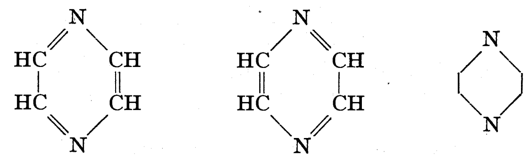
PYRARGYRITE, a mineral consisting of silver sulfantimonite, known also as dark red silver ore, is an important source of the metal. It is closely allied to, and isomorphous with. the corresponding sulfarsenite known as proustite (*q.v.*), or light red silver ore. "Ruby silver" or red silver ore (German *Rotgültigerz*) was mentioned by G. Agricola in 1546, but the two species were completely distinguished by J. L. Proust in 1804.

The composition of pyrargyrite is Ag_3SbS_3. The colour is usually grayish black and the lustre metallic-adamantine; large crystals are opaque. but small ones and thin splinters are deep ruby red by transmitted light; hence the name, from the Greek words for "fire" and "silver." The streak is purplish red, thus differing markedly from the scarlet streak of proustite and affording a ready means of distinguishing the two minerals. The mineral occurs in metalliferous veins with calcite, argentiferous galena, native silver, native arsenic, etc.

The best crystallized specimens are from St. Andreasberg in the Harz mountains and Freiberg in Saxony, Ger., and Guanajuato, Mex. It is found at Cobalt, Ont., and is not uncommon in silver mines in the U.S., in Colorado, Nevada. New Mexico and Idaho, but rarely as distinct crystals; and it has been found in Cornish mines.

PYRAZINES (PIAZINES or PARADIAZINES), in organic chemistry, nitrogenous compounds containing a ring composed of four carbon atoms and two nitrogen atoms, the latter being in the 1:4 relationship.

Pyrazine, $C_4H_4N_2$, crystallizes from water in colourless prisms having a heliotrope odour; it melts at 55° C. and boils at 115° C. Its structure, which is analogous to that of benzene (*q.v.*), may be described as a resonance hybrid between I and II (*see* RESONANCE, THEORY OF).



I II III

As with benzene, the structure is commonly expressed by the conventional symbol III.

Important derivatives of pyrazine include: hexahydropyrazine, or piperazine; the diketopiperazines or amino-acid anhydrides, which are obtained by the elimination of alcohol from the esters of a-amino acids; and the various groups of azine dyes. *See* DYES.

(G. W. WD.)

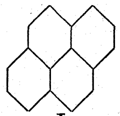
PYRAZOLES, in organic chemistry a series of compounds containing a five-membered ring with three carbon atoms united to two adjacent nitrogen atoms arranged as in formula I, which represents the structure of pyrazole itself.

I II

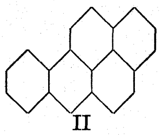
The application in medicine of such pyrazole derivatives as antipyrine and pyramidone, and the production of synthetic dyes of the pyrazoione type, lends a special interest to this chapter of organic chemistry. (G. T. M.; X.)

PYRENE, an aromatic hydrocarbon found with chrysene, in the coal-tar distillate boiling above 360° C. and also in "Stupp" fat, a by-product from the working up of mercury ores in Idria. It was long considered to be yellow but is now known to be colourless when pure. It melts at 156° C. and boils above 360° C.

Chromic acid oxidizes it successively to pyrene-quinone and pyrenic acid; permanganate oxidizes the latter substance to naphthalene-1:4:5:8-tetracarboxylic acid, which confirms the structure I ascribed to pyrene, $C_{16}H_{10}$.



I



II

1,2-Benzopyrene, II. occurs in coal tar to the extent of at least 0.003% and is of interest in that it is apparently the factor mainly responsible for the carcinogenic activity of the tar (*see* CARCINOGENIC CHEMICALS).

BIBLIOGRAPHY.—A. E. Everest, *The Higher Coal-Tar Hydrocarbons* (1927); L. F. Fieser, *The Chemistry of Natural Products Related to Phenanthrene* (1936). (*G. W.* WD.)

PYRENEES, a range of mountains in southwest Europe (Span. PIRINÉOS. Fr. PYRÉNÉES), separating the Iberian peninsula from France, and extending for about 273 mi.. from the Bay of Biscay to Cape Creus, or, if only the main crest of the range be considered, to Cape Cerbltre, on the Mediterranean sea. The main crest constitutes the Franco-Spanish frontier; except in the case of the valley of Aran, which belongs orographically to France but politically to Spain. The Pyrenees are conventionally divided into three sections, the central, the Atlantic or western and the Mediterranean or eastern. The central Pyrenees extend eastward from Canfranc to the valley of Aran. and include the highest summits of the whole chain, Aneto or Pic de Néthou (11.168 ft.) in the Maladetta ridge, Posets (11,073 ft.) and Mont Perdu or Monte Perdido (11,007 ft.). In the Atlantic Pyrenees the average altitude gradually diminishes westward; while in the eastern Pyrenees, except for one break at the eastern end of the Pyrénées Ariégeoises, the mean elevation is maintained, till a rather sudden decline occurs in the extreme eastern portion, the Albères. This threefold division is only valid so far as the elevation of the Pyrenean chain is concerned, and does not represent its geological structure or general configuration. The southern versant of the mountains is the more important. It is recognized that the range must be regarded as an elevated part of the earth's crust, the culminating portion of which is composed of a series of chains which do not coincide with the watershed, but cross it obliquely. Maps by Schrader and de Margerie (*Ann.* du Club *Alpin français,* 1891 and 1892) show the orderly arrangement of these chains. The primitive formations of the range are shown to be almost all continued diagonally on the Spanish side, and the central ridge thus presents the appearance of a series of wrinkles with an inclination (from northwest to southeast) greater than that of the chain as a whole. Other less pronounced wrinkles run from southwest to northeast and intersect the former series at certain points, so that it is by alternate digressions from one to the other series that the irregular crest of the Pyrenees acquires its general direction. Far from having impressed its own direction on the orientation of the chain at large, this crest is merely the resultant of secondary agencies by which the primitive mass has been eroded and lessened in bulk, and though its importance from a hydrographic point of view is still great, its geological significance is practically nil.

Geology.—The Pyrenees are divided into a number of longitudinal zones. The central zone (central Massifs) consists of Primary rocks, Archaean, Cambrian. Ordovician, Silurian, Devonian and Lower Carboniferous (Dinantian) together with great masses of granite. It forms most of the higher summits, but west of the Pic d'Anie it disappears beneath an unconformable covering of Cretaceous deposits. On the French side the central zone is followed by: (1) the zone of Arikge, consisting of Lower Cretaceous and Jurassic beds, together with granitic masses; (2) the zone of the Petites Pyrénées, Upper Cretaceous and Eocene; a thin outcrop of Jurassic and (3) the zone of Aragon, Eocene, and Primary rocks. On the Spanish side, from north to south, are: (1) the zone of Mont Perdu, Upper Cretaceous and Eocene with a thin outcrop of Jurassic; (2) the zone of Aragon, Eocene and (3) the zone of the Sierras, Trias. Cretaceous and Eocene. Although the number of zones is the same on the two flanks, they do not correspond. The zone of the Corbières has no equivalent in Spain, while in France there is no definite zone of Eocene like that of Aragon. The zone of the Petites Pyrénées, however. is clearly homologous with that of the Sierras. On the northern side granitic masses occur in the zone of Arikge among the Jurassic and Lower Cretaceous beds. On the southern side they are not found except in the axial zone, and the Jurassic and Lower Cretaceous deposits are reduced to a narrow band. In spite of these differences between the two flanks. the structure is to some extent symmetrical.

The tectonics of the Pyrenees are still only imperfectly understood. Some authorities consider the structure to be that of a fan, while others have shown that the phenomena of *recouvrement* play an important part there. Large masses of rock have been brought forward upon thrust planes over the edges of other beds with which they originally had no connection. Several cases have been described, but denudation has been carried further than in the Alps, and accordingly the masses overlying the thrust planes have been more completely removed.

The Pyrenean axis was outlined by the Hercynian movement and folding took place along it at the close of the Dinantian epoch and again before the Permian. Later the chain was completely submerged until early Cretaceous times, when the earth movements which raised the present mountains commenced and continued into the Oligocene period. The uplift of the Pyrenees was therefore completed before that of the Alps.

The arrangement of the Pyrenees in chains gently inclined near the centre but longitudinal everywhere else, is illustrated by the courses of the streams which flow down toward Spain. On the French side most of the longitudinal valleys have disappeared, except at the eastern end. On the south the principal streams, after cutting their way through the highest zone at right angles to the general direction of the range. become involved halfway to the plains in great longitudinal folds, from which they make their escape only after traversing long distances.

The total area of the Pyrenees is estimated at 21,044 sq.mi., two-thirds of which is on the southern versant. The mean elevation is placed at 3,930 ft.. while the highest summit Pic de Néthou, is 11.168 ft. above sea level. The passes show a greater altitude than those of the Alps.

Gaves.—Four features of Pyrenean scenery are the absence of great lakes, as in the Alps; the rarity and great elevation of passes; the large number of the mountain torrents locally called *gaves,* which often form lofty waterfalls, surpassed in Europe only by those of Scandinavia; and the frequency with which the upper end of a valley assumes the form of a cirque. The highest waterfall is that of Gavarnie (1.384 ft.), at the head of the Gave de Pau; the Cirque de Gavarnie, in the same valley, is perhaps the most famous example of the cirque formation. Low passes only occur at the two extremities of the range, where the principal highroads and railways run between France and Spain; a third railway (Pau to Jaca via the pass of Somport) was opened in 1928. In the mountains themselves there are only five passes practicable for motors—the Col de la Perche. Col du Pourtalet, Col de Somport, Roncevalles road and the road through the Baztan valley.

Projects for further railway construction. including the building of tunnels on a vast scale, have been approved by the French and Spanish governments.

The metallic ores of the Pyrenees are not important. There are considerable iron mines at Vicdessos in Arikge and at the foot of Canigou in Pyrénées-Orientales. Coal deposits capable of being profitably worked are situated chiefly on the Spanish slopes and the French side has numerous beds of lignite. Mineral springs are abundant and specially noteworthy are the hot springs. The latter, among which those of Bagnkres de Luchon and Eaux-Chaudes may be mentioned, are sulfurous and mostly situated high, near the margin of the granite. The lower springs, such as those of Bagnkres de Bigorre (Hautes-Pyrénées), Rennes (Aude) and Campagne (Aude). are mostly selenitic and not very warm. The use of hydroelectric power has been developed in the 20th century.

The amount of the precipitation, including rain and snow, is much greater in the western than in the eastern Pyrenees, causing a marked contrast between these sections of the chain in more than one respect. In the first place, the eastern Pyrenees are without glaciers, the quantity of snow falling there being insufficient. The glaciers are confined to the northern slopes of the central Pyrenees, and do not descend far down in the valleys, but have their greatest length in the direction of the chain. They form, in fact, a narrow zone near the crest of the highest mountains. There, as elsewhere in Europe, there are evidences of a much wider extension of the glaciers during the Ice Age. The best known glacier is that in the valley of Argelès. The snow line varies in different parts of the Pyrenees from 8,800 to 9.200 ft. above sea level.

A more marked effect of the high rainfall in the west is seen in the vegetation. The lower mountains in the extreme west are very well wooded, but the extent of forest declines eastward, and the eastern Pyrenees are peculiarly wild and naked, more so because there the granite massifs occur. There is a change, moreover, in the type of flora in passing from west to east. In the west the flora, at least in the north, resembles that of central Europe, while in the east it is distinctly Mediterranean in character. The Pyrenees are relatively as rich in endemic species as the Alps, and among the most remarkable instances of this is the occurrence of the sole European species of *Dioscorea* (yam), the *D. pyrenaica,* on a single high station in the central Pyrenees, and that of the monotypic genus *Xatardia,* only on a high pass between the Val d'Eynes and Catalonia. The genus most abundantly represented in the range is that of the saxifrages, several species of which are there endemic.

In their fauna also the Pyrenees present some striking instances of endemism. There is a distinct species of ibex *(Capra pyrenaica)* confined to the range, while the Pyrenean desman or water mole *(Mygale pyrenaica)* is found only in some of the streams of the northern slopes of these mountains, the only other member of this genus being confined to the rivers of southern Russia. Among the other peculiarities of the Pyrenean fauna are blind insects in the caverns of Ariège, the principal genera of which are *Anophthalmus* and *Adelops.*

The ethnology. folklore. institutions and history of the Pyrenean region form an interesting study: see ANDORRA; ARAGON; BASQUE; BEARN; CATALONIA; NAVARRE.

BIBLIOGRAPHY.—H. Béraldi, *Les Pyre'ne'es orientales et l'Ariège* (1904) and other works; P. Joanne, *Pyrdndes* (1905); H. Belloc, *The Pyrenees,* 3rd ed. (1923); A. Campagne, *Les forêts pyrénéennes* (1912); M. Sorre, *Les Pyrdndes,* bibl. (1922); A. Oakley, *Hill-towns in the Pyrenees* (1924); R. O. Sawtell and I. Treat, *Primitive Hearths in the Pyrenees* (1927); for geology *see* also A. Bresson, *Etudes sur les formations des Hautes et Basses Pyre'ne'es* (1903); L. Bertrand, *Sur la structure géol. des Pyre'ne'es* (1911); L. Carez, *Resume' de la géologie des Pyrénées* (1912); on the climate and flora, T. Cook, *Handbook to the Health Resorts of the Pyrenees* (1905).

PYRÉNÉES-ORIENTALES, a *de'partement* of southwestern France, bordering on the Mediterranean and the Spanish frontier, formed in 1790 of the old province of Roussillon and of small portions of Languedoc. Population (1954) 230,285, including many Spaniards. Area, 1,600 sq.mi. The *de'partement* is bounded north by Ariège and Aude, east by the Mediterranean, south by Catalonia and west by the republic of Andorra. Its borders are marked by mountain peaks, on the north by the Corbières, on the northwest and southwest by the eastern Pyrenees, on the extreme southeast by the Albères, which end in the sea at Cape Cerbera. The coast is low lying, with large lagoons. In the lowlands the climate is Mediterranean, with mild winters, dry summers and short and sudden rainstorms. Amélie-les-Bains is much frequented on account of its mild climate and sheltered position. The temperature ranges from 85° to 95° F. in summer, and in winter only occasionally falls as low as 26° or 27° F. The mean rainfall is 27 in. on the coast, but increases toward the hills. The most common wind is the tramontane from the north-northwest. as violent as the mistral of Provence and extremely parching. The marinada blows from the south-southeast.

On the Canigou massif to an altitude of 1,400 ft. are found the orange, the aloe, the oleander, the pomegranate and the olive; the vine grows at an altitude up to 1,800 ft.; next come the chestnut (2.625 ft.), the rhododendron (from 4,330 to 8.330 ft.), pine (6,400) and birch (6,560); while stunted. junipers grow to the summit. The cultivated land in Pyrénées-Orientales is devoted to winegrowing, market-gardening and fruit culture, the production of cereals being comparatively unimportant. The main source of wealth to the *de'partement* is its wine, of which some kinds are strongly alcoholic and others are in request as liqueur wines (Rivesaltes, Banyuls). Early vegetables are grown in the irrigated lowlands, and fruit-growing is chiefly carried on in the river valleys. In iron Pyrénées-Orientales is one of the richest *départements* in France, the greater part of the ore being transported to the interior. Lignite and various kinds of stone are worked. The mineral waters are popular. Amélie-les-Bains has hot springs, chalybeate or sulfurous. In the *arrondissement* of Céret there are also the establishments of La-Preste-les-Bains, near Prats de Mollo, with hot sulfurous springs, and of Le Boulou, the Vichy of the Pyrenees. Near Prades are the hot sulfurous springs of Molitg, and a little north of Mont Canigou are the hot springs of Vernet, containing sodium and sulfur. In the valley of the Ter the sulfurous and alkaline springs of Thuès reach a temperature of 172° F. The baths of Les Escaldas, near Montlouis, are hot, sulfurous and alkaline.

The chief route (Southern railway) across the Pyrenees is from Perpignan through Montlouis, a fortified place, to Puigcerda in the Spanish province of Gerona, through the pass of La Perche, skirting in the French *de'partement* an enclave of Spanish territory. Three other roads run from Perpignan to Figueras through the passes of Perthus (defended by the fort of Bellegarde), Banyuls and Balistres, the last-named being traversed by a railway. The chief towns of the three *arrondissements* are Perpignan, Céret and Prades: there are 18 cantons and 233 communes.

The *de'partement* constitutes the diocese of Perpignan under the archbishop of Albi, and is attached to the appeal court and the *acade'mie* (educational division) of Montpellier and to the region of the 16th army corps.

Perpignan, the capital town and a fortress of the first class, Amélie-les-Bains-Palalda and Elne are the chief towns.

Rivesaltes ([1954] 5,059) is the most populous town after Perpignan (63,863).

PYRETHRUM, formerly considered a genus of the composite family (Compositae) but now regarded as belonging to the genus *Chrysanthemum* of the same family.

The type form, the perennial C. *coccineum,* is the florists' pyrethrum, commonly called painted lady. Large daisylike flowers—deep rose-coloured petals surrounding the yellow centre or disk—are borne on long simple stems above the crown of finely cut leaves. Modern varieties are remarkable for the colours of their flowers—white, lilac and shades of red. They are most welcome ornaments for the flower borders and as cut flowers.

The powdered flower heads of C. *coccineum* and *C. anethifolium* are the source of Persian insect powder, and *C. cinerariaefolium* and *C. marschalli* yield Dalmatian insect powder. Both powders are important insecticide ingredients, commonly called pyrethrum. The active substances in pyrethrum—pyrethrins I and II and cinerins I and 11—are contact poisons for insects and cold-blooded vertebrates. The concentrations of pyrethrum powder used in insecticides are nontoxic to plants and higher animals; therefore, these insecticides find wide use in household and livestock sprays as well as in dusts for edible plants. Pyrethrum is the insecticidal basis of many aerosol "bombs" developed during and since World War II.

These highly aromatic plants, native to southwestern Asia, are now widely cultivated as fine hardy perennial garden subjects; they are grown for pyrethrum powder in Japan, Kenya and California. Seeds sown in the spring in ordinary well-drained garden soil in full sun will produce plants that bloom the following year; plants may be increased by division of the crown after flowering.

(N. TR.)

PYRGI, an ancient town of Etruria, Italy, on the southwest coast, 9 mi. W.N.W. of Caere. The name is Greek (*pyrgoi,* "towers"), and the place of considerable antiquity. Remains of its defensive walls exist in polygonal blocks of limestone and sandstone, neatly jointed. They enclosed a rectangular area about 200 yd. in width and at least 220 yd. in length, and there was a small harbour.

A rich temple of Leucothea there was plundered by Dionysius in 384 B.C. Later it became dependent on Caere, though it was not originally its harbour, for Alsium is a good deal nearer (5 mi. S.). The Romans planted a colony there about 200 B.C.

PYRGOS, a town of Greece. in the department of Elis and Achaea. 43 mi. S.S.W. of Patras. It is connected with its harbour, Katakolon, 7½ mi. distant, with Patras. Olympia and Kalamata (Kalámai), by rail. It has frequently been damaged by earthquakes. Pop. (1951) 17,996. Axis troops occupied it during World War II.

PYRIDINE, a colourless, liquid, nitrogenous base with a pungent odour, belongs to the class of heterocyclic aromatic bases and is the most fully investigated member of that class. It is obtained primarily from the noncondensable coke-oven gases together with the homologous methylpyridines, the picolines. Structurally, pyridine (C_5H_5N) may be regarded as benzene in which one CH group is replaced by N, and in analogy with benzene there is an entire series of compounds derived from pyridine as the parent compound. Although the pyridine nucleus does not occur so frequently in natural products as the derived condensed systems quinoline (*q.v.*) and isoquinoline, it is found in the alkaloids of the pomegranate, lobelia, hemlock, areca and tobacco species and in the B-complex vitamins. nicotinic acid and pyridoxine, compounds of great physiological and commercial significance. Pyridine, the picolines and the higher homologues such as the lutidines (dimethylpyridines) and collidines (trimethylpyridines), which are found in the light-oil and middle-oil fractions from coal tar, are known as the pyridine bases. These bases were first isolated and characterized by T. Anderson in England (1846–57) in his investigation of the oil formed in the dry distillation of bones. α-picoline, the first of these bases to be isolated as a pure substance, had been obtained from the basic constituents of coal tar in 1846. Pyridine and several of its homologues were obtained from bone oil shortly thereafter. Since their formation occurs on dry distillation only if the bones still contain unsaponified fat, they are regarded as end products of the interaction of acrolein formed from the glycerol of the fat and the ammonia from the nitrogenous constituents.

In addition to limited supplies from bone oil, pyridine bases have been commercially available from the condensation products of the coking of coal since 1860. With the advent of the successful use of the by-product oven in Germany in 1881 and its introduction later into the U.S. and England. the coal-tar industry was firmly established, but it was not until spurred by the demands of the growing pharmaceutical industries that, around 1920, the production of pyridine bases from coal tar began to expand rapidly. The pyridine and pyridine bases produced in the coking process are recovered from the ammonia saturator liquor from the ammonium sulfate .crystallization process at the by-product coal-carbonization plant and from a low-boiling fraction (middle oil) of the coal tar at the refining plant. The mother liquors from the distillation of the middle oil, after removal of naphthalene by centrifugation, are extracted with caustic soda, the residual oil distilled. the distillate treated with sulfuric acid, the acid solution neutralized with ammonia. the crude wet pyridine bases dried by azeotropic distillation with benzene and refined by fractional distillation to give some pyridine and picolines, but mainly the higher alkylated pyridine and quinoline bases. The ammonia saturator liquors, containing about 60% of the 0.15 lb. of total pyridine and quinoline bases per ton of coal coked, are saturated with ammonia in a continuous neutralizing still and distilled to give crude pyridine bases containing 15%–20% water, dried by azeotropic distillation with benzene and fractionated to yield pyridine, α-picoline, a β-picoline fraction and a mixture of higher alkylated pyridines.

Synthetic Processes. — The inherent limited production of pyridine bases from the coking industry encouraged commercial development of synthetic processes to meet the increasing demands for intermediates for the manufacture of pharmaceuticals, copolymers and detergents.

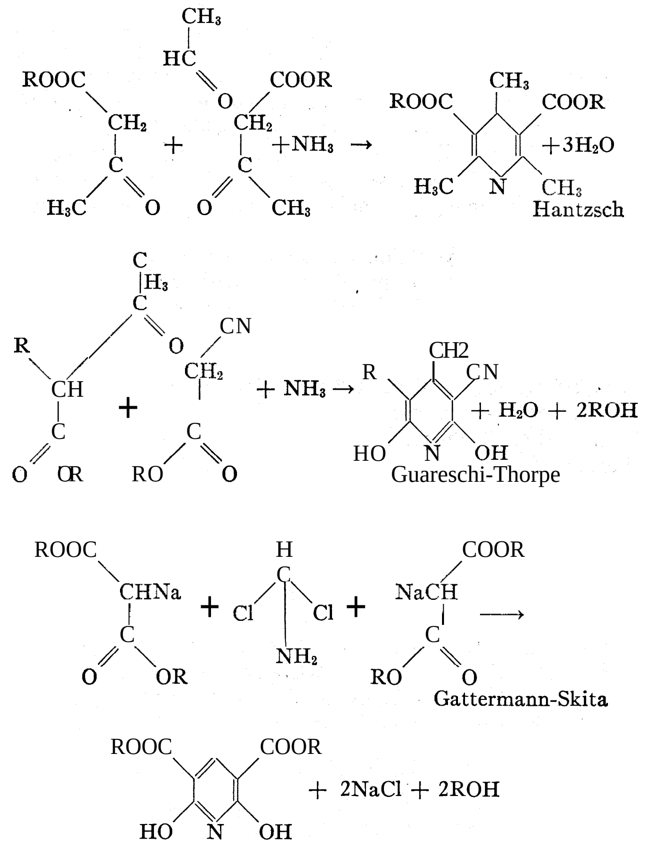
Examples of such processes are given:

1. Since pyrolysis of bones, shale and coal is actually a synthesis of pyridine bases, various pyrolytic syntheses by the vapour-phase reaction of ammonia with acrolein, acetylene derivatives, acetaldehyde or ethyl alcohol and hydrogen by passage of the mixed gases over metal oxide catalysts at 350°–500° C. have been investigated.

2. The reaction of paraldehyde with aqueous ammonia at 200°–250° C., the so-called Chichibabin synthesis, gives 70%–80% yields of 2-methyl-5-ethylpyridine (MEP, aldehyde collidine) with 5%–10% of α-picoline as by-product. MEP is oxidized to the corresponding dicarboxylic acid, which loses carbon dioxide at high temperatures and gives 75% yields of nicotinic acid. Catalytic dehydrogenation of MEP in the presence of an inhibitor gives 2-methyl-5-vinylpyridine (MVP), a valuable monomer for the preparation of synthetic rubbers and acrylonitrile polymers.

3. The classical Hantzsch pyridine synthesis (1882) involves the condensation of two moles of acetoacetic ester with one mole of aldehyde and ammonia (β-aminocrotonic esters can substitute for a mole of acetoacetic ester and ammonia). The dihydropyridine derivatives formed are readily oxidized to a substituted pyridine derivative. or the ester may be hydrolyzed and decarboxylated to bases such as 2.6-lutidine or collidine. Many modifications of this classical synthesis have been developed; the Knoevenagel-Fries condensation substitutes a mole of malonic ester for a mole of acetoacetic ester; the Guareschi-Thorpe modification involves the use of cyanoacetic acid derivatives; and the Gattermann-Skita method employs compounds of the type of dichloromethylamine reacting with diethyl sodiomalonate.

4. The pyridine ring can also be formed by condensation of hydroxylamine with 1,5-diketones, by replacement of the ring oxygen atom of pyrones with an N atom and by expansion of the five-membered ring of pyrroles.



Pyridine syntheses

Properties.—Pyridine is a stable. flammable, colourless liquid volatile with steam, m.p. −42° C.; b.p. 115.3° C. It readily adsorbs moisture to form an azeotrope corresponding to $C_5H_5N.3H_2O$, b.p. 92°–3° C. It is an excellent solvent for most organic compounds and gives conducting solutions with silver, copper, lead, mercury and iron halides, nitrates and acetates. It is a completely water-soluble, weak base (K_b 2.3 × 10^{-9}) forming salts with strong acids and as a tertiary amine yields typical quaternary salts.

The higher alkylpyridinium halides such as N-cetylpyridinium chloride are valuable cationic germicides. Pyridine, toxic to humans in daily doses of 1.8–2.5 c.c. per day, is detoxified in the dog by conversion to N-methylpyridinium hydroxide. Like ammonia it combines with the metals of the transitional groups of the periodic table to give stable co-ordination compounds whose study has been important in the development of the theory of co-ordination and in the stereochemistry of the metals. Oxidation of quinoline to quinolinic acid, in which the benzene ring is destroyed while the pyridine ring remains intact, shows the extreme stability of the ring to oxidation. Consequently, pyridine can be used as a solvent for oxidations and the pyridine homologues are oxidized to the corresponding pyridinecarboxylic acids. Degradation of alkaloids containing pyridine, quinoline and isoquinoline rings by vigorous oxidation often provides valuable structural information.

The similarity of behaviour of pyridine to that of benzene led to the adoption of a formula for pyridine similar to the Kekulé formula for benzene, but, at present, pyridine is considered to be a resonance hybrid of a number of structures which differ in their electronic distribution.

Pyridine is readily reduced catalytically, electrolytically or by sodium in alcohol to the saturated hexahydro derivative piperidine, $C_5H_{11}N$, m.p. −9° to 17° C., b.p. 106° C., d_4^{20} 0.8622, K_b 1.6 × 10^{-3}. It is a colourless liquid with a characteristic ammoniacal odour miscible with water and most solvents. It forms salts, ring-substituted derivatives and well-known N-derivatives such as N-acetyl- and N-benzoylpiperidines. Piperidine can be obtained by the hydrolysis of the alkaloid piperine, occurring in various peppers, and is present in coniine. the poisonous principle of hemlock. as the ester 2-propylpiperidine. In addition to the various synthetic anesthetics such as eucaine, prepared from 4-piperidone, the analgesic meperidine hydrochloride is an important derivative of piperidine. The elucidation of the structure of the pyridine carboxylic acids was an important stage in determining the structure of many alkaloids. The more commercially important carboxylic acids are the vitamin nicotinic acid, and isonicotinic acid, whose hydrazide has found use as an antitubercular agent. A synthesis of isonicotinic acid from citrazinic acid, produced by the amidation of citric acid, has been commercially developed. Other important pyridine derivatives of pharmaceutical interest in addition to vitamin B_6 and sulfapyridine are the urogenital analgesic 2.6-diamino-3-phenylazopyridine hydrochloride, the x-ray contrast materials sodium iodomethamate and iodopyracet and the antihistaminic 2-benzyl (2-dimethylaminoethyl) amino pyridine hydrochloride. In addition to the above-mentioned MEP and MVP, 2-vinylpyridine, used as a monomer for copolymerization with butadiene. styrene and acetonitrile, and the water-repellent stearamidomethylpyridium chlorides, produced by heating stearamide, paraformaldehyde and pyridine hydrochloride in pyridine, are important commercial pyridine base derivatives.

(C. R. AL.)

PYRIMIDINES: see NUCLEIC ACIDS.

PYRITE or IRON PYRITES, also known as fool's gold, is a naturally occurring iron disulfide. This compound is dimorphous, existing both as orthorhombic marcasite (white iron pyrites) and as cubic pyrite (see also MARCASITE). The name pyrite comes from the Greek *pyr,* "fire," in allusion to the fact that it emits sparks when struck by steel.

Nodules of pyrite have been found in prehistoric burial mounds, suggesting their use as a primitive means of producing fire. Wheel-lock guns. in which a spring-driven serrated wheel rotated against a piece of pyrite, were used for a period before the development of the flintlock.

Pure pyrite contains 46.67% iron and 53.33% sulfur. Nickel and cobalt may replace some of the iron, but the frequent presence of gold and copper is probably because of microscopic inclusions of other minerals containing these metals. In some localities auriferous pyrite is an important source of gold, and a considerable quantity of copper is obtained from certain pyrite deposits. In addition to the gold and copper which it may contain, the chief commercial use of pyrite is as a source of sulfur and sulfur dioxide (SO,), used for bleaching and in the manufacture of sulfuric acid (*q.v.*).

Unlike most sulfide ores, which have to be roasted to obtain the SO„ pyrite contains such a high percentage of sulfur that when reasonably pure, and in finely divided form, it will sustain its own combustion without the aid of an external source of heat. For the manufacture of sulfuric acid it is desirable that the ore be as free as possible from arsenic. Because of the availability of much better sources of iron (hematite, goethite and magnetite), pyrite is not generally used as an iron ore, although small quantities of sinter, or cinder from the burning of pyrite, may be mixed with the higher-grade ores.

For many years Spain was the largest producer, the large deposits at Rio Tinto being important also for copper. Other important producers are Japan, the United States (Tennessee, Virginia, California), Canada, Italy, Norway, Portugal and Czechoslovakia. Beautiful crystals are found in many localities, including Cornwall in England; Westphalia in Germany; St. Gotthard in Switzerland; Elba and Piedmont in Italy; and Colorado, New Jersey, Pennsylvania, Arizona and Utah in the United States. (See also NATURAL RESOURCES: Nonmetallic Minerals.)

Pyrite crystals are common and sometimes are beautifully developed. The commonest forms are the cube, octahedron and pentagonal dodecahedron (pyritohedron), either separately or in various combinations. The cubes frequently have very characteristic striations parallel to the cube edges. Penetration twins also occur. The hardness of pyrite is 6 to 6.5 and the specific gravity about 5, varying somewhat with composition. A conchoidal fracture is usually conspicuous on crystals and on coarse-grained material. It sometimes has an iridescent tarnish. The lustre is bright metallic and the streak greenish-black. The colour is brass yellow. In comparison marcasite is a paler yellow, while chalcopyrite (copper pyrites) is much deeper yellow as well as softer.

Pyrite weathers rapidly to hydrated iron oxide, goethite or limonite; pseudomorphs of goethite after pyrite are common. They vary from a thin coating of goethite on the pyrite crystals to those which have been completely altered. This weathering produces a characteristic yellow-brown stain or coating, such as is observed on rusty quartz or in the residual iron deposits, or "gossan" capping on exposed sulfide ore bodies.

Pyrite is a mineral of very wide distribution and it occurs under extremely varied conditions of mineral formation; thus it is said to be a "persistent" mineral. It has been reported as resulting from magmatic segregation; it occurs as an accessory mineral in igneous rocks and has been found as a sublimation product at Vesuvius. Especially important are the hydrothermal deposits, from medium- to high-temperature solutions. Pyrite is very common in vein deposits with other sulfide minerals and with quartz. It is common in sedimentary rocks, such as shale, coal and limestone. Pyritized fossils are of frequent occurrence in these rocks.

Pyrite is found in large deposits in contact metamorphic rocks. Deposits of copper-bearing pyrite are widely distributed and often of great size. They usually occur in or near the contact of eruptive rocks with schists or slates, the presence of the igneous rocks probably being connected genetically with the origin of the ore. Well-developed cubes of pyrite occur with magnetite in a chlorite schist at Chester, Conn.

Pyrite Group.——Pyrite has the composition FeS_2 and is the most important member of the pyrite group, an isomorphous series which also includes bravoite $(Ni,Fe)S_2$; laurite, RuS_2; sperrylite, $PtAs_2$; hauerite. MnS_2; and penroseite, $NiSe_2$. It is also closely related structurally to the cobaltite group, which consists of cobalt and nickel minerals in which the sulfur pairs (S_2) of pyrite are replaced by arsenic-sulfur (AsS) and antimony-sulfur (SbS), resulting in lower symmetry. (L. S. RL.)

PYROGALLOL or PYROGALLIC ACID, a trihydroxybenzene, 1,2,3-$C_6H_3(OH)_3$, first prepared by K. W. Scheele in 1786 by heating gallic acid. It is used as a photographic developer and also as an oxygen absorbent in gas analysis. It has antiseptic properties and is employed medicinally in the treatment of psoriasis. The process of manufacture is still based on Scheele's procedure. Gallic acid with half its weight of water is heated in an autoclave until the pressure reaches 12 atm. and the temperature registered is 175° C. Steam and carbon dioxide are then allowed to escape, leaving in sufficient water to keep the pyrogallol liquid. The cooled solution is decolorized with animal charcoal and evaporated down until the volatile pyrogallol has distilled over into flat iron receivers. The solidified material is purified by repeated distillation or sublimation. Pyrogallol crystallizes in colourless leaflets or needles, melts at 134° C. and is easily sublimed; it distills at 309° C. under the ordinary pressure with partial decomposition. It dissolves in $2\frac{1}{4}$ parts of water at 13° C., and its aqueous solution develops a blue colour with ferrous sulfate containing a little ferric salt.

Its alkaline solution. when exposed to air, rapidly becomes black because of the absorption of oxygen with the production of complex coloured substances. (G. T. M.)

PYROLUSITE, a mineral composed of manganese dioxide of great importance as an ore of manganese. It is used in the manufacture of steel and manganese bronze, as an oxidizing agent in the manufacture of chlorine and in dry cells, in glass, ceramics and paint pigments. It is mined in the U.S.S.R., Germany, Brazil, India, the United States (West Virginia, Georgia, Tennessee, the Lake Superior district and California), Cuba, French Morocco. Ghana and the Union of South Africa. This compound, which has the formula MnO_2, is dimorphous, occurring both as an orthorhombic form: ramsdellite, and as the tetragonal form pyrolusite. The latter is isomorphous with rutile and cassiterite, TiO_2 and SnO_2. Crystals are rare and have a hardness of 6 to 6.5, with a specific gravity of about 5, and have been called polianite because of the mistaken belief that they were essentially different from the commoner massive varieties. Pyrolusite is usually fine grained, often fibrous or powdery, and thus appears to be soft, as low as 2, and marks paper. Because of the fine-grained nature it may contain adsorbed water. The fine fibrous masses. sometimes radially arranged, are very characteristic. The soft powdery material. sometimes called wad (*q.v.*), may or may not be pyrolusite; likewise, harder dense material in crusts or nodules may be pyrolusite or may be one of the psilomelane (*q.v.*) type of minerals. Pyrolusite is formed by the alteration of other manganese ores, such as rhodochrosite and rhodonite, and frequently occurs as a pseudomorph after manganite. Black dendritic growths of manganese dioxide are frequently found in limestones and in moss agate quartz.

See also MANGANESE. (L. S. RL.; X.)

PYROMETER, an instrument for measuring high temperatures (Gr. *pyr*, "fire," *metron*, "a measure"). The term was first used by P. van Musschenbroek to denote an instrument wherein the expansion of a metal rod measured the temperature. Discontinuous thermoscopes, depending on the fusion of a metal or salt, have also been employed.

Prinsep prepared a series of alloys of silver and gold and of gold and platinum whose melting points, as determined by accurate instruments, covered a range of temperature from 954° C. to 1,775° C.. at intervals of from 25° C. to 30° C. By placing ingots in a furnace and observing which one melted a fair idea of the temperature was obtained. Carnelley and Williams employed certain salts of known melting point; however, the Seger's cones, employed in porcelain manufacture, depend on the softening of small cones made of clay.

The instruments employed today depend either on electrical effectsproduced in wires inserted in the furnace and so raised to its temperature, or upon measurements made on the radiation emitted by the furnace.

See also THERMOMETRY for scientific forms.

PYROMORPHITE, a mineral with the composition of lead chlorophosphate sometimes occurring in sufficient quantities to be mined as an ore of lead. Pyromorphite results from the alteration of galena in the oxidized portions of metalliferous veins and is frequently found in the upper levels of lead mines. The name is from the Greek pyr, "fire" and *morphē*, "form"; when a fragment is fused the globule assumes a faceted form on solidifying.

Crystals are common and have the form of a hexagonal prism terminated by the basal planes, often barrel shaped and sometimes hollow at the ends; globular and reniform masses are also found. The formula is $Pb_5Cl(PO_4)_3$ and all gradations in composition exist between pyromorphite and the isomorphous lead chloroarsenate, mimetite (*q.v.*). The resemblance in external characteristics is so close that as a rule it is possible to distinguish them only by chemical tests. Likewise, it is closely related to vanadinite (*q.v.*), in which the PO, is replaced by VO,. Pyromorphite is usually bright green, yellow or brown. sometimes orange-red and rarely colourless and transparent. The lustre is resinous to subadamantine.

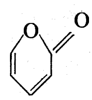
The hardness is 3.5 to 4 and the specific gravity about 7. (L. S. RL.)

PYROMUCIC ACID (FUROIC ACID): *see* FURFURAL.

PYRONES, a term used in organic chemistry to describe a group of six-membered heterocyclic compounds. Pyrones are of tno main types derived from 1:2-pyrone (I) or 1:4-pyrone (II); these two groups are often described as a-pyrones and y-pyrones respectively.

Pyrones are not in general degraded by acids, but in some cases show quite a strong basic character and yield oxonium salts with acids. Like esters, pyrones are hydrolyzed by alkali and this reaction is frequently of importance in the determination of their structure. They do not usually show ketonic properties. but possess a stability similar to that of aromatic compounds and may be regarded as heterocyclic analogues of benzene.

The main interest in the chemistry of pyrones has developed from the recognition that quite a large number of naturally occurring organic compounds are derivatives of either a- or y-pyrones. Thus 6-phenyl-1:2-pyrone (III) has been isolated from cotobark and about 70 natural products are known which are derived from 3:4-benz-1:2-pyrone (coumarin) (IV). Coumarin (*q.v.*) itself (IV) occurs in tonka beans, lavender oil and sweet clover and its pleasant fragrant odour has led to its use in perfumery and in foodstuffs. Umbelliferone (7-hydroxycoumarin) is present in many plants and is obtained by the distillation of the resins from various umbelliferae. Umbelliferone absorbs ultraviolet light and is used in some sun-screen lotions and creams.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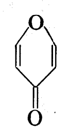
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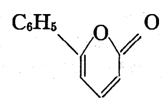
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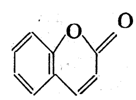
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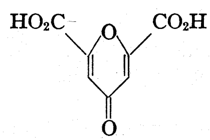
Derivatives of 1:4- or y-pyrone occur very widely in plants and to illustrate the variety of structure which is possible, the structures of chelidonic acid (V) from the lily of the valley and the celandine (*Chelidonium majus*), meconic acid (VI) from opium, maltol (VII) from malted barley and kojic acid (VIII) produced by the growth of the mold, *Aspergillus niger*, may be compared.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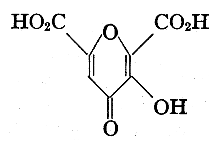
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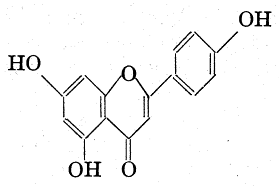
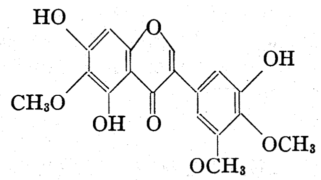
VII VIII

In determining the structure of these natural products advantage is often taken of their reaction with aqueous sodium-hydroxide. The following example illustrates the general method. The structure of chelidonic acid (V) was indicated by its alkaline cleavage yielding acetone and oxalic acid. This structure was confirmed synthetically by condensing acetone with diethyl oxalate. using sodium ethoxide. and then subjecting the intermediate ester ($EtO_2C.CO.CH_2.CO.CH_2.CO.CO_2Et$) to dehydration and acid hydrolysis.



IX



X

More complicated derivatives of 1:4-pyrones occur naturally and are probably the most widely occurring oxygen heterocyclic derivatives. They include flavones, e.g, apigenin (IX) from parsley, isoflavones, *e.g.*, irigenin (X) from orrisroot and xanthones. (W. D. Os.)

PYROPHORIC ALLOYS are groups of alloys nhich when filed or scratched give off bright sparks. Alloys containing about 15% iron and mixtures of rare-earth metals with small amounts of antimony, bismuth, copper and silicon are used in various lighters.

PYROPHORUS, a material which inflames spontaneously on contact with air. Homberg's pyrophorus (Gr. *pyr*, "fire," *phorein*, "to bear"), one of the earliest known, was prepared by heating alum with finely divided carbon or organic material (lampblack, starch or flour) in a closed tube. The product, a mixture of potassium sulfide, aluminum sulfate and carbon, is spontaneously inflammable.

PYROPHYLLITE, a mineral species composed of hydrous aluminum silicate. It resembles talc (*q.v.*) and has long been used in slate pencils and tailor's chalk.

Pyrophyllite was carved by the Chinese people into small images and ornaments and has also been included with talc and under the names agalmatolite and pagodite.

The production and uses of pyrophyllite expanded greatly in the second half of the 20th century. Major uses were in the manufacture of insecticides, ceramics, refractories, roofing, rubber and plaster products.

The most extensive commercial deposits of pyrophyllite are in the Cnited States in the Deep river region of North Carolina, the leading producing state. Pyrophyllite is also mined in California and in Canada. A massive variety produced in the Cnion of South Africa is marketed under the name of "wonderstone." Pyrophyllite occurs in shear zones in highly metamorphosed acid volcanic rocks. Pale-green foliated masses, very like talc in appearance, are found in the Urals, in Switzerland and in other localities.

Pyrophyllite is one of the silicates having a sheet structure, like the micas and chlorites. The composition is $Al_2(OH)_2Si_4O_{10}$; it is isomorphous with talc, $Mg_3(OH)_2Si_4O_{10}$, and the two minerals have similar properties as well as uses.

Both are soft and have a soapy feeling; pyrophyllite occurs in foliated and massive varieties corresponding to foliated talc and soapstone (steatite).

The folia of pyrophyllite have a pronounced pearly lustre and have a perfect cleavage parallel to their surfaces. They are flexible but not elastic and are usually arranged in fanlike or radiating groups.

The foliatkd variety, when heated, exfoliates and swells up to many times its original volume, hence the name pyrophyllite from the Greek *pyr*, "fire" and *phyllon*, "leaf." The colour of both varieties is white or pale green, grayish or yellowish. The specific gravity is 2.8 to 2.9. (L. S. RL.; X.)

PYROTECHNICS: *see* FIREWORKS.

PYROXENE, in mineralogy, the metasilicate group of minerals. Pyroxenes form one of the principal minerals in many common rock types, such as gabbro, norite, peridotite, pyroxenite and basalt. and occur as an accessory mineral in some granites, syenites, diorites and andesites. The pyroxenes are commonly dark green to black, but in the absence of iron they can be light-coloured to white. The physical aspects of the pyroxenes are characterized by two planes of well-developed cleavages 87° or 93° apart. Except for the sodium-containing varieties, which are usually needlelike, the pyroxenes usually occur as short, stubby, prismatic crystals or mineral grains. Some crystal faces are usually present so that, as the crystal is viewed parallel to the cleavages, the crystal outline is commonly an octagon.

Species.—Mineral names are given to the ideally pure compounds. The naturally occurring minerals usually are composed of mixtures of two or more of the ideal compounds because of the extensive degree to which different metal ions are accepted into the structure of a single crystal. The pyroxenes are subdivided into two groups according to the symmetry of their crystals. Orthorhombic symmetry characterizes the enstatite ($MgSiO_3$) to orthoferrosilite ($FeSiO_3$) series. Bronzite and hypersthene are mixtures of enstatite and orthoferrosilite. Monoclinic symmetry characterizes all other pyroxenes, of which diopside. $CaMg(SiO_3)_2$; hedenbergite, $CaFe(SiO_3)_2$; jadeite or jade, $NaAl(SiO_3)_2$; acmite (aegirite), $NaFe^{3+}(SiO_3)_2$; and spodumene, $LiAl(SiO_3)_2$; johannsenite. $CaMn(SiO_3)_2$; and the clinoenstatite ($MgSiO_3$) to clinoferrosilite ($FeSiO_3$) series are representative. The monoclinic pyroxenes augite and pigeonite can be considered as mixtures of the diopside-hedenbergite series with the clinoenstatite-clinoferrosilite series. plus some aluminum.

Spodumene (*q.v.*), as ceramic material and a source of lithium, and jadeite, as an ornamental stone (see JADE), are the only economically important pyroxenes. Crystals of diopside sometimes have been cut as gem stones.

Formations.— Most of the pyroxenes can be formed over a wide range of temperatures; *e.g.*, enstatite, $MgSiO_3$, can be formed theoretically by naturally occurring reactions as low as 95° C. ($MgCO_3 + SiO_3 \rightarrow MgSiO_3 + CO_2$ at 1 atm. CO_2 pressure) and by other natural reactions as high as 1.557° C. Diopside, $CaMg(SiO_3)_2$, can be formed theoretically by naturally occurring reactions as low as 135° C. [$CaMg(CO_3)_2 + SiO_2 + CaMg(SiO_3)_2 + CO$, at 1 atm. CO_2 pressure] and by other natural reactions up to 1,391° C. However, in the high-temperature metamorphic, igneous and volcanic environments the stability fields of the pyroxenes are relatively larger and, therefore, pyroxenes are commoner in these environments and are relatively rare in low-temperature environments.

The formation of pyroxene over a wide range of compositional environments is possible because of its ability to accept a large variety of different metal ions into its structure; it is, therefore, found associated with almost any of the other common silicate minerals. Pyroxenes are found in metamorphic, igneous and volcanic rocks as well as in pegmatites, ore deposits, as in the diamond mines of South Africa (see ECLOGITE), and many meteorites.

Chemical Structures.— In terms of chemistry the pyroxenes are characterized by the structure of the Si-0 groups in the crystal. The relative ionic sizes of Si^{4+} and O^{--} are such that Si^{4+} closely fits in the central space between four O^{--} ions arranged at the corners of a tetrahedron; thus, silicon always surrounds itself with four oxygen ions. Silicon can furnish only four of the necessary eight electrons needed to satisfy the four oxygen ions, and this results in an excess oxygen problem. The various ways in which this oxygen problem is solved form the basis of subdivision of the silicate group of minerals (see also AMPHIBOLE). The pyroxenes are characterized by the following type of solution: If each silicon ion shares two of its four oxygen ions with two other silicon ions, an endless chain results:

```
   O    O    O    O
   |    |    |    |
O–Si–O–Si–O–Si–O–Si–O
   |    |    |    |
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The remaining demands of the unshared oxygen ions for one electron each can be satisfied by the formation of bonds with other electron-donating ions. In this manner parallel Si-O chains are bonded together by rows of metal ions parallel to the chains. Almost any of the two-valent metal ions or mixtures of them, or a combination of a three- and a one-valent metal ion. are able to bind the chains together. The difference in the ionic sizes oi the metal ions causes slight angular adjustments in the relative position of one Si-O chain to another which result in the two different symmetry classes for the pyroxene group of minerals. Pure nickel, cobalt, zinc or iron pyroxenes or mixtures of them are not known to form, although these elements can be present in small amounts. The reason for the absence of such pyroxenes is that the pyroxene structure becomes unstable in the presence of large amounts of these high bonding energy ions.

For discussion of mineralogical and crystallographic concepts used in this article *see* MINERALOGY.

See also GEOCHEMISTRY: *Geochemistry of the Lithosphere: Crystallization of Magma;* SILICON: *The Silicates.*

(G. W. DEV.; X.)

PYROXENITE, a rock consisting essentially of minerals of the pyroxene group, such as augite and diallage (a diopside), hypersthene, bronzite or enstatite. Names have been given to members of this group according to their component minerals; *e.g.,* pyroxenite (augite), diallagite (diallage), hypersthenite (hypersthene), bronzitite (bronzite) and websterite (diallage and hypersthene).

Closely allied to this group are the hornblendites, consisting essentially of hornblende.

PYRRHO OF ELIS *(c.* 365–275 B.C.), the Greek philosopher from whom Pyrrhonism takes its name, had as a teacherrinaxarchus of Abdera, from whom he learned the view—a one-sided development of the system of Democritus—that every perception and judgment of value is relative. He joined the expedition of Alexander the Great and reached India, where he was able to see for himself, in the fakirs, an example of the total indifference to circumstances for uhich the Greek philosophers often yearned. About 330 B.C. he established himself as a teacher in his native Elis. His reputation spread to other parts of Greece, and later sceptics looked to him as their founder. Other philosophers before him had proclaimed that nothing is knoun with certainty; Pyrrho seemed to have carried doubt to its logical extreme. He wrote nothing, but some impression of his arguments can be gained from the fragments of the poems of Timon of Phlius (*q.v.*). The aim of the wise man is to become imperturbable and proof against the changes of fortune; he must utterly abstain from judgment and be prepared to doubt even sense-perception, for this is not the infallible test of truth which others have supposed it to be; however, he must equally not distrust perception on principle, for this would imply that it is known or judged to be false. A placid acceptance of things as they appear. fortitude against pain and indifference to external fortune seem to be the practical consequences. The sceptics of the New Academy (Arcesilaus and Carneades) professed to derive their scepticism from Socrates, not from Pyrrho.

See also SKEPTICISM. (D. J. A.)

See L. Robin, *Pyrrhon et le scepticisme grec* (1944).

PYRRHOTITE, a mineral species consisting of iron sulfide. Small amounts of nickel and cobalt are often present; the nickeliferous pyrrhotite of Sudbury, Ont., with its associated pentlandite (*q.v.*), is the most important source of nickel. The name is from the Greek *pyr,* "fire," and *rhotes,* "redness." The formula is $Fe_{1-n}S$, in which n may vary from o to 0.2. The variety troilite, having a composition near FeS, has been identified as an important constituent of some meteorites *(see* METEORITES: *Mineralogical Composition).* Crystals of pyrrhotite have the form of hexagonal plates bounded at their edges by faces of a hexagonal prism and pyramids, which are deeply striated horizontally More frequently, however, the mineral is massive, with a familiar or granular structure. It is magnetic, sometimes with polarity, and is therefore often called magnetic pyrite. The colour is bronze yellow, the lustre metallic and the streak grayish black. The hardness is 4 and the specific gravity 4.58–4.64. Pyrrhotite occurs in metalliferous veins and as grains and plates disseminated through various rocks. *See* also NICKEL.

PYRRHUS *(c.* 318–272 B.C.), king of Epirus in ancient Greece, whose costly military successes gave rise to the phrase, "Pyrrhic victory," nas the son of Aeacides and a member of the royal family of the Molossians. He claimed descent from Pyrrhus, the son of Achilles, and was also connected with the royal family of Macedonia through Olympias, the mother of Alexander the Great.

While still a boy, he became king of the wild mountain tribes of Epirus, and learned the art of war in the school of Demetrius Poliorcetes and his father Antigonus. He fought by their side at the battle of Ipsus in Phrygia (301), in which they were decisively defeated by the combined armies of Seleucus Nicator and Lysimachus. Soon afternard he was sent to the court of Ptolemy of Egypt at Alexandria as a pledge for the faithful carrying out of a treaty of alliance between his brother-in-law Demetrius and Ptolemy. Through Ptolemy, whose stepdaughter Antigone he married, Pyrrhus was enabled to establish himself firmly on the throne of Epirus, and became a formidable opponent to Demetrius, who was now king of Macedonia and the leading man in the Greek world. He defeated one of Demetrius' generals in Aetolia, invaded Macedonia and forced Demetrius to conclude a truce with him For some time he occupied most of Macedonia under the terms of the truce, but in 286 Lysimachus defeated him at Edessa and drove him back into Epirus.

In 281 Tarentum, in southern Italy, asked his assistance against Rome. Pyrrhus went with about 25,000 men, and might, with more wholehearted assistance from the Greek cities, have been a fatal obstacle to the growth of Rome, faced with Etruscans and Gauls in the north as well as this reinforced opposition in the south. Greeks and Romans met at Heraclea (280), and Pyrrhus, with the advantage gained by his cavalry and elephants, completely defeated the consul M. Valerius Laevinus, but at the cost of very heavy losses. He advanced on Rome through Latium, but the towns uere all garrisoned, and though the senate was inclined to agree to terms, the speech of Appius Claudius the censor decided them against it. Cineas, Pyrrhus' minister, was sent back with a refusal to negotiate as long as Pyrrhus' troops were in Italy

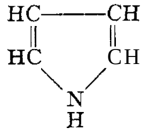
In 279 Pyrrhus won another costly victory at Asculum in Apulia. He then went to Sicily with the idea of driving the Carthaginians out; his military operations were successful, and Rome and Carthage united in an alliance against him, nhile his despotic methods alienated the Sicilian cities. He stayed three years in Sicily and then returned to Italy, but the Greek cities now entirely failed to support him and he was completely defeated at Bcneventum in 275. He left Italy, saying, "what a battlefield I am leaving to Rome and Carthage"—a remark of some insight. The rest of his life was passed in wars at home. including a victory over Antigonus Gonatas, and an unsuccessful expedition into Sparta at the invitation of Cleonymus in 273. He was killed in 272 in a night skirmish in a street in Argos.

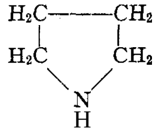
Pyrrhus wrote a history of the art of war, which is praised by Cicero and quoted by Dionysius of Halicarnassus and Plutarch, the chief ancient authority for his life.

PYRROLE. A colourless oil whose existence in coal tar was surmised by the German chemist F. F. Runge in 1834 but which was first isolated and studied by the Scottish chemist Thomas Anderson in 1857. The name is derived from Greek and Latin roots meaning "fiery oil." from the fiery red colour imparted by pyrrole to a wood splint previously moistened nith acid Pyrrole is of great historical interest because of the fact that one of its derivatives, indole (q *v.*), is the fundamental building block of the regal dye of the ancients, Tyrian purple. as nell as of the most important ancient and medieval dye, indigo. Pyrrole is also the structural unit of chlorophyll, the green portion of the pigment of leaves; of heme, the red portion of the pigment of blood, of the pigments of the bile; and of the pigments of numerous types of bacteria, algae and other living organisms. Pyrrole pigments are found in coal. petroleum and similar substances derived from plant and animal sources.

The colouring matters derived from pyrrole are the objects of extensive scientific investigations because their functions in plants and animals are so critically important to life. Atmospheric carbon dioxide, fixed by photosynthesis involving chlorophyll, is the ultimate source of most of our food and fuel, and the efficiency of transportation of oxygen by the blood pigment hemoglobin is indispensable to the rapid motions of higher animals. In addition, these pyrrole pigments are probably produced by living organisms in greater tonnage than any other class of pigments. Derivatives of pyrrolidine, which is completely reduced pyrrole, occur in alkaloids, such as cocaine and nicotine, and as building blocks of proteins in the form of the amino acids proline, hydroxyproline and tryptophane.

Pyrrole boils at 131° C., is slightly lighter than water (density 0.9669) and has the composition C_4H_5N. It is sparingly soluble in water but dissolves in alcohol, ether and many other solvents. Its structural formula was assigned correctly by the German chemist Adolf von Baeyer in 1870 in the course of his classical investigations on the structure of indigo. It is conventionally represented as in diagram I; diagram II is the formula for pyrrolidine:


I


II

Pyrrole is characterized by great chemical reactivity, being slowly destroyed by air with the formation of a brown pigment. It is also destroyed by strong acids, being partially converted into indole, and it enters into combination with a wide variety of chemical reagents. It has been obtained from bone oil and by destructive heating of proteins but is now available commercially from acetylene, formaldehyde and ammonia. Pyrrole is moderately toxic, acting as a nerve poison. Certain of its derivatives have found a limited application in medicine. Their main use is in organic chemical synthesis for the study of the structure and functions of the naturally occurring pigments.

The most important pyrrole derivatives are the porphyrins (from the Greek for purple) and the chlorines (from the Greek for yellow-green) and their metallic compounds. A typical iron-porphyrin compound is hemin, the oxidized form of the coloured portion of the blood pigment.

See Hans Fischer and Hans Orth, *Die Chemie des Pyrrols* (1934–40). (A. H. Cn.; X.)

PYRUVIC ACID or Pyroracemic Acid is an extremely reactive organic acid which occupies a central place in cellular metabolism. Formed duirng sugar fermentation, it may be oxidized to acetic acid or it may be reduced: (1) to lactic acid (glycolysis); (2) to ethyl alcohol (alcohol fermentation) through decarboxylation to acetaldehyde; (3) to malic acid by CO_2 fixation; or (4) to alanine by NH_3 fixation. The oxidation of pyruvic acid in living cells requires the presence of vitamin B_1 (thiamine) and its concentration in the blood increases in vitamin B_1 deficiency.

Pyruvic acid, $CH_3COCOOH$, is best prepared by heating together a mixture of six parts of fused potassium hydrogen sulfate and four parts of tartaric acid at 210°–220° C. The distillate is fractionated under reduced pressure, the yield being 50%–55%. Pyruvic acid was first obtained by J. J. Berzelius in 1835 by the dry distillation of tartaric acid. It is a colourless liquid boiling at 75°–80° C./25 mm. and at 165° C./760 mm. with partial decomposition; on redistillation at 60° C./10 mm. it forms crystals which melt at 13.6° C. With phenylhydrazine it gives crystalline phenylhydrazone and it combines additively with prussic acid and with alkali bisulfites. It forms mercaptals with mercaptans and is oxidized to acetic acid with hydrogen peroxide in neutral and with ceric sulfate in acid solutions. Its most characteristic reaction with aldehydes and aromatic amines (Doebner's reaction) leads to the production of arylcinchonic acids. It can be tested for by reduction to lactic acid through the action of magnesium and an acid.

See also Fermentation: *The Modern Position.*

Bibliography.—F. Feigl, *Qualitative Analysis by Spot Tests* (1937); O. Kamm, *Organic Syntheses*, vol. v (1925). (E. S. G. B.)

PYRZYCE (Ger. *Pyritz*), a town in the province of Szczecin, Pol., formerly in the Prussian province of Pomerania, Ger., 16 mi. S.W. of Starogród by the railway to Kostrzyn. Pop. (1939) 11,200, (1950) 2,694. It became a town in 1150. Near the town was the spring in which Otto, bishop of Bamberg, baptized the first Pomeranian converts to Christianity in 1124.

PYTHAGORAS (fl. 5th century B.C.), a noted Greek sculptor of Rhegium, a contemporary of Myron and Polyclitus and their rival in making statues of athletes. One of these, that of the boxer Euthymus of Locri, can be dated at 472 B.C. He was born at Samos and migrated in his youth to Rhegium, in Italy. He made a statue of Philoctetes notable for the physical expression of pain, an Apollo shooting the Python at Delphi and a man singing to the lyre. His technical improvements went far to ending archaic stiffness. No existing work can be certainly attributed to him, but the "Apollo on the Omphalos" at Athens and the "Choiseul-Gouffier" Apollo in the British museum have been identified as copies of his statue of Euthymus.

PYTHAGORAS AND PYTHAGOREANISM. The Greek philosopher Pythagoras, who was active *c.* 530 B.C. and gave his name to an order of scientific and religious thinkers, was born in Samos. Reputed by legend to have travelled extensively, he was certainly in contact with ideas native to Asia Minor. The historically important part of his career begins with his migration to Crotona, a Dorian colony in southern Italy, about the year 529. According to tradition, he was driven from Samos by the tyranny of Polycrates. At Crotona he became the centre of a widespread organization which was, in its origin, a religious brotherhood or an association for the moral reformation of society rather than a philosophical school. The Pythagorean brotherhood had much in common with the Orphic communities which sought by rites and abstinences to purify the believer's soul and enable it to escape from the "wheel of birth." Although its aims may have been primarily those of a religious order rather than a political league, it actively supported aristocracies. Indeed it gained control over many Western Greek colonies; and it was politics which led in the end to the dismemberment and suppression of the society. The first reaction against the Pythagoreans, led by Cylon, was able to bring about the retirement of Pythagoras to Metapontum, where he remained until his death at the end of the 6th or the beginning of the 5th century. The order appears to have continued powerful in Magna Graecia until the middle of the 5th century B.C. when it was violently trampled out, its meetinghouses being everywhere sacked and burned. Those Pythagoreans who survived took refuge abroad: Lysis went to Thebes, where he became the instructor of Epaminondas; and Philolaus, who according to tradition wrote the first exposition of the Pythagorean system, also lived at Thebes at the end of the 5th century. Philolaus, however, and some others were afterward able to return to Italy. Tarentum (Taras) then became the chief seat of the school: Archytas, the friend of Plato, was prominent there both as a philosopher and as a statesman in the first half of the 4th century B.C. About the middle of that century, however, the Pythagoreans disappeared as a philosophic school.

Philosophical Beliefs.—There seems to have been a split in the school, dating from about the middle of the 5th century B.C. On the one hand, there were "the mathematicians," represented by such names as Archytas and Aristoxenus, who were interested in scientific studies, particularly in mathematics and in musical theory; on the other, there were the more conservative members of the school, who concentrated on the moral or religious precepts and were called *akousmatikoi* (from *akousmata*, "oral traditions"). It is probable that both the scientific and the religious elements were present from the start in Pythagoreanism. Most of the evidence for the beliefs of Pythagoras himself is doubtful. It was customary for his later disciples to claim the master's authority indiscriminately; and Aristotle speaks only vaguely of "the so-called Pythagoreans," "the Italians," and so on. The doctrines that can reasonably be attributed to Pythagoras may however be summarized as follows:

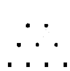
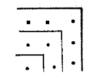
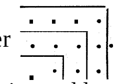
1. First and foremost is his account of the soul. He believed in the transmigration of the individual soul from one body to another, even of a different species. "Do not hit him," he once

said to a man who was beating a puppy, "it is the soul of a friend of mine. I recognized it when I heard it cry out." But if a man led a pure life, his soul might be released from all flesh. It is possible that this held good only for the exceptional man, a seer such as Pythagoras himself or Empedocles (*q.v.*). But the view of the body as the tomb or prison of every soul, with philosophy as the meditation of death and the release from the body, seems to be attributed to a Pythagorean in Plato's Phaedo (61 D ff.). Its importance in the history of religion need not be underlined. All this must be set in the framework of the belief, brought to the Greeks from Asia Minor. which ascribed to souls a future life in the starry heavens. For nearly all Pythagoreans the actual composition of the soul (*e.g.*, out of fire or air. the warmth or breath of life) gave it a natural affinity with the stars or the sky.

2. The pure life consisted in obeying precepts which are mostly recognizable as primitive taboos; *e.g.*, not to eat beans, not to poke a fire with iron. More strictly moral were the three questions which had to be put to oneself every evening: In what have I failed? What good have I done? What have I not done that I ought to have done? Of external aids to purification one of the most important was music.

3. The fascination of numbers for the school must go back to its founder. His greatest discovery was probably the dependence of the musical intervals on certain arithmetical ratios of lengths of strings at the same tension, 2:1 giving the octave, 3:2 the fifth and 4:3 the fourth. It must have contributed powerfully to the idea that "all things are numbers." Though not necessarily to be attributed to Pythagoras, this idea was the philosophical kernel of Pythagoreanism. Early forms of it probably did not distinguish between things being numbers, having numbers and merely resembling them. But in Aristotle's account of it (Metaphysics, i. ch. j and 8) numbers were the elements of everything. in the way that fire, water, etc. had been for other thinkers. The whole heaven formed a '(musical scale and number"; and even such things as reason, justice and marriage were identified with distinct numbers. The elements of numbers themselves were "the odd" and "the even" or "limit" and "the unlimited." which in Aristotle's view represent a primitive insight into the notions of form and matter. These two pairs headed a list of ten pairs of fundamental "opposites." the remaining eight being "one" and "many," "right" and "left," "male" and "female,)' "rest" and "motion," "straight" and "curved," "light" and "darkness." "good" and "evil," "square" and "oblong." It was a philosophy of metaphysical and moral dualism: but it came to see the universe as a harmony of opposites, in which "the one" generated the number series, or "limit" successively imposed itself on "the unlimited."

Thus music and the belief in a stellar heaven (especially if this had originally been associated with Babylonian astrology) are two links between the religious content of Pythagoras' outlook and the mathematical and astronomical studies made later by the scientific wing of his school. The first to have made a comprehensive system may have been Philolaus. Thereafter the three doctrines outlined above would have been common to the *akousm*-atikoi and to the "mathematicians" alike. Their development by the latter can be seen in what follows. Much of it had been known to the Babylonians.

Pythagorean Arithmetic. — The unit or 1 (which was not strictly a number) was assigned or equated to the point, 2 to the line, 3 to surface and 4 to solid. The assertion of J. Burnet and many others, that numbers were regularly held to be spatially extended, is open to question. The normal account seems to have been that the point "flowed into" the line, the line into surface, and so on. But numbers were certainly represented by arrangements of pebbles in triangles, squares, etc.; and the practice assisted the geometrical expression of arithmetical theorems. which was due fundamentally to the existence of both rational and irrational fractions, since these contradicted the strict definition of numbers as magnitudes. The holy tetractys, by which the later Pythagoreans used to swear, was a figure of this kind  representing the triangular number 10 and showing at a glance its composition as $1+2+3+4$. To add a row of five dots gives the next triangular number nith j as the side, and so on. showing that the sum of any number of the series of natural numbers beginning with 1 is a triangular number. The sum of any number of the series of odd numbers beginning with 1 is similarly seen to be a square; thus 3 and 5 added successively to 1 give figures of the kind  called gnomons. If we take the series of even numbers, we see that the sum of any number of them beginning with 2 makes an oblong number 

The successive odd numbers after 1 were themselves called gnomons because the addition of each to the sum of the preceding ones (beginning with 1) makes a square number into the next larger square. If the gnomon added to a square is itself a square number, there is a square number which is the sum of two squares; thus $1+3+5+7=16$ or 4^2, and the addition of 9 ($=3^2$) gives 25 or 5^2, that is, $3^2+4^2=5^2$. Pythagoras himself is credited with a general formula for finding two square numbers the sum of which is also a square, namely (if m is any odd number). $m^2+\{\frac{1}{2}(m^2-1)\}^2=\{\frac{1}{2}(m^2+1)\}^2$. This connects itself with the theorem of the square on the hypotenuse of a right-angled triangle, which tradition universally associates with the name of Pythagoras. In the case of the isosceles right-angled triangle the ratio of the hypotenuse to either of the other sides is what is written as $\sqrt{2}$, which is irrational in the sense that its value cannot be expressed exactly as a ratio between numbers. It was the Pythagoreans who discovered the irrationality of $\sqrt{2}$ and not only this but also the method of finding ever closer approximations to the value of $\sqrt{2}$ by forming the series of the so-called side and diagonal numbers that satisfy one or other of the two equations $zx^2-y^2=+1$ and $ax^2--y^2=-1$, when x stands for the length of one of the equal sides and y for that of the hypotenuse. The method depends on the proposition $2x^2-y^2=(2x+y)^2-2(x+y)^2$, whence it follous that, once one set of values for x and for y has been found such that $2x^2-y^2=+1$, then $2(x+y)^2-(2x+y)^2=-1$. the higher numbers $x+y$ and $2x+y$ in the latter equation taking the place of the x and of the y in the original; then, vice versa. with the higher numbers substituted, we may proceed from $2x^2-y^2=-1$ to $2(x+y)^2-(2x+y)^2=+1$, where $x+y$ and $2x+y$ stand for a second set of higher numbers; and so ad *infinitum*. Hence is derived the infinite series $\frac{1}{1}, \frac{3}{2}, \frac{7}{5}, \frac{17}{12}, \frac{41}{29} \ldots$ giving progressive approximations to $\sqrt{2}$.

Contributions **to Geometry.**—Other contributions to geometry were made by the Pythagoreans. In the first place Pythagoras. it is said. himself formulated definitions in geometry. Secondly, the Pythagoreans proved that the sum of the three angles of any triangle is equal to tno right angles: there is their proof, which, like Euclid's, uses the property of parallels; hence they knew the theory of parallels. Thirdly, they discovered the powerful method in geometry of the application of areas (cf. Eucl. i. 44, 45), including application with excess and defect (cf. Eucl. vi. 28. 29), which amounts to the geometrical solution of any quadratic equation in algebra having real roots. Fourthly, they discovered the theory of proportion, together with the arithmetic, the geometric and the harmonic means. The theory and the arithmetic mean appear in the middle terms of the proportion $a : \frac{a+b}{2} = \frac{2ab}{a+b} : b$, a particular case being $12:9=8:6$, from the terms of which the three musical intervals can be obtained. The Pythagorean theory of proportion was arithmetical (after the manner of Euclid, book vii) and did not apply to incommensurable magnitudes; it must not therefore be confused with the general theory due to Eudoxus, which is expounded in Euclid v. Fifthly, it was claimed that Pythagoras discovered the construction of the five regular solids. It was more probably Theaetetus who (as we read elsewhere) discovered the octahedron and the icosahedron; but the Pythagoreans were clearly acquainted with the pyramid or tetrahedron and the dodecahedron. The construction of the dodecahedron requires that of a regular pentagon. which again depends (as in Eucl. iv, 10, 11) on the problem of Eucl. ii. 11, about the division of a line in extreme and mean ratio. a particular case of the application of areas. The assumption that the Pythagoreans could construct a regular pentagon is confirmed by the fact that the pentagram, the triple interwoven triangle, or the star-pentagon, was used as a symbol of recognition between the members of the school and was called by them health. Sixthly, the Pythagoreans discovered how to construct a rectilineal figure equal to one and similar to another rectilineal figure.

To sum up, it may be said that Pythagorean geometry covered the bulk of the subject matter of Euclid's books i, ii, iv, vi (and probably iii), with the qualification that the Pythagorean theory of proportion was inadequate in that it did not apply to incommensurable magnitudes.

Pythagorean Astronomy.—It remains to speak of the Pythagorean astronomy. Pythagoras was one of the first to hold that the earth and the universe are spherical in shape. He appreciated that the sun. the moon and the planets have a motion of their own independent of the daily rotation and in the opposite sense. It is improbable that Pythagoras himself was responsible for the astronomical system known as Pythagorean, which deposed the earth from its place in the centre and made it a planet like the sun. the moon and the other planets; for Pythagoras apparently the earth was still at the centre. The later Pythagorean system is attributed alternatively to Philolaus and to Hicetas, a native of Syracuse. The system may be thus described. The universe is spherical in shape and finite in size. Outside it there is infinite void. which enables the universe to breathe, as it were. At the centre is the central fire, wherein is situated the force which directs the movement of the universe. Within the universe bodies revolve around the central fire as follows: nearest to the central fire is the counterearth, which always accompanies the earth; next in order (reckoning from the centre outward) is the earth, then the moon, then the sun: then the five planets and then. last of all, the sphere of the fixed stars. The counterearth, revolving in a smaller orbit than the earth, is not seen by us because the hemisphere in which we live is always turned away from the counterearth. This part of the theory involves the assumption that the earth rotates about its own axis in the same time as it takes to complete its orbit around the central fire; and as the latter revolution was held to produce day and night, it is a fair inference that the earth was thought to revolve around the central fire in a day and a night, or in 24 hr. The counterearth may have been invented to explain the comparative frequency of lunar eclipses. The system amounts to a first step toward an anticipation of the Copernican hypothesis, and Copernicus himself referred to it as such.

Later **Pythagoreanism.**—A survival (sometimes called Neopythagoreanism) of Pythagorean practices and doctrines, particularly that of immortality, is attested in Rome from the 1st century B.C. As a philosophical theory it merged with Platonism. But it was also a kind of cult; and the frescoes in the underground basilica of the Porta Maggiore have been claimed as Pythagorean. In imperial times there were Pythagoreanizing philosophers and mathematicians in Alexandria, in Syria and elsewhere. Plato's immediate successors had already made a partial return to more purely Pythagorean theory; and Neoplatonists. such as Iamblichus in the 4th century A.D., drew on them as well as on more recent, forged Pythagorean writings (*e.g.*, the *Orphic Hymns*).

For Christian Fathers, such as Ambrose, Pythagoras was an authoritative figure because he was thought to have been a Jewish intermediary between Moses and Plato. By the 16th century he was liable to be reckoned, and his beliefs cited, according to the interests of the writer, as a poet, as a magician, as the father of the Cabbala, as a mathematician or as a champion of the contemplative life. He is depicted, characteristically an old man, among the philosophers, in Raphael's "School of Athens." *See* ARCHYTAS; PHILOLAUS.

BIBLIOGRAPHY.—Greek texts are given by H. Diels and W. Kranz, *Fragmente der Vorsokratiker,* vol. i, 7th ed. (1954). *See* further E. Zeller, *History of Greek Philosophy,* Eng. trans. by S. F. Alleyne, vol. i (1881); J. Burnet, *Early Greek Philosophy,* 4th ed. (1930) and *Greek Philosophy, part i, Thales to Plato* (1914); T. L. Heath, *History of Greek Mathematics,* vol. i (1921), and, for astronomy, *Aristarchus of Samos* (1913); B. L. Van der Waerden, *Science Awakening,* Eng. trans. by A. Dresden (1954); and S. Dill, *Roman Society from Nero to Marcus Aurelius* (1904).

(T. L. H.; A. C. LD.)

PYTHEAS OF MASSALIA (Marseilles), Greek explorer and geographer of *c.* 300 B.C., was the first Greek to visit and describe the Atlantic coast of Europe (including Britain). His main work, *On the Ocean,* is lost; citations in later authors do not give a coherent picture of it or even show exactly how far he traveled. There is one fragment of a second work, perhaps a complementary description of the Mediterranean coast of Europe. Pytheas' writings were extensively used by later geographers, notably Eratosthenes and Poseidonius; but he was attacked as a Munchhausen by equally eminent men, particularly the historian Polybius (followed by Strabo). Modern scholars have rehabilitated him, often to excess. He certainly visited some northern countries, and his comments on small points, *e.g.,* on the native drinks made from cereals and honey and on the use of threshing barns (contrasted with open-air threshing in the Mediterranean sun), show acute observation. His scientific interests appear from his calculation of the ratio of the hand of a sundial to its shadow at the summer solstice, and from his notes, sometimes rather puzzling, on the length of the longest day as he traveled northward. These observations were used by his successors (not, it seems, by Pytheas himself) for establishing parallels of latitude. He also noticed that the Pole star is not at the true pole and that the moon affects the tides.

Pytheas is at his worst in giving measurements, whether in day's journeys (five from Cadiz to Cape St. Vincent, three from Ushant to the French coast) or in stadia (40,000, *i.e.,* over 4,000 mi., for the circumference of Britain). His Thule—the northernmost inhabited island, six days' sail from northern Britain and extending at least to the Arctic circle—cannot be identified. It may be Norway (but not Iceland).

Pytheas was too ready to believe what he was told: the story of the Stagnant sea bounding the earth in the far north—a mixture of earth, air and water, like a "sea-lungs" (jellyfish?)—deserves Polybius' ridicule. His work laid a valuable foundation for greater men, though, as Polybius saw, he often misled them.

(E. BA.)

PYTHIAS, KNIGHTS OF, a fraternal and benevolent order of secret character, founded in Washington, D.C., Feb. 19, 1864, and chartered by a special act of congress. In the second half of the 20th century the order maintained more than 50 grand lodges or grand domains in the states of the United States and in provinces of Canada. There were also about 3,000 local or subordinate lodges. The governing body is the Supreme Lodge. There were four recognized auxiliary bodies, the military department, the Dramatic Order Knights of Khorassan, the Junior Order Princes of Syracuse and the Pythian Sisters which, founded in 1888, was open to all women relatives of members of the Knights of Pythias.

PYTHIUS (PYTHIOS, PYTHEOS), noted Greek architect of the 4th century B.C. With the architect Satyrus he built the great Mausoleum at Halicarnassus (353 B.C.), one of the seven wonders of the world, ordered by Queen Artemisia as a tomb for her husband. Mausolus. A number of restorations of the mausoleum were made in the 19th century. Pythius cultivated the Ionic style, in which he also constructed the temple of Athena at Priene. The dedicatory inscription, which is in the British museum. records that the founder was Alexander the Great. Pythius is mentioned by Pliny and Vitruvius.

PYTHON, a snake of the family Pythonidae, and more especially any one of the species of the genus *Python.* The snakes of this genus are large, and its various species are found throughout the tropics of the old world. The snakes of the python family are distinguished from the boas (*q.v.*), with which they are often confused, by the presence of the supraorbital bone in the skull. As in the boas, vestiges of the hind limbs are present, visible externally as a pair of claws adjacent to the anal cleft. The teeth are strong and adapted for catching and holding the prey. There is no venom or venom-conducting apparatus.

Killing of the prey is effected by constriction; one or more coils of the body are thrown around the victim, following up the stroke of the head, and pressure is applied by the powerful body muscles. The pressure exerted by a large python must be terrific. Thk prey is killed, however, by suffocation rather than by any actual crushing of the ribs. During the swallowing process much saliva is secreted, and should the prey be disgorged, as may happen if the snake is disturbed, it will be found to be covered with this secretion. This evidently accounts for the fable that pythons cover their prey with saliva before swallowing it.

There can be no doubt that large pythons are strong enough to kill an animal the size of an ox, but stories of their killing and eating cattle and horses are not to be credited. The prey is swallowed whole, and though the mouth is greatly distensible, it cannot be stretched beyond the calibre of a moderate-sized pig. Authentic accounts of attacks on man are extremely few.

Most pythons are partly arboreal and are likely also to be found in the vicinity of water, in which they lie and soak. Reproduction is by means of leathery shelled oval eggs, of which there may be a hundred or more in a clutch. The eggs are laid in a heap and are guarded and incubated by the mother, who coils herself around them, and who is known from observation in zoological gardens to have a higher body temperature than the surrounding air while so occupied.

The largest species is the reticulated python (Python *reticulatus)* of the Malay region, which occasionally reaches a length of 30 ft. The Indian python (P. *molurus)* is frequently seen in zoological gardens, as is the African rock python (P. sebae). Other members of the python family include the remarkable arboreal green python of New Guinea (Chondropython viridis) and various other Australasian types. Two species (*Loxocemus*) inhabit western Mexico, as the only American members of the family. (H. W. P.; K. P. S.)

PYTHON, a huge serpent, nameless and female in the earliest account (Hymn. Homer iii, 300 et seq.), which was killed by Apollo at Delphi (older name Pytho), either because it would not let him come near the oracle—in one version (Hyginus, *fab.* 140), it used itself to give oracles—or because it persecuted his mother Leto during her pregnancy. It is generally said to be the child of Earth, and in all probability is to be connected with the reliable tradition that there was an oracle of Earth at Delphi before Apollo came.

In Hellenistic belief, a python was a spirit which possessed certain persons and prophesied unknown to them through their mouths.

See Farnell, *Cults of the Greek States,* iii, 9; iv, 180; also Preller-Robert, i, 239.

PYTHONOMORPHA, the mosasaurs, a group of large marine lizards of Upper Cretaceous age.

See REPTILES.

PYX, a term for various forms of receptacles, from the Greek. *pyxis* ("a box" or "chest"). In ecclesiastical usage it is the sacred vase or tabernacle in which the Host is reserved. In the English mint the pyx is the chest in which are placed one coin from every 15 lb. of newly coined gold and one from every 60 lb of newly coined silver to await the "trial of the pyx" (see MINT). This chest was formerly kept in the Chapel of the Pyx in Westminster abbey.

Q THIS letter corresponds to Semitic Ϙ (koph), which may derive from an earlier sign representing the eye of a needle, and to Greek Ϟ (*koppa*). The form of the majuscule has been practically identical throughout its known history. In the form found on the hloabite stone the vertical stroke extended to the top of the loop, and the same is the case with an early form φ from the island of Thera. The Etruscan form was identical with the Greek. The Latin alphabet had two forms, Q and Q.

In the minuscule form the stroke has moved to the right side of the letter owing to the speed of writing. This produced the cursive form q occurring in the 6th century A.D. Uncial writing also had the form q and the Carolingian form nas practically identical.

In Semitic the sound represented by the letter was an unvoiced guttural pronounced farther back than that represented by the letter *kaph*. In Greek the letter was largely redundant. and in the eastern alphabet was entirely superseded by *kappa*. In the Chalcidic alphabet, however, it lingered and spread from there. probably through the Etruscan. into the Latin alphabet. where it was used only with a following *u*, the combination representing the unvoiced labiovelar sound in such words as *quaero*. The combination of these two letters holds to the present day. and in modern English *q* is not used unless followed by *u*, even if, in words such as "oblique," the sound is a simple velar and not a labiovelar. The most usual position of the sound is initial in words such as "queen." "quick." Q is used apart from *u* only very rarely in words of iorrign origin. especially to represent a Semitic guttural, as in "Qabala," "Iraq." (B. F. C. A.; J. W. P.)

QAIN is the administrative headquarters of the district of Qainat, province of Khurasan, in Iran. Camels are reared and the principal products are grain, saffron, wool and opium.

The town of Qain (pop. [1956] 4,416) is about 200 mi. S. of Meshed in a broad valley. The cultivation of saffron is a specialty of the neighbourhood. The chief industries are the making of felts and carpets. Southeast of the town are the ruins of a great fort. Qain was built by Shah Rukh to replace an older town which he is said to have destroyed. After a time the Uzbegs took possession of and held the place until Shah Abbas I (1587–1629) expelled thern. In the 18th century it fell under the sway of the Afghans and was a dependency of Herat until 1851.

(P. Z. C.; X.)

QAIRWAN (KAIROUAN, KAIRWAN), the sacred city of Tunisia, 36 mi. S.W. from Sousse, and about 80 mi. due south from Tunis. Pop. (1956) 33,968 (commune). The chief buildings are the mosques, which are open to Christians.

In the northern quarter stands the great mosque founded by Sidi 'Oqba ibn Nafi, containing his shrine and the tombs of many Tunisian rulers. It was several times rebuilt; that which subsists dates from the period of the Aghlabites (3rd century of the Hegira, 9th century of the Christian era). In the northern side of the courtyard rises a massive square minaret.

The Mosque of Sidi 'Oqba is the prototype of many other notable mosques. (*See* MOSQUE.) Of greater external beauty than that of Sidi 'Oqba is the Mosque of the Three Gates. Cufic inscriptions on the facade record its erection in the 9th and its restoration in the 15th century A.D. Internally, the mosque is a single chamber, supported by 16 Roman columns. One of the finest specimens of Moorish architecture in Qairwan is the *zawia* of Sidi Abid-el-Ghariani (d. c. A.D. 1400), one of the Almoravides, in whose family is the hereditary governorship of the city. The entrance, a door in a false arcade of black and white marble, leads into a court whose arches support an upper colonnade. The Mosque of the Companion (*i.e.*, of the Prophet), outside the walls to the northwest, is also important. This mosque is specially sacred as possessing what are said to be three hairs of the Prophet's beard, buried with the saint, who was one of the companions of Mohammed. (This legend gives credence to the belief that the tomb contained the remains of Mohammed's barber.)

The town is the centre of fairly active trade and industry, especially in leather goods and carpets.

The legend says that 'Oqba in AD. 671 (A.H. 50) determined to found a city as a rallying point for the followers of Mohammed in Africa He led his companions into the desert and, having exhorted the serpents and wild beasts, in the name of the Prophet, to retire he struck his spear into the ground exclaiming "Here is your Qairwan" (resting place). In the 8th century Qairwan was the capital of Ifrikia province. Later it became the capital of the Aghlabite princes, thereafter following the fortunes of successive rulers of the country. *See* TUNISIA: *History*. (P. W. I.)

QAIS, an island in the Persian gulf lying about 10 mi. off the mainland of Iran is the site of a trade emporium of great importance in former times. The island, measuring 9 mi. by 5 mi., rises 120 ft above sea level to a plateau and is bare of vegetation except for small patches of cultivation and a few date groves and stunted herbage. It is surrounded by a reef and pearl banks. Pop. (1954 est.) 1.686.

In the Mohammedan period it formed a part of the province of Fars. but it was only in the later middle ages that the place attained importance. when a prince of south Arabian origin obtained possession of it, built a fleet there, and gradually extended his power. He captured Siraf (modern Tahiri) which was then the principal emporium of the Persian-Indian-Chinese trade. Siraf gradually—in the first half of the 11th century—became more and more deserted under the suzerainty of the princes of Qais, and finally Qais supplanted Siraf.

At its period of greatest power. the dynasty of Qais also ruled over the district of Oman on the opposite Arabian shore. The Rabbi Benjamin of Tudela visited Qais between A.D 1164 and 1173, and noted the rich market of the island whose chief business was the exchange of Persian. Mesopotamian, Arabian and Indian manufactures and produce. The site of the old city is marked by the ruins known as Harira on the north coast. Qais in turn lost its importance—for what reason is not precisely known—somewhere in the 14th century, and its trade passed to Hormuz.

(P. Z. C.)

QARO (or CARO), **JOSEPH BEN EPHRAIM** (1488–1575), codifier of Jewish law, whose code is still authoritative with the mass of Jews, was born in 1488. As a child he shared in the expulsion from Spain (1492), and like most prominent Jews of the period was forced to migrate from place to place. In 1535 he settled in Safed, Palestine, where he spent the rest of his life. Safed was then the headquarters of Jewish mysticism. Qaro's mysticism did not take the form of a revolt against authority, but was rather the spiritual flower of pietism. It is, however, as a legalist that Qaro is best known. In learning and critical power he was second only to Maimonides in the realm of Jewish law. He was the author of two great works. In the earlier and greater book, in the form of a commentary (entitled *Beth Yoseph*) on the *Turim* (*see* JACOB BEN ASHER) designed exclusively for specialists, Qaro shows an astounding mastery over the Talmud and the legalistic literature of the middle ages. He felt called upon to systematize the laws and customs of Judaism in face of the disintegration caused by the Spanish expulsion. But the *Beth Yoseph* is by no means systematic. Qaro's real aim was effected by his second work: the *Shulhan Arukh (Table Prepared)*. Finished in 1555, this code was published in four parts in 1565. The work gradually became the almost unquestioned authority of the whole Jewish world. 'Its influence was to some extent evil. It "put Judaism into a strait jacket." Independence of judgment was inhibited, and the code stood in the way of progressive adaptation of Jewish life to the life of Europe. But its good effects far outweighed the bad. It was a bond of union, a bar to latitudinarianism, an accessible guide to ritual, ethics and law. It sanctified the home, it dignified common pursuits. When, however: the era of reform dawned in the 19th century, the new Judaism assumed an attitude of hostility to Qaro's code.

QATAR, an independent sheikhdom on the Persian gulf coast of Arabia. Area approximately 8,500 sq.mi. Pop. (1957 est.) 30.000. Its boundaries with Saudi Arabia and the neighbouring sheikhdom of Abu Dhabi are undefined. It is a peninsula about 90 mi. by 40 mi., stretching northward into the gulf between Salwa bay and the Khor 'Udaid. Structurally it is a limestone upfold. Its surface is a gravelly, almost waterless desert crossed by low ridges with a maximum height of over 250 ft. and without vegetation except for a little scrub in the depressions. Water supplies are mainly obtained from distillation plant. Its main resources formerly were pearling (greatly declined) and fisheries. The development of the country from the late 1940s onward resulted from the exploitation of its oil resources, which proved to be much greater than those of the neighbouring island of Bahrein. An artificial port for oil loading was created at Umm Said on the east.

The only town is Doha (pop. [1957 est.] 20,000) with a market and anchorage for dhows. (T. HER.)

QENA, a town of upper Egypt on a canal about 1 mi. E. of the Nile and 380 mi. S.S.E. of Cairo by rail. Pop. (1957) 46.091 (mun.). Qena, the capital of a province of the same name. was called by the Greeks Caene ("New Town") in distinction from Coptos (Qift. Quft), 15 mi. S., to whose trade it eventually succeeded. It is noted for the manufacture of the porous water vessels used throughout Egypt. Its earlier extensive commerce with Arabia and India had been reduced to trade with Arabia in dates and grain. but during World War II revived. (A. J. AL.)

Q FEVER (also known as BALKAN GRIPPE; Ger. QUEENSLAND FIEBER or Q FIEBER; Fr. FIÈVRE Q or MALADIE DE DERRICK-BURNET; Ital. FEBBRE Q) is an acute, self-limited. systemic disease caused by Rickettsia burneti (Coxiella burneti), a microorganism of the family Rickettsiaceae. The rickettsiae approximate the smaller bacteria in size and appearance but are obligate intracellular parasites, as are the viruses. Biologically, the rickettsiae occupy a position between the bacteria and the viruses.

History.—Q fever was first recognized as a new disease in 1935 in Queensland. Austr., by E. H. Derrick. According to him. Q stands for "query," an appellation applied because of the many unanswered questions posed by the new disease at the time of its first description. The term "Queensland fever" is therefore unjustified historically (or geographically). The causal organism was originally designated Rickettsia *burneti* by Derrick. after F. M. Burnet, who isolated it. It is frequently referred to also as Coxiella burneti, after H. R. Cox, who found that Montana ticks were infected by a rickettsia later shown to be indistinguishable from that recovered in Australia, and who uncovered evidence of the possible existence of Q fever in the United States.

The disease, originally encountered almost entirely among abattoir workers, cattle ranchers and dairy farmers in Australia, and just recently among sheep ranchers, was thought for many pears to be restricted to that continent. However, several outbreaks of pneumonitis. later shown to be outbreaks of Q fever, occurred among Axis and Allied troops in the eastern Mediterranean during the minter of 1944–45. These were the first naturally occurring outbreaks of Q fever recognized outside Australia; the disease thereafter was reported from various parts of the world.

Transmission. — While many species of ticks in various parts of the world have been found to be naturally infected, the role of this arthropod in the dissemination and maintenance of the rickettsiae is unclear. It seems likely that some small mammal, perhaps a rodent, serves as a reservoir of the rickettsiae and that ticks keep the infection alive in nature by spreading the rickettsiae from animal to animal within the host species. Man and his livestock (viz., cows, goats and sheep) are not necessary to survival of the rickettsiae in nature and are infected only accidentally.

Tick-transmitted Q fever appears to be rare in man and, in some parts of the world at least, in domestic livestock as well. Since the rickettsiae are excreted in the milk of dairy cows and goats. ingestion of infected dairy products may play a role in the infection of man and livestock. Inhalation of infected material, however. appears to constitute the common mode of infection. The infected animal sheds the rickettsiae through the milk, excreta and, most importantly, through the placenta and the birth fluids. Contamination of the environment leads to air-borne dissemination of the rickettsiae and subsequently to infection of persons in close contact with livestock, contaminated clothing, etc.

Symptoms, Treatment and Prevention. — The incubation period of the disease is from two to four weeks, averaging about 18 to 21 days. The onset of the illness may be gradual but generally is sudden, and the disease is ushered in by fever, chills or chilly sensations, headache. muscle aches, loss of appetite, disorientation and profuse sweating. Symptoms referable to the upper respiratory tract may be present but generally are infrequent and minimal, and pneumonia, even uhen relatively extensive, may be detectable only by X-ray examination. Although Q fever is, on the whole, a mild disease, it can sometimes result in a severe and protracted illness The outlook for recovery is excellent; the mortality rate is believed to be less than 1%. The disease is amenable to therapy with wide-spectrum antibiotics, which are highly effective.

Since Q fever appears to be, in large part. an infection associated with occupation, vaccines prepared from killed R. burneti can be used to protect those persons exposed to infection. Milk, whether used for table purposes or for manufacture of dairy products should be pasteurized. See also RICKETTSIAE. (E. H LEN.)

QIFT (Arabic, KUFT, ancient COPTOS, KOPTOS), a small village in Egypt on the east bank of the Nile. 25 mi. N. of Luxor, known to the ancient Egyptians as Qebti. The town was an early dynastic foundation, the predynastic settlements having been at Ombos (ancient Nubyt) on the west bank of the river which the early routes followed. Qebti owed its importance to the gold and porphyry mines in the district; inscriptions there show that they were being worked in the 1st and 2nd dynasties Just outside Qift Flinders Petrie excavated a temple dedicated to Min of the Desert Routes and containing three important archaic statues of the god. The town was also associated with Isis, who was said to have found Osiris's body there. By Old Kingdom times Qebti was a place of some importance; both Pepi I and II built and restored temples there, and it was the starting point of expeditions for Punt. By the time of Thutmose III the importance of the city had declined, but it revived in the Ptolemaic period through trade with the east. Queen Asinoe was banished to Qebti by Ptolemy Philadelphus, and held her court there for some years. A rebellion directed against Diocletian's taxation on the transit trade led to the destruction of the city in A.D. 292, but later it became the centre of a thriving Christian community and the Christian inhabitants of Egypt, the Copts, derived their name from the town. It retained its influence during the middle ages, until replaced as the caravan trade terminal by Kus (Qus) Largely as a result of Petrie's work there. Qift has supplied skilled workers for all major excavations in Egypt and neighbouring countries. (M. V. S.-W.)

QISHM, also pronounced Jishm and sometimes styled by the Arabs al-Jazirat al-Tawilah (Long Island), is the largest island in the Persian gulf It lies parallel to the coast between Lingeh and Bandar Abbas and is separated from the Persian mainland by a channel known to mariners as Clarence strait. It is 68 mi. long and has a very irregular outline, with an average breadth of about 10 mi. although it exceeds 20 mi. abreast of Hanjam Island. The coast is generally rocky but the southeastern and western shores have sandy bays and the northwestern is fringed by mud flats. Irregular table-topped hills almost cover Qishm. The geological formation resembles that of the adjacent coast; upper strata of coarse sandstone grit and conglomerate supported by blue Lias marl interrupted by salt hills. Salt is mined on the southeastern coast and there are naphtha springs. Cereals. vegetables, melons and dates are gronn near the villages in the north and around the coasts. The main occupations of the inhabitants are fishing and boatbuilding with some camel breeding, stock raising and weaving. Wild goats, partridges and rock pigeons are found in the hills, and some gazelle in the plains. The population in 1954 was about 15.000; 5,781 live in Qishrn town. They are mainly of Arab origin and are administered by a sheikh of the Bani Ma'in tribe on behalf of the Iranian government. (K. C. B.)

QUACKERY, the characteristic practice of quacks or charlatans, who pretend to knowledge and skill that they do not possess, particularly in medicine. The quack makes exaggerated claims as to his power to heal disease, generally for financial gain. The conditions usually treated by quacks are those for which specific methods of treatment, or "cures," have not yet been developed; those particularly feared, such as cancer, venereal diseases and, in the past, tuberculosis; those nith frequent remissions and recurrences, such as arthritis, neuritis and migraine; and mental disturbances. People yield to quackery in times of great stress, pain or sorrow. In the absence of exact knowledge, and sometimes even in its presence in the face of insurmountable difficulties, the credulous person craves a miracle. He is ready to be overwhelmed by the personality and the claims of the charlatan.

The typical quack may be a man or a woman, but is likely to be striking in appearance and personality. In the past crippled persons, such as hunchbacks; rulers, such as high priests and kings; mystics and mentally disturbed persons were believed to possess special powers in healing disease. The modern charlatan in his announcements features an alphabetical appendage, indicating the possession of academic degrees that, however, were not conferred by any recognized scientific organization or university. The charlatan originally may be self-deluded as to his powers, but sooner or later he becomes aware of his failures. He then continues in his practice, consciously deluding those who depend upon him. He is aided by the reluctance of persons who have consulted him with disadvantage to acknowledge the fact, and by magnification of his apparent successes. Advances in psychosomatic medicine have helped to explain some of the healings recorded by quacks.

Techniques. — Whenever a new discovery is made in any field of science, the charlatan may take advantage of public interest and lack of information to utilize it with exaggerated claims. Lack of general knowledge encourages occultism, and the characteristic claim of the auack is the possession of a formula. method, device or product unknown to other physicians or scientists. At the time of the American Revolution. for example, a quack named Elisha Perkins (1741–99), aware of public interest in the recently discovered electricity, invented "metallic tractors" to draw disease out of the body. These were two rods of brass and iron, about three inches long, one of copper, zinc and gold, the other of iron with some other metals; they cost 1*s.* to manufacture and sold for $5. James Graham (1745–94) in England set up a temple of healing in which he burlesqued the principle of electricity, promising cures and rejuvenation.

Knowledge of powerful drug substances derived from plants (digitalis, belladonna. cascara, quinine and castor oil) or from metals (mercury, arsenic and particularly gold) led to the development of nostrums that mere exploited with false, misleading or exaggerated claims to cure such diseases as tuberculosis, syphilis, cancer. kidney diseases and gynecological, digestive and rheumatic disorders. Sometimes the quack or purveyor of nostrums did not trouble to include a potent drug but merely used any bitter-tasting, dark herb or vegetable with common salt or sulfur. Toward the end of the 19th century alcohol was used as a solvent, and it yielded its typical effects to the satisfaction of the users. Many modern nostrums depend principally on aspirin.

With the discovery of radium, claims were made for mixtures said to contain this substance. In a few instances some radium actually was included, and users died years later from the effects of radium on the bones. Radium was said to be incorporated in magical magnetic belts, and radium plasters with infinitesimal amounts of radioactivity were purveyed.

Increasing knowledge of the glands of internal secretion gave rise to preparations for rejuvenation, beautification and sexual power. Vitamins have been incorporated in preparations for growing hair or preventing grayness, without any real evidence that they could be helpful. Indeed, in the realm of cosmetology, quackery and nostrums seem destined forever to reap a pecuniary harvest.

Because peopie believe in "nature," uncooked foods, systems of exercise, recital of ritualistic codes, manipulation of bones, muscles and tendons, complicated machines of no particular merit. heat, cold, baths, lights (plain and coloured), static electric currents and even radiozctivity have been vaunted as useful in the control of disease and the promotion of health.

With the development of techniques for advertising and promotion, the quacks thrived until legislative controls were broogh tinto action. As early as 1843 a leader in advertising said that pain or the fear of pain attracted the greatest interest in mankind, and that for this reason medical advertising took most of the space available in the press. Vanity had the next strongest appeal Education of the public in physiology, anatomy and hygiene have not served to dispel gullibility. Quack advertising still relies on blatant exaggeration, use of unusual terms (such as "dyskinesia" for constipation), creation of fear, promise of secrecy and financial saving (actually the employment of nostrums and quackery invariably results in greatly increased and prolonged expense). With the coming of radio, some quacks secured radio stations to sell promised cures, and even television has been so employed.

Legislation.—In the United States. quackery varies from state to state according to the limits permitted by law. In some states it is limited almost entirely to the sale of drugs and herb preparations. In other states institutes or sanatoriums are conducted by quack doctors.

In Great Britain a violator is held liable if he holds himself out as a "listed" or recognized medical practitioner or if a death occurs associated with his ministrations; there the law considers that a person consults a quack at his own risk. The continental European countries have not been successful in curbing quackery. In Germany during World War II the unlicensed healers were actually encouraged and formed an association which received governmental recognition. In Latin America quackery is rampant.

In the United States the Food and Drug act of 1906 eliminated the widely advertised quack cures for cancer, tuberculosis and other serious diseases; thereafter the same preparations were sold as cures for coughs, colds, pains and aches and minor complaints. Labels were required to carry information as to content of certain ingredients, warning as to hazards and, in some instances, references to diseases that would not be helped by the preparation. The Federal Food, Drug and Cosmetic act of 1938 and the Wheeler-Lea act (also 1938) provided a certain amount of governmental control over claims made in advertising, in newspapers and magazines, over radio and television, in circulars and on labels. Such controls are exercised, however, only on products in interstate commerce. Individual states vary in the amount and kind of control they exert. More recently new drugs, devices or cosmetics may not be released until submitted with evidence to the appropriate governmental agency. Finally, the post office department has authority to forbid the use of the mails when convinced that they are being used fraudulently.

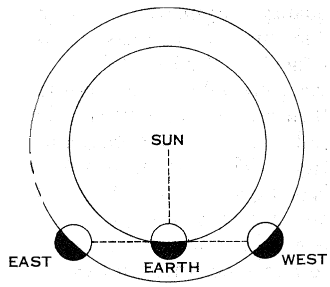
Organizations concerned with such conditions as cancer and heart disease conduct continuous campaigns of public education, warning against the depredations of medical quackery and the sellers of nostrums, and the United States public health service also has undertaken such activities. The state medicai licensing boards, medical societies and Better Business bureaus also are concerned with the protection of the public in these fields.

For these reasons quackery has steadily diminished, and the depredations of quacks have been severely limited. Nevertheless the nature of the human mind is such that charlatans will no doubt continue to appear and wreak damage from time to time until society with a social conscience and legal controls catches up with them. See also FRAUD.

See Morris Fishbein, *Fads and Quackery in Healing (1932)*; Grete de Francesco, *The Power of the Charlatan (1939).* *(M. Fi.)*

QUACK GRASS (Agropyron *repens*), a perennial grass of the barley tribe (Hordeae), called also couch grass or quitch grass. It is native to Europe, common in northern Europe and widely naturalized in North America. Quack grass has bright-green, smooth, stiffly erect stems. one to four feet high; leaves with flat or inrolled blades; and terminal flowering spikes, two to six inches long, composed of numerous, usually five-flowered spikelets, which often bear short awns. Sometimes it is grown for forage, but it is better known as a troublesome weed in cultivated fields, especially on rich soil, spreading rapidly by its creeping rootstocks. The best method to eradicate it is to plow the land, after it has been left in sod two or more years, just after the flowers appear, and to harrow at weekly intervals for about six weeks.

QUADRATURE (Lat. quadratura, a making square), in astronomy, that aspect of a heavenly body in which it makes a right angle with the direction of the sun. The moon at first or last quarter is said to be at east or west quadrature, respectively. A superior planet (outside the earth's orbit) is at west quadrature when its position is 90° W. of the sun (see drawing). It rises around midnight, reaches the south meridian near sunrise and sets near noon. At east quadrature the planet is near the meridian at sunset and sets near midnight. At both quadratures, the planet is at gibbous phase, but only in the case of Mars does it show up conspicuously gibbous.

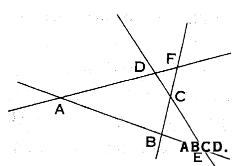


QUADRATURE OF A SUPERIOR PLANET

In mathematics, quadrature is the determination of a square equal to the area of a curve or other figure. Integration by quadratures means calculation by a step-by-step process when no analytical expression for the integral is available. (H. M. Lo)

QUADRILATERAL, in geometry, a figure formed by four straight lines. It is said to be plane or skew according to whether the four lines do or do not lie in one plane.

Let us consider the plane figure bounded by four lines terminated at the vertices. A line joining a pair of opposite vertices is called a diagonal. The area of such a quadrilateral is half the product of the length of one diagonal by the sum of the perpendiculars drawn to this diagonal from the other two angular points. The sum of the squares of the four sides of such a quadrilateral is equal to the sum of the squares of its diagonals increased by four times the square of the line joining the midpoints of the diagonals. If the vertices of such a quadrilateral lie on a circle, the product of the diagonals is equal to the sum of the products of the opposite sides. It is in projective geometry that the quadrilateral plays its most interesting role. If A, B, C, D are four points in a plane no three of which are collinear, then the lines AB, BC, CD, DA, each taken to be of indefinite extent, form a quadrilateral (see figure). These sides intersect in pairs not only in the four given points (called vertices) but also in a point E on both AB and CD, and in a point F on both BC and AD. The points E and F are also called vertices. Then each side of the quadrilateral contains three vertices. Two vertices not on the same side are called opposite. A line joining two opposite vertices is called a diagonal. The configuration so described is called a complete quadrilateral. The dual figure is called a complete quadrangle. These figures are of fundamental importance in projective geometry (*q.v.*).



ALL LETTERED POINTS ARE VERTICES

QUADRILLE, a lively dance, executed by four couples arranged in a square. A form of contredanse known by 1710, the quadrille crystallized about 1815 in the general form popular since then, and consisting of five figures: *le* pantalon, *l'été,* la poule, la pastourelle or la trknise, and the finale. The music was often based on operatic melodies; dance patterns were subject to great variation. Although steps and figures have undergone considerable modification, quadrilles such as the Lancers are still among the most popular square dances. In theatrical terminology, quadrille has denoted: (1) small groups of dancers in 18th-century ballet; (2) Paris night-club dancers of the 1890s, immortalized by Henri de Toulouse-Lautrec; (3) divisions of ensemble dancers at the Paris opera in the 20th century. (LN. ME.)

QUAESTOR (Lat. quaerere, "to investigate"), a Roman magistrate whose functions, in the later times of the republic, were principally financial, although he was originally concerned with criminal jurisdiction. The quaestorship was probably instituted in 509 B.C. simultaneously with the consulship. The number of quaestors, originally two, was successively increased until Julius Caesar raised it to 40 (45 B.C.); Augustus reduced it to 20, which remained the regular number under the empire. When the number was raised from two to four in 421 B.C., the office was thrown open to the plebeians. The quaestorship was the lowest of the great offices of state, and hence the first sought by aspirants to a political career (*cursus* honorum). The candidate was bound to have completed his 30th year before he entered office, but Augustus lowered the age to 25. Quaestors were elected by the comitia tributa (see COMITIA) under the presidency of a consul or another of the higher magistrates. They held office for one year, but, like the consuls and praetors, they were often continued in office. It was a rule that the quaestor attached to a higher magistrate should hold office as long as his superior; hence, when a consul presided over the city for one year and afterward as proconsul governed a province for another year, his quaestor also held office for two years. A peculiar burden laid on the quaestors, as a sort of fee exacted from all who entered on the political career, was the paving of the high roads, for which the emperor Claudius substituted the exhibition of gladiatorial games.

Various classes of quaestors may be distinguished:

Urban **Quaestors.**—Originally the duties of the quaestors, like those of the consuls, were undefined; the consuls were the superior magistrates of the republic, the quaestors their assistants. From a very early time, however, the quaestors possessed criminal jurisdiction; political crimes only seem to have been excepted. The criminal jurisdiction of the quaestors appears to have terminated only when trial by permanent courts (quaestiones *perpetuae*) was extended to criminal cases.

The quaestors had also charge of the public treasury (*aerarium; q.v.*) in the temple of Saturn, and this was in later times their most important function. They kept the keys of the treasury and had charge of its contents, the coin and bullion, the military standards and a large number of public documents, which comprised all the laws as well as the decrees of the senate. Their functions as keepers of the treasury were withdrawn from urban quaestors by Augustus and transferred to other magistrates.

Military **Quaestors.**—These were instituted in 421 B.C. and were clearly distinguished from the urban quaestors by the fact that a nonurban quaestor was assigned as an assistant or adjutant to every general in command. whose name or title the quaestor usually added to his own. Originally they were the adjutants of the consuls only, afterward of the provincial praetors and still later of the proconsuls and propraetors. The governor of Sicily had two quaestors; all other governors and commanders had but one. Between the quaestor and his superior a close personal relation existed, and was not severed when their official connection ceased. The duties of the military quaestor, like those of the treasury quaestor, were primarily financial. Moneys due to a provincial governor from the state treasury were often, perhaps regularly, received and disbursed by the quaestor; the magazines seem to have been under his charge; he coined money, on which not infrequently his name appears alone. But, though his duties were primarily financial, the quaestor was the chief assistant or adjutant of his superior in command, and was invested with a certain degree of military power. When the general left his province before the arrival of his successor, he usually committed it to the care of his quaestor, and, if he died or was incapacitated from naming his successor, the quaestor acted as his representative.

Italian **Quaestors.**—The subjugation of Italy occasioned the institution (267 B.C.) of four new quaestors, who appear to have been called quaestores classici because they were originally intended to superintend the building of the fleet (classis); their functions, however, are very imperfectly known.

See Mommsen, *Staatsrecht; A.* H. *J.* Greenidge, *Roman Public Life* (1901); *J.* E. Sandys (ed.), *Companion to Latin Studies* (1921); *W.* E. Heitland, *The Roman Republic* (1923).

QUAGGA, an animal of the genus *Equus* (E. quagga), allied to Burchell's zebra, formerly met with in vast herds on the great plains of South Africa between Cape Province and the Vaal river, but now extinct, the last having died in 1872 in the London zoo. The colour of the head, neck and upper parts of the body was reddish brown, irregularly banded and marked with dark-brown stripes, stronger on the head and neck, and gradually becoming fainter until lost behind the shoulder. There was a broad, dark, median dorsal stripe. The undersurface of the body, the legs and tail were nearly white, without stripes. The crest was high, surmounted by a standing mane, banded brown and white. *See* ZEBRA.

QUAHOG, also spelled QUAHAUG or QUAUHOG, is a corruption of the word paquahock used by the New England Indians for the hard-shell clam Mercenaria *mercenaria* in the family Veneridae. The name quahog is used only on the Atlantic seaboard of the United States and particularly in New England. The shell of this clam is large, thick and solid, marked with concentric growth lines and ridges. It is a dirty gray in colour outside; inside it is often marked with purple, and it was from this that the Indians made their purple wampum. The quahog has short siphons and so does not burrow deeply into the sand; often a portion of the valves is protruding, or the shell may lie on the surface. It ranges from the intertidal zone out to depths of several fathoms and is found on sandy muddy bottoms. This clam was an important item of food to the Indians and the early settlers and continues to support an important industry on the Atlantic coast from Nova Scotia to Maryland. The young clams, known as cherrystones, are eaten raw; the larger ones are cooked in a variety of ways, though chowder is perhaps the commonest. The black, mahogany or ocean quahog, *Arctica* islandica, has a heavy dark covering on the outside of the shell. This edible species lives in deeper water and is dredged in quantity off the New England coast. Young of both species are important food for bottom feeding fishes. *Mer*cenaria campechiensis, the southern quahog, is also fished commercially. See also CLAM. (R. D. T.)

QUAIL, a game and table bird known throughout Europe, Asia and Africa. The common quail (Coturnix *coturnix*) varies in colour, but in general is reddish-brown above marked with dark brown and buff and pale buff below, passing into white on the belly. Essentially migratory, the quail breeds on the ground, laying 9 to 15 yellowish eggs spotted with dark brown. Immense numbers are netted during the autumn migration in Mediterranean countries. The quail is now rare in Great Britain. It feeds largely on weed seeds and insects and is decidedly a beneficial species. Related forms include the rain quail (C. coromandelica) of India, the African quail (C. delegorguei) and the Australian stubble quail (C pectoralis). The North American quails belong to a different subfamily of the Phasianidae. They include the bobwhite (Colinus *virginianus*) and the California tufted quail (Lophortyx californica).

The button quails (Turnix), lacking the hind toe in most species, are now regarded as related to the cranes. Turnix sylvatica ranges from Spain to the East Indies, with various races. (K. P. S.)

QUAKERS, originally a cant name applied in derision to the members of the Society of Friends, but now used without any contemptuous significance. It was used as early as 1647, and arose from the physical manifestations of religious emotion characteristic of many early Friends.

See FRIENDS, SOCIETY OF.

QUALITIES. The word "quality" has, both in philosophy and ordinary speech, a long history. It appeared in English as a translation of the Latin qualitas, a word coined by Cicero to translate the Greek poiotes; and this Greek word had itself been coined by Plato (*Theaetetus*, 182a), with apology for its barbarous character. and employed as a technical term by Aristotle in his doctrine of categories (*see* CATEGORY). In spite of this highly artificial beginning, the word "quality" soon became acclimatized in ordinary English; in philosophy, however, its uses have been various and somewhat obscure.

The ordinary uses of the word (which cannot here be exhaustively dealt with) may be broadly distinguished under two headings. First, the word is sometimes employed as a synonym of "property" or "characteristic": in this sense it would cover almost anything that might be ascribed to an object for the purpose of describing it—its colour, shape, dimensions and so on. In the same sense honesty, prudence. obstinacy, etc., may be spoken of as "qualities of character." Second, the word is used, perhaps more commonly, in contexts where merit, grade or value is in question. Where, for example, two kinds of cloth are said to differ "in quality," it would usually be meant not merely that they differ but that one kind is better (by the appropriate standards) than the other; it might indeed be said to be of better, or higher, quality. Similarly, when Emerson'wrote that "there is more difference in the quality of our pleasures than in the amount," he undoubtedly meant to convey that some of our pleasures are better, more valuable, and not merely more intense or more prolonged than others. It is usually in this way that the word "quality" is to be understood when a contrast is stated or implied with "quantity." The word is also often employed by itself in the sense of "good quality," as in the old phrase "persons of quality" or in such advertisers' phrases as "quality groceries." In view of the existence and, perhaps, prevalence of this second use, it is important to remember that (in the first sense) a "quality of character," for example, is not necessarily good or desirable. Cowardice is as truly a quality of character as bravery.

Qualities and Relations.—The traditional distinction betaeen qualities and relations, so common that it can hardly be regarded as technical or philosophical, has sometimes been attacked as being philosophically unimportant. It cannot be denied, however. that there is such a distinction, or that it is sometimes convenient to employ it. What the distinction is can be roughly indicated by examples. Colour would be said to be a quality, since, in saying of what colour an object is, nothing need be mentioned other than that object to which the colour is ascribed. Proximity. on the other hand, would be said to be a relation, since, in employing the phrase "is close to," two objects must be mentioned, one of which is said to be close to the other. Similarly, a statement of the form "*Y* is between X and *Z*" might (rather artificially) be said to assert the relation of intermediacy—a "three-term" relation, since mention must be made in the statement of three things, one being said to be between the other two. A connected and sometimes convenient notion is that of "relational quality." For example, it might be said that being tall is a relational quality since, though it is clearly not a relation (the sentence "Jones is tall" is complete in itself), it could be held that in calling someone tall a comparison is implied between his height and (roughly) that of most other men.

Qualities and Predicates.—The foregoing brief distinction between qualities and relations might suggest the view that, in all subject-predicate (as distinct from relational) statements, the predicate is employed to ascribe a quality to that which the subject-expression is used to designate. It would be usual, however, and seems desirable, not to accept such a general principle without qualification; for there are many expressions. properly used as predicates and not obviously complex, which are yet used so differently from others that it seems inadvisable to regard them all as alike in standing for qualities. It would, for example, be reasonable to deny that the word "real" stands for a quality. For whereas the word "yellow," for instance, is ordinarily (literally) employed in just one way, namely in ascribing a particular colour, and so might be said always to stand for the same quality, the force of the word "real" varies greatly from context to context. It would be most unnatural to insist that a real (as opposed to a pantomitne) horse and a real (as opposed to an illusory) advantage share a single quality, reality; the word "real" takes its particular force in each context from the implied contrast, and in this respect, if in no others, the cases differ completely.

Nonnatural Qualities.—An instance which has aroused more controversy, though it is not perhaps of greater importance, is that of the predicate "good." G. E. Moore, in his influential *Principia Ethica* (Cambridge, 1903), launched an attack on what he called the naturalistic fallacy. He distinguished in the course of his argument between the "natural qualities" of objects—for example their colour. shape, texture or weight—and "nonnatural qualities," of which his primary instance was goodness: and the naturalistic fallacy. he claimed was committed by anyone who sought to define a nonnatural quality in terms of a natural quality or qualities. Doubts nere soon expressed, both by Moore himself and by others, about the meaning to be attached to his expressions "natural" and "nonnatural." But other critics were inclined to question whether goodness was a quality at all. of any variety; and some insisted that it was not. (*Cf.* the symposium "Is Goodness a Quality?" in the Aristotelian society's *Supplementary Volume XI,* London, 1932.)

Now this denial might seem surprising in the light of the ordinary use of the word "quality." For one of its most common uses, as remarked above. is in contexts where merit goodness or badness. is at Issue: good apples are of better quality than bad ones. Moreover, it seems entirely natural to say that goodness of heart is an admirable quality of character. If so, it would seem that there could be no objection to the assertion that goodness is a quality.

The philosophical objections to this assertion are somewhat complex but may be summarized as follows. It has been urged that to classify goodness as a quality reveals. or at least invites, misunderstanding of the distinctive character of value judgments. To say that anything Q is a quality, it is said, is to imply that a statement of the form "*X* is (or possesses) *Q*" gives a description of X, or states a fact about X; and it has commonly been held that descriptions or statements of fact, properly so called, must be sharply distinguished from judgments of value (or, that describing an object must be distinguished from expressing commendation or condemnation of it). Hence, Moore's distinction between "yellow" as standing for a natural quality and "good" as standing for a nonnatural quality was held to be Inadequate; for it implied that judgments of value were no more than a special kind of statements of fact, or statements of a special kind of facts, thus obscuring the supposedly more fundamental distinction between statements of fact, of whatever sort and judgments of value. Moore's argument was also held to raise needless apparent problems about the ways in which judgments of value could be supported or attacked, disputed or justified; for it appeared that nothing clear and satisfactory had been said. or could be said about the way in nhich the presence or absence of nonnatural qualities could be detected.

However, this criticism of Moore is inconclusive. For it is not in fact the case, as has often been assumed, that descriptions or statements of fact must be evaluatively neutral. It is proper to say that a man may be *described* as dishonest, though thereby his character is condemned; it may be a *fact* that he is dishonest and hence a statement of fact to say so. But if so, to say that goodness is a quality and to concede that the assertion "*X* is good" may be a statement of fact or a description does not oblige one to misrepresent the peculiar character of value judgments. One may say that, in stating the fact that X is good or in describing X as good, one is necessarily also commending X—that goodness is precisely the quality which commendable things are said to possess. Those philosophers who have distinguished so sharply between "descriptive" and "evaluative" terms might well be held themselves to have misstated the same distinction which Moore was accused of misstating, in his distinction between natural and nonnatural qualities.

A better reason for denying that goodness is a quality might be found in the extreme generality of the word "good" (*cf.* Aristotle, *Nicomachean Ethics,* I, v). It would be unplausible to maintain that the word is actually ambiguous; but if it is not ambiguous and if it stands for a quality, one must hold that, whatever things are called good, the same quality is thereby ascribed to them. But this in its turn seems most unnatural. Can good arguments, good apples, good deeds and good cricketers be plausibly said to share one common quality of goodness? If so, should one not expect a sound judge of cricketers to be thereby equipped to judge apples also, or arguments? But this is obviously contrary to facts. It is noteworthy that the "admirable quality of character" mentioned earlier was not in general goodness but in particular "goodness of heart." It seems that some such particularization of goodness is essential if it is to seem natural to speak of it as a quality. Moore, indeed, when he said that goodness was a nonnatural quality, had restricted his discussion to the alleged special use of "good" in moral contexts. But this restriction seemed somewhat arbitrary, nor is it clear how his argument could be extended if the restriction were dropped. It could not well be held that "good" in other contexts stands simply for natural qualities; but if not, it is not clear how Moore could distinguish between moral and other contexts, nor why he should be at such pains to do so.

Primary and Secondary **Qualities.**—Locke's celebrated distinction between primary and secondary qualities (*Essay Concerning Human Understanding,* ii, ch. 8), of which some notice must be taken here, in fact exhibits the disconcerting feature that some of those things between which he thus distinguishes would not naturally be regarded as qualities at all. The primary qualities of matter, he says, are "solidity, extension, figure, motion or rest, and number"; the secondary qualities are "colour, sounds, tastes, etc."—the "etc." being evidently designed to cover at least smells and warmth and cold. Of these "motion or rest" would usually be spoken of as states, not qualities—partly at least because an object that was at rest, being set in motion, would not be said itself to undergo alteration, as would be implied by saying that it had lost one quality and acquired another. Number also is not commonly thought of as a quality: yellow flowers are all individually yellow, but ten flowers are not all individually ten. To this it might be replied that the quality of being ten belongs not certainly to the members of a collection of ten things but simply to the coilection itself. There are further objections to this reply (*cf.* G. Frege, *Foundations of Arithmetic,* Eng. trans. by J. L. Austin, Oxford and New York, 1950, p. 39e *ff.*); but here it will be sufficient to appeal to the obvious difference between the question "Of what sort? (*qualis?*)" and the question "How many?" as a sufficient reason for refusing to classify number as a quality. From the list of secondary qualities, sounds at least seem to be similarly misclassified. It is clear enough that an actual sound is not a quality of that which makes it, though the capacity, tendency or disposition to make that sort of sound or to be concerned in the making of it might well be so regarded.

Apart from these perhaps minor points, Locke's own account of his important distinction is regrettably confused. He says that our ideas of primary qualities "resemble" those qualities ("their patterns do really exist in the bodies themselves") but that our ideas of secondary qualities are wholly unlike that in objects which causes us to have them. Sometimes, apparently confusing qualities with ideas, he says that secondary qualities, unlike the primary, would not exist at all in the absence of suitably sensitive observers. Sometimes he seems to contend that our ideas of secondary qualities are so various and fluctuating that we cannot say that any such qualities are really "in" objects themselves. He certainly comes very close to saying, and by Berkeley was understood to mean, that our ideas of secondary qualities are only a "false imaginary glare," tempting us to ascribe to objects qualities which really they do not possess at all. It is accordingly necessary to inquire what it was that he was seeking, though unsuccessfully, to convey; and here we must take notice of two different distinctions, with both of which Locke was evidently concerned, though he does not clearly indicate that they are two and different.

First, he was clearly influenced strongly by current scientific accounts of the process of perception. He officially regards the qualities of matter as the causes of our "ideas of sensation" and hence is led to think of matter as really characterized by those qualities required in the current explanatory theory. Now the theory current in Locke's time was a mechanical one, "corpuscles" being supposed to act "by impulse" on the sense organs; it is accordingly not surprising that his list of primary qualities includes all and only those features that are of mechanical importance—solidity, shape, size, motion and number. The secondary qualities, perception of which is accounted for by the action of corpuscles supposed to have primary qualities only, are thus thought of as an almost irrelevant intrusion, making their appearance because and only because the world happens to contain appropriately sensitive organisms.

But, second, Locke also says that primary qualities are those which "the mind finds inseparable from every particle of matter"; and he later suggests that they constitute the "red essence" of matter. Now here his case seems to be founded not on scientific but on logical or conceptual considerations. He seems to say that possession of the primary qualities is, and possession of secondary qualities is not, essential to being "material" — that the concept of materiality includes the primary qualities but not the secondary. And this view, though baldly stated, seems to be right. It is clear enough that anything that we should regard as a material object must be individually distinguishable from other things (countable); must have some shape and dimensions; must be moving or at rest in space; and must be "solid" (in the sense at least of excluding other things from the volume of space occupied by itself). It is equally clear that a material thing is not logically required to make any sound, or to have any taste or smell. The case of colour is more controversial. For sight is in practice the most important of our senses, and it might be urged that any material object must be at least so far coloured as to be visible, accessible to the important sense of sight.

It appears, however, that visibility is actually less important than this would suggest; there is, for example, no conceptual difficulty in the idea of the Invisible Man. By contrast, an "intangible man" would be thought of not as a genuine though peculiar kind of man but rather as not a man at all—as a ghost, a vision or a hallucination.

Many other questions of intricacy and interest are suggested by Locke's distinction, though not raised by Locke himself—questions, for example, about the importance and limitations of measurement in our dealings with material things and about the relation between actual or conceivable metrical scales and the (usually) rough "qualitative" distinctions marked in everyday speech.

There is also a large family of questions which might be grouped under the heading "appearance and reality." It is, however, impossible to pursue these topics in the present context.

Qualities and Substance. — Something perhaps should be said here of the not wholly obsolete question, whether a material object can be identified with the sum of its qualities, or whether we must (as Locke held) "suppose always something besides" the qualities, in which they inhere or to which they belong — something to which he and others have given the name of substance (*q.v.*). The disagreement on this question appears to be a case of cross-purposes. On the one hand. an object clearly cannot be simply identified with a collection of qualities: for it is an elementary point of logic that qualities must be qualities of something — that there must indeed be something which they qualify. On the other hand, there is no need to reach Locke's conclusion that this is always a "something we know not what," for which "substance" is simply an arbitrary name. For that in which. say, the qualities of a table inhere is of course a table. a something we know quite well. Historically. the controversy on this issue seems to have arisen from a *prima facie* perverse but in fact not unpersuasive tendency to regard the ultimate possessor of qualities as an essentially characterless and hence unperceivable and indescribable stuff; while the justified opposition to this line of thought expressed itself by reaction in the mistaken form of a denial that anything but qualities need be admitted.

To escape from the dilemma it is necessary to see that. while qualities must certainly inhere in or belong to substances (or at any rate things which are not themselves qualities'). there is no need to suppose the existence of a single characterless stuff in which all qualities ultimately inhere. A thorough removal of the difficulty could probably be best secured by an examination of the related but contrasting roles of substantival and adjectival expressions, together with some investigation of such pedestrian expressions as "stuff." "matter" and "something."

Quality of Propositions. — A specialized use of "quality" has long been made by logicians in the Aristotelian tradition. Under this heading propositions are classified as either affirmative or negative. The term "quality" is employed in this way in contrast with a technical use of "quantity" — the three quantities of propositions being "universal," "particular" and "singular." Kant attempted to introduce, symmetrically with the three headings of quantity, a third quality which he called "infinity"; but this alleged further distinction was not well founded and did not find favour.

(G. J. WK.)

QUANTICS, the study of homogeneous algebraic functions of two or more variables which generally contain only positive integral powers of the variables. *See* ALGEBRAIC FORMS.

QUANTITY THEORY OF MONEY, a theory concerning the relationship between the amount or supply of money and the purchasing power or value of one unit of money. Since the value of one unit of money varies inversely nith prices of things for which it is exchanged, the quantity theory has to do with the relationship between the amount of money and the average price, or price level, of things other than money.

In its extreme variant, the quantity theory alleges that the price level changes because the amount of money changes, in the same direction and in the same proportion. This implies that the total amount of money remains constant in value however many units of money there may be.

The quantity theory of money is typically deduced from one form or another of quantity equation. The equations in commonest use have been $MV=PT$ and $\frac{N}{K}=P$. The former is the Fisherian equation. named in honour of Irving Fisher: the latter is the Cambridge equation developed principally by Alfred Marshall and A C Pigou at Cambridge university

M and N in these equations are the supply of money. commonly defined as the sum, expressed in a nation's monetary unit. of coin and paper currency and bank deposits subject to check. P in both equations is an average or index of prices for the marketable goods and services that are measured hv T and K Current usage is to include in T and K only the goods and services that comprise national product or national income. omitting the stock of existing wealth and all securities. PT and PK, then, are aggregate market values of goods and services currently produced and exchangeable for money.

V and K are related reciprocally, and express the desire of persons, firms and governments to have money rather than things included in T and K. The Fisherian equation is relevant to a period of time. and its V is the frequency during the period with which the average unit of money is spent. This frequency is low if money users wish to retain money for relatively long periods in relatively high proportion to income. high if they dispose of it quickly after receipt. MV is evidently spending of money during a period of time, as PT is the value of goods on which it is spent. The Cambridge equation is relevant to a moment of time. and its K is the real or physical amount of goods which money users do without in order to hold N money. If K is relatively high at each moment of time, the spending of money or V is low over a succession of moments.

The derivation statistically of either quantity equation is difficult. There is no unambiguous measurement of the real goods T or K or of the price levels at which they are traded for money. V is measurable only as the quotient of PT divided by M. Finally, there is disagreement as to whether the money supply should include not only coin, currency and checking deposits but also savings accounts and similar claims on banks and other institutions. For these and other reasons the quantity equation is not actively employed in empirical analysis of price levels and other economic variables.

The quantity theory of money, that price levels vary as a result of and in proportion to changes in the supply of money, specifies that T and V or K should be stable. Otherwise. the effect of, say. an increase in M in inflating P would be either suppressed or magnified by changes in the flow of goods or in the desire of money users to have money rather than goods and services that money buys.

The theory may be expressed more conservatively, that changes in the money supply tend to affect the price level proportionately, and that the tendency will work itself out if factors quite independent of money and the price level do not concurrently disturb T and V or K.

The quantity theory implies a process by which changes in the supply of money can influence prices. This process is an adjustment of the demand for money by money users to the supply of money. The demand for money may be visualized as $M'=\frac{PT}{V}$ demand M' depends positively on PT and negatively on V; that is. on the value of goods to be exchanged for money and on the frequency with which each unit of money is used in buying these goods. The supply of money M depends not on money users but on the ability and willingness of the monetary system to create money. There is equilibrium when $M'=M$. If equilibrium is disrupted by an increase in M, the excess supply of money is spent on goods and services. If the flow of goods and services is given, and if both old money and new circulate at the same V, commodity prices P must rise until M' is once more equated with M and the excess supply of money is dissipated by price inflation. In the process of adjusting demand to supply, prices have risen less than in proportion to the increment of money, but when the process is done and a new equilibrium established the price inflation is proportional.

The quantity theory that proportional changes in price levels adjust the demand for money to the supply has been an integral part of some formal systems of economic reasoning. These bodies of doctrine, not infrequently brought to bear on economic problems of the 20th century, presume to explain the behaviour of the entire economic system. They assume that V is stable, or very slow to change. reflecting persistent habits of money users in holding money balances and making money payments. They assume, further, that T is determined by such nonmonetary factors as the labour force, labour productivity and the relationship of wage rates to prices of output. The composition of T and the ratios of individual prices to each other reflect ,comparative costs of different goods and their comparative utilities to buyers. Everything that is real is determinable independently of money. hloney merely determines. via quantity-theory reasoning, rhe absolute level at which price relationships are established. In this view, money is a veil which in equilibrium may obscure but does not affect real determinants of economic welfare. Moreover. it should be the goal of monetary policy to keep money in this neutral role.

Neutral money. the argument continues. may be distorted by unsound policies on the part of treasury or monetary system. Monetary expansion will lead to both intermediate and ultimate consequences that are socially objectionable. The intermediate consequences are a fall in interest rates below "natural" levels that maintain stable full employment and stable prices. An excessive demand for goods and services ensues that will eventuate in cumulative and unlimited inflation of price levels if the excess supply of money is stubbornly replenished. If monetary expansion ceases, the high level of demand for goods and services collapses, and economic recession follows. The outcome of continuous inflation is maldistribution of income and wealth, perhaps a catastrophic paralysis of the economic and social structure. The outcome of abbreviated inflation is the business cycle, with its various wastes of scarce resources.

It is concluded that, in the transitional phases of inflation or of cyclical movement, the quantity theory of money does not apply precisely. In these phases. when the demand for money is adjusting to an altered supply, both V and T are subject to change. According to neutral-money doctrine, the quantity theory does explain differencesin price levels between states of general economic equilibrium. Since the quantity of money affects only price levels and not welfare in equilibrium, and since changes in the quantity of money reduce economic welfare in transitional phases, the optimal policy regarding money is to stabilize its quantity. Even in economic recession, "cheap" or "easy" money should not be adopted as one aspect of recovery policy.

The quantity theory has been brought to bear on other issues of policy. As developed by John Locke in the 17th century, David Hume in the 18th century, and others, it was used to attack the doctrines of mercantilism. If the accumulation of money by a nation merely raises prices. the mercantilist goal of export surpluses and imports of monetary metals for enhancement of national wealth must be illusory.

In the 19th century the quantity theory contributed to the gains of free-trade doctrine over protectionism. If the intermediate effect of import duties is to create an export surplus of goods and services, the ultimate effect is that the export surplus stimulates imports of gold. an expansion of the supply of money and a rise in domestic price levels that nullifies the trade restriction. The duties are eventually self-defeating.

In the 20th century the quantity theory played a part not only in analysis of inflation and business cycles but also in analysis of foreign-exchange rates and international commerce. The doctrine of purchasing-power parity, as developed primarily by Gustav Cassel, emphasizes that monetary expansion within a single country results in domestic price inflation. The inflation of prices. in turn, implies a decline not only in the internal purchasing power of the currency but also in the purchasing power of the inflated currency over money balances of other countries. The corrective for a depreciating exchange rate is stabilization of the supply of money and of the domestic level of prices.

From its primitive antecedents in the economic literature of Greece and Rome to its modern formulations, the quantity theory of money has been an important strand in the development of economic thought.

In the modern consensus, especially as a result of the influence of Lord Keynes, the tendency is to dispense with the Fisherian and Cambridge equations and to regard as a very special case the circumstances under which a proportional change in prices would follow a change in the supply of money.

It is widely agreed among economists that a change in prices may initiate disturbance, with subsequent adaptation of the supply of money: the causal sequence may be reversed. It is agreed. furthermore. that changes in V and T over both short periods and long may be expected typically to minimize or aggravate the impact of money on prices. The changes in V and T may be independent of developments in the realm of money or may alternatively be induced by monetary change. In any specific case, the effect of change in the money supply depends on the public's response in the spending of money and on the availability of goods to buy with money at alternative price levels.

The inflation of prices as the money supply expands, is probable when money users are expecting prices to rise. Then, reluctant to hold money as it depreciates, the public spends money balances more rapidly, increasing V. Inflation is probable, too. nhen the nation's capacity to produce goods and services is in intensive use. Then a rise in money and in money spending meets on the markets an inelastic supply of goods and services T. When either of these circumstances or both prevail in extreme degree an especially violent inflation may surpass the prediction of quantity theory and reduce even toward zero, rather than leave constant, the purchasing power of the total money supply. When opposite circumstances prevail. as in deep recession or depression. expansion of the money supply notoriously fails for at least limited periods to stimulate money spending at rising prices. In more commonplace circumstances productive growth and relatively stable price expectations provide a powerful antidote for the inflationary potential of increasing amounts of money.

There has been some disposition, on the basis that prices do not vary as quantity theory predicts, to minimize the effect of changes in the money supply on money spending and hence on either value of output PT or on prices alone. Correspcndingly monetary policy and techniques of managing the money supply have been reduced to a subsidiary role, at various times in different countries, in comparison with fiscal techniques for regulating money spending, the demand for goods and services and the levels of employment and prices.

See also BANKING; CURRENCY; INFLATION AND DEFLATION; MONEY; PRICE.

BIBLIOGRAPHY.—I. Fisher and H. G. Brown, *The Purchasing Power of Money*, new ed (1911); F. A. Lutz and L. M. Mints (eds.), *Readings in Monetary Theory*, American Economic Association (1951, 1952); Arthur W. Marget, *Theory of Prices*, 2 vol (1938–42).

(E. S. S.)

QUANTUM MECHANICS. Following are the main sections and divisions of this article:

I. INTRODUCTION

Throughout the 19th century most physicists regarded Newton's dynamical laws as sacrosanct. During the 20th century, however, it became increasingly clear that many phenomena, especially those connected with radiation, defy explanation on Newtonian principles. It is well recognized that two major innovations are essential. One of these is the introduction of the principle of relativity. The relativistic corrections are important only for bodies moving with velocities comparable with that of light, and as a result experimental confirmation is possible only in very special types of laboratory experiments or in the cosmological field. The other innovation is quantum mechanics. Although rather less publicized than relativity, the quantum concepts have equally drastic philosophical implications and furnish richer and more diversified fields for investigation in the laboratory.

Quantum mechanics is the mechanics governing phenomena which are so small-scaled that they cannot be described in classical terms. Thus quantum rather than Newtonian dynamics must be used in dealing with the motions of electrons or nuclei inside atoms and molecules. In the equations of quantum mechanics, Max Planck's element of action, $h = 6.625 \times 10^{-27}$ erg sec., plays a central role. This constant, which is one of the most important in all of physics, has the dimensions

$$\text{mass} \times \text{length}^2/\text{time}.$$

The term "small-scale" used to delineate the domain of quantum mechanics should not be literally interpreted as relating necessarily to extent in space. A more precise criterion as to whether quantum modifications of the Newtonian laws are of importance is whether or not the phenomenon in question is characterized by an "action" (time integral of the kinetic energy) which is large compared to Planck's constant. Thus, if a great many quanta are involved, the Planck idea that there is a discrete, indivisible quantum unit loses importance, just as to a millionaire it would make little difference whether the smallest unit of currency is the cent or the dollar. This fact explains why our ordinary physical processes appear to be so fully in accord with the laws of Newton. Planck's element of action is, for example, far too fine-grained to have any bearing on the driving of an automobile. Since ultimately all matter is built out of atomic or small-scale ingredients, it must be possible to describe the properties of even large-scale bodies by means of quantum mechanics. In other words, Newtonian dynamics must represent a special case of quantum dynamics appropriate to cases where the action is very large compared to the elementary quantum. This is indeed true; it should be emphasized, however, that quantum mechanics is really an extension of classical statistical mechanics rather than of the deterministic laws of Newton. As a result, one of the most important philosophical implications of quantum mechanics concerns the apparent breakdown of the causality principle in atomic phenomena. (See UNCERTAINTY PRINCIPLE, THE.)

The history of quantum mechanics may be divided into three main periods. The first of these began with Planck's theory of black-body radiation in 1900, and may be described as the period in which the reality of Planck's constant of action was demonstrated, but its real meaning was rather obscure. The second period began with the Bohr quantum theory of spectra in 1913. Niels Bohr's ideas gave the correct formula for the frequency of spectral lines in many cases, and were an enormous help in the codification and understanding of spectra. Still they did not represent a consistent, unified theory, as he himself recognized, but rather a sort of patchwork affair in which classical mechanics was subjected to a rather extraneous set of so-called "quantum conditions," which restrict the constants of integration to certain particular values. The true quantum mechanics appeared in 1926, reaching fruition almost simultaneously in a variety of forms, *viz.*, the matrix theory of Max Born and Werner Heisenberg, the wave mechanics of Louis V. de Broglie and Erwin Schrodinger, and the transformation theory of Paul A. M. Dirac and Pascual Jordan. These different formulations are in no sense alternative theories, but rather they are different aspects of a consistent body of law.

Near mid-20th century the status of quantum mechanics was aptly described as follows (from Dirac in *Proceedings of the Royal Society, A*, vol. cxxiii): "The general theory of quantum mechanics is now almost complete, the imperfections that still remain being in connection with the exact fitting in of the theory with relativity ideas. These give rise to difficulties only when high-speed particles are involved, and are therefore of no importance in the consideration of atomic and molecular structure, and ordinary chemical reactions. . . . The underlying laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known, and the difficulty is only that the exact solution of these laws leads to equations much too complicated to be soluble." It should be added perhaps that quantum mechanics makes no pretense of describing completely what goes on inside the nucleus. In other words, the details of the short-range dynamics of the neutrons, protons, etc., of which the nucleus is composed are not known, although quantum mechanics has been a help in understanding many nuclear phenomena. such as the emission of alpha particles and photodisintegration, and although the rather intricate field theory of quantum mechanics has provided some insight into the properties of mesons, particles of transient life which are of interest mainly in connection with nuclear phenomena. In short, by the second half of the 20th century the theory of nuclear physics was in a more or less embryonic stage comparable, say, with extranuclear quantum theory in its early days.

Thus, quantum mechanics gave us the appropriate laws of nature down to distances of the order 10^{-10} cm., but we still do not know the rules in detail when we seek to probe below nuclear radii of the order 10^{-12} cm.

II. QUANTUM THEORY PRIOR TO THE BOHR ATOM

First will be described the earlier investigations in quantum theory which anteceded the discovery of the true quantum mechanics in *1926*. This procedure is not merely an attempt to preserve historical order, but is also advisable because some of the primitive theories describe some subjects fairly well and help in the visualization of the later. more recondite developments.

1. Black-Body Radiation. — The quantum of action had its birth in the studies of black-body radiation in *1900* by Planck, professor of physics at the University of Berlin. All black (*i.e.,* perfectly absorbing) bodies heated to a given temperature should emit radiation having the same spectrum. The latter can be shown to be identical with the spectral distribution of energy in a so-called *Hohlraum; i.e* , a cavity whose radiation is in thermal equilibrium with matter. *(See* BLACK BODY.) According to classical physics, the density of radiant energy should be proportional to the square of the frequency, and so increase without limit as the wave length is made progressively shorter. This prediction is sometimes called the "ultraviolet catastrophe," and the corresponding analytical formula for the energy density is called the Rayleigh-Jeans law. It yields the dashed curve of fig. 1. The observed distribution is that indicated by the solid curve, which Planck was able to deduce theoretically by making a quantum hypothesis.

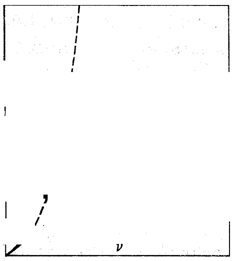


FIG 1.—THE ENERGY DENSITY (ρ_ν) OF BLACK-BODY RADIATION AS A FUNCTION OF FREQUENCY (ν). CLASSICAL AND QUANTUM THEORIES GIVE RESPECTIVELY THE DASHED AND CURVES

We shall now indicate how the Rayleigh-Jeans and Planck radiation laws can be derived and shall formulate them mathematically. The method which we sketch is a well-known but rather formal one. It may be characterized as the application of classical equipartition *(see* KINETIC THEORY OF MATTER) or of classical statistics to the degrees of freedom of the ether. It is not presumed that a material ether really exists; this term is used merely to indicate that the standing electromagnetic naves in an enclosure are handled by the same type of statistical procedure as those of a material medium. The first step is the enumeration of the different types of standing waves or modes of vibration of the ether in a rectangular parallelopiped of volume V. Just as a rope with fixed ends can vibrate only in certain ways, represented by the fundamental and the various harmonics, so also in the three-dimensional case only certain modes of oscillation are compatible with the boundary conditions. If the edges of the parallelopiped are large compared to the wave length, the number of possible vibrations in the frequency interval ν, $\nu + d\nu$ can be shown to be

$$(8\pi\nu^2 V/c^3).d\nu, \tag{1}$$

where c is the velocity of light. Let the mean energy of an oscillation of frequency ν be denoted by ϵ_ν. Then the density of radiant energy in the irequency range $\nu, \nu + d\nu$ is $\rho_\nu d\nu$ with

$$\rho_\nu = \epsilon_\nu \cdot (8\pi\nu^2/c^3). \tag{2}$$

It is now necessary to evaluate ϵ_ν. This is done by treating each characteristic mode of vibration as a harmonic oscillator. According to classical statistical mechanics,

$$\epsilon_\nu = KT, \tag{3}$$

where k is Boltzmann's constant 1.38×10^{-16} erg/degree. Equation (3) is a direct consequence of the classical theory of equipartition. The latter demands that the mean kinetic energy per degree of freedom be $\frac{1}{2}kT$, and a harmonic oscillator has equal mean kinetic and potential energies, so that the total energy is kT. Substitution of (3) in *(2)* yields the Rayleigh-Jeans law

$$\rho_\nu = 8\pi\nu^2 kT/c^3. \tag{4}$$

The fact that ρ_ν increases without limit when ν is made arbitrarily large is the ultraviolet catastrophe mentioned above.

In quantum theory, however, the mean energy of a harmonic oscillator is taken to be

$$\epsilon_\nu = \frac{h\nu}{e^{h\nu/kT} - 1}. \tag{5}$$

This formula is obtained by assuming that the energy of a harmonic oscillator is restricted to the "quantized" values $0, h\nu, 2h\nu, 3h\nu, \ldots$. The mean energy is calculated by weighting these values in accordance with the usual Boltzmann factor, so that

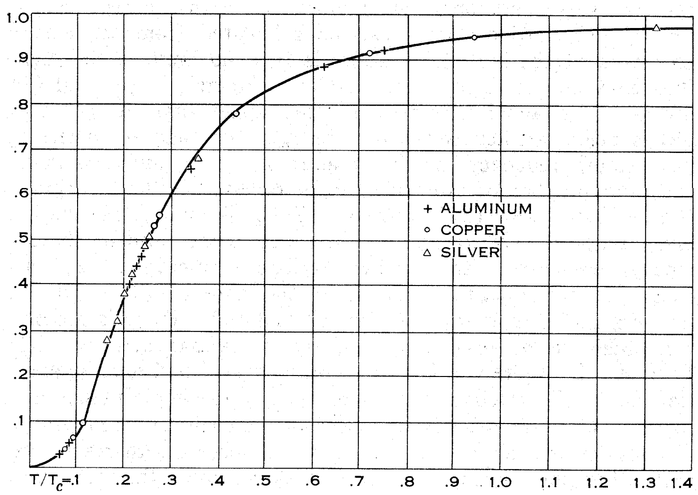
$$\epsilon_\nu = \frac{h\nu e^{-h\nu/kT} + 2h\nu e^{-2h\nu/kT} + \cdots}{1 + e^{-h\nu/kT} + e^{-2h\nu/kT} + \cdots}. \tag{6}$$

The series in the numerator and denominator of (6) are readily summed, and the result is (5). Substitution of (5) in (2) gives

$$\rho_\nu = \frac{8\pi h\nu^3}{c^3} \cdot \frac{1}{e^{h\nu/kT} - 1}. \tag{7}$$

This is the celebrated Planck radiation formula. This represents essentially one approach used by Planck. He also had other ways of obtaining his formula, but most of these have been discarded. The best present derivation of the Planck radiation formula is probably one due to Albert Einstein in 1916, which is based on so-called detailed balancing for a system of matter and radiation.

2. Specific Heats. — Another early success of quantum theory was in the field of specific heats, where it explained the deviations from the law of P. L. Dulong and A. T. Petit. This law states that the specific heat per gram atom is very nearly the same, about six calories, for many solid elements. Honever, there are many exceptions. Also. if the temperature is lowered sufficiently, the specific heat approaches zero, instead of remaining constant, as predicted by the law. The behaviour of three metals, for instance, is shown in fig. *2.* The law of Dulong and Petit is a direct consequence of the classical theory of equipartition, provided the latter is applied to the atom as a whole and no attempt is made arbitrarily to apply classical statistics to the motion of the electrons inside the atom. The specific heat is then independent of temperature, and so in fig. *2* would be represented by a horizontal straight line of unit height in the scale employed there. Debye's quantum model, on the other hand, yields the solid curve, which is in good agreement with experiment. This curve approaches unity if the temperature is raised sufficiently. More generally, all classical and quantum theories of specific heats



ADAPTED FROM T PRESTON THEORY OF HEAT (MACMILLAN)

FIG 2 —SPECIFIC HEAT OF A MONATOMIC SOLID AS A FUNCTION OF TEMPERATURE THE CURVE IS CALCULATED FROM DEBYE'S QUANTUM THEORY. THE SCALE OF ORDINATES IS SO CHOSEN THAT CLASSICAL THEORY GIVES UNITY

agree asymptotically at high temperatures. On the other hand. the vanishing of the specific heat at the absolute zero is a characteristic quantum phenomenon.

In the mathematical analysis the difference between the classical and quantum theories of the specific heats of solids parallels closely that between the proofs of the Rayleigh-Jeans and Planck laws for radiation. Instead of considering the electromagnetic vibrations of the ether, it is necessary to deal with the vibrations of the atoms composing the solid with respect to each other. If the forces binding the atoms to their equilibrium positions obey Hooke's law, the vibrations are simple harmonic. The dynamical system represented by the aggregate of atoms constituting the solid obviously is exceedingly complicated, but, in principle, modes of vibration can be sorted out according to frequency. Let there be $n_\nu d\nu$ such modes in the interval ν, $\nu + d\nu$. Let the mean energy of a harmonic vibration be denoted by ϵ_ν, which, as before, has the value (3) or (5) depending on whether classical or quantum theory is used. The total energy is obtained by integrating over all frequencies, and the specific heat c_V is the temperature derivative of the energy. Hence

$$c_V = \frac{d}{dT}\left[\int_0^\infty n_\nu \epsilon_\nu d\nu\right]. \tag{8}$$

The determination of the factor n_ν specifying the distribution of vibration frequencies represents an exceedingly difficult problem, as n_ν is no longer given by the simple expression (1) which applied in the radiative case. However, if the classical result $\epsilon_\nu = kT$ is employed, it is not necessary to determine n_ν, as kT is merely a constant factor, which can be taken outside the integration. The integral can then be immediately evaluated from the relation

$$\int_0^\infty n_\nu d\nu = 3N, \tag{9}$$

which states that the total number of independent modes of oscillation, or in other words the total number of degrees of freedom, must be three times the total number of atoms N. Hence, according to classical equipartition,

$$c_V = 3Nk. \tag{10}$$

This is essentially the law of Dulong and Petit. If we take an amount of material equal to a gram atom, so that N becomes the Avogadro number, and if we express the specific heat in calories rather than in ergs, then (10) gives a specific heat of 5.96 cal. per degree.

In quantum theory, on the other hand, it is necessary to evaluate n_ν. Peter J. W. Debye assumed a distribution law for n_ν analogous to that (1) for the radiative case, but with allowance for transverse and longitudinal vibrations with different velocities of propagation, which can be calculated from the elastic constants of the material. There is then no limit to the high-frequency end of the spectrum, and the integrals in (8) and (9) diverge. To avoid this difficulty the upper limit in (8) and (9) is rather artificially taken to be ν_c rather than ∞, where ν_c is a "cutoff frequency" so chosen as to satify (9) and thus make the total number of vibrations equal to $3N$. With this model, Debye found $c_V = f(T/T_c)$, where $f(T/T_c)$ is a universal function of a "reduced temperature" T/T_c, which is the ratio of the ordinary temperature to a "characteristic temperature" T_c calculable from the elastic properties of the material. This reduced temperature is used for the abscissa in fig. 2. Debye's method for obtaining n_ν originally appeared somewhat artificial, but Born and Theodore von Kármán showed that it had some dynamical basis. The Debye model applies only to simple monatomic solids. When the solid is composed of molecules, it is necessary to consider the vibrations not only of molecules with respect to each other but also the vibrations of atoms inside the molecules. As emphasized by Einstein, the latter effect gives sharp maxima of n_ν at certain frequencies. Improved methods of calculating n_ν have been developed, and the theory correspondingly refined. So far only solids have been referred to. There is also considerable literature on the specific heats of gases. Here again, quantum theory explains deviations from the classical theory of equipartition, especially at low temperatures, which are particularly pronounced for hydrogen.

3. Photoelectricity.—Nowhere, perhaps, is the inadequacy of classical theory revealed more strikingly than in the subject of photoelectricity, which is concerned with emission of electrons by an illuminated body. (See PHOTOELECTRICITY.) Photoelectric phenomena exhibit two main features: (1) no emission occurs at all unless the frequency ν of the incident radiation exceeds a certain critical value, called the threshold frequency; and (2) the kinetic energy of the ejected electrons depends on the frequency of this radiation, and not on its intensity. In other words, if a light source is removed farther and farther from the body which it illuminates, the emitted electrons are undiminished in their velocity of escape, but are decreased in number. Such a state of affairs was a complete conundrum at the turn of the century, since in classical electromagnetic theory, diminished incident intensity implies a lowering of the energy traversing the absorbing "target area," and as a result of the lower energy flow, the velocity imparted to the electron should be decreased, contrary to experiment. In 1905 Einstein showed that the observed behaviour could be explained if in the emission of the electron a quantum of energy $h\nu$ is picked up by matter from the radiation, regardless of the latter's intensity. The process merely becomes less likely when the intensity is low. Just how such a corpuscular model was to be reconciled with the undulatory features of light, such as interference, was something not understood for two decades or so, but was finally clarified by the Heisenberg uncertainty principle and by Bohr's theory of complementarity. From the less sophisticated outlook of 1905, Einstein showed that if the conflict with the wave viewpoint was ignored, his picture did indeed account for the salient factors of photoelectricity. The kinetic energy of escape of the electron will not in general be the same as the quantum $h\nu$ absorbed from the radiation inasmuch as part of the energy is consumed in liberating the electron from the metal. This portion is called the thermionic work function, and will be denoted by the letter ϕ. Einstein's equation for determining the velocity of escape v of an electron is thus

$$\tfrac{1}{2}mv^2 = h\nu - \phi. \tag{11}$$

Since the kinetic energy $\frac{1}{2}mv^2$ is necessarily positive, emission is possible only if $\nu > \phi/h$. Hence ϕ/h is the threshold frequency.

Closely related to the photaelectric effect is the Compton effect (*q.v.*), which also reveals the need of the quantum hypothesis.

III. BOHR ATOM

A signal advance in quantum theory was achieved when the Danish physicist Niels Bohr propounded his theory of the spectrum of hydrogen, in 1913. By that time there was no doubt as to the validity of the Rutherford picture of the atom as a miniature solar system, with the nucleus and electrons playing respectively the role of the sun and the planets. (See ATOM.) The number of electrons in the neutral atom is the same as the chemists' atomic number, one for hydrogen, two for helium, etc. Therefore, the dynamics of the orbits of the electrons in the various atoms will be very complex except in the hydrogenic case, for the mathematical difficulties associated with even a three-body problem (*e.g.,* neutral helium, with one nucleus and two valence electrons) are enormous. By a hydrogenic atom is not necessarily meant a hydrogen atom, but any other atom which has been stripped of all but one valence electron as a result of ionization. Examples are singly ionized helium, doubly ionized lithium, etc. Clearly, the study of the spectrum of hydrogen, because of its comparative simplicity, should be the most likely starting point of any attempt to decipher the complexities of atomic spectra.

1. Balmer Formula.—It has long been known that there are some remarkable regularities in the spectrum of hydrogen. As early as 1885, J. J. Balmer showed that the wave lengths λ of many lines are well represented by the empirical formula

$$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n'^2} - \frac{1}{n''^2}\right], \tag{12}$$

in which n', n'' are integers, and R is a constant, the so-called Rydberg constant. If, for instance, one takes $n' = 2$ and $n'' = n' + 1, n' + 2, \ldots$, the expression (12) gives the wave lengths of the lines in what is called the Balmer series. The choices $n' = 1$, 3, 4 and 5 yield respectively the Lyman, Paschen, Brackett and Pfund series, which were discovered later. Since the atomic number Z is unity for hydrogen, the factor Z^2 in *(12)* is unnecessary for present purposes, but is included to permit later extension to atoms of higher nuclear charge.

2. Postulates of the Bohr Theory.—For many years, the *raison d'être* for the formula (12) was completely obscure. It is not surprising that the subject of line spectra was a closed book to the classical physicist. As some one has said, the task of constructing a model of the atom merely from knowledge of its spectra radiated under violent electrical or thermal excitation is comparable with trying to learn about a piano merely from the noise emitted when it is dropped downstairs. Bohr, however, showed that the behaviour *(12)* could be explained by means of two postulates, as follows:

1. The existence of stationary states: In every atom there is a discrete succession of states, in any one of which the electrons can move without appreciable radiation, and which can be identified by a set of integers, usually called quantum numbers. The designation of these states as stationary refers to the absence of radiation from the orbits, in contravention of classical electrodynamics, and does not imply a static atom. Except for omission of the radiation corrections, the motion of the electrons in the stationary states is assumed to conform to the laws of classical mechanics.

2. The Bohr frequency condition: It is assumed that an electron can sometimes pass discontinuously from one allowed orbit to another. In such a transition, the initial and final states will have different amounts of mechanical energy E'' and E'. To secure conservation of energy, the change in the mechanical energy must be counterbalanced by the absorption or emission of a light quantum, whose energy is $h\nu$ if the frequency is ν. This requirement yields the so-called Bohr frequency condition

$$h\nu = E'' - E'. \tag{13}$$

The analogy to Einstein's photoelectric equation *(11)* is obvious.

In connection with the first postulate it is necessary to formulate the quantum conditions which restrict the energies of the atoms to certain particular values. The easiest case to handle is that of a simply periodic system, where the orbit repeats itself after a given interval of time τ. Here the quantization is effected by the relation

$$\overline{T} = \tfrac{1}{2}nh\nu_0, \tag{14}$$

in which n is an integer, $\overline{T}$ is the mean kinetic energy of the system (*i.e.,* the average of the kinetic energy T over a period) and $\nu_0 = 1/\tau$ is the frequency with which the orbit repeats itself. It is to be emphasized that the orbital frequency ν_0 is in general not the same as that ν given by the Bohr frequency condition (13). This nonidentity of the orbital and radiated frequencies is a celebrated paradox of the Bohr atom, as according to classical mechanics or actual observations on large-scale phenomena there is no distinction between the frequencies of motion of a system and those of the waves which it radiates. It should be mentioned, however, that in the Bohr theory there is an asymptotic agreement of the two frequencies for large quantum numbers, which is usually termed the "correspondence principle for frequencies."

3. Derivation of the Balmer Formula From the Bohr Theory.— It will now be shown that the Balmer expression *(12)* is a consequence of the quantum condition *(14)* and the Bohr frequency condition. This derivation is such a simple and classic one that it seems worth giving, even though in a sense it is outmoded by later but more intricate calculations by means of wave mechanics, which also yield the result *(12)* with identically the same value of the Rydberg constant R as that obtained from the Bohr theory.

To simplify the calculations, it will be assumed that the orbit is circular but it can be shown that the energy levels are no different in the general case of ellipses. Let the mass of the nucleus and electron be denoted by M and m respectively, and let the nuclear and electronic charges be Ze and $-e$. Here e has the value 4.80×10^{-10} in electrostatic units. and Z is the atomic number. The centre of gravity, which may be supposed stationary, divides the line connecting the two particles in the inverse ratio of their masses. Hence. the electron and nucleus revolve around this centre in circles of radii $Ma/(m + M)$ and $ma/(m + M)$ respectively. where a is the distance from the nucleus to the electron. Since the angular velocity is $2\pi\nu_0$, the kinetic energy is

$$T = \tfrac{1}{2}\left[m\left(\frac{M}{m+M}\right)^2 + M\left(\frac{m}{m+M}\right)^2\right](2\pi\nu_0)^2a^2. \tag{15}$$

This equation can also be written as

$$T = \tfrac{1}{2}\mu(2\pi\nu_0)^2a^2, \tag{16}$$

where μ is the so-called reduced mass, given by

$$\mu = mM/(m + M). \tag{17}$$

As T is constant in time, there is no distinction between T and $\overline{T}$. Thus application of the quantum condition (14) gives

$$(2\pi\nu_0)\mu a^2 = nh/2\pi. \tag{18}$$

In other words, the angular momentum of the system is an integral multiple of $h/2\pi$ The equality between the centriiugal force on the electron and the Coulomb attraction due to the nucleus yields a further relation

$$\mu a(2\pi\nu_0)^2 = Ze^2/a^2. \tag{19}$$

When equations (18) and (19) are solved for a and ν_0, the result is

$$a = n^2h^2/4\pi^2Ze^2\mu, \qquad \nu_0 = 4\pi^2\mu Z^2e^4/n^3h^3. \tag{20}$$

The first relation of (20) shows that the allowed or "quantized" values of the radius of the atom form a progression of the form $a_0, 4a_0, 9a_0, \ldots$, where a_0 is a fundamental unit $h^2/4\pi^2\mu Ze^2$ called the Bohr radius, and having the numerical value 0.53×10^{-8} cm. if $Z = 1$ (hydrogen). Substitution of (20) in (16) gives

$$T = 2\pi^2\mu Z^2e^4/n^2h^2,$$

while the potential energy is

$$V = -Ze^2/a = -4\pi^2\mu Z^2e^4/n^2h^2.$$

Hence the total energy $E = T + V$ is

$$E = -2\pi^2\mu Z^2e^4/n^2h^2. \tag{21}$$

When we substitute this value of E in the Bohr frequency condition (13) and remember that $\lambda = c/\nu$, we have indeed the Balmerformula (12), provided the Rydberg constant R has the value

$$R = 2\pi^2\mu e^4/ch^3. \tag{22}$$

The question immediately arises whether (22) yields a value of R in agreement with the optical measurements, when the numerical values of the constants e, h, μ, c are substituted. The answer is that there is certainly agreement within the precision with which these constants are known, for e, h, μ are known only to one part in a thousand or so. On the other hand, since optical wave lengths are known so very accurately. the Rydberg constant R can be determined to within less than *1* part in *1,000,000*. *A* valuable cross-check on the values of the various atomic constants is thus provided. namely. use of *(22)* along with the spectroscopic determination of R permits determination of one of the four quantities e, **h**, μ, **c** if the other three are known. It is thus possible to increase the accuracy with which the value of the particular one of the four constants is known (viz., h) which otherwise cannot be as precisely determined as the other three.

4. Correction for the Motion of the Nucleus, and Spectroscopic Determination of e/m.—If we neglect the motion of the nucleus. or in other words consider the mass M of the nucleus to be infinite, then equation (17) shows that the reduced mass becomes identical with the mass m of the electron. When allowance is made for the finite mass of the nucleus, μ will differ slightly from m. The neutral hydrogen atom and ionized helium atom resemble each other in having only one electron, so that formula (22) should be applicable to either. However, the different masses of the hydrogen and helium nuclei will make the Rydberg constant slightly different for the two. Just this state of affairs is found experimentally: the best spectroscopic value of the Rydberg constant for hydrogen is $R_H = 109677.58$ cm.$^{-1}$, while that for helium is $R_{He} = 109722.27$ cm.$^{-1}$ (Du Mond and Cohen's figures). The corresponding value for a hydrogenic atom of infinite nuclear mass in $R_{H\infty} = 109737.31$ cm.$^{-1}$.

Equation (22) shows that the ratio of the Rydberg constants for hydrogen and ionized helium is equal to the ratio of the reduced masses, the other constants canceling out. When (17) is used,

$$\frac{R_{He}}{R_H} = \frac{1 + m/M_H}{1 + m/xM_H}, \tag{23}$$

where x is the ratio M_{He}/M_H of the mass of the helium nucleus to that of hydrogen. This ratio can be regarded as known from determinations of atomic weights, since practically all of the atom's mass arises from the nucleus. Hence, by means of (23) and the spectroscopic determinations of R_H, R_{He}, it is possible to evaluate the ratio m/M_H of electronic to protonic mass. Furthermore, it is possible to go a step farther and determine e/m spectroscopically, inasmuch as one has $e/m = (e/M_H)(M_H/m)$ and as the value of e/M_H is known from electrolysis; *i.e.*, from the so-called electrochemical equivalent. In this nay, the shift between the Rydberg constants for hydrogen and ionized helium furnishes perhaps the most accurate means of determining elm In the early 1930s there appeared to be a discrepancy between the values of e/m determined spectroscopically and by more direct deflection methods. This difficulty has disappeared, and the generally accepted value of elm is 1.759×10^7 e.m.u.

During the first years of Bohr's theory, the only known hydrogenic atoms (i e., those with one valence electron) were H and He+. Subsequently. X-ray measurements at Uppsala, Fin., revealed lines due to Li^{2+}, Be^{3+}, B^{4+} and C^{5+}. These lines are particularly useful because they furnish wave-length standards in the X-ray region. Another subsequent development was the discovery of the hydrogen isotope deuterium, nhich has about double the value of M for ordinary hydrogen and hence a slightly different Rydberg constant. This difference, in fact, historically furnished the first means of demonstrating the existence of deuterium with certainty.

5. Relativity Fine Structure. — A great triumph of the Bohr atom was the theory of the relativity fine structure in hydrogen, which was developed by Arnold Sommerfeld in 1916. In the preceding discussion. the problem was treated by means of Newtonian mechanics. When the relativity corrections are introduced, the orbits cease to be periodic, and the quantization becomes more complicated. It is necessary to introduce two quantum conditions, mathematical details of which will be omitted here except for mentioning that they restrict the values of certain so-called "phase integrals" to integral multiples of Planck's constant. If the nuclear mass is treated as infinite, the formula for the energy can be shown to be

$$E = mc^2\left\{\left[1 + \left(\frac{\alpha Z}{n - k + g}\right)^2\right]^{-\frac{1}{2}} - 1\right\}, \tag{24}$$

where

$$\alpha = 2\pi e^2/hc, \qquad g = (k^2 - Z^2\alpha^2)^{\frac{1}{2}}. \tag{25}$$

If (24) be expanded as a power series in α^2, and terms beyond α^4 are disregarded, the expression for E takes the form

$$E = -\frac{2\pi^2 mZ^2e^4}{n^2h^2}\left[1 + \frac{\alpha^2Z^2}{n^2}\left(\frac{n}{k} - \frac{3}{4}\right) + \cdots\right]. \tag{26}$$

Since $m = \mu$ if $M = \infty$, the first term of (26) is the same as the Newtonian result (21). and involves only the principal quanturn number n. The remainder of (26) is due to the relativity corrections, and involves a second quantum number k, which is the so-called azimuthal quantum number. Its physical significance is that the angular momentum is $kh/2\pi$, and the range of values for k is $1, 2, \cdots n$. The dependence of the energy on k is only a minor effect because of the smallness of α $(= 1/137.0)$, but it causes lines which would otherwise coincide to be slightly separated so as to form the components of a multiplet. A decomposition is indeed found experimentally, and on the whole the observed spacing of the components agrees nell with theory.

6. Stark Effect. — Still another quantitative success of the Bohr theory of the hydrogen spectrum is provided by the Stark effect, or splitting of the energy levels and hence of the spectral lines by means of an electric field. The separation and number of the components accords with theory in a remarkable fashion. The formulas for the displacement in frequency involve Planck's constant h, and so classical theory was powerless to explain any of the features of the Stark effect. On the other hand, in the alternative phenomenon of the Zeeman effect (separation of lines in a magnetic field), Planck's h cancels out of the final formula for the shift in frequency, and so classical and quantum theories give identical results for the normal Zeeman effect (*q.v.*).

7. Moseley's Relation. — In attempting to apply the Bohr concepts to nonhydrogenic atoms, the mathematical complexities are so great that the permitted energy levels or frequencies cannot be exactly determined. Nevertheless, certain successes of the theory should be stressed. One of these is the explanation of Moseley's relation in X-ray spectra. wherein the frequencies of the K lines—*i.e.*, the hardest lines (lines of shortest wave length or highest frequency) — are proportional approximately to the square of the atomic number. This is simply an expression of the factor Z^2 in (21). The result (21) applies approximately to an interior electron of a nonhydrogenic atom if the screening of the nucleus by the other electrons is so poor that the field is substantially that of the bare nucleus. This approximation will be a good one only for electrons which are deep-seated in the atom, such as are responsible for the emission of X-rays.

8. Relation Between Critical Potentials and Spectral Frequencies. — By electron bombardment it is possible to "excite" an atom from one stationary state, say of energy E', to another of higher energy E''. To be able to do this, the impinging electron must have at least a kinetic energy equal to $E'' - E'$, as otherwise conservation of energy cannot be secured. The energy which an electron acquires in falling through a difference of potential V is Ve. Hence, the minimum or "critical" accelerating potential required for the excitation is given by $Ve = E'' - E'$. Alternatively, the Bohr frequency condition states that $h\nu = E'' - E'$. Thus, $Ve = h\nu$, and this relation holds as a useful consequence of the theory, even though the mechanics of the many-body problem is so intricate that it is not possible to calculate theoretically the energy levels E', E''.

9. Stern-Gerlach Effect. — The application of the quantum conditions to an atom in a magnetic field shows that its component of angular momentum in the direction of the field should be "quantized" and equal to an integral multiple of $h/2\pi$. The corresponding magnetic moment, which is proportional to the angular momentum, should hence likewise acquire only discrete values. Otto Stern and Walther Gerlach verified this prediction by observing the deflections of atoms in an inhomogeneous magnetic field. We cannot overemphasize how beautifully the existence of only certain particular deflections in their experiments demonstrates the reality of the quantized positions which are the essence of quantum theory. It is true that the explanation of the precise quantitative values of the deflections found by Stern and Gerlach requires inclusion of electron spin and the refinements of quantum mechanics in certain cases. However, the broad outlines of the phenomenon were clear even in the days of the Bohr theory, especially the complete contradiction between the classical continuous distribution of orientations and quantum discreteness. The Stern-Gerlach experiment decided unequivocably in favour of the latter.

10. Harmonic Oscillator and Rotator — Molecular Spectra. — There are two very simple schematic models which are particularly easy to quantize and which are rich in physical applications. They are the harmonic oscillator and the rigid rotator or "rotating dumbbell."

For a particle which is harmonically bound (*i.e.,* subject to a linear restoring force) the mean kinetic energy is equal to the mean potential energy. Hence the total energy, which is the sum of the kinetic and potential, is equal to twice the mean kinetic energy. Furthermore, the frequency ν_0 of a harmonic oscillator is independent of the initial conditions. Therefore, application of (14) immediately yields the result

$$E = nh\nu_0. \tag{27}$$

The quantized values of the energy of a harmonic system given in (27) are the same as those used above in discussing black-body radiation and specific heats.

For a rigid rotator, there is no potential energy, and the kinetic energy has the constant value $\frac{1}{2}I(2\pi\nu_0)^2$, where I is the moment of inertia, and ν_0 is the rotation frequency. The quantum condition (14) yields $2\pi\nu_0 I = nh/2\pi$. The quantization thus consists in equating the angular momentum to an integral multiple of $h/2\pi$. The corresponding quantized value of the energy is, since E = T,

$$E = n^2h^2/8\pi^2I. \tag{28}$$

These formulas have a direct application to the spectrum of a diatomic molecule such as HCl. As a first approximation, the energy of the molecule can be divided into contributions from (1) the electronic motion relative to the two nuclei regarded as fixed attracting centres, (2) the vibration of the two nuclei along the line connecting them, and (3) "end-over-end" rotation of the molecule as a whole. Effects (2) and (3) are respectively portrayed by the harmonic oscillator and the rotator. The quantum numbers associated with (2) and (3) are not, of course, the same, and so the letters v, J are used for them instead of n. The total energy of the molecule is thus

$$E = E_e + vh\nu_0 + J^2h^2/8\pi^2I. \tag{29}$$

The electronic term E_e will be a function of numerous quantum numbers other than v, J, but is too difficult to compute explicitly because of the complexities of the many-body problem. The dependence on the rotational and vibrational quantum numbers a, J predicted by (29) agrees nicely with experiment.

11. Intensities and Transition Probabilities in the Bohr Theory.— The theory so far presented is one-sided, as it tells how to calculate the frequency but nothing about the intensity. In order to have information about the latter, it is necessary to know the transition probability. It is a fundamental concept of the Bohr theory that radiation takes place sporadically and discontinuously, when an electron passes from one stationary state to another, rather than continuously as in classical theory. The transitions between states are governed by the statistics of random processes. like radioactive decay. Thus, if an electron is initially in a state l, there is a certain probability $A_{l\rightarrow m}$ that it will pass to another state m. Let us denote by $\nu(lm)$ the frequency associated with this transition, which by (13) is the same as $(E_l - E_m)/h$. Since an amount of energy $h\nu(lm)$ is radiated in each transition, the total rate at which energy is radiated in the frequency $\nu(lm)$ is

$$I_{l\rightarrow m} = h\nu(lm)A_{l\rightarrow m}N_l, \tag{30}$$

where N_l is the number of atoms in the state l.

Part of the contribution to $A_{l\rightarrow m}$ in the case of emission, and all in the case of absorption, will come from transitions induced by a radiation field. Even in the absence of the latter, however, there is a certain probability of "spontaneous radiation," provided the energy E_m of the final state is less than that E_l of the initial one. For simplicity, only the spontaneous effect will be considered.

The problem is now to calculate the transition probability in the absence of a radiation field. Here the Bohr theory gave no clear-cut answer. The best that could be done was to make an approximate estimate by means of the so-called correspondence principle, which has been described as a "magic wand which enables one to borrow the results of classical theory for quantum theory." According to classical electrodynamics, an electron moving in a periodic orbit described by Fourier series such as

$$x = \sum_{\tau=-\infty}^{\infty} x_\tau e^{2\pi i\tau\nu_0 t}$$

radiates energy in the harmonic $\tau\nu_0$ at a rate

$$(4e^2/3c^3)(2\pi\tau\nu_0)^4[|x_\tau|^2 + |y_\tau|^2 + |z_\tau|^2].$$

The correspondence principle for frequencies shows that if the difference in quantum number between the initial and final states is τ, the quantum frequency $\nu(lm)$ approaches asymptotically the classical overtone $\tau\nu_0$ if the quantum number is large. Hence. a formula by which the transition probability can be estimated qualitatively or asymptotically is

$$A_{l\rightarrow m} = (4e^2/3hc^3)(2\pi)^4\nu(lm)^3[|x_{l-m}|^2 + |y_{l-m}|^2 + |z_{l-m}|^2]. \tag{31}$$

It is to be emphasized that (31) never gives a clear-cut and unambiguous answer, as there is no way of telling whether the Fourier coefficients should be evaluated for the initial or the final orbit of the transition, or should represent some sort of compromise between the two.

IV. ADVENT OF TRUE QUANTUM MECHANICS

Although the Bohr theory had the many triumphs indicated above, still as time progressed, especially in the early 1920s. it became increasingly apparent that it was not adequate. With much labour it was possible to determine the energy levels of the neutral helium atom, a three-body problem, and these did not accord with experiment. Unjustifiable half-quantum numbers (*i.e.,* half rather than whole integers) kept appearing in the empirical description of band spectra. Numerous other difficulties could be recited. It was clear that the trouble was simply that the "old" or Bohr quantum theory was a patchwork doctoring of classical mechanics, wherein the quantum conditions were added in a rather artificial way. What was needed was a rational, self-consistent quantum mechanics, which started afresh and evolved a mathematical framework and philosophy all its own This was discovered in 1926, which was thus an epoch-making year in the history of quantum theory.

This remarkable new mechanics cannot be regarded as the product of any one man, and was instead the result of the impact of mind on mind among the leading theoretical physicists of the time. It was developed in a diversity of mathematical forms, which present a rather confusing array to the student beginning the subject. However, these various formulations, though different in superficial mathematical structure, are basically in harmony with each other. The three main mathematical forms are the following: (1) the matrix theory of Born, Heisenberg and Jordan; (2) Schrodinger's wave mechanics. the outgrowth of De Broglie's concept of "phase waves"; and (3) the so-called transformation theory. based on kinetical indeterminism, developed by Dirac and Jordan, and interpreted by Heisenberg.

A. Wave Mechanics

1. Hamiltonian Analogy and De **Broglie Waves.**—We shall begin with the "wave" formulation, as this is the version most universally used, and perhaps the easiest to understand The impetus to the development of this form of quantum mechanics nas furnished by De Broglie's interpretation of the classical Hamiltonian analogy between optics and dynamics This analogy, which is readily demonstrated from Fermat's principle in optics and the principle of least action in mechanics, establishes a formal similarity between the path of a particle in a mechanical system and a hypothetical optical system in which the refractive index is correlated in a rather arbitrary nay with the potential energy $V(x, y, z)$ in the mechanical problem. This comparison always seemed highly artificial because the velocity in the optical system was different from that in the mechanical one. However if somehow it is possible to introduce the concept of wave length into the analogy, so that it is meaningful to talk about dispersion, then besides the phase velocity there is also a group velocity, which is the velocity with which signals or modulations are propagated. De Broglie showed that although the velocity of the mechanical particle differed from the phase velocity, it became identical with the group velocity, provided the wave length has the value

$$\lambda = \frac{h}{\sqrt{2m(E - V)}} = \frac{h}{mv}. \tag{32}$$

The second form of (32) is obtained by noting that the energy constant E is the sum of the kinetic energy $\frac{1}{2}mv^2$ and the potential energy $V(x, y, z)$. Formula (32) gives the celebrated De Broglie wave length which occurs so characteristically in quantum-mechanical diffraction problems. When De Broglie first propounded his ideas in 1925, it was not clear whether they had much physical significance, but only a year or so after his paper, the existence of the De Broglie wave length was confirmed in a most striking fashion in the experiments of Clinton J. Davisson and Lester H. Germer on the diffraction of electrons by a crystal. They showed that beams of electrons passing through a crystal were diffracted in many ways like X-rays, but with the wave length given by the formula $\lambda = h/mv$.

2. Schrodinger Wave Equation.— Prior, however, to the Davisson-Germer experiments, Schrodinger recognized the great portent of the De Broglie wave length, and by means of it was led to the fundamental equation of wave mechanics, usually called the wave equation. Schrodinger conjectured that true quantum mechanics stands in the same relation to ordinary classical mechanics that physical optics does to geometrical optics. Just as the ray-tracing characteristic of the latter is unable to explain the phenomena of diffraction and interference, so, Schrödinger reasoned, ordinary mechanics could not explain atomic phenomena, the reason in each case being that the dimensions are not large compared to the wave length. Hence he sought to establish a procedure analogous to that used in physical optics. Now the fundamental "wave equation" of the latter is

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2} = \frac{1}{u^2}\frac{\partial^2 f}{\partial t^2}. \tag{33}$$

Here the phase velocity u may be a function of x, y, z. In the monochromatic, or periodic, case, the solutions can be written in the form $f = \psi(x, y, z)e^{2\pi i\nu t}$, where the space factor ψ satisfies the equation

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} = \frac{4\pi^2}{\lambda^2}\psi, \tag{34}$$

with $\lambda = u/\nu$. For the wave length λ, Schrodinger inserted the De Broglie value (32). Then (34) becomes

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0. \tag{35}$$

This is the Schrodinger wave equation. One immediately wonders how quantized phenomena can be extracted from (35), as a partial differential equation suggests things continuous rather than discrete. The answer is that one must confine one's attention to the "physically admissible," or, colloquially, "civilized" solutions of (35), which meet certain requirements of continuity, single-valuedness, etc. Solutions which fulfill these demands are called characteristic functions, proper functions or eigenfunctions. The precise conditions that these physically admissible solutions need to meet vary somewhat with the physical nature of the problem. It is usually sufficient that ψ be single-valued, continuous, together with its first derivatives, and finite, except perhaps at a few points at which ψ becomes infinite in such a way that

$$\iiint |\psi|^2 dv \text{ and } \iiint \left\{\left|\frac{\partial \psi}{\partial x}\right|^2 + \left|\frac{\partial \psi}{\partial y}\right|^2 + \left|\frac{\partial \psi}{\partial z}\right|^2\right\} dv$$

exist. Also, ψ must vanish at infinity. Now, to be sure, (35) possesses an infinity of solutions, since the latter involve arbitrary constants of integration and even arbitrary functions. Nevertheless, it often happens that not one of these solutions has the properties demanded of a characteristic function. Instead, an admissible solution is usually obtained only if E is given certain particular values, called characteristic values, proper values or eigenvalues. These values of E are those which are to be substituted into the Bohr frequency condition (13).

3. Rotator and Harmonic **Oscillator.**—A simple illustration of how the condition that the solution be physically admissible limits the parameter E is provided by the two-dimensional rotator; *i.e.*, the rotating dumbbell whose motion is confined to a plane. Here the wave equation analogous to (35) is

$$\frac{\partial^2 \psi}{\partial \varphi^2} + \frac{8\pi^2 IE}{h^2}\psi = 0, \tag{36}$$

as is seen by specializing (35) to one co-ordinate, with $V = 0$, and noting that in a rotational problem the moment of inertia I and angle φ replace the mass and a linear displacement. The solution of (36) is

$$\psi = A\cos[(8\pi^2 IE/h^2)^{\frac{1}{2}}\varphi - \epsilon], \tag{37}$$

where A and ϵ are arbitrary constants. The requirement of single-valuedness as a function of position on the circular path of rotation demands that $\psi(\varphi + 2\pi) = \psi(\varphi)$. This is possible only if the coefficient of φ in the argument of the cosine is an integer n. Thus

$$E = n^2h^2/8\pi^2 I. \tag{38}$$

This is exactly the same formula for the energy of a rotator as that (cf. equation [28]) obtained with the old quantum theory. It would thus at first appear that the new quantum mechanics did not remove the difficulty that half rather than whole integers are required to obtain agreement with experiment on rotational energy levels. Actually, however, the end-over-end rotation of a molecule should be represented by a rotator not confined to a particular plane, and so associated with a three- rather than two-dimensional space. When this extra degree of freedom is added, it is found that the factor n^2 in (38) is replaced by $(n + \frac{1}{2})^2 - \frac{1}{4}$, so that, apart from an unimportant additive constant, the result is the same as though half quantum numbers were used in the Bohr theory. Details of the analysis are omitted here, but it is essentially the same as that in classical potential theory where it is shown that the characteristic values of the differential equation for surface harmonics are proportional to $n(n + 1)$.

Of course, in most problems the mathematical analysis is more complicated than in this purposely simple illustration of the rotator. When exact, closed expressions are obtained for the characteristic values of a system with one degree of freedom, they are usually derivable by the so-called polynomial method. In this, the solution is expressed as a power series, and it is shown that if the series does not terminate, the solution is not physically admissible. The termination condition then usually restricts the energy parameter E to certain particular or "characteristic" values.

The polynomial method may be illustrated by the one-dimensional harmonic oscillator. Here the wave equation (35) takes the form

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}(E - \tfrac{1}{2}ax^2)\psi = 0. \tag{39}$$

On the introduction of the following abbreviations and changes of variable,

$$A = \frac{4\pi E}{h}\left(\frac{m}{a}\right)^{\frac{1}{2}}, \qquad u = \frac{m^{\frac{1}{4}}a^{\frac{1}{4}}(2\pi)^{\frac{1}{2}}}{h^{\frac{1}{2}}}x, \qquad \psi = e^{-u^2/2}g, \tag{40}$$

equation (39) becomes

$$\frac{d^2 g}{du^2} - 2u\frac{dg}{du} + (A - 1)g = 0. \tag{41}$$

A series solution is assumed:

$$g = c_k u^k + c_{k+2}u^{k+2} + c_{k+4}u^{k+4} + \cdots. \tag{42}$$

After the indicated operations are performed, the entire left side of (41) can be expressed in the form of a series. The coefficient of each power of u in the latter must vanish if (41) is satisfied. The vanishing of the coefficient of the lowest power (viz., u^{k-2}) requires either $k = 0$ or $k = 1$. On equating to zero the coefficient of u^n, one obtains the recurrence formula

$$\frac{c_{n+2}}{c_n} = \frac{2n+1-A}{(n+1)(n+2)}$$

for determining the ratio c_{n+2}/c_n. The series *(42)* will terminate at the term $c_n u^n$ if $A = 2n + 1$ or, in other words, by (40) if

$$E = (n + \tfrac{1}{2})h\nu_0, \quad \text{with} \quad \nu_0 = \frac{1}{2\pi}\left(\frac{a}{m}\right)^{\frac{1}{2}}. \tag{43}$$

It can be shown that if the series does not terminate, then ψ increases without limit as x becomes arbitrarily large, and the solution is not physically admissible. Hence, the only characteristic values of the harmonic oscillator are those given by (43). Comparison with (27) shows that the new quantum mechanics gives the same energy levels for the harmonic oscillator as does the old Bohr theory, except for an additive constant which is equivalent to the use of half quantum numbers in (27). Usually it is unimportant whether the extra term $\frac{1}{2}h\nu_0$ is included, but by study of the shift between the electronic spectra of diatomic molecules differing only in being composed of different isotopes. it is possible to decide experimentally between (27) and (43), and the results unequivocably favour the latter.

4. Hydrogen Atom. — The focal point of the old Bohr theory was its success with the hydrogen atom, and one is naturally anxious to know whether these triumphs are reproduced by wave mechanics. It turns out that the Schrodinger theory usually gives exactly the same energy levels for a hydrogenic atom as did that of Bohr. This remarkable coincidence holds even inclusive of the corrections for the motion of the nucleus, and in the first-order Stark effect. Thus, all the standard achievements of the old Bohr theory regarding the Rydberg constant, hydrogen-helium shift, spectroscopic determination of *elm*, etc., are reproduced with wave mechanics. When second powers of the electric field are included in the Stark effect, the results are slightly different with wave mechanics, and the experimental results favour the new formula, though observation of the effect of the second-order corrections requires such high field strengths that precision is difficult. The details of the mathematical analysis will not be given here, but a few salient points will be cited. The calculation for hydrogen is unlike the illustrations of the rotator and oscillator given above, inasmuch as there are three degrees of freedom rather than only one. A problem involving more than one co-ordinate is exactly soluble in wave mechanics as a rule only if the variables are separable; *i.e.*, if co-ordinates can be found such that the wave equation admits a solution which can be resolved into products of factors. each of which involves only one co-ordinate. Fortunately such a decomposition is possible for the hydrogen atom. Variables can be separated by using polar co-ordinates, and the wave function then takes the form

$$\psi = A R_{nl}(r) P_l^{|m_l|}(\cos\theta) e^{im_l\varphi}. \tag{44}$$

Here $P_l^{|m_l|}$ is an associated Legendre function (in which $|m_l|$ is the absolute value of m_l), and R_{nl} is the product of an exponential factor and a polynomial in r (a derivative of the so-called Laguerre polynomial). The constant A is arbitrary, while n, 1. m_l are integers. The mathematical problem is very similar to the familiar one of the solution of Laplace's equation in polar co-ordinates, except that the differential equation satisfied by the radial factor is different, no longer admitting a solution in the form of a simple power of r as in the Laplacian case. For the Stark effect, the separation of variables is achieved by using parabolic rather than polar co-ordinate. Both of these types of co-ordinates are special cases of elliptical co-ordinates. and Eisenhart showed generally that if the Schrodinger equation for a single particle admits separation at all, it must be with elliptical co-ordinates.

5. Continuous Spectra. — So far the impression has been given that the characteristic values form a discrete rather than continuous manifold. However, there are certain ranges within which any value of the energy is allowable. The simplest example is furnished by the hydrogen atom. Here, in addition to any of the discrete negative values (21), any positive value of the energy is allowable. The reason for this distinction is the following The differential equation satisfied by the radial factor of the wave function for the hydrogen atom has two singular points; viz., the origin and the point at infinity. There is always one solution which is regular at the origin, but it will in general increase without limit at infinity if $E < 0$ Only certain special negative values of E avoid this catastrophe, and these are the characteristic values. When, however, the energy constant E is positive, all solutions vanish at infinity, and so the solution which behaves properly at the origin also necessarily does the same at infinity. Hence any positive value of E is a characteristic value. This remark applies even to nonhydrogenic atoms if the origin of the energy is chosen at ionization The existence of this continuous manifold of positive energy values is reflected experimentally in the continuous absorption beyond the series limit. In fig. 3 the transitions from a fixed lower state to upper states with larger and larger values of n give rise to lines which crowd closer and closer together. Because there can also be transitions to states in the continuum there is a continuous spectrum beyond the limit corresponding to $n = \infty$. There can also be transitions between two values of the energy in the continuous domain, and it is by this mechanism that the continuous X-ray spectrum is emitted from the anode of an X-ray tube.

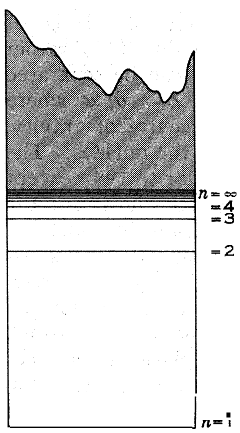


FIG 3 — DISCRETE AND CONTINUOUS ENERGY LEVELS OF HYDROGENIC ATOM

6. More General Form of the Wave Equation. — So far, in (35), we have given the form of the wave equation for a conservative system consisting of a single particle and having a definite energy. We need a rule for forming the wave equation in other cases, involving either more than one particle or an indefinite energy, or both. In classical theory a conservative system necessarily has a definite, constant energy, but in quantum mechanics this need not be so, as is discussed below more fully in connection with the Heisenberg uncertainty principle. As a result, it is no longer redundant to say that a conservative system has a definite energy. The more general scheme for forming the wave equation given here also applies to the nonconservative case in which the potential energy V contains the time explicitly.

The procedure is as follows. First of all, the Hamiltonian technique is to be used; *i.e.*, the system is to have associated with it a classical Hamiltonian function $H(q_1, \ldots, q_f, p_1, \ldots, p_f, t)$, which is a function of the co-ordinates and momenta. We replace p_k by the operator $\frac{h}{2\pi i}\frac{\partial}{\partial q_k}$, and in this fashion we can form a linear differential equation

$$\left[H\left(q_1, \cdots, q_f, \frac{h}{2\pi i}\frac{\partial}{\partial q_1}, \cdots, \frac{h}{2\pi i}\frac{\partial}{\partial q_f}, t\right) + \frac{h}{2\pi i}\frac{\partial}{\partial t}\right]\Psi = 0. \tag{45}$$

This is the general wave equation. One is led to it primarily by comparison with other forms of quantum mechanics, especially transformation theory, rather than through the De Broglie and Schrödinger interpretation of the Hamiltonian analogy.

In case the system is conservative, so that t does not enter explicitly, (45) will admit a solution of the form

$$\Psi = e^{-2\pi i E_m t/h}\psi_m(q_1, \cdots, q_f), \tag{46}$$

where ψ_m is independent of t and satisfies the equation

$$\left[H\left(q_1, \cdots, q_f, \frac{h}{2\pi i}\frac{\partial}{\partial q_1}, \cdots, \frac{h}{2\pi i}\frac{\partial}{\partial q_f}\right) - E_m\right]\psi_m = 0. \tag{47}$$

However, (46) does not represent the most general solution of *(45)* for a conservative system, which is

$$\Psi = \Sigma_m c_m e^{-2\pi i E_m t/h}\psi_m, \tag{48}$$

where the summation is over all the characteristic values E_m and where the c_m are arbitrary constants. The expression (46) presupposes that the energy has a definite value, whereas (48) does not involve this restriction.

Equation (47) reduces to (35) for a one-particle system, where the classical Hamiltonian function is $(p_x^2 + p_y^2 + p_z^2)/2m + V$. To include the correction for the motion of the nucleus, it is necessary to add to this Hamiltonian function an extra term $(p_\xi^2 + p_\eta^2 + p_\zeta^2)/2M$, where M and p_ξ, p_η, p_ζ are respectively the mass and components of momentum of the nucleus. It is, of course, then necessary to use the general equation (47) rather than (35). It can be shown that the variables can be separated by changing them from x. y, z, ξ, η, ζ to X, Y, Z, r, 0, φ where X. Y, Z are the Cartesian co-ordinates of the centre of gravity, and r, θ, φ are polar co-ordinates with origin at the nucleus. The solution of the wave equation takes a form similar to (44) except that there is an extra factor $e^{ik_1X}e^{ik_2Y}e^{ik_3Z}$ which allows for the motion of the centre of gravity of the system, and in which k_1, k_2, k_3 are arbitrary constants. The differential equation satisfied by the "internal" part of the wave function (*i.e.*, the part depending on r, 0, φ) can be shown to be the same as for the one-body problem, in which the nuclear motion is disregarded, except that the reduced mass (17) appears in place of the electronic mass m. The total energy—*i.e.*, the characteristic value of (47)—is the sum of the internal energy given by (21) and an extra term $(k_1^2 + k_2^2 + k_3^2)h^2/8\pi^2(m + M)$ which represents the translational kinetic energy of the centre of gravity of the system. In the discussion of the Bohr theory above, this translational energy was omitted, but its inclusion in the Bohr frequency condition introduces a correction to the frequency nhich is essentially the quantum analogue of the classical Doppler effect, and yields results substantially equivalent to the latter.

An important property of (47) is that its solutions can be shown to be orthogonal. provided the operator is of the so-called self-adjoint type. This condition is one which can practically always be met. If, in addition, the arbitrary proportionality constants in the wave function are so chosen that they are normalized to unity, one has the relation

$$\int \psi_l^* \psi_m d\tau = \delta^l_m, \tag{49}$$

where $d\tau$ is a volume element embracing the co-ordinate space of all the particles (of dimensionality $3n$ if there are n particles), and where the integration is over all the co-ordinates. The expression δ^l_m is the usual Kronecker delta, and has the meaning that $\delta^m_m = 1$ and that $\delta^l_m = 0$ $(l \neq m)$. The asterisk is used here and elsewhere to denote the complex conjugate. It is necessary to distinguish between ψ_m and its conjugate ψ_m^*, because the solutions of the Schrodinger wave equation are not necessarily real. In (49) the case $l \neq m$ expresses the orthogonality, and $l = m$ embodies the normalization.

B. Matrix Form of Quantum Mechanics

A few months prior to Schrodinger's discovery of wave mechanics, another, superficially very different approach to quantum mechanics was developed by Born and Heisenberg. The impetus to this other approach was Born's repeated emphasis to his colleagues at Gottingen that the reason the old quantum theory was then (1925) failing was that it sought to use the same kinematical concepts of space and time within the atom as in ordinary measurable large-scale events. After all, the concepts of space and time have a meaning only when we tell how they can be measured, and obviously at atomic distances we cannot use ordinary measuring rods or clocks. Guided by this philosophy based on the so-called operational viewpoint, Heisenberg discovered his matrix mechanics. He did not originally recognize his formulation as a matrix one—Born was the first to see that the equations were best interpreted in the language of matrices.

The basic idea of the matrix mechanics is that the co-ordinates and momenta associated with the electrons in the atom are to be treated as matrices rather than as quantities having a definite numerical value. A matrix is an array of the form

$$\boldsymbol{a} = \begin{Bmatrix} a(11) & a(12) & a(13) & \dots \\ a(21) & a(22) & a(23) & \dots \\ a(31) & a(32) & a(33) & \dots \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & a(nn) \end{Bmatrix}$$

The matrices involved in quantum mechanics are infinite ones; *i.e.*, have an infinite number of rows and columns.

The Heisenberg matrix elements are quantities which are intimately connected with the concept of the transition probability in the old quantum theory, and alternatively with Fourier coefficients in classical mechanics. For simplicity consider a system with only one degree of freedom. Then the matrix index can be identified with the quantum number, and a matrix element $a(lm)$ is correlated with a transition between states of quantum numbers 1 and m. The exact matrix expression replacing (31) is

$$A_{l\to m} = (4e^2/3hc^3)\,(2\pi)^4\nu(lm)^3[|x(lm)|^2 + |y(lm)|^2 + |z(lm)|^2]. \tag{50}$$

Here $x(lm)$ refers to an element of the x co-ordinate matrix, etc., and is the quantum analogue of the Fourier coefficient x_{l-m} involved in the rough formula (31) arrived at by means of the correspondence principle. As presented here. and as Heisenberg reasoned historically, (50) is obtained by analogy with classical theory, but it should be mentioned that (50) can also be derived independently from the Dirac radiation theory, which applies quantum mechanics to the degrees of freedom of the ether. By means of (50) the intensity of a line can be calculated if the Heisenberg matrices are known.

In order to compute the matrix elements needed for use in (50), it is necessary to transcribe atomic mechanics into the mysterious matrix language, and for this a matrix algebra and calculus are necessary. The sum of two matrices is formed by adding corresponding elements, so that $(a + b)(lm) = a(lm) + b(lm)$. Matrices are multiplied together in the same way as determinants; *i.e.*,

$$(ab)(lm) = \Sigma_n a(ln)b(nm). \tag{51}$$

There is, however, the difference that whereas a determinant has a numerical value, a numerical meaning is attached only to the individual entries of a matrix and not to its entirety. This loss of numerical value corresponds to the abandonment of ordinary kinematical relationships within the atom. The multiplication is in general noncommutative; *i.e.*, $(ab)(lm) \neq (ba)(lm)$ or more symbolically $\boldsymbol{ab} \neq \boldsymbol{ba}$, if boldface type is isued to designate the entire matrix rather than a single entry.

By repeated additions and multiplications it is possible to construct functions of matrices which are in turn matrices, and thus develop a matrix algebra. In order to transcribe atomic mechanics into the mysterious matrix language, it is necessary to have some sort of rule for constructing the derivative of one matrix with respect to another. A consistent mathematical framework is obtained if one defines the derivatives of a function $f(q_1, \dots, q_f, p_1, \dots, p_f)$ in the following way:

$$\frac{\partial f}{\partial p_k} = \frac{2\pi i}{h}(fq_k - q_k f), \quad \frac{\partial f}{\partial q_k} = -\frac{2\pi i}{h}(fp_k - p_k f). \tag{52}$$

The special cases $f = p_j$ or q_j yield the so-called quantum conditions

$$\begin{aligned} p_k q_k - q_k p_k &= (h/2\pi i)1, \qquad p_k q_j - q_j p_k = 0 \qquad (k \neq j) \\ p_k p_j - p_j p_k &= 0, \qquad q_k q_j - q_j q_k = 0. \end{aligned} \tag{53}$$

A diagonal matrix is one which has vanishing entries except down the principal diagonal—*i.e.*, $a(lm) = 0$, $1 \neq m$—while a unit matrix has the additional property $1(ll) = 1$. A diagonal matrix is the quantum analogue of a Fourier series which contains nothing but a single constant term. Hence, in a conservative system with a definite energy. the energy matrix must be a diagonal one.

It should be pointed out that the Heisenberg matrices are infinite ones in the sense that they involve an infinite number of rows of columns. Namely, each index (number of row or column) is correlated with a stationary state, and there is an infinite number of such states. Furthermore, in connection with fig. 3 me have seen that often the permitted stationary states form a continuous rather than discrete manifold. In the continuous region it is necessary to introduce the rather recondite concept of a matrix with continuously varying indices, so that it cannot then even be tabulated in terms of rows and columns. When there is a continuum, the summation in (51) must be replaced by an integration. Similarly, in the expansion (48) the summations are to be construed as including integrations over the continua when these are present.

1. Relation of Matrix and Wave Theories.—It is possible to work out the energy levels of the harmonic oscillator, rotator, hydrogen atom, etc., by means of pure matrix theory, and the results are always the same as those obtained with wave mechanics. One immediately suspects that the two approaches are interrelated. This is indeed the case. If the Schrodinger wave functions are known, the Heisenberg matrix elements can be computed by a straightforward integration. Suppose that we desire the matrix elements of a function $f(q_1, \ldots, q_f, p_1, \ldots, p_f)$ of the co-ordinates and momenta. Then the appropriate formula is

$$f(lm) = \int \psi_m{}^* f\left(q_1, \cdots, q_f, \frac{h}{2\pi i}\frac{\partial}{\partial q_1}, \cdots, \frac{h}{2\pi i}\frac{\partial}{\partial q_f}\right)\psi_l d\tau, \qquad (54)$$

where the integrand contains an operator f formed by replacing each p_k by $\frac{h}{2\pi i}\frac{\partial}{\partial q_k}$. We shall not attempt to prove (54) but shall note one or two simple consequences. In the first place, the quantum conditions (53) are satisfied. For instance, if $f = p_k q_k - q_k p_k$, then

$$f\psi_m = \frac{h}{2\pi i}\left[\frac{\partial}{\partial q_k}(q_k\psi_m) - q_k\frac{\partial \psi_m}{\partial q_k}\right] = \frac{h}{2\pi i}\psi_m,$$

and except for a factor $h/2\pi i$, the integral (54) becomes identical with (49), so that we have $f(lm) = (h/2\pi i)\delta_m^l$. This result agrees with the first relation of (53), since the elements of a unit matrix are equivalent to a Kronecker delta. The remaining relations of (53) are obviously satisfied. The third relation, for instance, follows since $\partial^2\psi/\partial q_j\partial q_k = \partial^2\psi/\partial q_k\partial q_j$.

Satisfaction of the wave equation (47) for a conservative system with definite energy is tantamount to making the energy a diagonal matrix. To see this we note that by (47) the operator H is equivalent to multiplication by a constant E_m. Hence, if f in (54) is taken to be the Hamiltonian operator H, the integral differs from (49) merely by a constant factor and so has the value $E_m\delta_m^l$.

If one is wedded to the extreme matrix viewpoint, one regards the wave functions merely as mathematical auxiliaries used to compute the Heisenberg matrix elements by means of the "matrix computing machine" (54). Such a viewpoint is undoubtedly too one-sided, and is offensive to physicists nho take comfort from the parallelism of wave mechanics to classical mathematical physics, and to optics, in particular.

2. Intensities and Polarizations of Spectral Lines.—By combining (54) (as applied to f = x, y, z) with (50), it is possible to compute the intensities of spectral lines. Furthermore, by examination of the relative magnitudes and phases of the corresponding x, y, and z components involved in (50), predictions can also be made regarding the polarization behaviour. In this fashion, for example, the intensities in the various components in the Stark effect for hydrogen can be calculated. Also, and even more important, it is possible to derive the various so-called "selection rules," which forbid certain quantum numbers changing except by a specified number of units. It can be demonstrated, for instance, that the quantum number for a harmonic oscillator cannot change by more than one unit. With the restriction $n'' - n' = \pm 1$, the quantum-mechanical frequency v obtained by substituting (43) in (13) becomes identical with the classical frequency ν_0. Without the restriction, v could be any multiple of ν_0, a highly unreasonable situation since classically overtones are always absent for a simple harmonic system.

A particularly important case of the selection principle is that for the so-called azimuthal quantum number 1, which is involved in the relativistic hydrogen atom and especially in Newtonian nonhydrogenic atoms with one valence electron. By means of (54) it can be proved that 1 cannot change except by one unit. The quantum number 1 plays a vital role in interpreting the spectra of alkali atoms. (See SPECTROSCOPY.) An energy level is classified of the s, p, d, f character according as $l = 0, 1, 2, 3$. The selection principle $l' - l'' = \pm 1$ materially limits the "combinations" of the terms; *i.e.*, the possible transitions between the different energy states. The predictions are strikingly confirmed by experiment.

C. Statistical Significance of Quantum Mechanics

1. Interpretation of the Wave Function.—We have not as yet given sufficient emphasis to the physical meaning of the solution of the Schrodinger wave equation, as distinct from its relation to the matrix formalism. The wave function satisfying the general equation (45) has an important physical interpretation. The square of its modulus is proportional to what may be called a statistical charge density. Let us consider first a system with only one particle. Then the probability that the particle will be in the volume element dxdydz at time t may be taken to be

$$|\Psi|^2 dxdydz, \qquad (55)$$

provided the total probability is normalized to unity; *i.e*,

$$\iiint |\Psi|^2 dxdydz = 1. \qquad (56)$$

This scheme of interpretation is a consistent one, as it can be shown that it is a consequence of the differential equation (45) that the integral on the left-hand side of (56) is independent of time. Otherwise the normalization condition (56) could not be imposed. Similarly, when there are n particles, $|\Psi|^2$ determines the probability in a $3n$ dimensional space whose volume element $d\tau$ is $dx_1, \ldots, dz_n$.

It is to be emphasized that the density given by (55) is inherently statistical in character. We do not say that the particle is in the element dxdydz at time t, but merely that there is a certain probability of the particle being there. In the particular case of a conservative system in a definite stationary state, the relation $|\Psi|^2 = |\psi_m|^2$ is satisfied by virtue of (46), and then the probability becomes independent of time. The places where $|\Psi|$ or $|\psi_m|$ is large are those where the particle is likely to be located, but it is never possible to say when it is there. The situation may be compared to the information obtainable from the time exposure of a firefly on a dark night. Where the photographic plate reveals the most brightness is where the firefly has spent most of the time, but one cannot infer just when the insect was at a particular spot. Similarly in quantum mechanics, the information about particles is inherently restricted because of its statistical nature.

When quantum mechanics was first discovered, there was considerable controversy as to whether it was necessarily statistical in character. For a while many physicists maintained that a deterministic picture was possible, in which the electron was considered to be a fluidlike affair whose density distribution is governed by (55). It is now, however, generally conceded that such attempts are untenable and involve the same fallacy as reasoning from the time exposure of the firefly that the latter is a luminous fluid rather than a discrete insect. It should be regarded as an advantage rather than a drawback that quantum mechanics must be interpreted statistically. When atomic experiments are analyzed from the "operational" viewpoint, it is found that the measurements always involve statistical features inasmuch as some of the parameters are distributed over a range of values and are not determined with complete precision. It is not the co-ordinates alone which must be statistically interpreted, but also other dynamical quantities, such as energy, momentum, etc.

2. Probability Distribution in Momentum Space.—Again confining attention to one particle, it is possible, for instance, to inquire concerning the probability that its components of momentum fall within a certain range at time t. The symmetrical roles of co-ordinates and momenta in the Hamiltonian technique suggest that there is a function χ such that

$$|\chi(p_x, p_y, p_z, t)|^2 dp_x dp_y dp_z \qquad (57)$$

determines the probability that the momenta are in the element $dp_x dp_y dp_z$ at time t. There is indeed such a function, and the relation between the two functions Ψ, χ is similar to that between a function and its Fourier transform. Namely, it can be shown that

$$\Psi = h^{-3/2}\iiint \chi(p_x,p_y,p_z,t)e^{2\pi i(p_xx+p_yy+p_zz)/h}dp_xdp_ydp_z, \tag{58}$$

$$\chi = h^{-3/2}\iiint \Psi(x,y,z,t)e^{-2\pi i(p_xx+p_yy+p_zz)/h}dxdydz. \tag{59}$$

Equation (58) has intuitively a very reasonable form, as it is natural to regard any disturbance as being built up of a superposition of De Broglie waves, each of the structure $e^{2\pi ipx/h}$ in one dimension or $e^{2\pi i(p_xx + p_yy + p_zz)/h}$ in three. In any principle of superposition in physics, the square of the amplitude governs the intensity, and so it is natural to assume that $|\chi|^2$ gives the probability. It can be shown from the mathematical theory of Fourier transforms (Plancherel's theorem) that

$$\iiint |\Psi|^2dxdydz = \iiint |\chi|^2dp_xdp_ydp_z. \tag{60}$$

If (60) were not satisfied, the physical interpretation given 9, χ would lack consistency, for it is necessary that the total probability for either co-ordinate or momentum distribution be unity; or in other words, the normalization (49) in co-ordinate space must imply a corresponding normalization in momentum space. Another relation which can be established, and which shows the intimate relation between momentum and the operator $\frac{h}{2\pi i}\frac{\partial}{\partial x}$, is

$$\iiint p_x{}^n|\chi|^2dp_xdp_ydp_z = \iiint \Psi^*\left(\frac{h}{2\pi i}\frac{\partial}{\partial x}\right)^n\Psi dxdydz, \tag{61}$$

where n is an integer. Also there is a symmetrical relation

$$\iiint x^n|\Psi|^2dxdydz = \iiint \chi^*\left(-\frac{h}{2\pi i}\frac{\partial}{\partial p_x}\right)^n\chi dp_xdp_ydp_z. \tag{62}$$

Clearly (62) and (61) give respectively the mean value of the nth power of the x-component of displacement and of momentum.

3. Interference of Probability Amplitudes.— In ordinary probability theory, probabilities are compounded in accordance with the law

$$P(b) = \int P(b,\, a)P(a)da, \tag{63}$$

where $P(a)$ is the probability of occurrence of a, and $P(b,$ a) is the probability of occurrence of b when a is given. On the other hand, since $|\Psi|^2$ or $|\chi|^2$ is the density in position or momentum space, the functions involved in the compounding relation (58) are the square roots of probabilities and are spoken of as "probability amplitudes." The function $e^{2\pi i(xp_x + yp_y + zp_z)/h}$ is essentially a De Broglie wave and is called the probability amplitude connecting co-ordinates and momenta. The fact that in quantum mechanics there exists a compounding relation analogous to (63) with $P^{\frac{1}{2}}$ rather than P is sometimes called the phenomenon of the "interference of probability amplitudes." Although no logical inconsistencies are ultimately involved, still this somewhat curious way of associating probabilities leads to many paradoxes which look rather strange from the standpoint of large-scale statistical mechanics. There is a certain amount of parallelism to the unintelligibility of interference phenomena in optics, wherein amplitudes rather than intensities are added, to a person who has been versed only in geometrical optics, ray tracing, and perhaps the corpuscular theory of light. It is now well recognized that radiation has both corpuscular and undulatory aspects. The former, for instance, stands out clearly in the photoelectric effect. As emphasized in Bohr's principle of complementarity, the two aspects are not contradictory but instead play complementary roles. So also, matter has both corpuscular and undulatory features. The type of compounding involved in (58) implies use of the wave amplitude in much the same way as in optics. It is well knoan that interference phenomena in the latter must be treated by superposing wave amplitudes rather than intensities or the number of corpuscular light quanta.

D. Transformation Theory

1. General.— The general interpretation of quantum mechanics as essentially a theory of probability amplitudes has been developed particularly by Jordan and by Dirac. The details of this so-called "transformation theory" are too intricate and abstract to be treated here, but their formulation of quantum mechanics has elegance. generality and a unifying influence on the interpretation of the various other viewpoints. The Schrodinger wave equation, from the standpoint of transformation theory. may be regarded as an equation for finding the probability amplitude for distribution-in-position when the energy is known. One might ask for the probability amplitude for the distribution of other functions than positional co-ordinates—for instance, momenta—and the known quantity might not necessarily be the energy, as certain experiments correspond to fixation of other quantities than the energy. Such more general problems can be solved by means of transformation theory.

2. Uncertainty Principle.— It is to be noticed that in (55) or (57) expressions have been given for the probability of the particle being in an element of volume dxdydz of position space. or in an element of momentum space, but that there is no probability function for a concurrent occurrence of given values of position and momentum associated aith a volume element $dxdydzdp_xdp_ydp_z$. This fact takes us to the heart of the Heisenberg uncertainty principle. The latter limits the accuracy with which it is possible to specify simultaneously the values of a co-ordinate and its canonically conjugate momentum. If Δp_x and Δx be the limits of precision within which p_x and x can simultaneously be determined, there exists the inequality

$$\Delta x\Delta p_x \geqq h/4\pi. \tag{64}$$

For illustrations of this concept, see Uncertainty Principle, The. It is meaningless to talk about the probability of a simultaneous occurrence of a given value of a co-ordinate and its conjugate momentum, for by (64) there is infinite uncertainty in a momentum if the position is known with complete precision, or vice versa.

The uncertainty principle should not be regarded as an additional hypothesis artificially injected into quantum mechanics. Instead, it is something which can be proved as a consequence of the latter, along the following lines. By proper choice of the origin for position and velocity, the mean position and velocity can be made zero; in other words, $I_{61}{}^{(1)} = I_{62}{}^{(1)} = 0$, where $I_{61}{}^{(n)}$, $I_{62}{}^{(n)}$ denote respectively the integrals (61) and (62). The uncertainty in position and momenta can then be regarded as measured by the root mean square displacement and momentum, so that we can take $\Delta p_x{}^2 = I_{61}{}^{(2)}$, t ~ = $I_{62}{}^{(2)}$ provided Ψ is normalized in accordance with (56). Now it can be shown by pure mathematics, largely by the aid of the so-called Schwarz inequality, that any function Ψ normalized in accordance with (56) and satisfying the requirements of continuity, etc. required of a physically admissible wave function satisfies the identity $I_{61}{}^{(2)}I_{62}{}^{(2)} \geqq (h/4\pi)^2$. The uncertainty principle is hence proved for the type of system under consideration. The equality sign in (64) corresponds to the minimum possible value of the product of the two errors, and this is achieved only when the probability functions have a Gaussian distribution.

It can be shown that the time is canonically conjugate to the energy. Hence, if we make an experiment whose span in time is limited, as is always the case, the energy cannot be known with complete precision, and so the appropriate wave function is (48), in which there is a dispersion of energy values, rather than (46), in which it is supposed that the energy is completely determinate. Wave functions of the general form (48), in which a number of stationary states are superposed and thus co-exist, are sometimes spoken of as "wave packets." It is through the construction of the latter that classical and quantum theories merge when the amount of action is large.

V. ELECTRON SPIN

4 very important development practically concomitant with the advent of the true quantum mechanics was the discovery of electron spin. The basic idea of the latrer is that the electron has an extra degree of freedom which may be likened to the spin of a top about an axis. Or, if the electron moving about the nucleus is compared to the earth in the solar system, then there is an obvious analogy of the spin of the electron to the diurnal rotation

of the earth about its own axis. The important features of the spinning electron were first presented by two young Dutch physicists, George E. Uhlenbeck and Samuel A. Goudsmit, in 1925, although some of the earlier literature did contain suggestions of a rotating electron in rather different connections.

The various dilemmas of spectroscopic theory and magnetism which are resolved by the introduction of electron spin are many. One of them is the existence of multiplets in molecular spectra. The simplest and most familiar example of a multiplet is provided by the two components of the D lines of sodium, which arise because the energy level of the upper state is double; *i.e.,* consists really of two stationary states. A single level, however, is obtained if the ordinary theory of a point electron is used. It is hence necessary to introduce a fourth quantum number, whose values subdivide the energy levels more than if only the quantum numbers associated with the external degrees of freedom of the electron were introduced.

If an electron model without spin is used, then there are three quantum numbers per electron. If the force field is dominantly central, as is usually the case even in nonhydrogenic atoms, then these three can be interpreted as the principal quantum number n, the azimuthal quantum number l, and the "magnetic" or "equatorial" quantum number m_l. The range of values of l is $0, \ldots, n-1$, and that of m_l is $-l, \ldots, +l$. The azimuthal quantum number l has the physical significance of specifying the angular momentum of the electron, in multiples of $h/2\pi$, while m_l fixes the component in a particular direction. The mathematical significance in terms of the indices of Tesseral harmonics involved in the wave function is that revealed in equation *(44)*.

1. Pauli Exclusion Principle. — Wolfgang Pauli proposed that besides n, l, m_l there be a fourth quantum number, or index m_s, which can take on the values $\pm\frac{1}{2}$. He then (1925) introduced his famous exclusion principle, for which he was awarded the Nobel prize in 1945. This principle states that no two electrons can have all four quantum numbers n, l, m_l, m_s the same. From this, the properties of the chemists' periodic table flow out automatically, including the existence of the "long" periods containing the iron, platinum and palladium groups, and of 14 rare earths. For instance, the choice $n = 1$ for the principal quantum number corresponds to the first or hydrogen-helium period, which has two elements, and $n = 2$ to the second or lithium-neon period. Namely, if $n = 1$, we can have $l = 0$, $m_l = 0$, $m_s = \pm\frac{1}{2}$, two possibilities in all, whereas if $n = 2$, we can have $l = 0$, $m_l = 0$, $m_s = \pm\frac{1}{2}$ and also $l = 1$, $m_l = 1$, $m_s = \pm\frac{1}{2}$; $l = 1$, $m_l = 0$, $m_s = \pm\frac{1}{2}$; $l = 1$, $m_l = -1$, $m_s = \pm\frac{1}{2}$ giving eight possibilities all told. In this general fashion the numbers of elements in the different rows of the periodic table are deduced by a simple enumerative process.

When Pauli published his celebrated paper in 1925, the significance of the fourth quantum number was a complete mystery. The great contribution of the theory of Uhlenbeck and Goudsmit, which appeared less than a year later, was to show how naturally the spinning electron accounts for the Pauli formalism. The two choices $m_s = \pm\frac{1}{2}$ are interpreted as determining the two possible orientations of the spin angular momentum relative to the axis of quantization. In order that there be two choices, and no more, it is necessary to postulate that the electron has a "half quantum" $\frac{1}{2}(h/2\pi)$ of spin angular momentum.

2. Interpretation of the Exclusion Principle in Terms of Antisymmetric Wave Functions. — The spin hypothesis of Uhlenbeck and Goudsmit furnished an explanation of the fourth quantum number. It did not, however, give any indication of why it is that no two electrons have all four quantum numbers the same. Heisenberg was the first to point out that the Pauli exclusion principle has a rudimentary interpretation in terms of the symmetry properties of wave functions. When one solves the wave equation for a system of several like particles, their identity introduces special properties of symmetry, and permits classification of the solution according to symmetry characteristics, the precise codification of which involves complicated group theory. For the very simple special case of only two identical particles, for instance, the solutions are either symmetric or antisymmetric, as regards interchange of the corresponding co-ordinates of the two particles. In other words, the wave function is either invariant or reverses sign when the electrons are permuted. When there are more than two electrons, there are many types of symmetry intermediate between the symmetric and antisymmetric cases, which represent two extremes but which still have a meaning. Furthermore, the antisymmetric solution can never be constructed when the electrons are in identical states (*i.e.,* have all four quantum numbers the same) for then the wave function would have to reverse sign as a result of an operation which does not change the arguments, an obvious impossibility. Hence, the Pauli principle is an automatic consequence of the formalism of quantum mechanics if it is postulated that only those solutions of the Schrodinger equation which are antisymmetric under permutation of the electron co-ordinates are physically realizable. In other words, nature somehow has a penchant for antisymmetric wave functions. In this connection it is to be understood that all four co-ordinates are to be permuted; *i.e.,* the spin co-ordinate as well as the three ordinary orbital ones x, y, z. The spin co-ordinate, unlike the variables x, y, z, which are continuous, assumes only the two values which correspond to the two possible orientations of the spin angular momentum relative to the axis of quantization. The wave function, on the other hand, need not be antisymmetric with respect to permutation of the orbital co-ordinates alone. In fact, no rigorous delineation of symmetry types under purely orbital permutation is possible, although it can be shown that symmetry characteristics associated with the orbital part of the problem determine the multiplicity of a spectral term; *i.e.,* whether it is a singlet, doublet, triplet, etc. The purely orbital forms of the wave equation given in (35) or (45) do not take cognizance of the spin. Inclusion of the latter introduces certain small magnetic interaction terms involving spin operators in the Hamiltonian function, and requires that the arguments of the wave function include spin variables as well as the ordinary orbital co-ordinates $q_1, \ldots, q_f$.

3. Electron Spin and Magnetism. — Electron spin plays a leading role in the theoretical interpretation of magnetic phenomena. A fuller description will be found in the article on MAGNETISM; only two points will be mentioned here. One is that ferromagnetism arises almost entirely from spin rather than from orbital magnetic moment, for in the solid state the crystalline electric fields usually quench the orbital contributions to the magnetic moment. The other is that in the Uhlenbeck-Goudsmit model of electron spin the ratio of magnetic moment to angular momentum is taken to be e/mc, whereas the classical value of the ratio which applies to the orbit is $e/2mc$. In other words, the so-called gyromagnetic ratio has an anomalous factor 2 when applied to the spin. This anomaly is confirmed not only by measurements on the gyromagnetic effect (rotation of a body by magnetization, or magnetization by rotation). but also by those on the anomalous Zeeman effect. In the latter the so-called Landé g-factor expresses the fact that part of the contribution to the magnetic moment is of the normal orbital type, and part of the anomalous spin variety. *(See* ZEEMAN *EFFECT.)*

VI. DIRAC ELECTRON

1. General. — In the Uhlenbeck-Goudsmit theory, the half quantum of spin angular momentum and the anomalous factor 2 in the gyromagnetic ratio are introduced in a purely ad *hoc* fashion. Another approach, which avoids this arbitrariness, was developed by Dirac in 1928. In the original Schrodinger theory without spin, the behaviour of an electron was described by a single second-order differentia! equation. The spin properties assumed by Uhlenbeck and Goudsmit involved two different possible settings of space-quantized spin angular momentum, and were interpreted by means of the matrix theory. Pauli, however, soon showed how the Schrodinger wave theory could be generalized to include the spin, by introducing two wave functions, ψ_1, ψ_2, which satisfy two simultaneous second-order differential equations. Dirac had the revolutionary idea that the electron be described by four wave functions, $\psi_1, \psi_2, \psi_3, \psi_4$, which satisfy four simultaneous first-order differential equations. If the electron is subject to an electrostatic potential $\varphi(x, y, z)$ and vector potential A, these equations are as follows:

$$\begin{aligned}(p_0 + mc)\psi_1 + (p_1 - ip_2)\psi_4 + p_3\psi_3 &= 0,\\ (p_0 + mc)\psi_2 + (p_1 + ip_2)\psi_3 - p_3\psi_4 &= 0,\\ (p_0 - mc)\psi_3 + (p_1 - ip_2)\psi_2 + p_3\psi_1 &= 0,\\ (p_0 - mc)\psi_4 + (p_1 + ip_2)\psi_1 - p_3\psi_2 &= 0,\end{aligned} \tag{65}$$

where

$$p_0 = \frac{h}{2\pi ic}\frac{\partial}{\partial t} + \frac{e}{c}\varphi, \qquad p_1 = \frac{h}{2\pi i}\frac{\partial}{\partial x} + \frac{e}{c}A_x,$$

$$p_2 = \frac{h}{2\pi i}\frac{\partial}{\partial y} + \frac{e}{c}A_y, \qquad p_3 = \frac{h}{2\pi i}\frac{\partial}{\partial z} + \frac{e}{c}A_z.$$

When first viewed, these equations certainly look arbitrary and artificial. Space will not permit description of how, to the first approximation in the dimensionless constant $(2\pi e^2/hc)^2$, they are equivalent to the more conventional theory based on second-order differential equations. It was this equivalence that first led Dirac to hit upon the equations of the structure (65). If the solutions are normalized to unity in the sense that

$$\iiint [|\psi_1|^2 + |\psi_2|^2 + |\psi_3|^2 + |\psi_4|^2]dxdydz = 1,$$

then $(|\psi_1|^2+|\psi_3|^2)dxdydz$ and $(|\psi_2|^2+|\psi_4|^2)dxdydz$ are respectively the probabilities that the electron be in the volume element $dxdydz$ with spin parallel or antiparallel to the axis of quantization. It can further be shown that the simultaneous equations (65) have the proper invariance under a Lorentz transformation, so that the requirements of the special theory of relativity are satisfied. This is not true of the simple Schrödinger equation (35), which is essentially Newtonian in character. The relativistic transformation properties of ψ_1, ψ_2, ψ_3, ψ_4 are those appropriate to a pair of spiriors, each of which has two components. This result is rather surprising, as one's first conjecture would be that the ψ's would transform like the components of a four-vector.

All the properties of electron spin, including the proper amount of angular momentum, relativistic fine structure and even the gyromagnetic ratio: flow out of the Dirac formalism in an almost miraculous fas ion suggestive of a magician's extraction of rabbits from a silk hat. Of course! some mathematical calculation, omitted here, is required to demonstrate that these various properties are indeed implied in (65), but it should be emphasized particularly that when (65) is used, no additional postulates are necessary as in the original theory of Uhlenbeck and Goudsmit. Thus (65) can be regarded as the basis of a relativistic electron, with spin as a by-product. In fact, the discovery of (65) and related methodology must be regarded as one of the most brilliant achievements in the whole history of mathematical physics.

When the Dirac equations (65) are used, the expressions for the energy levels of a hydrogenic atom have exactly the same form (24) as in the original relativistic Bohr-Sommerfeld theory. This identity of results must be regarded as one of the strangest coincidences in all of physics. In other words, the new quantum mechanics with spin is equivalent to the old theory without spin. Unless the spin is included in some form, either explicitly through the Uhlenbeck-Goudsmit model (which, however, is reliable only to the approximation [26]) or implicitly through the more refined Dirac equations, relativistic wave mechanics gives results different from (24j and not in accord with experiment. There is an important difference between the new and old interpretations of (24). The integer k no longer has the significance of being the azimuthal quantum number, as in the old quantum theory, but rather is equal to $j + \frac{1}{2}$, where j is the so-called inner quantum number which takes on half-integral values. The selection principles allow transitions in which the inner quantum number is unaltered as well as those in which it changes by ± 1, whereas only the ± 1 changes are allowed for the azimuthal quantum number. Hence, even though the energy levels are exactly the same, more spectral lines are allowed in the new than in the old interpretation of the relativistic fine structure. The extra components are confirmed experimentally, although the resolution is generally inadequate to detect them except as satellites of other lines.

Another success of the Dirac model is that it yields the so-called Klein-Nishina formula for the scattering of X-rays, which, unlike previous expressions, agrees well with experiment.

2. Negative Energy States and the Positron.— To this point, only the triumphs of the Dirac theory have been stressed. Some of its difficulties should also be mentioned. One is that it is uncertain how the relativistic theory should be extended to include the interaction between electrons found in nonhydrogenic atoms. A more serious trouble is the existence of the so-called negative energy states. It is convenient and hence customary in relativity to include, as will be done henceforth, the so-called rest energy mc^2 of the electron in the total energy. This inclusion is equivalent to omitting the term -1 from the brace in (24), and with this modification the energy levels given by (24) are all positive. The dividing line between the discrete and continuous levels in fig. 3 then comes at $E = mc^2$. The equivalence of energy levels in the old and new theories mentioned above applies only so long as attention is confined to states of positive energy. The old quantum theory gave no negative ones. However, it can be shown that with the Dirac equations (65) there is a continuum of states of negative energy, filling the entire range of energies below $-mc^2$. The rest energy mc^2 is enormously greater than the binding energy of the hydrogen atom, represented by the span of the discrete levels in fig. 3. The interval between the lowest positive state and the highest negative one is thus very approximately $2mc^2$, or about 1,000,000 ev. To show even the highest negative energy level, it would be necessary to extend fig. 3 about two miles below the bottom of the page. the intervening interval being void, and from there down to minus infinity the figure should be shaded to indicate a continuum. (By contrast it should be noted that the relativity fine structure, first revealed by the second member of the expansion [26] of [24], also cannot be shown in fig. 3, but for a different reason, as on the scale of fig. 3 the splitting would amount to only about a millionth of an inch.)

The states of negative energy are obviously supernumerary and superfluous if viewed in a conventional fashion, and to get a theory that has a meaning, they must somehow be stricken off the books. Dirac suggested that the negative states are to be regarded as filled, each having the one electron allowed by the Pauli exclusion principle. This idea, of course, mould not work with conventional Boltzmann statistics without the exclusion principle, as then there would be an overwhelming probability that the electrons be in states of negatively infinite energy. As there is a nondenumerable infinity of negative energy levels, there would be an infinite number of electrons housed in such states, even with the limitations imposed by the Pauli rule. Since the electron has a negative charge, there would hence be an infinite negative charge density. Dirac proposed that the charge is not to be counted in computing the charge density to be used in the Poisson law. etc.

According to this apparently fantastic conception, if an electron were somehow taken from one of the normally filled states of negative energy and placed in one of the conventional ones of positive energy. not only mould an electron be created, but also a particle of equal mass but positive charge, now called the positron. Namely, a deficit in the full complement of negative charge, carried, so to speak, at zero on the books, is equivalent to a corresponding surplus of positive charge. (Dirac suggested originally that the shortage might coi-respond to the proton, but this idea is now considered untenable as, for one thing, no explanation is given of the diversity of mass between electron and proton.) Fantasy turned to reality, however, when Anderson obtained cloud chamber photographs showing the existence of positrons; *i.e.*, particles equal to the electron in mass but positively charged. They should not be confused with protons, which are almost 2.000 times heavier. Unlike the protons, which are stable! positrons are extremely short-lived, as there is always the possibility that an electron will be captured out of a state of positive energy and fill the gap in the negative one. Raising of an electron from a negative to a positive level is equivalent to the creation of an electron and a positron, or in other words to "pair production." The minimum energy involved in such a transition is' very approximately $2mc^2$.

Hence, the absorption of gamma-rays can give rise to pair production if, and only if, their frequency exceeds $2mc^2/h$. In the experimental confirmation of this phenomenon, an apparent difficulty of the Dirac theory is turned into a triumph.

A positron and electron which are near each other move about their common centre of gravity in much the same fashion as do the electron and proton in the hydrogen atom but without the disproportionality in mass between the two constituents. The quasi-atom thus formed is called positronium and is highly ephemeral. The existence of positronium was definitely, though rather indirectly, confirmed in the experiments of Martin Deutsch in 1951.

By analogy with antielectrons (*i.e.*, positrons) one wonders whether antiprotons exist as well. Such particles, which have the same mass as the proton but a charge of opposite sign, and which can be regarded as holes in a continuum of positive charge, were first detected in 1955 by Owen Chamberlain, Emilio Segrè, Clyde E. Wiegand and Thomas Ypsilantis.

VII. QUANTUM ELECTRODYNAMICS

So far the impression has been given that the relativistic fine structure of hydrogen agreed with the Dirac theory within the limits of accuracy of the measurements. Beginning in 1934, however, there mas some indication that the separation between the two peaks of the H a doublet in hydrogen was smaller than predicted by theory. (Each peak of the doublet results from a number of unresolved components, and rather careful analysis is necessary to evaluate properly their combined effect.) Whether there was a real discrepancy was for a number of years a matter of controversy, but painstaking spectroscopic measurements by L. Giulotto and others in 1947–48 made it clear that the discrepancy was real.

At about the same time it occurred to a number of theoretical physicists that an explanation of the discrepancy was that there are corrections because of the interaction of the electron mith the electromagnetic field, which is represented in quantum mechanics by a series of quantized oscillators. This is a tricky subject, for the energy associated nith this interaction turns out to be infinite, a difficulty nhich had been appreciated since 1930 and which is known as the divergence in the self-energy of the electron. Nevertheless, by a proper system of bookkeeping, not without elements of arbitrariness and inconsistency, it is possible to compute the differences in the electrodynamic corrections for the various states of the hydrogen atom, and these turn out to be finite. The differential effects agree well with experiment. and so, despite its bothersome divergences, there is more physical reality in the quantum-mechanical formalism of the electromagnetic field than was realized before 1947.

Most of the experimental verification of the quantum electrodynamical theory is concerned aith the fine structure of the levels in hydrogen for which the principal quantum number has the value 2. Without the electrodynamical corrections, there are two such levels, given by (24), with $n = 2$ and $k = 1$; or $n = 2$ and $k = 2$. In the uncorrected theory the level $n = 2, k = 1$ actually consists of two coincident states, called $2^2S_{\frac{1}{2}}$, $2^2P_{\frac{1}{2}}$ in the terminology of the spectroscopists; while $n = 2, k = 2$ is designated as $2^2P_{\frac{3}{2}}$. (The subscript gives the value of J, and the letters S, P mean that the so-called azimuthal quantum number has respectively the values 0, 1). The electrodynamical corrections prove to be practically the same for the two P levels but differ for the S state. As a result the two coinciding levels $2^2S_{\frac{1}{2}}$, $2^2P_{\frac{1}{2}}$ are split apart, and $2^2S_{\frac{1}{2}}$ is displaced toward $2^2P_{\frac{3}{2}}$, a phenomenon known as the Lamb shift. This decomposition is too small to resolve by conventional optical experiments, but makes the apparent doublet width separating the $J = \frac{3}{2}$ state from the $J = \frac{1}{2}$ state smaller than the difference calculated from (24) with the choices $k = 1$ or $k = 2$. The discrepancy with the best optical measurements is thus explained.

Much more quantitative—in fact, spectacular—tests of the electrodynamic corrections have been made, however, with the microwave and molecular beam techniques, which make possible the direct observation of the small energy differences represented by the transitions $2^2S_{\frac{1}{2}} - 2^2P_{\frac{1}{2}}$ and $2^2S_{\frac{1}{2}} - 2^2P_{\frac{3}{2}}$. With ordinary optical measurements, where the wave length is of the order 0.0001 rather than 10 cm., these intervals can be observed only as small fine structures or modulations in the Balmer series. The microwave measurements require intricate and difficult detection techniques, which Willis E. Lamb, Jr.. and Robert C. Retherford successfully devised and instrumented in 1950.

The Lamb shift for hydrogen. $2^2S_{\frac{1}{2}} - 2^2P_{\frac{1}{2}}$, calculated from the electrodynamical corrections is 0.035264 cm.$^{-1}$ (1057.19 mc.), while Lamb's most recent experimental value is 0.035283. For deuterium (heavy hydrogen) the corresponding figures are 0.035307 and 0.035324. The large number of significant figures for such small energy differences reveals graphically the high precision of microwave and molecular beam spectroscopy. It is a particular triumph both of theory and experiment that there is such good accord (0.000043 *v.* 0.000041 cm.$^{-1}$) between the calculated and observed difference in the shift for hydrogen (H^1) and deuterium (H^2), obviously a delicate, high-order correction.

In 1947 Julian Schwinger showed that the electrodynamical corrections make the magnetic moment of the electron somewhat greater than the conventional expression $eh/4\pi Mc$. The most accurate theoretical value, inclusive of fourth-order electrodynamical corrections computed by Robert Karplus and Norman M. Kroll, introduces an extra factor 1.0011454. The molecular beam experiments of Polykarp Kusch and collaborators give 1.001146 ± 0.000012. The work of Lamb and Kusch in confirming quantum electrodynamics won them joint award of the Nobel prize for physics in 1955.

A field theory analogous with that of quantum electrodynamics is used to describe the properties of mesons. transient particles of intermediate mass used in the mechanics of the interior of the nucleus.

VIII. WHAT QUANTUM MECHANICS HAS ACCOMPLISHED

By way of summary, it is perhaps well to list some of the outstanding contributions which quantum mechanics has made to the understanding of atomic physics.

1. The old Bohr theory owes its success to quantum mechanics. The great triumph of the original Bohr version of quantum theory was its ability to explain the spectral frequencies of hydrogenic atoms; *i.e.*, hydrogen, ionized helium, etc. This is done equally well by wave mechanics—in fact, better in some respects.

2. Quantum mechanics has provided a procedure for calculating the intensities rather than merely the frequencies of spectral lines.

3. Qualitative explanation of the spectra of nonhydrogenic atoms is now possible. The reason that quantitative precision is usually not possible is simply that when there is more than one electron the wave equation becomes too complicated mathematically to solve exactly. In the particular case of the neutral helium atom, which involves a three-body problem, it is possible to calculate the energy levels very accurately after considerable labour. The computed energy of the ground state of the neutral helium atom agrees mith the observed energy to within 1 part in 10,000. This atom, on the other hand, was a stumbling block of the old Bohr theory.

4. Electron spin has played an important part in understanding of the phenomena of magnetism.

5. A quantum theory of the chemical bond has been formulated. Although chemical processes are so complicated that one cannot hope to calculate accurately from theory the heats of the reactions, still quantum mechanics does enable one to understand the salient features—why valence rules are as they are, why there should be saturated bonds, etc. The Pauli exclusion principle is the key to the interpretation. The spin quantum number of an atom is intimately connected with its valence. Atoms aith spins other than zero can be regarded as having unsaturated valences. The bonding is not due to any large magnetic coupling between the spins, and usually arises from the so-called exchange energy, which is electrostatic in character but which is correlated with spin alignment because of the constraints imposed by the Pauli exclusion principle. As a rule, the exchange energy is favourable to bonding when the spins are antiparallel. Besides codifying

valence numbers, quantum mechanics has furnished a qualitative understanding of the directional valence characteristic of stereochemistry. It has also introduced the concept of resonance energy in chemical bonds. Previously the molecule was thought of as having a fixed structure, but quantum mechanics shows that it can coexist in several states at once, and a lower energy is often obtained if a molecule resonates among a variety of configurations.

6. A quantum theory of the solid state has been formulated. Thanks to quantum mechanics. it can be explained in a general way how atoms are held together in solid bodies. Various properties of solids, such as compressibility, thermal and electrical conductivity, specific heat, etc., also can be explained. Because solids involve more complicated aggregates of atoms than do individual molecules, the difficulties in the way of a strictly rigorous numerical computation are even greater than for the calculation of chemical binding. Nevertheless, semiquantitative as well as qualitative predictions are sometimes possible.

7. Quantum mechanics provides the basis. for the interpretation of ionization potentials, capture phenomena and especially questions connected with the scattering of electrons or other particles (neutrons, protons, etc.) when they come near atoms or molecules.

8. Numerous phenomena associated with the interaction of radiation with matter were first adequately explained by quantum mechanics. Examples are the Compton effect or the photoelectric effect, and various questions connected with absorption and emission. By means of the so-called Kramers formula. a far more profound and realistic description of dispersion is provided than in classical theory.

9. Quantum mechanics provides an explanation of the existence of the positron and antiproton.

10. A quantum electrodynamics, describing many phenomena associated with radiation and with the coupling of electrons, has been formulated.

11. Finally, the philosophical implications of quantum mechanics must not be forgotten. The Heisenberg uncertainty principle, which shows that there is a limit to the precision with which nature can be observed, is particularly important in this respect.

See ATOM; NUCLEUS; RADIOACTIVITY, ARTIFICIAL; RADIOACTIVITY, NATURAL; SPECTROSCOPY; UNCERTAINTY PRINCIPLE, THE; *see* also Index references under "Quantum Mechanics" in the Index volume.

BIBLIOGRAPHY.—Relatively elementary: L. C. Pauling and E. B. Wilson, Jr., *Introduction to Quantum Mechanics With Applications to Chenistry* (1935); V. B. Rojansky, *Introductory Quuntum Mechanics* (1938); W. V. Houston, *Principles of Quantum Mechanics* (1951); D. Bohm, *Quantum Theory* (1951); F. Mandl, *Quantum Mechanics* (1954).

More advanced: P. A. M. Dirac, *The Principles of Quantum Mechanics*, 3rd ed. (1947); L. Schiff, *Quantunz Mechanics*, 2nd ed. (1955); E. C. Kemble, *The Fundamental Principles of Quantum Mechanics* (1937); J von Neumann, *The Mathematical Foundations of Quantum Mechanics*, Eng. trans. by R. T. Reyer (1955).

The following hooks are concerned with applications of quantum mechanics to particular fields: E. U. Condon and G. H. Shortley, *The Theory of Atomic Spectra* (1935); W. Kauzmann, *Quantum Chemistry* (1957); N. F. Mott and H. S. W. Massey, *The Theory of Atomic Collisions*, 2nd ed. (1949); C. Kittel, *Introduction to Solid State Physics*, 2nd ed. (1956); R. E. Peierls, *Quantum Theory of Solids* (1955); W. Heitler, *The Quantum Theory of Radiation*, 3rd ed. (1954); J. F. Jauch and F. Rohrlich, *The Theory of Photons and Electrons* (19.55). For a series of papers dealing with the experimental confirmation of quantum electrodynamics, and references on this subject, *see* the *Physical Review*, *89:92–115* (1953); N. F. Ramsey, *Molecular Beams*, ch. xii *(1956)*. (J. H. V. V.)

QUARANTINE AND ISOLATION. Quarantine is the complete or partial limitation of the freedom of movement of well persons or animals that have been exposed to a communicable disease; its purpose is to prevent further transmission of the disease Segregation of a sick person or carrier is also commonly called quarantine but is more properly designated isolation.

Venice in 1374 imposed nhat was probably the first quarantine by hanning travelers suspected of having been infected with bubonic plague. In 1377 the Adriatic port of Ragusa (modern Dubrovnik, Yugos.) required all travelers from plague districts to remain for a month at one of two designated points before entering the city. The first quarantine station was erected in 1383 in Marseilles, where all travelers from infected ships were detained for 40 days.

It is from this 40-day period of detention that the term quarantine is derived (It. *quaranta*, "forty").

The purpose of isolation is to prevent transmission of the infectious agent from the infected person or animal to a susceptible person by placing the person or animal under such conditions that the possibilities of transmission are minimized. Strict isolation of the patient for the period of communicability (which is determined by experience) is necessary in diseases such as smallpox. In other diseases, such as malaria, the patient need only be protected by screens from the mosquito vector. In still other diseases isolation is not utilized nowadays, either because the method of transmission is not fully understood or because it has been discovered that isolation of the few frank cases of the disease does not prevent further transmission from much larger numbers of mild, unrecognized cases.

Modified isolation may be carried on voluntarily by a person's remaining at home when he has a mild infectious disease such as a cold.

While isolation to be effective must be imposed until the end of the period of communicability, the exposed person or animal, called a contact, must not be permitted to expose healthy susceptible persons during the incubation period of the disease. The incubation periods of different diseases or of different cases of the same disease vary in length; but for purposes of quarantine the periods are considered to be the longest usual intervals between first exposure and development of the first signs of infection. Quarantine is often modified so that those contacts who are presumed to be immune because of their ages or histories may be permitted to go about their usual business. Quarantine also is being superseded to some extent by surveillance. the practice of close supervision of contacts so that they may be isolated at the first signs of illness without restricting their freedom prior to that.

Ships usually are no longer quarantined in the earlier manner; the word of the ship's physician is accepted that there are no cases of communicable disease on board. Rapid travel by air, however, has necessitated the institution of new types of quarantine. For example. travelers from an area in which yellow fever is prevalent may be required to remain in quarantine until the end of the incubation period; otherwise they may become sources of infection to the people in the country of their destination.

Quarantine and isolation may be voluntary or official; the latter is enforceable by the government. Official quarantine or isolation is not invoked so often as in the past because in some diseases there are so many unrecognized or missed cases that the identity of the majority of cases and contacts is unknown. When quarantine is employed, it usually is enforced to a greater degree against the more susceptible groups in the population or against those who may be dangerous to public health if they become infected; *e.g.*, schoolteachers or food handlers. More efficient methods of controlling communicable disease, such as vaccination (when available) or control of vehicles or vectors of disease, have to a great extent replaced isolation and quarantine.

See American Public Health Association, *Control of Communicable Diseases in Man*, 8th ed. (1955); H. R. Leavell and E. G. Clark (eds.), *Textbook of Preventive Medicine* (1953). (H. J. SY.)

QUARE IMPEDIT, in English law, a form of action by which the right of presentation to a benefice is tried. It is so called from the words of the writ formerly in use, which directed the sheriff to command the person disturbing the possession to permit the plaintiff to present a fit person, or to show cause "why he hinders" the plaintiff in his right.

QUARITCH, BERNARD (1819–1899), English bookseller and collector, born at Worbis, Ger., on April 23, 1819, went to London in 1842. In 1847 he started a bookseller's business off Leicester square and in 1860 moved to Piccadilly. About 1858 he began to purchase rare books. In 1873 he published the *Bibliotheca Xylographica, Typographica et Palaeographica*, a remarkable catalogue of early productions of the printing presses of all countries, and from time to time published a variety of other catalogues of old books. Quaritch developed the largest trade in old books in the world. He died at Hampstead on Dec. 17, 1899.

QUARLES, FRANCIS (1592–1644), English religious poet remembered for his *Emblemes and Hieroglyphikes,* the most notable emblem book in English. Born at Romford, Essex, he was baptized on May 8, 1592. He was educated "at schoole in the Countrey," at Cambridge, taking his degree from Christ's college in 1609, and at Lincoln's Inn, London. In 1618 he married Ursula Woodgate, and made his home in London. He had private means, and was happiest living in scholarly seclusion. He began his literary career with a series of lugubrious biblical paraphrases, the first, *A Feast for Wormes*, appearing in 1620. These were collected as *Divine Poems* (1630), his most substantial volume. About 1626 Quarles went to Ireland, where he became secretary to Archbishop Ussher. There he completed his first secular work, *Argalus and Parthenia* (1629), a heroic romance based on a story from Sir Philip Sidney's *Arcadia.* By 1633 he had settled in Essex.

With *Emblemes* (1635) Quarles produced a new type of emblem book. Most of the 79 plates for it, and some of his ideas, were borrowed (though he was a devoted member of the Church of England) from two Jesuit manuals. But his characteristic use of conventional material and the merit of his verse gave the emblem book its initial claim to serious consideration as literature. *Emblemes* was so successful that Quarles produced another emblem book, *Hieroglyphikes of the Life of Man* (1638). Printed together in 1639, *Emblemes and Hieroglyphikes* became the most popular book of verse of the 17th century.

The last years of Quarles's life were overshadowed by poverty. Probably for this reason he obtained the post of chronologer to London in 1640, and virtually abandoned poetry to employ his pen more lucratively. His first prose work, *Enchiridion* (1640), became the most popular book of aphorisms of its time.

Civil war found Quarles unhappily conscious of conflicting loyalties, yet a staunch Royalist. He is said to have suffered for his allegiance and for writing *The Loyall Convert* (1644). a pamphlet defending the king's position. Quarles died on Sept. 8, 1644 His wife, with 9 of 18 children who had been born to them. was left in want.

BIBLIOGRAPHY.—*Complete Works,* ed. by A. B. Grosart, 3 vol. (1880–81); *Threnodes* and *Hosanna* (omitted by Grosart), ed by J. Horden (1959); J. Horden, *Quarles: A Bibliography of His Works to the Year 1800* (1953). A primary biographical source is the memoir by Quarles's widow in his *Solomons Recantation* (1645). *See* also R. Freeman, *English Emblem Books* (1948). (JN. HN.)

QUARRYING, the art of obtaining stone from the earth's crust. Rocks that are quarried for commercial use fall into three great groups: igneous, sedimentary and metamorphic. Granite is the most important of the igneous type. The sedimentary rocks, the most important of which are limestones, sandstones and shales, are sometimes termed stratified because they have been deposited in successive layers. The third group, metamorphic, contains rocks of both igneous and sedimentary origin that have been changed by tremendous mountain-building forces.

There are two main products of the quarrying industries—dimension stone and crushed and broken stone. The term dimension stone is applied to blocks or slabs of natural stone that are cut to definite shapes and sizes. Crushed and broken stone includes irregular fragments produced by passing the stone through crushers or by grinding the rock to a fine powder.

Dimension Stone.—Although rock deposits are abundant, only in certain places have they the necessary qualities that make them suitable for use as dimension stone. Generally the rock must be uniform in grain size and coloration, and must have attractive colours. Most rock deposits are intersected by natural partings called joints. If the joints are closely spaced the rock is valueless. The most favourable deposits are those in which the joints are vertical, in two more or less parallel systems at right angles to each other and spaced four or more feet apart.

When a rock deposit is located the first step is to clear the surface of soil, gravel or other debris—a process known as stripping. After the surface of the rock has been cleared, the next step is to separate masses of rock from the parent ledge. It is important in quarrying dimension stone to avoid the use of powerful explosives that would shatter the rock and destroy its usefulness. Blocks must be removed with care to preserve their strength and weather resistance. The first operation is to make a cut or channel which will separate a block from the solid bed. For the softer rocks such as limestones and sandstones. the channeling machine generally is used. This has a cutting tool consisting of several chisel-edged steel bars clamped together. As the power-driven machine travels back and forth on a track it cuts a channel 2 to $2\frac{1}{2}$ in. wide and several feet deep.

In the harder rocks such as granites, channeling machines cannot be used. One method of making primary cuts in granite, and sometimes in marble and slate, is to drill a row of closely spaced holes to a depth of eight or ten feet, and to cut the webs or cores between them with a flat broaching tool, thus making a continuous channel. Another method is to use a wire saw. This consists of a three-strand or single-strand wire rope about $\frac{3}{16}$ in. in diameter which runs as a belt, and cuts by abrasion when fed with sand or other hard grains in water.

When the primary cuts have been made, if floor seams are absent, the mass of rock must be separated at the quarry floor. Horizontal holes may be drilled beneath the blocks, and the blocks then can be broken loose by driving wedges in the holes. The masses of rock thus set free may be very large. In limestone they may be 80 or 100 ft. long, 8 or 10 ft. high and 4 ft. wide. These large blocks are subdivided into smaller sizes generally by the plug and feather method. The blocks are marked out to desired sizes with square and straightedge. A man with a compressed-air hammer drill then sinks a row of shallow holes along the chalk line. Separation is made by wedging. The so-called feathers are strips of iron flat on one side for contact with the wedge, and curved on the other to fit the wall of the drill hole. The plug is a steel wedge which is driven between each pair of feathers. When the plugs are sledged lightly in succession the force generated is so great that the rock breaks. The separated blocks are conveyed to mills where they are sawed into slabs, shaped to desired dimensions or turned on lathes into columns. They are then rubbed or polished to give the desired surface finish.

The principal uses of dimension stone are for both exterior and interior building construction. Granites and marbles are also used extensively for memorials ranging from simple markers and headstones to elaborate mausoleums. Slate is used for roofing, stair treads. blackboards and many other applications. Sandstones are used as building stone and for abrasive wheels such as grindstones. Quartzites are used chiefly for flagging.

Crushed Stone.—Although the use of stone in fragmentary form is a comparatively recent development, the crushed stone industry has far outstripped the dimension stone industry in tonnage. The chief varieties of rock used are limestone, sandstone, granite and basalt (traprock). As the purpose is to obtain small fragments, explosives are used for shattering.

The first operation is to drill deep holes in rows. The churn drill or well drill is widely used to sink holes 6 in. or more in diameter and 50 or more feet deep. The distance of the row of holes from the quarry face is known as the burden; it is commonly 20 to 30 ft. The distance from one hole to another in the row is known as the spacing and is usually less than the burden. In large quarries a row of 15, 20 or more holes, and two or more rows may be drilled for a single blast. The size of the charge in each hole is calculated according to the toughness of the rock. When the explosive charge is in place the upper part of the hole is tamped with sand or rock dust. The charges are fired simultaneously and a single blast may throw down 20.000 or more tons of broken stone, which is then conveyed to the crushers where it is reduced to a maximum size of about six inches. The fines are separated by screening, and the larger sizes are reduced in smaller secondary crushers. Crushed stone is used chiefly for road building, concrete aggregate and railroad ballast. Limestone has special uses such as fluxing stone in blast furnaces and for many chemical applications.

BIBLIOGRAPHY.—Oliver Bowles, *The Stone Industries*, 2nd ed. (1939); A. R. Warnes, *Building Stones, Their Properties, Decay and Preservation (1926)*; *The Quarry Managers' Journal* (monthly); *Pit and Quarry* (monthly); *Rock Products* (monthly). (O. Bs.)

QUARTER DAYS, the days that begin each quarter of the year; in England, March 25 (Lady day), June 24 (Midsummer day), Sept. 29 (Michaelmas day) and Dec. 25 (Christmas day). They are the days on which it is usually contracted that rents should be paid and houses or lands entered upon or quitted. In Scotland there are two legal terms, May 15 (Whitsunday) and Nov. 11 (Martinmas); these, together with the two conventional terms, Feb. 2 (Candlemas) and Aug. 1 (Lammas), make up the Scottish quarter days. In the Scottish burghs, however, the removal terms are May 28 and Nov. 28. In the United States the quarter days are, in law, the 1st of January, April, July and October.

QUARTERMASTER. In the U.S. army this term denotes a member, usually a commissioned officer, of the quartermaster corps. This corps is responsible for the procurement and supply of food, clothing, fuel, and individual and housekeeping types of equipment (but not weapons), the collection and interment of war dead and the maintenance of national cemeteries.

The term quartermaster has a long history in European warfare, dating back at least to the 15th century. In general, quartermasters superintended arrangements for the quartering. and sometimes the subsistence and movement, of troops. In Europe. quartermaster officials on the staffs of higher commanders had evolved by the 18th century into something like the modern chief of staff, or chief of the general staff. In Great Britain and the United States, by contrast, the quartermaster remained a specialized administrative and logistical functionary. (See LOGISTICS.)

The U.S. army's quartermaster corps traces its beginnings back to June 1775, when the army itself was first established. From the beginning, the basic function of the quartermaster organization mas to help plan marches, lay out camps and provide the army's transportation. In 1812 the quartermaster department (as it was then called) acquired broad though ill-defined purchasing responsibilities that conflicted with those assigned to the commissary general of purchases.

By 1842, however, the quartermaster's department was procuring and distributing to the army all its noncombat supplies and equipment except food, which was the responsibility of the subsistence department. During the Civil War the quartermaster general was responsible for all the army's transportation, on water as well as land, and including all its animals with their forage and equipage. He was also responsible for providing clothing; for the operation of utilities at military camps; for military real estate and construction, except fortifications and railway bridges; for operation of military telegraphs; and for interment of war dead. His control of military railroads and military telegraphs was purely nominal, however, as both these services were operated as virtually independent agencies directly under the secretary of war.

On the eve of World War I the quartermaster corps (now so designated) absorbed the functions of the subsistence and pay departments. During the war, all supply and transportation functions were temporarily concentrated in the general staff, but under the National Defense act of 1920 the corps was re-established with most of its old responsibilities (except the pay function). World War II brought a significant reduction in the scope of these responsibilities through creation of a separate transportation corps and assignment of most types of military construction to the corps of engineers. By 1950 the quartermaster corps had thus become essentially a supply service, feeding, clothing' and fueling the army and providing much of its noncombat equipment. Under a broadening system of interservice pooling of logistical responsibilities, some of these functions were also performed for the navy and the air force.

The U.S. quartermaster corps has no exact counterpart in the British service. The royal army service corps (R.A.S.C.) stores and issues expendable noncombat supplies such as food, forage and fuel. The R.A.S.C. is also responsible for most transportation except that organic to units. The royal army ordnance corps stores and issues equipment, clothing, ammunition and explosives and certain motor vehicles. The civilian ministry of supply, rather than the military services, handles procurement of supplies. In British army staff organization, the quartermaster general's branch, or "Q" staff, has co-ordinating responsibility for supplying the material needs of troops and for all military movement (except operational, which is controlled by the "G" or general staff branch). Personnel administration is the responsibility of the adjutant general's branch, or "A" staff.

In the naval service, both American and British, quartermasters are petty officers or selected seamen who perform certain navigational and administrative duties under supervision of the captain, navigating officer or officer of the deck, including manning the wheel while at sea.

See Erna Risch, *The Quartermaster Corps: Organization, Supply, and Services*, vol. i (1953); Erna Risch and Chester L. Kieffer, *The Quartermaster Corps: Organization, Supply, and Services*, vol. ii (1955). (R. M. LN.)

QUARTER SESSIONS, COURT OF, in English law, the name for the justices of the peace of any county, riding, parts, division or liberty of a county, or of any county of a city or county of a town, in general or quarter sessions assembled; it includes the court of the recorder of a municipal borough having a separate court of quarter sessions. The word "general" in this context is contrasted with "special" or "petty." The court is a local court of record having a limited criminal jurisdiction, and also to some extent civil jurisdiction. As a court of record it has, in addition to its other jurisdiction, power to punish summarily without the assistance of a jury contempts committed in its presence, such as insults to the justices or disturbance of its proceedings. At the present time the whole of England and Wales is within the local jurisdiction of some court of quarter sessions.

The court derived its name from the direction in a statute of 1388 that the "justices shall keep their sessions in every quarter of the year at the least." By s. 22 of the Criminal Justice Act 1925, general quarter sessions for any county must be held at such times within the period of 21 days immediately preceding or immediately following March 25, June 24, Sept. 29 and Dec. 25 in every year as may be fixed. The justices are free to sit oftener by adjournment of the quarterly sessions to another time, and even to another place, in their county, or to hold additional sessions. All the sessions thus held are "general," though not all may be "quarter" sessions. The Assizes and Quarter Sessions Act 1908 gave the useful power of dispensing with the holding of quarter sessions if there is no business to transact, and under the Criminal Justice Act 1925 there' is power to dispense with the grand jury where all persons committed have pleaded guilty.

In all the counties, except that of London, the justices in the commission elect a chairman and vice-chairman, neither of them necessarily a lawyer, to preside at the sittings of the court. In the county of London there are a paid chairman and deputy chairman, who must be barristers of at least ten years' standing, and are appointed by the Crown. Under the Quarter Sessions Act 1858 the court may sit in two divisions of at least two justices at the same time and place, but not simultaneously in separate parts of the same county.

The jurisdiction of the court of quarter sessions of a borough does not depend upon the commission of the peace, but upon the Municipal Corporations Act 1882. Before the Municipal Corporations Act 1835, many boroughs had criminal jurisdiction under their charters. Under that Act and the Act of 1882 a grant of quarter sessions to a city or borough is made by the crown in council on petition of the town council. The recorder (*q.v.*), a barrister of not less than five years' standing appointed by the Crown, is sole judge of the court.

The city of London is not subject to the Municipal Corporations Act 1882, and its court of quarter sessions is created by the city charters, and is held before the mayor and aldermen with the recorder. It does not now sit to try indictments, which all go to the Central Criminal Court.

Criminal Jurisdiction.—Courts of quarter sessions in counties and boroughs have both original and appellate jurisdiction depending on the commission of the peace and on legislation beginning in 1344. This jurisdiction is derived in counties from the commission of the peace The jurisdiction of quarter sessions is governed chiefly by the Quarter Sessions Act 1842, and they are forbidden to try the following offences: treason or misprision of treason; murder, capital felony or any felony (except burglary) which is punishable on a first conviction by penal servitude for life; offences against the king's title, prerogative, person or government, or against either House of parliament; offences against the Official Secrets Acts 1911 and 1920; offences subject to the penalties of praemunire; blasphemy and offences against religion, and composing or publishing blasphemous, seditious or defamatory libels; and various other offences prohibited by statutes. But their jurisdiction has been extended by the Criminal Justice Act 1925 and certain offences under the Perjury and Forgery Acts and other statutes and the so-called "long firm" frauds are cognisable by quarter sessions Trials before the court with a jury are governed by the same procedure as trials on indictment in a court of assize. Under the Vagrancy Act 1823 and amending Acts, they have special powers of sentencing incorrigible rogues sent to them by courts of summary jurisdiction

An appeal lies to quarter sessions from convictions by a court of summary jurisdiction only where such an appeal is expressly given by statute. (See SUMMARY JURISDICTION)

Civil Jurisdiction.—By legislation in and since 1888 most of the administrative powers and duties of justices in general and quarter sessions have been transferred to the incorporated and elective councils of counties, boroughs and urban and rural districts. But the justices still possess certain original, civil or quasi-civil jurisdiction with respect to licensing and as to closing highways. Most of the civil jurisdiction of quarter sessions is now appellate, *i.e.*, with reference to orders made by justices.

Rating appeals, although they are still made to quarter sessions, are heard by a committee of the justices of the county appointed by such sessions (Rating and Valuation Act 1925). The procedure as to each form of appeal depends partly on the statute by which it is given and partly on the general provisions of the Summary Jurisdiction Acts. Decisions on law may be reviewed by the High Court (king's bench division) by means of *certiorari, mandamus* or prohibition. Convictions on indictment before courts of quarter sessions are within the provisions of the Criminal Appeal Act of 1907, except convictions on indictments for obstruction or non-repair of a public bridge, highway or river, from which an appeal lies to the court of appeal in the same way as in the case of civil actions tried at assizes. Persons dealt with as incorrigible rogues are also within the Act of 1907. Quarter sessions can state a case on a point of law on an appeal to them against a conviction by a court of summary jurisdiction, and if they decline to do so may be ordered to state a case by the High Court (Criminal Justice Act 1925).

(W. F. C.; W. DE B. H.)

United States.—There are one or two courts of quarter sessions in the United States but in general, courts of other names, differing in the various jurisdictions, perform its functions

QUARTER SQUARES. The product of two numbers is equal to the difference of one fourth the squares of their sum and their difference: $ab = \frac{1}{4}(a+b)^2 - \frac{1}{4}(a-b)^2$. This fact has been used to reduce multiplication to addition with the aid of tables of quarter squares, or using other methods of generating quarter squares. The quarter square of an odd number always has a fractional part $\frac{1}{4}$, which can be ignored in applying the formula. The method is very old and many tables of quarter squares have been prepared, but few are easily available. The most extensive table lists quarter squares of integers not exceeding 200,000. Various mechanical and electrical applications have been suggested. The method is still frequently useful and economical.

See J. Blater, *Tafel der Vzertel-Quadrate aller ganzen Zahlen von 1 bis 200,000* (1887). For reference to other tables *see* A. Fletcher, J C P. Miller, L. Rosenhead, *An Index of Mathematical Tables* (1946 and later) and mathematical review journals.

(C. B. To)

QUARTERSTAFF, a staff of wood from six to nine feet in length. used as a means of attack and defense; originally, no doubt, it was the cudgel or sapling with which many heroes are described by early writers as being armed. Egerton Castle (Schools and *Masters* of *Fence*) says that the staff was the "foil," or practice substitute for the long sword or two-hander. In earlier times it may also have been used as a practice weapon for the spear and bill. It was usually made of oak, the ends often shod with iron, and was held with both hands, the right hand grasping it one quarter of the distance from the lower end (whence the name) and the left at about the middle.

The quarterstaff attained great popularity in England in the middle ages, and was still in use in the 17th century.

(A. R. H.; X.)

QUARTON (CHARONTON, CHARRETON), **ENGUERRAND,** French religious painter, famous for his "Coronation of the Virgin," was born in the diocese of Laon and was active in Provence (1444–66). His real name was transformed in the south into Charreton or Charretier and in modern times, with no reason, into Charonton or Charenton He is one of the best-documented French medieval artists and details exist of six commissions for important paintings, two of which have survived: the "Virgin of Mercy" (1452, Chantilly), an altarpiece the predella of which, painted in collaboration with Pierre Villate, is missing; and the "Coronation of the Virgin" (1453–54, Hospice de Villeneuve-les-Avignons), the contract for which is one of the most complete and interesting documents on medieval art. showing that the composition was minutely prescribed. Both paintings reveal a very original style, partly northern (showing affinities with the tapestries of Arras and sculptures from Picardy) and partly southern (a sort of "Cubist," sharp, sculptural stylization of figures, folds and rocks). Exactly the same style is to be found in the famous "Avignon Pietà" (shortly before 1457? now in the Louvre), which is most probably the work of Quarton.

Quarton is in the first rank of French painters. He is full of imagination. creating very original types of Virgin and saints; his drawing is precise and graceful, his composition majestic and rich. Like Jean Fouquet. Quarton combines the grandeur of monumental decoration with the subtlety of book illumination.

BIBLIOGRAPHY.—Charles Jacques Sterling, *Le Couronnement de la Vièrge par E. Quarton* (1939), *Les Peintres du Moyen Age* (1941); Grete Ring, *A Century of French Painting, 1400–1500* (1949); Abbé Requin, *Documents inédits sur les peintres d'Avignon* (1889).

(C. SG.)

QUARTZ, a widely distributed mineral species, consisting of silicon dioxide, or silica (SiO_2). It is one of the commonest minerals and is found in many varieties and with very diverse modes of occurrence. The various forms of quartz have attracted attention from the earliest times, and the water-clear crystals were known to the Greeks as *crystallos,* "clear ice," being supposed by them to have been formed from water by the intense cold of the Alps; hence the name crystal, or more commonly rock crystal, applied to this variety. The name quartz is an old German word of uncertain origin. first used by Georg Agricola in 1530.

Following a description of the uses, occurrence and general properties of quartz this article deals with its crystallography, the varieties of quartz, electrical properties and optical properties and discusses the changes, known as inversions, quartz undergoes when heated.

Uses.—Quartz is a mineral of great economic importance. Many varieties are in popular use as gem stones, such as agate, amethyst, aventurine, bloodstone, cairngorm or smoky quartz, carnelian, chrysoprase, citrine, onyx (for cameos), rock crystal, rose quartz and tigereye (see also GEM). In localities where satisfactory material is available, sandstone, composed mainly of quartz, is an important building stone. Large amounts of sand are used in the manufacture of glass and porcelain. Sand is widely used for foundry molds for casting metals. Quartz is an abrasive, as in sandpaper, sandblasting, millstones and grindstones. Quartz brick is a high-grade refractory (see INVERSION, below) and quartz is used as a flux in smelting calcareous ores. Both quartz and silica glass transmit ultraviolet light and are used optically for this purpose. Because of the low coefficient of expansion and the refractory nature, tubing and various vessels of fused quartz have important laboratory applications: fibres are used in extremely sensitive weighing devices (see BALANCE: Ultramicrobalance). Thin plates cut from quartz crystals are used for frequency control in electronic communications equipment (see Electrical Properties, below).

Occurrence. — Quartz occurs as a primary and essential constituent of igneous rocks of acidic composition. such as granite, quartz porphyry and rhyolite. It is an abundant mineral in pegmatite~,sometimes making up the major part, and often being intergrown with feldspar (graphic granite). It is a common constituent in many gneisses and crystalline schists. By the weathering of silicates, silica passes into solution and is redeposited as quartz in cavities, crevices and along joints of rocks of all types.

Extensive veins of quartz are frequent in schistose rocks. Quartz veins, of economic importance as a matrix of gold, are probably related to igneous action. In mineral veins and lodes, quartz is often the most abundant gangue mineral. Quartz, being a mineral very resistant to weathering, forms the bulk of sands and sandstones, the latter being sand cemented with calcite, gypsum or hematite. A siliceous cement gives an orthoquartzite, while such a rock after being metamorphosed and recrystallized is called metaquartzite. Quartz occurs as pseudomorphs. replacing other minerals, and frequently is the petrifying material in petrified wood.

For ordinary uses, quartz is abundant and cheap. However, lack of adequate supplies of suitable crystals for electrical use has led to many attempts to grow synthetic quartz. Successful methods have been found. and good crystals, free from twinning, have been produced.

General Properties. — Quartz is a hardness standard, being 7 on Mohs' scale; it cannot be scratched with a knife. The specific gravity is 2 6j. There is no distinct cleavage, but plunging a heated crystal into cold water may develop planes of separation parallel to the rhombohedra1 and prism faces. A conchoidal fracture is characteristic of most varieties Coarse-grained varieties have a vitreous to greasy lustre; fine-grained varieties may be waxy or dull. The mineral is a nonconductor of electricity; it is not attacked by acids, except hydrofluoric, and is only slightly dissolved by solutions of caustic alkalies. It is infusible in the ordinary blowpipe flame. but will fuse in the oxyhydrogen flame to a clear colourless glass.

Crystallography. — Quartz crystallizes in the trigonal trapezohedral class of the hexagonal system. The crystals possess no planes or centre of symmetry, but only axes of symmetry. The vertical (c) axis is a threefold axis, and the three lateral (a) axes are twofold and polar; that is, the opposite ends are not alike. Usually, however, this lower degree of symmetry is not indicated by the face development of the crystals. Many crystals are bounded only by the faces of a hexagonal prism m $(10\bar{1}0)$ and what appears to be a hexagonal bipyramid (fig. 1), although sometimes the prism is absent (fig 2). Frequently the crystals are distorted (fig. 3), with similar faces varying in size but still having their proper angular positions. If the distortion is extreme,

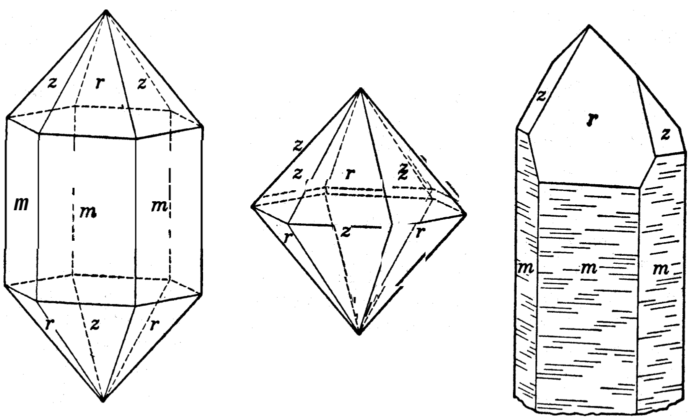


FIG 1, 2 AND 3 —QUARTZ CRYSTALS SHOWING RELATIONSHIPS OF FACES AND CHARACTERISTIC STRIATIONS

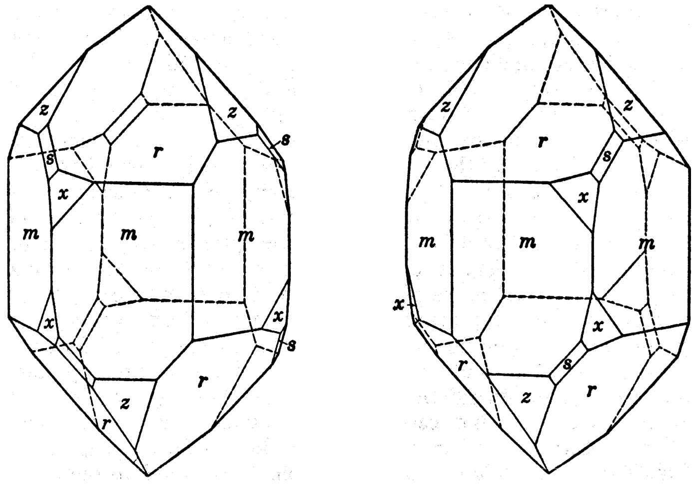


FIG. 4 AND 5.— LEFT-AND RIGHT-HANDED QUARTZ CRYSTALS ILLUSTRATING MIRROR IMAGE SYMMETRY

at first glance the crystals may be difficult to interpret, but they can usually be oriented by aid of the very characteristic horizontal striations on the prism faces. These striations (fig. 3) are parallel to the edges of intersection between the prism and terminal faces, and are due to the frequent oscillatory combination of these forms. The apparent hexagonal bipyramid is really a combination of two rhombohedrons, one positive, *r* $(10\bar{1}1)$, and the other negative, z $(01\bar{1}1)$. Although many exceptions occur, *z* is usually smaller than *r* (fig. 4 and 5) and sometimes completely absent. The six small faces *s* $(11\bar{2}1)$, situated on alternate-corners, are those of a trigonal bipyramid, while the faces *x* (5161) are those of a trigonal trapezohedron. The latter are of comparatively rare occurrence, except on crystals from a few localities. These *x* faces clearly distinguish between the two types of quartz crystals, left-handed (fig. 4) and right-handed (fig. 5). Such crystals are said to be enantiomorphous. They are not superposable, but one is the mirror reflection of the other, like the right and left hands. In some cases the *s* faces are striated parallel to their intersection with r; this serves to distinguish *r* and z, and thus show the right- or left-handed character when the *x* faces are missing. Numerous other faces have been observed on quartz, but they are of rare occurrence. The basal plane, so common on many crystals, is of the greatest rarity on quartz, and when present appears only as a small rough face formed by corrosion of the crystal. Natural etching, or artificial etching by hydrofluoric acid, produces etch figures, which are small pits or depressions of characteristic shape. As would be expected, the etch figures are different on the *r* and *z* faces, and on right-handed crystals the etch figures are reversed in position with respect to left-handed, thus clearly revealing the true symmetry and enantiomorphous character. This feature of the crystals is of course related to the internal grouping of the atoms, which actually consists of a spiral arrangement that may be either right- or left-handed.

Twin crystals of quartz are very common; in fact those without twinning are rare. The twinning may not be obvious unless the *s* or the *x* faces are present. Penetration twins are the commonest, with the prism planes of both individuals coinciding, and may be of two types. Dauphine or electrical twins consist of two right-handed or two left-handed crystals intergrown so that the *r* faces of one coincide with the z faces of the other, which brings the *x* and *s* faces on all six corners, both above and below. The contact between the two portions may be very irregular, or there may be a complicated patchwork of the two orientations. Brazil or optical twins are intimate intergrowths of right- and left-handed quartz, laminae or polygonal inclusions of one being enclosed within the other. These twins are readily detected by use of polarized light. Both types of twinning may be present in the same crystal. Dauphiné twinning is revealed by etching with hydrofluoric acid, and sometimes, probably as a result of natural etching, it is possible to trace the twin boundaries between duller *z* and brighter *r* areas in the same plane. In a rarer type in which the twin plane is $(11\bar{2}2)$, two individuals are united in juxtaposition with their vertical axes nearly at right angles (84° 33'). Such twins have been found in Isère, in the former province of Dauphine. France, and in Japan they are fairly abundant.

Varieties. — Quartz crystals have many interesting variations. They may show a skeletal development, or they may have a helical twist. They may have successive layers of growth. If transparent, the outlines of the inner layers may be faintly visible, giving a "phantom" crystal. In "cap" quartz, the successive layers may separate. "Sceptre" quartz has a short. thick crystal perched in parallel position on a longer slender crystal. Many crystals have cavities. usually filled with a liquid (water. carbon dioxide or a hydrocarbon) and containing a movable bubble of gas. Among the many varieties of quartz are amethyst, rose, milky and smoky quartz, which have characteristic colorations. In addition to the pink colour, properly cut rose quartz may show a star-shaped figure (asterism). Citrine is a yellow variety. Some types of quartz contain inclusions of other minerals, such as rutilated quartz, which has long needles of rutile. Aventurine contains glistening scales of mica, hematite or chlorite; moss agate has inclusions of manganese oxide or chlorite. Tigereye is a replacement of asbestos, and retains the fibrous structure; hence it has a beautiful chatoyant (cat's-eye) lustre when cut and polished. There are many fine-grained varieties of quartz. Chalcedony has a waxy lustre, and occurs in botryoidal and stalactitic forms. Agate and onyx are banded, being formed by the successive deposition of very thin layers. Many agates used for ornaments have been artificially coloured. Carnelian is red; chrysoprase and plasma are green; bloodstone is green with red spots. Basanite or touchstone is black. and was formerly used for testing precious alloys by means of the colour of the streak they left when rubbed on the stone. Jasper is impure, and coloured red, brown or yellow by iron oxide. Flint and chert are gray and occur as nodules in chalk and limestone. For particulars concerning the appearance, properties, occurrence, etc., of varieties of quartz *see* AGATE; AVENTURINE; BLOODSTONE (or heliotrope); CARNELIAN; CAT'S-EYE; CHERT AND FLINT; JASPER; MOCHA STONE (or moss agate); ONYX.

The reader is also referred to the listings under quartz and variety names in the index volume.

Electrical Properties. — Quartz is piezoelectric; that is, a crystal develops positive and negative charges on alternate prism edges when it is subjected to pressure or tension. The charges are proportional to the change in pressure. The pyroelectric effect supposedly observed on quartz is actually attributable to differential expansion during heating, hence is really a piezoelectric effect. This behaviour is related to the low symmetry, especially to the polar character of the lateral axes. Because of the piezoelectric property, a quartz plate can be used as a pressure gauge, as in depth-sounding apparatus. Moreover, if compression and tension produce opposite charges, the converse effect is that alternating opposite charges will cause alternating expansion and contraction. A section cut from a quartz crystal, with definite orientation and dimensions, has a natural frequency of this expansion and contraction (*i.e.,* vibration) which is very high.

Properly cut plates of quartz may have frequencies measured in millions of vibrations per second, and are used for frequency control in radio and other electronic communications equipment and for crystal-controlled clocks. Quartz plates for this purpose must be from portions of a crystal free from twinning (electronic grade); otherwise the vibrations would be in opposition in the two twin areas.

Optical Properties. — In its optical behaviour, quartz is also of interest, since it shows rotary polarization. This phenomenon is related to the enantiomorphous character of quartz. A ray of plane-polarized light traversing a right-handed crystal in the direction of the vertical axis has the plane of polarization rotated to the right, while a left-handed crystal rotates it to the left. A section one millimetre thick, cut perpendicular to the vertical axis of a quartz crystal, rotates the plane of yellow light (D line) through 22° and of blue light (G line) through 43°. Such a section when examined between crossed nicols with the petrographic microscope shows an interference figure with a coloured centre, there being no black cross inside the innermost ring (this is not shown in very thin sections). Superimposed sections of right- and left-handed quartz, as may be present in twinned crystals. exhibit interference figures with Airy spirals. The indexes of refraction of quartz for yellow light (D) are $o = 1.5442$ and $e = 1.5533$; the optic sign is therefore positive.

See also LIGHT: *Refraction and Double Refraction: Natural Optical Gyration.*

Inversion. — When heated, quartz undergoes a series of remarkable changes. At ordinary temperatures it exists as a-quartz, but at 573° C. it passes over into β-quartz, with a change from trigonal trapezohedral to hexagonal trapezohedral symmetry and an alteration in other properties. At 867° C. this β-quartz changes to β-tridymite, and again at 1,470° C. changes to β-cristobalite. These changes are known as inversions. The inversion from a- to β-quartz is reversible, so that quartz is always the a-form at ordinary temperatures. After β-tridymite or β-cristobalite are formed, they remain as tridymite or cristobalite, but upon cooling they invert to metastable a forms, which may exist for indefinitely long periods. Accordingly, all three α forms are found in nature. The six crystalline modifications have closely related structures, in which each silicon atom is surrounded tetrahedrally by four oxygen atoms. Adjacent tetrahedrons are linked by sharing of oxygen atoms, and the various modifications differ only in the arrangement of these linked tetrahedrons. 'The change from quartz to tridymite at the inversion temperature is very sluggish. This is of practical importance in the manufacture of silica refractory brick. The original quartz brick must be heated well above the inversion temperature if the inversion is to be completed in a reasonable time. This is necessary before the brick can be used in a furnace lining, since there is about a 15% increase in volume in the inversion from quartz to tridymite. Cristobalite, on the other hand, has nearly the same volume as tridymite, so that it does not matter which is present in the finished brick. For additional information on inversion *see* SILICA.

For discussion of crystallographic and mineralogical concepts used in this article *see* also MINERALOGY. (L. J. S.; L. S. RL.)

QUARTZITE is a sandstone which has been converted into a solid quartz rock. Unlike sandstones, quartzites are free from pores and have a smooth fracture; if struck with a hammer they break through the sand grains, whereas in sandstones the fracture passes through the cementing material and the rounded surfaces of the grains are exposed, giving the broken surface a rough and granular appearance. Conversion of sandstone to quartzite may be accomplished by precipitation of silica from interstitial waters (hydrous metamorphism) at no great depth and under ordinary pressures. In contrast with these rocks, termed orthoquartzites, those produced by recrystallization under high pressure and elevated temperatures are called metaquartzites.

In microscopic section the clastic structure of some quartzites is well preserved; the rounded sand grains are seer, with quartz overgrowths deposited in crystalline continuity so that the optical properties of the grains are similar to those of the material which surrounds them: a line of iron oxides or other impurities may indicate the boundary of the original sand grain. Many quartzites, however, have been crushed and the quartz consists in large part of a mosaic of small crystalline fragments of irregular shape with interlocking margins; these are the "sheared quartzites"; and if they contain white mica in parallel crystalline flakes they become more fissile and pass into quartz schists.

The term quartzite implies not only a high degree of induration or "welding" but also a high content of quartz. Rocks of like induration but containing appreciable quantities of other minerals and rock particles are impure quartzites, more appropriately called graywacke, etc. Most quartzites contain 90% or more of quartz, and in some the quartz content exceeds 99%. These constitute the largest and purest concentrations of silica in the earth's crust. Quartzites are snowy white. less often pink or gray; they commonly have a fine angular jointing and break up into rubbie under the action of frost. They yield a thin and very barren soil, and because they weather slowly tend to project as hills or as mountain masses. Many of the prominent ridges in the Appalachian mountains are the topographic expression of highly resistant tilted beds of Paleozoic quartzite. The Pre-Cambrian rocks of the Lake Huron and Lake Superior regions include thick and very pure quartzites. The Baraboo quartzite in Wisconsin is often deep red in colour. In Scotland. Schiehallion, Perthshire and the Paps of Jura form conspicuous conical mountains of quartzite in the Dalradian system of the highlands and Cambrian quartzites cap mountains in western Sutherland. The pure quartzites are a source of silica for metallurgical purposes and for the manufacture of silica brick. Quartzite is also quarried for paving blocks, riprap, road metal (crushed stone), railroad ballast and roofing granules. (F. J. P.; X.)

QUARTZ PORPHYRY, in petrology, a group of acidic igneous rocks that are porphyritic, that is, composed of larger crystals in a fine-grained groundmass. They contain visible crystals of quartz in a fine-grained matrix which is usually minutely crystalline in structure. In hand specimens the quartz appears as small, rounded, clear, grayish, vitreous blebs, which are crystals (double hexagonal pyramids) with their edges and corners rounded by resorption or corrosion. Under the microscope rounded enclosures of the groundmass or fluid cavities are often seen; these frequently have regular outlines resembling those of perfect quartz crystals and are known as negative crystals. Many of the quartz crystals contain liquid carbonic acid and a bubble of gas which may exhibit vibration under high magnifying powers. In addition to quartz there are usually prominent crystals (phenocrysts) of feldspar, mostly orthoclase, though a varying amount of plagioclase is often present. The feldspars are usually cloudy from the formation of secondary kaolin and muscovite throughout their substance; their crystals are larger than those of quartz and sometimes attain a length of two inches. It is not uncommon for scales of mica to be visible as hexagonal plates. Other porphyritic minerals are few, but hornblende (an amphibole), and augite and bronzite (pyroxenes) are sometimes found; the augite and hornblende are in most cases green, and are frequently decomposed into chlorite, but even then can usually be identified by their shape. A colourless rhombic pyroxene (enstatite or bronzite) occurs in a limited number of the rocks of this group and readily weathers to bastite. a variety of chlorite.

Apatite, magnetite and zircon, all in small but frequently perfect crystals, are almost universal minerals of the quartz porphyries.

Structure.—The groundmass is finely crystalline. To the unaided eye it usually appears dull, resembling common earthenware; it is gray, green. reddish or white. Often it is streaked or banded by fluxion during cooling but as a rule these rocks are not vesicular. Two main types may be recognized by means of the microscope—the felsitic and the microcrystalline. In the former the ingredients are so fine grained that even in the thinnest slices they cannot be identified under the microscope. Some of the rocks show perlitic or spherulitic structure; such were probably originally glassy (obsidians or pitchstones), but by lapse of time have slowly passed into a very finely crystalline state. This change is called devitrification; it is common in glasses, as these are essentially unstable. A large number of the finer quartz porphyries are also in some degree silicified or impregnated by quartz. chalcedony and opal. derived from the silica set free by decomposition (kaolinization) of the original feldspar. This redeposited silica forms veins and patches of indefinite shape or may bodily replace a considerable area of the rock by metasomatic substitution. The opal is amorphous, the chalcedony finely crystalline and often arranged in spherulitic growths which yield an excellent black cross in polarized light.

The microcrystalline groundmasses are those which can be resolved into their component minerals in thin slices by use of the microscope. They prove to consist essentially of quartz and feldspars, which are often in grains of quite irregular shape (microgranitic). In other cases these two minerals are in graphic intergrowth, often forming radiate growths of spherulites consisting of fibres of extreme slenderness; this type is known as granophyric. There is another group in which the matrix contains small rounded or shapeless patches of quartz in which many rectangular feldspars are embedded; this structure is called micropoikilitic (from the Greek for variegated or mottled), and though often primary is sometimes developed by secondary changes which involve the deposit of new quartz in the groundmass. As a whole those quartz porphyries which have microcrystalline groundmasses are rocks of intrusive origin.

Older Forms.—Many of the older quartz porphyries which occur in Paleozoic and Pre-Cambrian rocks have been affected by earth movements and have experienced crushing and shearing. In this way they become schistose, and from their feldspar minute plates of sericitic white mica are developed, giving the rock in some cases very much of the appearance of mica schists. If there have been no phenocrysts in the original rock, very perfect mica schists may be produced, which can hardly be distinguished from sedimentary schists, though chemically somewhat different on account of the larger amounts of alkalis which igneous rocks contain. When phenocrysts were present they often remain, though rounded and dragged apart while the matrix flows around them. The glassy or felsitic enclosures in the quartz are then very suggestive of an igneous origin for the rock. Such porphyry schists have been called porphyroids or porphyroid schists, and in North America the name aporhyolite has been used for them. They are well known in some parts of the Alps, Westphalia, Charnwood (England) and Pennsylvania. The *hälleflintas* of Sweden are also in part acid igneous rocks with a well-banded schistose or granulitic texture.

The quartz porphyries are distinguished from the rhyolites by being intrusive rocks.

See also PETROLOGY. (J. S. F.; X.)

QUASIMODO, SALVATORE (1901–), Italian poet who received the Nobel prize for literature in 1959. He was born at Modica Sicily, on Aug. 20, 1901, and had a technical education, which may explain the enthusiasm for technological progress of his later poems. After graduating in engineering at the Rome polytechnic. he spent ten years in different parts of Italy in the state engineering service's department of geometrical design, writing poetry in his spare time.

In 1935 he settled in Milan where he was appointed professor of Italian literature at the Conservatoire. Later he became dramatic critic for the Milan Tempo and a regular contributor to various reviews.

Quasirnodo published his first poems in the avant-garde review Solaria. In the 1930s he became a leader of the *ermetismo,* a school of poetry which derived from the French Symbolistes an experimental attitude to verse form and the theory that words should be used to convey unconscious associations of feeling and thought by being linked in unexpected arrangements. At first a disciple of G. Ungaretti and E. Montale (*qq.v.*), he soon developed a personal style with its own haunting music, introducing into the frigid and calculated skill of his technical innovations a human warmth and a consciousness of the mysterious power of man's ancestral hopes and fears. From Acque e terre ("Waters and Land," 1930) to La terra *impareggiabile* ("The Incomparable Earth," 1958) Quasimodo's poetry showed coherent development from a dry, sophisticated perfection of style to understanding of life and a commitment to contemporary struggles, expressed in his statement, "The ultimate conquest of poetry is reality." In his translations, notably Lirici Greci (1940), *Il fiore* delle Georgiche (1942) and La *Tempesta* (1952) he combined feeling for the original with modern taste and sensibility. (F. MI.)

QUASSIA, the generic name given by Linnaeus to a small tree of Surinam (Quassia amara), superseded for medical purposes in 1809 by the bitter wood or bitter ash of Jamaica, Picrasma excelsa, which has similar properties and can be obtained in larger pieces. Since that date this wood has continued in use in Great Britain under the name of quassia to the exclusion of the Surinam quassia, which, however, is still employed in France and Germany.

Picrasma excelsa is a tree 50 to 60 ft. in height, and resembles the common ash in appearance. It is found also in other West Indian islands. as Antigua and St. Vincent.

Quassia amara is a shrub or small tree belonging to the same family as *Picrasma,* namely, Simaroubaceae. but is readily distinguished by its large handsome red flowers arranged in terminal clusters. It is a native of Panamá, Venezuela, Guiana and northern Brazil.

Jamaica quassia is imported into England in logs several feet long and often nearly one foot thick. The wood is nearly white, has a pure bitter taste, and is without odour or aroma. It is usually met with as turnings or raspings, the former being obtained in the manufacture of the "bitter cups" which are made of this wood. The chief constituent is a bitter neutral principle known as quassin. It exists in the wood to the extent of about 0.1%. It forms crystalline needles soluble in alkalis, chloroform and 200 parts of water. There is also present a volatile oil. The wood contains no tannin, and for this reason quassia, like chiretta and calumba, may be prescribed with iron. The infusion is useful as a bitter tonic—a group of substances of which calumba is the type—and is also a very efficient anthelmintic for the threadworm (*Oxyuris vermicularis*). It is a substitute for hops.

QUATERNARY, in geology, is the latest chapter in the earth's history and comprises the time that has elapsed from the end of the Pliocene (*q.v.*) to the present day. It is the second division of the Cenozoic era (*q.v.*) as indicated in the accompanying geologic time chart but represents such a short time that some geologists hesitate to give it equal rank and regard it as merely a subdivision of the preceding Tertiary period. T o divisions of the Quaternary period are usually recognized: (1) the Pleistocene, the larger part; (2) and the Holocene or Recent, a short period following the Last Glaciation. For a brief history of the origin and application of the term *see* GEOLOGY: *Historical Geology: Paleontology and the Scale of Tzme.*

The Quaternary is characterized by wide climatic fluctuations. Compared with the Tertiary period. the climate was much colder: ice sheets developed in Scandinavia, on the higher mountain ranges of Europe and Asia and in North America. In the southern hemisphere the Antarctic ice, like that of Greenland, was larger and the Andes, Tasmania and New Zealand had important icecaps. Hence the term Ice Age or Glacial period is often used for the Pleistocene, though the Holocene, usually called "postglacial," may still be considered in the Ice Age.

The northern hemisphere probably had four separate ice advances; these ice advances comprise the major divisions of the Pleistocene. Elsewhere, Lower, Middle and Upper Pleistocene are paleontologically distinguished, though strict contemporaneity in different parts of the world has not been established. The Holocene is subdivided on the basis of its vegetational development (see *Vegetation,* below).

The beginning of the Quaternary is difficult to define since the transition from the last phase of the Tertiary (the Pliocene) was

Geologic Time Chart

System and Period	Series and Epoch	Distinctive Records of Liie	1,000 Yea:s
		CENOZOIC ERA	
Quaternary	Recent	Modern man	11
	Pleistocene	Early man	1,000
Tertiary	Pliocene	Large carnivores	
	Miocene	Whales, apes, grazing forms	
	Oligocene	Large browsing mammals	
	Eocene	Rise of flowering plants	
	Paleocene	First placental mammals	70,000
		MESOZOIC ERA	
Cretaceous		Extinction of dinosaurs	130,000
Jurassic		Dinosaurs' zenith, primitive birds, first small mammals	160,000
Triassic		Appearance of dinosaurs	200,000
		PALEOZOIC ERA	
Permian		Reptiles developed, conifers abundant	235,000
Carboniferous			
Upper (Pennsylvanian)		First reptiles, coal forests	260,000
Lower (Mississippian)		Sharks abundant	285,000
Devonian		Amphibians appeared, fishes abundant	320,000
Silurian		Earliest land plants and animals	350,000
Ordovician		First primitive fishes	400,000
Cambrian		Marine invertebrates	500,000
		PRE-CAMBRIAN TIME	
		Few fossils	3,500,000–4,000,000

in every respect gradual. Thus the gradation of animal life is imperceptible from the Late Pliocene into the Lower Pleistocene (Villafranchian). The onset of the First Glaciation is the event most widely accepted as marking the opening of the era.

This article deals with the stratigraphy and climate of the Pleistocene or glacial epoch of the Quaternary in Europe and Great Britain, the pluvial phases to the south of the glaciations and corresponding to them, the chronology, animal life and vegetation of the time up to the Recent or Holocene and briefly discusses the Quaternary as the age of man. For details of the glacial epoch in North America, its correlations with European and other regions and for a more detailed discussion of the extent and effects of glaciation, the glacial and interglacial ages and the life and climate of the epoch, *see* PLEISTOCENE EPOCH.

Stratigraphy.—A. Penck and E. Brückner in their classical work recognized four Alpine glaciations which they named in alphabetical and chronological order, Gunz, Mindel, Riss and Würm. The glaciations were separated by three mild interglacial epochs, Günz-Mindel, Mindel-Riss and Riss-Würm. Of these: the Mindel-Riss or Great Interglacial was the longest: it lasted almost half the total length of the Quaternary. Some geologists subdivide the glaciations: the first three into two and Würm into three phases, the phases being separated by minor mild phases called interstadials. While the interglacial epochs were warmer than the present—the Great Interglacial was warmer by about 2.5° C.—the interstadials remained cold.

A vast Scandinavian ice sheet radiated outward over the Netherlands, against the northern slopes of the Hartz and Sudeten mountains and over the plains of Russia to the Urals and down the valleys of the Don and Dnieper. In Germany three glaciations, Elster. Saale and R'eichsel, are recognized. A Warthe stage was intercalated between the Saale and Weichsel; whether it was a separate glaciation, a late phase of the Saale or an early phase of the Weichsel remains undecided. R'eichsel is equated with the Alpine Würm. Saale with the Riss and Elster with the Mindel. No northern European equivalent of the Alpine Gunz is definitely known, though Germany has indications of an Elbe or Baltic glaciation which preceded the Elster.

Britain was covered with ice as far south as the Bristol channel and the Thames valley; Ireland apparently was completely glaciated. In both countries the ice of the Last Glaciation (Newer drift) was much smaller in extent. The southern quarter of Ireland. parts of Wales, the Midlands, Derbyshire and Lincolnshire were also ice-free, though land ice in the North sea moved southward over Holderness to leave the Humber unobstructed. East Anglia, the classical region of the British Pleistocene, has the following succession: marine deposits called crags (see *Marine Animal Life,* below); North sea drift (Cromer till and Norwich brick earth); Great Chalky boulder clay; and Upper Chalky drift (with the Hunstanton boulder clay a product of the Warthe glaciation). The three intervening interglacial horizons are the Cromer forest bed; the Corton sands (Great Interglacial); Hoxne and other lake sites. Hoxne probably immediately preceded the Upper Chalky drift, though some writers place it in the Great Interglacial.

The North American ice sheet, unlike the ice masses of Europe, was mostly centred on low ground, namely, a Labrador centre east of and a Keewatin centre west of Hudson bay. Only in the west was the Cordilleran ice nurtured on high mountains. These coalescent ice sheets flowed northward to the Arctic ocean and southward across the Canadian boundary, extending as a group of vast lobes over the Great Lakes as far as St. Louis. As in Europe, four glaciations are usually distinguished, the Nebraskan. Kansan, Illinoian and Wisconsin. The Iowan, previously regarded as a separate glaciation or a late Illinoian phase, is now thought to have been the initial phase of the Wisconsin glaciation, corresponding perhaps to the European Warthe. The intervening interglacial~are the Aftonian, Yarmouth (Great Interglacial) and Sangamon.

The Alpine Würm, North European Weichsel and British Newer drift are almost certainly contemporaneous. The correlation of the earlier glaciations is less certain; they are usually bracketed as shown in the accompanying table (interglacials in italics).

Alps	North Germany	British Isles	North America
Würm	Weichsel	Newer drift	Wisconsin
Riss-Würm	*Eemian sea*	*Hoxne*	*Sangamon*
Riss	Saale	Great Chalky	Illinoian
Mindel-Riss	*Holstein sea*	*Corton sands*	*Yarmouth*
Mindel	Elster	North sea drift	Kansan
Günz-Mindel	*Mauer*	*Cromerian*	*Aftonian*
Günz	Elbe?	Later craes	Nebraskan

Climate. — At the beginning of the Quaternary, the climate of temperate Europe appears to have resembled that of the present day. Considerable cooling took place during the Early Glaciation, sufficient to exterminate many Pliocene types of mammals and to enable arctic species to spread southward. But on the whole, the effect of the first Quaternary Glaciation was slight and in the Antepenultimate Interglacial (that of the Cromer forest bed of East Anglia) decidedly temperate conditions prevailed again. The Antepenultimate Glaciation, however, was more intense and it caused a sharp break in animal life. In a broad zone surrounding the ice sheets (periglacial zone) the climate became cold and pronouncedly continental. Tundra and steppe prevailed; from northern France to southern Russia a broadening belt of loess (windblown dust) was deposited. Those Pliocene elements in the animal life that had survived into the Antepenultimate Interglacial died out. The following Penultimate or Great Interglacial was a prolonged period of temperate climate, at times apparently milder than the present (e g., *Rhododendron ponticum* in the Alps). The Penultimate Glaciation, being much the same size as the Antepenultimate, had similar effects on the environment. By this time, however, many animals had adapted themselves to the recurrent phases of rigid climate and they assumed a Pleistocene aspect, with ancestral mammoth, wooly rhinoceros, etc. Man had also adapted his economy to the cold and stayed in the periglacial zone. The Last Interglacial witnessed a repetition of the mild conditions of the Great Interglacial. Fossil soils, animal life and vegetation suggest higher summer temperatures and an absence of frost. The Last Glaciation, though smaller than the preceding two, appears to have had pronounced climatic effects. Its periglacial zone was slightly smaller than that of the two preceding glaciations, but many interglacial mammals which had survived into the Last Interglacial (*e.g.,* straight-tpsked elephant, Merck's rhinoceros) became extinct and a most characteristic arctic animal life reigned north of the Alps. A second break in animal life is thus observed in the Quaternary at the beginning of the Last Glaciation. Since the Last Glaciation the climate has returned to the temperate conditions of the present day, with fluctuations for which the vegetation provides evidence.

Pluvials.—In the countries around the Mediterranean basin, including north Africa from Morocco to Egypt, pluvial phases corresponded to the glaciations. The anticyclonic conditions reigning over northern Europe forced more cyclones onto a Mediterranean course than is now the case; lakes were deeper and more widespread; the higher mountains, *e.g.,* the Atlas, were clothed with ice; and the Mediterranean countries were covered with deciduous forests of the temperate type. Pluvial conditions occurred elsewhere on the polar side of the subtropical high pressure zones; e g., in North America (Great basin), Asia and in the southern hemisphere in the three southern continents. Pluvials and glaciations are generally thought to have been coeval.

Sea Level. — The formation of large ice sheets, especially in Europe and North America, resulted in the withdrawal of a large amount of water from the oceans. The sea level therefore was low during the glacial and high during the interglacial phases. These fluctuations of the sea level are called eustatic. Eviden'ce for low sea levels is provided by submerged terrestrial deposits (peats, etc.) and drowned river valleys; for high sea levels by traces of ancient shore lines (raised beaches) and terraces in the mouths of rivers. Raised beaches observed on coasts unaffected by tectonic movements or isostasy suggest two Pliocene phases: Calabrian and Sicilian, the latter about 80–100 m. above present sea level; and three interglacial phases: *Milazzian* (60 m.), Tyrrhenian (32 m.) and hlonastirian (18–7.5 m.). The fact that the order in time is one of successively lower levels shows that the eustatic fluctuations are superimposed on a general and persistent drop in sea level which continued from the Tertiary into the Quaternary.

The volume of the Scandinavian icecap of the Last Glaciation has been estimated at 5,000,000 cu.km.; that of the icecap of North America at 21,000.000 cu.km. These masses, by their weight, depressed the ground covered by them. When the ice disappeared and its load was removed, the earth's crust responded elastically by plastic deformation and subcrustal flow and the regions recovered from the depression. This phenomenon is called isostasy. The isostatic rise of Scandinavia was over 300 m. and because of isostatic lag is still taking place at a maximum rate of 1 m. per century. In North America, the uplift was about 1,000 ft. and is also still continuing and tipping the waters of the Great Lakes southward.

Chronology. — Quaternary chronology usually rests on the succession of climatic phases which provide convenient divisions: glaciations, pluviations and phases of high sea level are also used as outlined in the preceding paragraphs. In many parts of the world, however, paleoclimatic evidence is very incomplete and paleontological divisions based on mammals and marine mollusks are used instead. Where prehistoric implements are abundant, chronologies of a more or less local nature have been based on them.

Many attempts have been made to develop an absolute chronology of the Quaternary: several depend upon the time rates of erosion, sedimentation and soil formation. In the Alps, Penck arrived at 600.000 years for the Quaternary; other estimates extend the range to 1,000,000 or 2,000.000 years. A more elaborate time scale correlates the geologically established climatic phases with fluctuations of solar radiation caused by the perturbations of the earth's orbit. This method yields 600,000 years for the Quaternary, 190,000 for the Great Interglacial and 20.000 years for the interval since the Last Glaciation. This astronomical method, which may allow the dating of minor climatic phases, was conceived by J. Adhemar in 1842 and developed by the British scientists J. Croll and Sir Robert Ball in the second half of the 19th century. M. Milankovitch, from 1913 onward. undertook a recalculation of the astronomical tables. His theory, however. is not generally accepted and cannot be regarded as an explanation of the Ice Age as such.

Animal Life. — Terrestrial Animal Life. — The land animal assumed its modern character in the course of the Quaternary. This was due to three causes: (1) dying out of Tertiary elements; (2) appearance of new Pleistocene types; and (3) change of Pliocene forms into modern species by gradual evolution. It is noteworthy that in mammals, the lineages of which have been traced from the Villafranchian to the Holocene. the change in specific characters is slight; differences between Pliocene ancestors and Holocene descendants being no greater than differences between existing related species. In the Mollusca, which have been studied equally closely, these phylogenetic changes are even slighter and changes in the composition of the animals are chiefly the result of migration; *e.g.,* the fresh-water shell Corbicula in the Pleistocene of Britain, now from Egypt southward.

Characteristic mammals of the European Villafranchian are: monkeys (Macacus), a cheetah, sabre-tooth tiger, zebralike horses (Equus *stenonis*), Etruscan rhinoceros, tapir, primitive ox (*Leptobos*). mastodon, southern elephant; of the Lower Pleistocene: the same, except cheetah, tapir and Leptobos, but with red deer, elk (Alces), roe deer and a giant beaver (*Trogontherium*). Middle Pleistocene animal life is devoid of earlier exotic elements and new types appear which survive into the Upper Pleistocene. In the latter, the warm interglacial animal life and the cold glacial animal life have become more sharply separated. Interglacial species are the brown bear, beaver, Merck's rhinoceros, hippopotamus (west Europe), red deer, etc., straight-tusked elephant; glacial species are the arctic fox, varying hare, susliks (*Citellus*), lemmings, jerboa (loess steppe), true horses, wooly rhinoceros, reindeer, musk ox, mammoth, etc. Some of these became extinct before the Holocene began.

Marine Animal Life. — The marine animal life of the Quaternary shows slight evolution in the species, but there is evidence of much migration caused by climatic changes. The crags of East

Anglia, Lower Pleistocene beach deposits rich in shells, illustrate this point. In the Sicilian (Mediterranean deposits of the Günz glacial stage), temperate shells like *Cyprina islandica* and the common whelk extended to the Mediterranean. The Tyrrhenian and Monastirian animal life (collectively called Tyrrhenian by paleontologists) is generally warmer than the modern ones, with the west African *Strombus bubonius* in the Mediterranean and *Astralium rugosum* in the Channel Islands.

Vegetation. — The specific composition of the vegetation has changed much less than that of the animal life insofar as it is the result of phylogenetic evolution, though the shifting of vegetational zones in connection with climatic changes is a most characteristic phenomenon. With the growth of the ice sheets, the forest belts moved southward and tundra and cold steppe covered much of the periglacial zone. Each time the ice retreated, the vegetation belts moved northward again, producing a succession of plant associations which have been studied in peat deposits by means of pollen analysis, chiefly for the time since the Last Glaciation. The subdivisions of the Holocene make use of these changes in vegetation. Complicated divisions are now used in technical papers, but the classical scheme of Axel Blytt and R. Sernander may, with modifications; still serve in summarizing the major features: (a) Subarctic phase (to *c.* 8.000 B.C.), treeless, with *Dryas octopetala*, dwarf willows and birches, interrupted by the mild Allerod Oscillation, when Scotch pine and tree birches appeared temporarily; (b) Preboreal (8,000–7,000 B.C.), birch and pine immigrating; (c) Boreal (7,000–5.500 B.C.), with pine and birch dominating and alder, oak, lime and elm as subordinate, but increasing associates — later. hazel woods become prominent. climate continental; (d) Atlantic (5,500–2,000 B.C.), mixed oak forests culminate, hazel reduced to undergrowth, climate oceanic and in part warmer than at the present; (e) Subboreal (2.000–500 B.C.), climate begins to deteriorate, mixed oak forest retreats from the extreme limits reached, pine increases, but beech and hornbeam continue to spread north; (f) Subatlantic, mixed oak forest continues to retreat, beech culminates. present-day conditions.

Man. — The Quaternary is the age of man. Though it is now probable that man originated in the Tertiary, his skeletal and industrial remains are known from the Quaternary only. Pithecanthropus of Java and Sinanthropus of China are of Lower Pleistocene age. In the Middle Pleistocene, types like Smanscombe man (from the lower Thames) are regarded by some authorities as closer to modern *Homo sapiens* than Neanderthal man, who is characteristic of the lower division of the Upper Pleistocene. In Europe. *Homo sapiens* appears around the second phase of the Last Glaciation as an immigrant from the south and east.

The cultural evolution of man in Quaternary times is evidenced by his implements. mostly of stone. At the beginning of the Pleistocene, very primitive tools (the human origin oi which is debated) have been found in East Anglia. In the Antepenultimate Interglacial, the Chellian or Abbevillian hand-ax culture flourished and flake industries of the Clactonian variety appear. By Great Interglacial times. the Chellian had developed into the Acheulian which used the refined "wood technique" in manufacturing implements. The Clactonian persisted, but later the Levalloisian technique of making flakes from specially prepared cores marks another step forward in mental evolution. In the Last Interglacial, the Acheulian develops its final phase, the Micoquian; Levalloisian persists and from the fusion of these the Mousterian results, the culture of Neanderthal man par excellence. All these cultures are grouped together as Lower Palaeolithic. *Homo sapiens* brought with him the Upper Paleolithic culture of blade industries (Aurignacian, Gravettian. Solutrian. Magdalenian) which flourished during the Last Glaciation. When the Holocene began, man had reached the Mesolithic stage: many of his stone tools were now composite, being made up of numerous hafted, small microliths.

In temperate Europe, the Mesolithic was replaced by the Neolithic which introduced agriculture, about 5.000 B.C. *See* ARCHAEOLOGY; MAN, EVOLUTION OF; *see* also Index references under "Quaternary" in the Index volume.

BIBLIOGRAPHY.—E. Antevs, *The Last Glaciation* (1928); *M.* Boule, *Les Hommes fossiles,* 3rd ed. by H. Vallois (1946) ; J. K. Charlesworth, *The Quaternary Era, 2* vol. (1957) ; R. A. Daly, *The Changing World of the Ice Age* (1934) ; G. Dubois, "Recherches sur les terrains quaternaires du Sord de la France," *Mém. Soc. Géol. Nord,* viii (1924) ; R. F. Flint, *Glacial Geology and the Pleistocene Epoch* (1917) ; *H.* Godwin, *The History of the British Flora* (1956) ; *S.* A. Huzayyin, "The Place of Egypt in Prehistory," *Mém. Inst. Egypt. (Égypte),* xliii (1941) ; R. von Klebelsberg, *Handbuch der Gletscherkunde und Glazialgeologie,* 2 vol. (1948–49) ; L. S. B. Leakey, *Stone Age Africa* (1936) ; *R.* C. Moore, "The Quaternary Period," *Historical Geology* (1933) ; T. T. Paterson. "Studies on the Ice Age in India and Associated Human Cultures," *Publ. Carneg. Instn.*, 493 (1939) ; A. Penck and E. Bruckner, *Die Alpen im Eiszeitalter,* 3 vol. (1909) ; P. Teilhard de Chardin, *Early Man in China* (1941) ; *H.* de Terra, "Pleistocene Geology and Early Man in Java," *Trans. Amer. Phil. Soc. Phila.,* (n.s.) 32 (1943) ; P. Woldstedt, *Norddeutschland und angrenzende Gebiete im Eiszeitalter* (1950), *Das Eiszeitalter,* 2nd ed. (1954) ; W. B. Wright, *The Quaternary Ice Age,* 2nd ed. (1937) ; F. E. Zeuner, *The Pleistocene Period* (1945), *Dating the Past,* 4th ed. (1958). (F. E. Z.; J. K. C.)

QUATERNIONS, a linear algebra consisting of four-dimensional vectors nhose coordinates are any real numbers. The theory of this algebra was discovered by Sir William Rowan Hamilton in 1843 while he was trying, by analogy with the complex number representation of real two-dimensional vectors, to represent space vectors by the elements of a number system. For the definition of the algebra of quaternions and its place in the theory of algebras, *see* ALGEBRAS (LINEAR). Quaternions were intensively studied during the early part of the 20th century before the general theory of linear algebras came into being. Later, they were usually thought of as a special case of such algebras. Their early importance lay in applications to geometry and mathematical physics. These applications later became a part of vector theory. *See* also VECTOR *ANALYSIS*. (A. A. AT.)

QUATORZAIN, the term used in English literature. as opposed to "sonnet," for a poem in 14 rhymed iambic lines closing (as the Italian sonnet never does) with a couplet. The distinction was long neglected, because the English poets of the 16th century had failed to apprehend the true form of the sonnet. and called Petrarch's and other Italian poets' sonnets quatorzains, and their own incorrect quatorzains sonnets. Almost all the so-called sonnets of the Elizabethan cycles, including those of William Shakespeare, Sir Philip Sidney, Edmund Spenser and Samuel Daniel, are really quatorzains. They consist of three quatrains of alternate rhyme, not repeated in the successive quatrains. and the whole closes with a couplet. *See* SONNET. (G. W. A.)

QUATRAIN, sometimes spelled quartain, a piece of verse complete in four rhymed lines. The length or measure of the line is immaterial. This form has always been popular for use in the composition of epigrams, and may be considered as a modification of the Greek or Latin epigram. The commonest in English poetry is the ballad stanza, an outgrowth of the church hymn, in iambic metre rhyming *abcb*, with alternating four and three stresses to the line. Tennyson in "In Memoriam" used an iambic stanza rhyming *abba*. Though he did not invent it, it is often called the "In Memoriam" stanza. (G. W. A.)

QUAY, MATTHEW STANLEY (1833–1904), U.S. politician, was born in Dillsburg. Pa., on Sept. 30. 1833. His father was Anderson Beaton Quay, a Presbyterian minister. In 1850 Quay was graduated from Jefferson college, at Canonsburg, Pa., which later became Washington and Jefferson college. He was admitted to the bar in 1854. During the Civil War he served as colonel of the 134th Pennsylvania infantry, Aug.–Dec. 1862, and was Gov. Andrew G. Curtin's military secretary, 1863–65. Quay was awarded the congressional medal of honor for his war services.

Quay was a member of the state house of representatives, 1865–67, and was onner and editor of the *Beaver Radical,* 1867–72. He then became secretary of the commonwealth, holding that office until 1878. when he took the newly created position of recorder of Philadelphia. He nas also chairman of the Republican state committee. Resigning as recorder, he was again secretary of the commonwealth, 1879–82. After retiring from public office for a brief period. he served as state treasurer, 1886–87. In 1888. as chairman of the Republican national executive campaign committee, Quay managed the successful presidential campaign for Benjamin Harrison. Quay later broke with Harrison and did not actively participate in the campaign of 1892, in which Harrison was defeated by the Democratic candidate. Grover Cleveland. Quay was a United States senator from Pennsylvania, 1887–89 and 1901–04.

For nearly 20 years he dominated the government of Pennsylvania and also played a prominent part in national affairs. Quay died May *28,* 1904.

QUEBEC. The northeastern mainland province of Canada. bounded on the southwest and west by part of Ontario. James bay and Hudson bay, on the north by Hudson strait and Ungava bay. on the east by the coast of Labrador and the Gulf of St. Lawrence, on the south by the Bay of Chaleur, New Brunswick, Maine, New Hampshire. Vermont, New York and part of Ontario. Its greatest extent is from the U.S. border, about 45° N., to Cape Wolstenholme, about *62" 30'* N., and from Hudson bay, at a point about 79° *30'* W., to Anse Sablon, about *jj°* W. The total area is *594,860*sq mi., or about one-sixth the total area of Canada. The area includes 71,000 sq.mi. of fresh water.

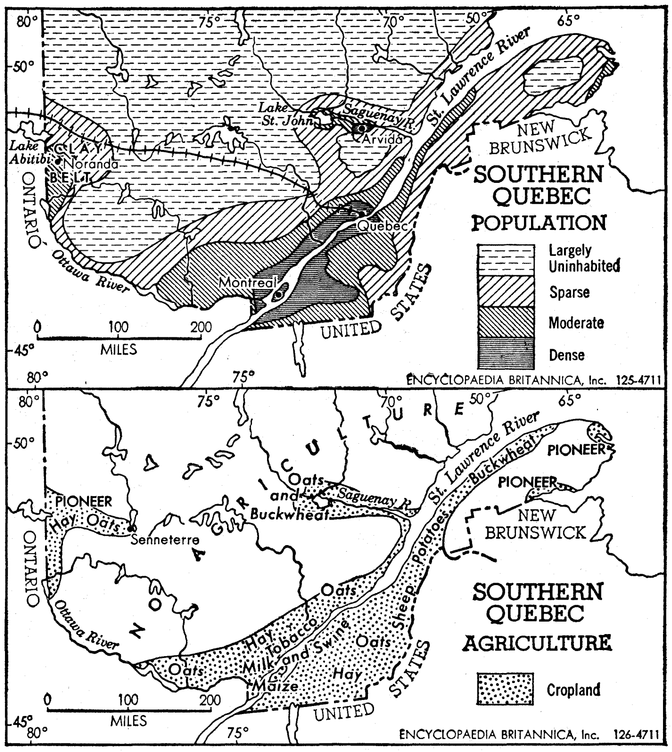
Climate. — The wide spread of latitude and the considerable distance from the Atlantic to the western parts of Quebec produce marked continental characteristics in the climate. In the centre of northern Quebec the range of temperature probably is as much as 70° F.; but along the St. Lawrence river near Montreal the range (between January and July) is about 57° F. (*i.e.,* from 13° to 70° F.). In July the isotherm of 57° F.—which determines the northern limit of the growth of crops—runs west-east through James bay. Hence it is the poor quality of the soils in southern Quebec rather than the temperatures which limits the northern extension of agriculture.

The outstanding feature of the climate is of course the constant passage of low-pressure eddies (cyclones) along the St. Lawrence. This results in an almost uniform type of rainfall in the southern part of the province, since these cyclones are the rain bringers in this part of the world. The weather, however, is quite variable, since the front of such a cyclone gives warm moist winds from the south, while the rear is accompanied by cold dry uinds from the north. The annual rainfall increases fairly regularly from 15 in. in the north to more than *40* in. on the southern boundary of the province.

The snowfall in the high plateau behind Quebec (in the vicinity of the Laurentides provincial park) is perhaps the highest in the continent. and usually exceeds *120* in. in winter. This in part accounts for the popularity of skiing in this part of Canada.

Physiography and Geology.—Physiographical studies divide the province into three main regions: Canadian shield, St. Lawrence and Appalachian. More than 90% of Quebec is built up of the Pre-Cambrian rocks of the shield. In general these consist of various forms of granite and gneiss, of which most perhaps belong to the Algoman formation. There are, however, large areas of altered sediments and of ancient lavas and ash beds; so that there is plenty of variety among the rocks of the shield. The shield exhibits an undulating surface or peneplain, possibly dating back to a period of 500,000,000 years ago. This peneplain surface is by no means near sea level, for large areas of it in Quebec province at the head of Moisie river are more than 2,000 ft. above the sea. It is clear that quite late elevation en masse affected a considerable area of the shield. One of the highest points reaches 3,900 ft. and is only about 50 mi. N.E. of the city of Quebec. Covering this extremely ancient peneplain surface is a layer of glacial till, spread in a haphazard fashion all over the shield. This deposit was only laid down in the last phases of the Ice Age, about *30,000*years ago. Hence we find in this part of Canada a curious association of an extremely old surface of rock covered by a thin veneer of the youngest deposit of all. So comparatively recent has been the deposition of the till that the rivers have not developed a regular drainage pattern. An infinite number of small lakes fills the hollows in the till, river divides are very low, and as a result the topography lends itself well to widespread canoe travel.

The most remarkable of the river valleys is that of the Saguenay which, after a swift descent from the Lake St. John reservoir, falls into a vast chasm running from west to east, in places almost 2,000 ft. above and *300* fathoms below sea level. Hundreds of rivers,



ABOVE: POPULATION. WITH TWO SMALL EXCEPTIONS. THE AREAS OF DENSE AND MODERATE SETTLEMENT ARE ALONG THE ST. LAWRENCE RIVER ON THE FLOOR OF THE FORMER CHAMPLAIN SEA. BELOW: AGRICULTURE. AREAS OF PRODUCTLON ARE CONCENTRATED IN THE ST. LAWRENCE LOWLAND AWAY FROM THE INFERTILE CANADIAN SHIELD

large and small! flow southward and northwestward ensuring to Quebec a huge potential water power which, with the forests covering the hills and valleys, preserving and preserved by this water supply, constitute an enormous reservoir of resources.

One subregion, Abitibi, on both sides of the Canadian National main line and reaching the Ontario border, is heavily mineralized; both Abitibi and the level region surrounding Lake St. John have soils suitable for cultivation, the former largely clay covered by other soils of varying nature, the latter also clay with a lighter topsoil. The rest of the area has a light moraine soil supporting both softwood and hardwood forests but not otherwise fertile.

The St. Lawrence region seems to be separated from the shield by a major fault and includes: *(1)* an area divided by the river, narrowing from about 60 mi. breadth at Montreal to about 20 mi. breadth at Quebec; *(2)* an area on the south side of the river only, stretching about *300* mi. N.E. from Quebec and *6* to 10 mi. in depth. This region has been divided into three subregions, the Montreal plain, the St. Lawrence valley between Montreal and Quebec and the south shore (Cote Sud) below Quebec. The Montreal plain is low, 250 ft. or less above sea level. The surface slopes evenly and very slowly down to the river on both sides and also downward from northeast to southwest; *i.e.,* against the direction of the river. The basement is of Ordovician rock broken near Montreal by the Monteregian hills, remnants of considerable volcanic mountains now almost completely eroded.

After the ice cap vanished, the sea temporarily invaded the lowlands forming the Champlain sea. The soil consists of clay and sand from the Champlain sea with more recent deposits: and is in most places good, although large parts have become sour. Considerable areas are covered by newly formed peat.s The St. Lawrence valley basement is likewise Ordovician rock; a mixed soil lies on a clay bed, much deeper on the south than on the north shore. The south shore is comparatively level, ba ed on Ordovician rock with many outcrops. The soil is mainly sandy, although there are considera'ble areas of black vegetable deposit, in one section already turned to peat, and is strewn with glacial boulders.

The rest of the province constitutes the Appalachian region, mainly Ordovician with lesser amounts of Cambrian and Devonian dotted with granite. and serpentine hills, well weathered and largely tree-clad, rising in the south of the region to about 3,000 ft. Logan's fault separates the folded rocks of the Appalachian region from the less disturbed area near the St. Lawrence. The Gaspé peninsula in the east has a central axis of Devonian rocks, and rises steeply from the north coast, ending in a high, narrow and precipitous promontory (Cape Gaspé). On the north side are the Shickshock mountains, much folded and faulted. On the south side is another range, with red sandstone and conglomerate along the western end of the Bay of Chaleur. At the east end of the south shore of the peninsula is a much eroded shore line of rocks filled with fossil shells from uhich a one-time peninsula, Perct! rock, has comparatively recently been cut.

History. — Prior to its cession to Britain most of the present province of Quebec and also a vast ill-defined area stretching from the far west to the Alleghenies and from the Great Lakes to the Gulf of Mexico. as well as the French territories on the North Atlantic, were subject to the crown of France under the name of New France; the district in the St. Lawrence and watershed area was called Canada. Government was held closely in the hands of the crown at Paris; the governor, advised by a "sovereign council," had some powers of initiative but he was called to task if he overstepped and was rivalled by the bishop. His chief financial adviser, the intendant, was responsible to Paris for economic control. Except for elections of churchwardens, very few official traces of democratic government existed. "Canada" was by 1750 the home of about 65,000 French Canadians, descendants of settlers who had been arriving during a century and a half. They had a quasi-manorial system of land tenure: seigneurs received grants of about six miles' frontage and generally greater depth on the St. Lawrence and like areas in the interior. These were parcelled out to habitants who paid annual dues, mostly in kind, to the seigneur as well as making special payments on transfers of property. Some traces of the system were still visible at mid-20th century. There were about 15,000 bourgeois in Quebec, Montreal and Trois-Rivières where the seigneurial system also existed There was a complete system of land registration and a notarial system for land transfers, marriage contracts, gifts, etc., which were unchanged at the cession and which, modernized, remained at mid-20th century. Births, marriages and deaths were recorded in the church of one or both of the persons concerned. These French Canadians who had become completely differentiated from the French (now mainly officials and soldiers), calling themselves "Canadiens" and not French. attributed vast importance to all theie customs, to the civil law and to their religion.

After the victory of James Wolfe at Quebec, a British military government carried on satisfactorily, making no important changes. By the treaty of Paris, Feb. 10, 1763, New France passed formally to Britain. This treaty followed in one respect the terms of the capitulation of Quebec in 1759, which had provided *inter alia* that the French Canadians were to retain their houses, goods, effects and privileges and that the Catholic Church was to be preserved. The treaty also provided for the maintenance of the Catholic Church but subject to the laws of Britain (under which Catholics were debarred from almost all offices). The "privileges" of the capitulation, taken as meaning French civil law and customs. were maintained, but English law was to be followed so far as compatible with them. This to most judges meant that the common law of Britain prevailed and as no French Canadians knew what that law was there was great confusion.

The province of Quebec as a governmental and geographical entity first appeared under the name of the Government of Quebec in a proclamation made by the crown of Great Britain (in virtue of the somewhat dubious royal prerogative right to legislate for newly conquered territory) on Oct. 7, 1763. This proclamation reached Quebec Aug. 10, 1764. The "Government" included the St. Lawrence valley, except for what is now the Ontario section, and the Ottawa valley, bounded on the north by a line from Lake Nipissing to Lake St John. The governor and captain general was authorized to. and did, set up a council to make laws and ordinances replacing the sovereign council. The governor in council was also authorized to. but did not, set up a popular assembly. The confusion as to law and religion resulting from the proclamation, as well as the wish of the British government to curb the American settlers to the south, brought about the Quebec act of 1774 which set up the "Province of Quebec" including most of the area now in the United States west of the Alleghenies. This act guaranteed the maintenance of French civil law and customs and freedom of worship. An executive and a legislative council, both nominated by the crown, were created and both continued in existence, although the executive council, under the same name. became a provincial cabinet.

The French Canadians were used to bureaucracy and were well enough pleased with the Quebec act to fight the invading Americans in 1775, and not at all concerned when the treaty of Paris in 1783 set the southern boundary west of the Quebec-Maine mountains back to the 45th parallel. In 1791, by the Constitutional act (enacted June 10, 1790), a government was set up for "Upper Canada" west of the Ottawa (except for a small triangle at the junction of the Ottawa and St. Lawrence) and "Lower Canada" extended by the act over the Magdalen Islands. Anticosti and Quebec Labrador. The act provided for Lower Canada an appointive legislative council (15) and an elective assembly (50).

The appointive council was at first all-powerful and there were many abuses of power, but there was little complaint until after the War of 1812, in which the French Canadians again fought and, in Lower Canada, defeated the Americans. The revolutionary ideas inspired liberals (French- and English-speaking) in the assembly; the struggle for responsible government and judges independent of the government which ensued culminated in the "rebellion" of the *patriotes* in 1837.

The Union act (July 23, 1840) became law on July 23, 1841, uniting Lower and Upper Canada as Canada East and Canada West, with one council and one assembly in which the two sections had equal numbers, the French language being for the first time recognized although only for debate.

After a conflict with the governor responsible government, in the modern sense, came into effect in 1841. The union nas never much more than nominal, since the practice was to require a majority of the representatives from each section to pass any act while many acts referred to one section alone. The powers of self-government vested in the colonial parliament gradually increased, judicial reform was obtained, the French language was accepted for all purposes in 1849. In 1867, at confederation, the province of Quebec reappeared with its own lieutenant governor, legislative council and assembly. French-Canadian control of Quebec was assured but the rights of the powerful and rich English-speaking minority were carefully safeguarded, particularly their control over their own education. At mid-20th century they constituted only about 15% of the population, but the growing French-Canadian majority had scrupulously regarded its obligations.

The boundary of Quebec on the north at confederation was the height of land north of the St. Lawrence valley. This was extended to the Eastmain and Hamilton rivers in 1898 and to Hudson strait in 1912. The boundary between Quebec and Labrador (as an adjunct of Newfoundland) was decided by the Labrador act (1825). The boundary was placed as a line due north from Anse Sablon, and for more than a century Newfoundland was presumed to have jurisdiction only over the coastal strip of Labrador, not over the interior (practically unknown). Exploration and the prospect of development raised dispute as to the boundary and in 1927 a decision of the privy council awarded to Newfoundland all of interior Labrador draining to the Atlantic (112,000 sq mi.). The period after confederation left the government of Quebec practically unchanged; parliamentary procedure and democratic practice follow British precedent even more than that of most other provinces, but the French-Canadian majority is quite firmly in the saddle. Quebec is a French-speaking island in North America owing allegiance to a queen who for it (and perhaps correctly) is queen of Canada, interpreting the Atlantic charter as confirming its right to its own religion, laws and language.

Population.- he 1961 census was 5,259.211, mostly French-

Canadians. English-speaking people were mainly centred in the larger cities, in Pontiac and Abitibi counties, where there were many new Canadians, the Saguenay'and St. Maurice industrial areas, Gaspe and the eastern townships north of the New Hampshire and Vermont border.

Government. — The queen is represented by the lieutenant governor: appointed for a renewable term of years by the governor general in council. The legislative council at mid-20th century had 24 members-, each sitting for a geographical district, appointed for life by the lieutenant governor in council (Quebec is the only peovihce with such a body). The legislative assembly had 95 members! each elected for a constituency. Rural constituencies are larger but far less populous than urban. The distribution of powers between the three'sections is identical with that between queen, lords and commons in Britain, the assembly having complete control of taxation and finance. Treasury bills issued under orders-in-council must be covered by appropriate votes. All private and some public bills are discussed in and reported by appropriate committee sessions at which persons affected may appear personally or by legal representative before passage. Otherwise the formalities duplicate those of the parliament at Westminster. The premier leads in the assembly, and a leader named by the government, generally also a minister without portfolio: in the council. The executive council is the provincial cabinet; its members must, as a rule! hold seats in the assembly, thus ensuring maintenance of the representative principle. Members are premier, provincial treasurer, provincial secretary, attorney general. ministers of roads. public works, colonization, agriculture, game and fisheries, lands and forests, trade and commerce, municipal affairs, health, labour, mines, social welfare and youth, each of whom has one or more deputies while the premier has a chef *du* cabinet ranking as a deputy minister. There are generally a number of ministers without portfolio, of whom the leader of the council is generally one. Elections are governed by the Provincial Elections act, substantially in accord with British practice. There are two parties, Liberal and National Union; a local organization of each usually selects a candidate prior to an election. Independents may run if nominated. Municipal government is carried on by 76 county municipalities and rural and urban municipalities generally under the Cities and Towns act and municipal code, although there are many special charters and acts which demand much parliamentary time for their enactment and revision.

Agriculture. — Main agricultural products of Quebec are wheat, oats, barley, rye, peas, beans, buckwheat, potatoes, turnips, hay, clover, alfalfa, fodder corn and sugar beets.

The main features of Quebec agriculture are: (1) Family farming: on most farms most of the work is done by the farmer and his family, eliminating most of farm labour costs. (2) Farm arts and crafts, mainly in the eastern section where most of the wool produced is woven locally. (3) Co-operation increasing rapidly. (4) Farm credits (under revised statutes of Quebec 194, chap. 113): a farmer whose debts exceed 65% of the value of his farm may borrow 75% thereof, provided his creditors accept this in full payment, A farmer establishing a new farm may borrow 75%. Interest is 3% per-annum, plus 2.714% amortizing loan in 25 years.

The department of agriculture comprises ten services: education, rural economics, extension, animal husbandry, horticulture, field husbandry, information and research, handicrafts and home economics, health of animals, rural engineering. There are also special provincial organizations of farm credit bureau, research council, rural electrification bureau, dairy industry commission. The province is divided into 20 districts, in each of which there is a district agronomist with a staff of one agronomist for each county and a number of assistant and special agronomists with demonstration farms, etc. The province assists agricultural colleges, holds county farm improvement contests, conducts drainage projects, maintains plant-breeding stations.

Environment and Settlement. — The people of Quebec, except for two districts, settled in the lands south of the shield. However, the accompanying population map shows that there is a notable number of settlers near Lake St. John at the head of the Saguenay river. As usual this can be explained in terms of the structure. A block of the earth's crust has sunk, forming a graben. In this depression clays and silts have accumulated, giving rise to much better soils than those which generally characterize the peneplain surface of the shield. Here also the waters of the lake rushing through gorges to the Saguenay have been harnessed by many power stations. Hence, there is a close industrial settlement around the towns of Arvida, Chicoutimi, etc., where large supplies of aluminum and other manufactured goods are produced. At the western margin of the shield there is a large area covered with the clays of the "clay belt." These are due to lake silts deposited in a bygone glacial lake and. as at Lake St. John, the soils are relatively fertile. From Senneterre to Abitibi lake there are many families of habitants who have developed a pioneer hay-oats-dairy economy, which is able to supply many of the needs of the flourishing mines around Noranda.

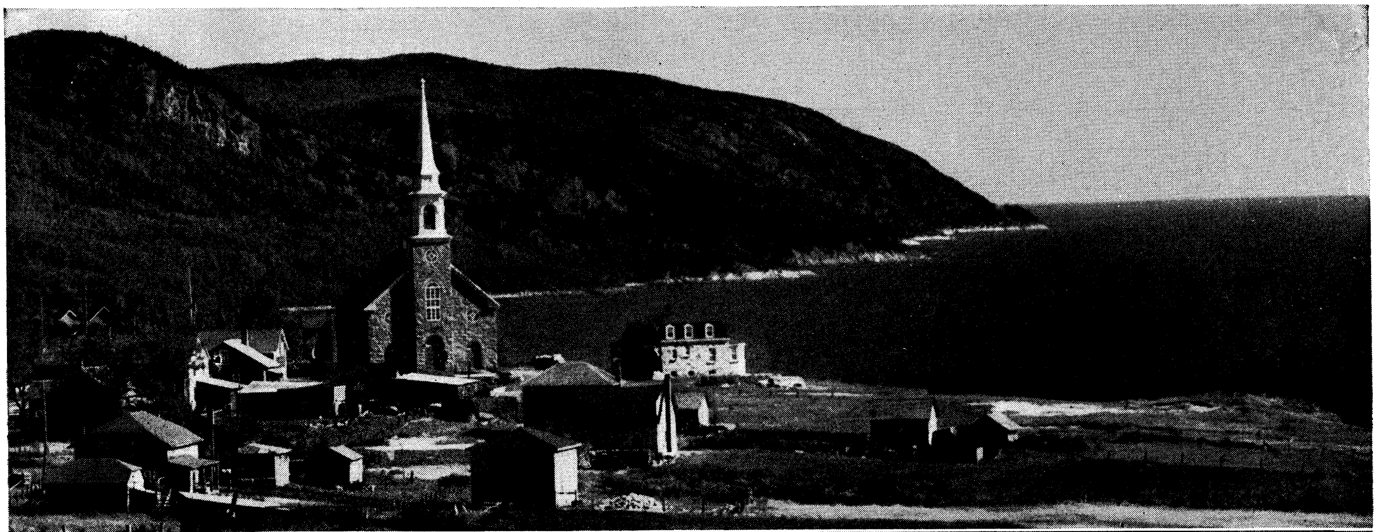
In the St. Lawrence valley there is extensive farming based in part on the good soils laid down in the temporary Champlain sea. In the warmest part of the province there is a large area devoted to tobacco. and also to maize. The latter is, however, fed green to animals. and the cobs do not generally ripen. In the same rich agricultural region is the densest dairy distribution and on the skim milk many swine are fed, as indicated in the map. Throughout the southern part of the province oats and hay are grown, while in the colder districts potatoes and buckwheat become relatively more important. In the rough foothills of the Appalachians, along the southeast border, is one of the main areas for sheep in eastern Canada.

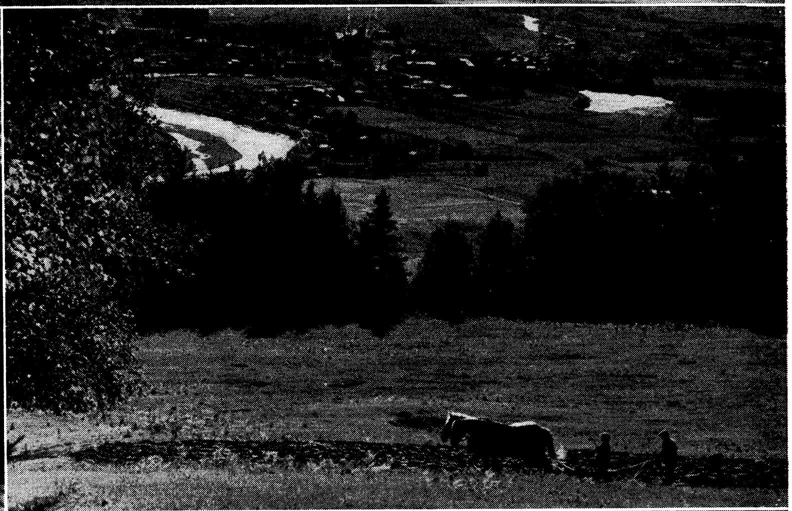
Education. — Education in Quebec has three main branches: (1) formal school system; (2) college and university system; (3) technical and special schools. There is a growing system of adult education.

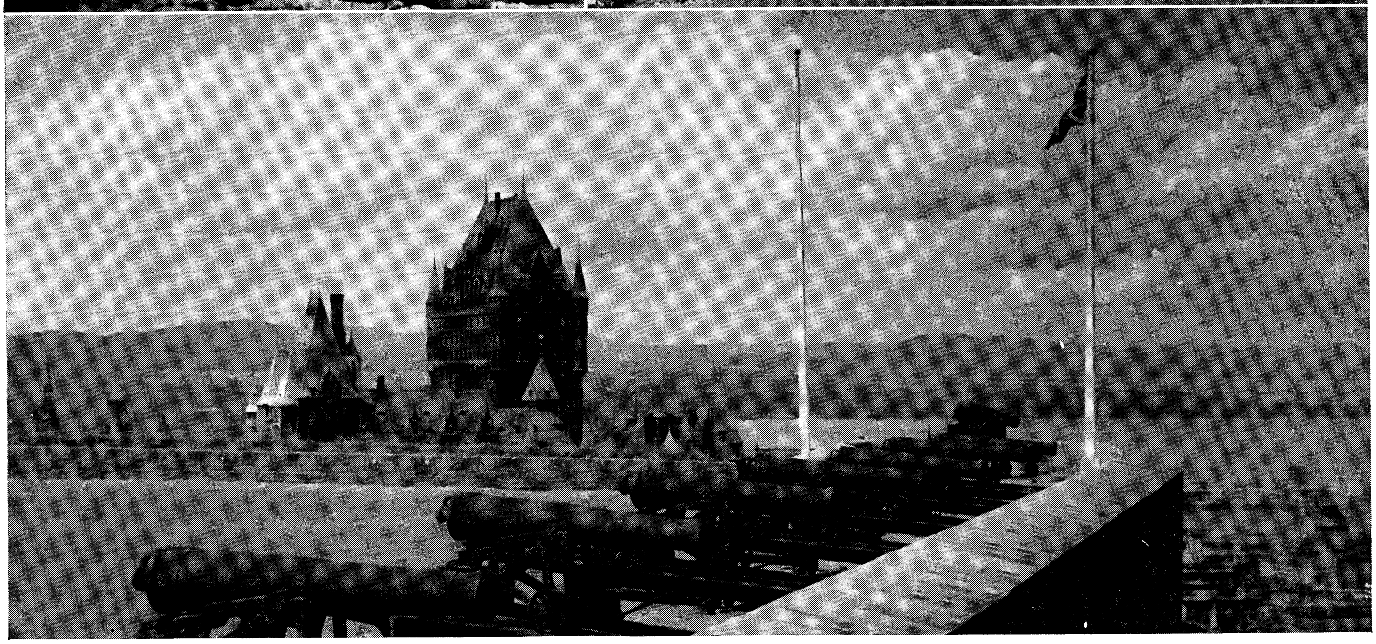
1. The formal system is under the control partly of government, partly of committees. Superintendent of education (appointed by the government) is chairman of a council of education which does not sit as such but is divided into a Catholic and a Protestant committee. each with its secretary (a deputy minister). The Catholic committee includes all Roman Catholic bishops, an equal number of laymen and some additional members. The Protestant committee has half the number of members and a number of associate members. In virtue of sec. 93 of the British North America act the Protestant committee has sole control of the curriculum in, and recommends all government grants to, Protestant schools. The Catholic committee deals likewise with Catholic schools. Under jurisdiction of the committees are: (a) Catholic-elementary, complementary, intermediate and high schools, colonization area schools and Catholic high schools; (b) Protestant elementary, intermediate and high schools. With the universities each committee controls normal schools. There are a few private schools (English-speaking). In school municipalities (erected and divided by the government), commissioners are elected by majority (Protestant or Catholic) and trustees by minority. In large cities there are two sets of commissioners. These finance schools and pay teachers.

2. The college and university system is independent of government control except where agreements exist There are a number of classical colleges (Roman Catholic) which give an eight-year arts and science course leading to a university baccalaureate. Convent schools train a large number of girls. Sir George Williams university (Y M C A). Montreal, gives a degree course. McGill university inon-sectarian), Montreal, Ste. Anne de Bellevue and St. Johns, have arts and science, professional and graduate faculties. Three Protestant theological colleges are affiliated. Bishop's university (Anglican) at Lennoxville, mainly residential. gives several degree courses. Laval university, Quebec. and the University of Montreal. with several affiliated schools, provide many branches of professional training.

3. The technical schools of Quebec are not concentrated under a department of education but are spread through the fabric of the government. For example, the department of agriculture is responsible for schools of veterinary medicine, dairy science, pot-







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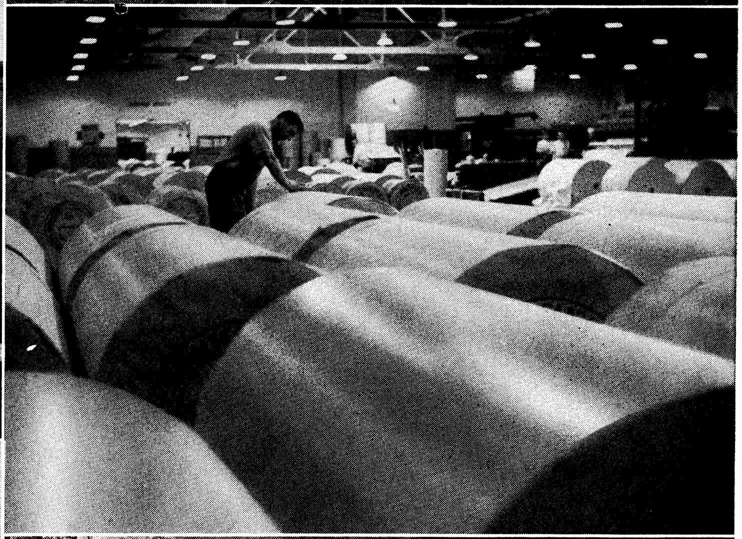
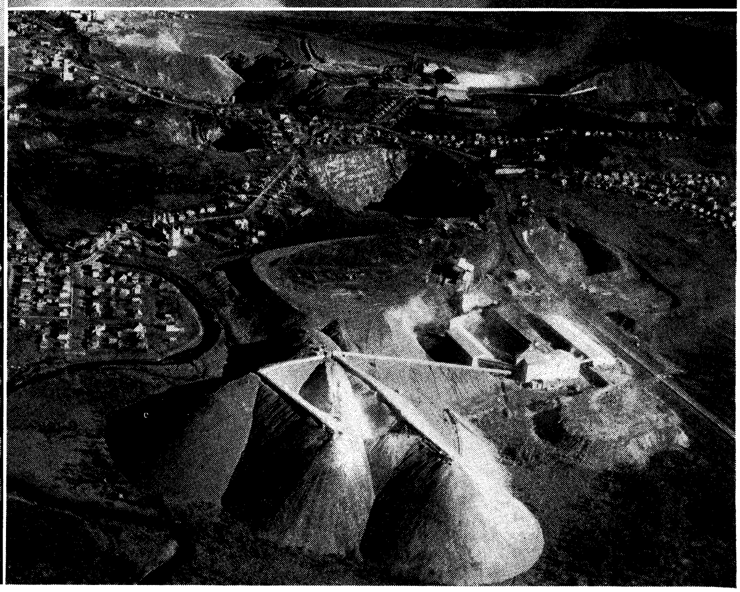
VIEWS OF QUEBEC

Top: St. Siméon, a village on the St. Lawrence river
Centre **left:** Percé rock, Gasp6 peninsula, as seen through drying fish nets
Centre right: Father and son plowing hilly land. In the background are Baie St. Paul and the St. Lawrence river (left)

Bottom: A view of the St. Lawrence river from the citadel, an old French fort in Quebec city that was rebuilt by the English in 1823–32. In the background is the Château Frontenac

QUEBEC





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SCENES IN QUEBEC

Top *left:* Notre Dame church at Montreal, built in 1824
Top right: Windmills remain as sources of power on some Quebec farms
Centre right: Rolls of newsprint being labelled at Kenogami in northern Quebec

Bottom left: Quebec seminary at Quebec city was founded in the 17th century
Bottom right: Aerial view of Ti-etford Mines south of Quebec city. Quebec leads in world production of asbestos

tery making. fisheries, forestry and domestic science; the department of youth and social welfare is responsible for schools of furniture making. papermaking and graphic arts. and in addition for schools teaching common trades and schools recognized as youth protection schools. Under the department of the provincial secretary there are several special schools affiliated to universities for standards and degrees, including the Montreal school of higher commercial studies, and the Montreal polytechnical school; and an institute of music and dramatic art, and a school of fine arts, which give instruction in Montreal and Quebec city.

4. Adult education is carried on in housekeeping schools. night schools and dressmaking schools. by McGill university in Montreal and rural areas, by the department of education and Canadian Legion educational services.

Forests. — Quebec forests are the most important asset of the province. The total forest area covered 356,059 sq.mi., of which 329,154 sq.mi. were still in the hands of the crown and 26,737 sq mi. were privately owned. Varieties are spruce, balsam fir, white pine, red pine, jack pine, hemlock, cedar (white and red), tamarack, birch, maple, basswood. elm, ash, white birch, aspen. poplar, oak (white, red, burr), butternut, cherry. beech, walnut, hickory. Control is by the department of lands and forests.

Mineral Production. — Mineral production at mid-century was characterized by rapid recent growth resulting from the rediscovery of copper (known to the Indians and described by them to Jacques Cartier in 1535) in Abitibi and the finding of gold in the same district. The region as known stretches about 120 mi. E. from the Ontario border about the northern line of the Canadian National railways and varies from 10 to 40 mi. in width. A considerable group of modern cities and towns (Rouyn. Noranda, Amos, Val d'Or, Duparquet, La Sarre, etc.) developed in consequence. As a world producer Quebec takes first place in one article only. asbestos of the serpentine type which exists throughout the Appalachian region. Gold is also mined.

Power and Manufactures. — The development of manufactures marched with that of hydroelectric power. The Shipshaw plant near Arvida on the Saguenay was the world's largest hydroelectric plant at mid-20th century. Main products were pulp and paper, nonferrous metals, women's factory clothing, cotton yarn and cloth, men's factory clothing and electrical apparatus.

Transportation and Communication. — The St. Lawrence seaway forms a section of the shortest route between Europe and the central U.S., furnishing deepwater communication to Quebec's main ports. Montreal is one of the most important rail-water-air connecting points in North America and Quebec manufactures are largely based on transportation facilities.

The province has railway lines of the Canadian National and Canadian Pacific railways, as well as pulp and paper company lines, together with about 50 mi. of New York Central feeder line into Montreal. In the 1950s a 360-mi. railway was built at Sept-Îles to run to the iron-ore deposits adjacent to the Labrador boundary. Montreal and Quebec city are major ocean ports used regularly by about a score of Canadian and foreign shipping lines.

BIBLIOGRAPHY.—Canadian Census (decennial); *Canada Year Book;* provincial annual reports of departments. General works: J. C. Sutherland, *The Province of Quebec* (1922); Wilfrid Bovey, *The French Canadians To-day* (1938); E. C. Woodley, *Quebec Through the Years* (1946), *Old Quebec: Trails and Homes* (1947); Amy and Thornton Oakley, *Kaleidoscopic Quebec* (1947); Blodwen Davies, *Gaspé, Land of History and Romance* (1949), *Quebec: Portrait of a Province* (1951); W. P. Percival, *The Lure of Quebec* (1941); Joan E. Morgan, *Castle of Quebec* (1949); S. W. Dean and M. M. Marshall, *We Fell in Love Wzth Quebec* (1950); A. D. Angus, *Old Qwebec* (1950); John and Marjorie Mackenzie, *Quebec in Your Car* (1951); *Quebec Guide* (66th ed., 1950).
(W. BY.; G. TR.; C. CY.)

QUEBEC, the oldest city of Canada and the capital of Quebec province, is situated on the north bank of the St. Lawrence river at its junction with the St. Charles, about 400 mi, from the Atlantic ocean and 180 mi. by river northeast of Montreal. It consists of an upper and a lower tomn. The upper town is built on the northern extremity of an elevated tableland which forms the left bank of the St. Lawrence for a distance of 8 mi. The highest part of the headland is Cape Diamond, 333 ft. above sea level, and crowned by the citadel; toward the St. Lawrence it presents a bold and precipitous front, while on the landward side and toward the St Charles the declivity is more gradual. The lower tomn is built all around the tableland, at the foot of the cliffs and in the basin of the St. Charles river, and expands on the Beauport coast. Steep, winding streets and an inclined elevator connect the two towns.

The climate of Quebec is severe but bracing, the mean temperature in winter being 12° and in summer 68° F. The city returns four members to the provincial house of assembly and three to the house of commons.

History. — The first known white man to visit Quebec was Jacques Cartier. the French navigator who, in 1535, found on the site a large Indian village called Stadacona. In July 1608, the present city nas founded and named by Samuel de Champlain. The origin of the name Quebec has been much disputed. but it is apparently the Algonkin word for a sudden narrowing, a strait, such as the case opposite Cape Diamond where the St. Lawrence narrons to 1,314 yd.

The most westward French settlement in America, Quebec mas captured in 1629 by the English under Sir David Kirke. They held it until the treaty of St Germain-en-Laye of 1632, when it mas restored to the French. When the colony of New France was made a royal province in 1663 Quebec became the capital and the centre of French operations in North America for a century. In 1690, Sir William Phips, governor of Massachusetts, attempted to reconquer it with a fleet and army fitted out by New England but was defeated by the French governor. the comte de Frontenac. In 1711 a great British expedition sent against Quebec under Sir Hovenden Walker was shipwrecked in the Gulf of St. Lanrence, and the French held possession until the Seven Years' War. In 1759, a young British general. James Wolfe (*q.v*), was given the command of an expedition against Quebec from the lower St. Lawrence. while Lord Jeffrey Amherst led a force from New England by Lake Champlain on Montreal. With 8.000 men convoyed by a powerful fleet, Wolfe tried unsuccessfully to disembark at Beauport and Montmorency below the city: seizing Point Lévis. he bombarded Quebec from there. Many weeks later he decided to land at the Foulon cove above Quebec, and move the main body of his troops to the top of the cliffs on the heights of Abraham. There he was able to fight and defeat the French army commanded by the marquis de Montcalm. Both Wolfe and Montcalm were killed. Quebec surrendered on Sept. 18, five days after the battle. New France was ceded to Great Britain by the treaty ending the French and Indian War in 1763.

In 1775 American forces under Richard Montgomery and Benedict Arnold attacked the city, but Montgomery was killed (Dec. 31, 1775) and Arnold was compelled to retreat in the following spring. Quebec was the capital of the province of Quebec (1763–91) as then existing; the capital of Lower Canada (1791–1841); the capital of the United Province of Canada. 1851–55 and again in 1859–67; and from 1867 the capital of the province of Quebec During World War II Pres. Franklin D. Roosevelt and Prime Minister Winston Churchill held a conference at the citadel in 1943, known as the Quebec conference, that prepared for the invasion of Europe by Allied forces.

Urban Characteristics.—The most notable feature of Quebec is the city within the walls, the only remaining enclosed city in North America. The present walls and the citadel that crowns Cape Diamond cover an area of about 40 ac.; they were built in 1823–32. Since then several of the gates have been destroyed and others rebuilt; among the most well-known are St. Jean and St. Louis gates. Between 1865 and 1871 three forts were built on the Lévis side of the river but were neither manned nor armed.

In the city. with its narrow and irregular streets, the visitor will discover the old world character of Quebec. Several houses built during the French regime are still occupied. Among the famous buildings located in this part of Quebec are the Chbteau Frontenac, a large hotel erected by the Canadian Pacific railway; the Anglican cathedral, built in 1804; the Roman Catholic basilica, founded in 1647, enlarged at various times. destroyed by fire in 1922 and rebuilt on the original site; the old Roman Catholic seminary, founded in 1663; Laval university; and the Ursulines convent. Th Dufferin terrace is a magnificent 1,400-ft, long promenade overlooking the St. Lawrence, 200 ft. above the level of the river. From the terrace one can see the Laurentian hills, Ile d'Orléans, the Lauzon-Lévis south shore communities. the ferry boats plying between the banks of the St. Lawrence, the traffic of ships on the river, and the lower town with the Louise basin and some of the port facilities such as the grain elevator. During the winter, the terrace is a favourite winter sport centre for skating and toboggan rides. The lower town (*basse-ville*) is a mixture of old buildings such as the Notre Dame des Victoires church (erected in 1688. but so named in memory of the defeats of Phips in 1690 and Walker in 1711), old houses and new warehouses and other commercial buildings. It is the financial and wholesale district of Quebec

In the upper town, beyond the walls, are the historic Plains of Abraham. a national battlefield park and site of the museum of the province of Quebec; the parliament buildings of French Renaissance style, built in 1878–92; and the Bois de Coulonge residence, seat of the lieutenant governor of the province.

Churches and Institutions.— The numerous spires and towers of buildings is another distinctive feature of Quebec. The city is 90% Roman Catholic and 92% French Canadian; many religious orders and congregations have established their mother houses there. Quebec is the seat of Laval university, named after the first bishop of Quebec, founded in 1852 by royal charter from Queen Victoria and in 1876 received a charter from Pope Pius IX. It includes faculties of theology, philosophy, law, medicine, sciences, arts, letters, forestry and commerce, a library, a museum and a picture gallery. In 1952 the university began its move to a new campus in the suburb of Ste. Foy. The principal benevolent institutions of Quebec are also administered by religious congregations. The Hôtel Dieu, one of the largest hospitals of the city, was founded in 1639 by the duchess of Aiguillon and has continuously served the public. Under the dual system of education in the province (French and English), there are two separate groups of primary and secondary schools and colleges. A number of government buildings are scattered over the city and in some of the suburbs.

Commerce, Industries and Transportation.— Quebec was long the chief port of Canada and one of the most important wooden shipbuilding and repair centres on the continent. With the deepening of the St. Lawrence channel upstream in the second half of the 19th century, Montreal became the great shipping port of Canada and Quebec suffered a serious economic setback. Later. with the construction of railway lines in all directions from the old capital, the building of new harbour facilities, the abundant services of hydroelectric power and the availability of skilled labour, an important industrial development followed. The chief industries are shipyards and shipbuilding, pulp and paper, shoe and leather, textiles, clothing, mechanical industries, gunpowder, ropes and food and beverages. Quebec is the main trade and commercial centre of the eastern part of the province. The principal commodities handled in the port are grain, coal, petroleum products, asbestos, steel. cement, pulp and paper, newsprint and general cargo. The port, formerly icebound between Christmas and the end of March, is now open to winter navigation. Quebec harbour is the seat of the regional administrator of the federal department of transport for marine operations, who is responsible for the maintenance of the St. Lawrence waterway from the ocean to Quebec From the Dufferin terrace one can see the Queen's wharf at the bottom. where arctic supply ships are loaded, buoys manufactured and repaired, maintenance barges and ships loaded or unloaded and icebreakers assigned to special duties in the winter.

To improve transportation of passengers and commodities between the municipalities on both shores of the St. Lawrence, the Quebec bridge, 7 mi. above the city, was completed in 1917, after ten years of work and two serious accidents to the structure (on both occasions one of the sections fell into the river). It is used by railway and vehicular traffic. Quebec is a major railroad centre, the terminal of the transcontinental line from Prince Rupert (British Columbia), the Lake St. John-Saguenay line and the North Shore line to Murray Bay (La Malbaie). These lines and the modern freight yard of Charny are operated by the Canadian National railway. Quebec is also the terminal of the Montreal-Quebec line of the Canadian Pacific railway and is linked with major Canadian and U.S cities by bus and truck transport service. The Quebec airport is located at Ancienne-Lorette. 10 mi. W. of the city. and is served by Trans-Canada air lines and Quebecair, with several daily flights to Montreal, Chicoutimi, the iron ore district of Sept Îles-Schefferville and other Canadian metropolitan districts

The Quebec metropolitan area has a population (1961) of 357.-568 (Quebec city proper. 171.979) and comprises 30 municipalities: several of these municipalities are located on the south shore. Lévis and Lauzon being the most important ones. Sainte-Foy and Sillery are two residential suburbs in the upper town. There is a Huron Indian reservation near Loretteville. See also references under "Quebec" in the Index volume.

BIBLIOGRAPHY.—Sir G Parker and C. G Bryan, Old *Quebec* (1903) ; B. Sulte, *History of Quebec* (1908) ; *The King's Book of Quebec*, 2 vol. (1911); J. C. Sutherland, *The Province of Quebec* (1922); M J Pelton, *Natural Resources of Quebec* (1923) ; Willa Cather, *Shadows on the Rock* (1931) ; M de la Roche, *Quebec, Historic Seaport* (1944) ; C. M Barbeau, *J'ai vu Quebec* (1957). (P CA.)

QUEBEC ACT, the title usually given to a bill which received the royal assent on June 22, 1774. This act extended the boundaries of Quebec to include much of the country between the Ohio and the Mississippi. The French inhabitants of the province were granted the liberty to profess "the religion of the Church of Rome"; the French civil law was established, though in criminal law the English code was introduced. Government was vested in a governor and council, a representative assembly not being granted till the Constitutional act of 1791.

The granting of part of the western territory to Quebec, and the recognition of the Roman Catholic religion, greatly angered the American colonies. On the other hand, it did much to keep the French Canadians from joining the Americans in the coming struggle. The act is still regarded by the French in Canada as their great charter of liberty.

QUECHUAN LANGUAGES: see SOUTH AMERICAN LANGUAGES.

QUEDLINBURG, a town in the district of Halle, Ger.. on the Bode, near the northwest base of the Harz mountains, 12 mi. S E. by rail from Halberstadt. Pop. (1959 est.) 31,282. Quedlinburg was a fortress of Henry the Fowler about 922, its early name being Quitlingen. It joined the Hanseatic League. The abbey of Quedlinburg was founded by Otto the Great. and it owned, at one time. a territory about 40 sq.mi. in area. The abbesses ranked among the princes of the empire and had no ecclesiastical superior except the pope.

The town at first strove to maintain its independence of them, and to this end invoked the aid of the bishop of Halberstadt. In 1477. however, the abbess Hedwig compelled the bishop to withdraw. and for the next 200 years both town and abbey were under the protection of the elector of Saxony. In 1539 the townsmen accepted the reformed doctrines. and the abbey was converted into a Protestant sisterhood In 1697 the elector of Saxony sold his rights over Quedlinburg to the elector of Brandenburg. The abbesses, however, retained certain rights of jurisdiction, and disputes between them and the Prussian government were frequent until the secularization of the abbey in 1803.

QUEEN, the title of the consort or wife of a king (queen consort). or of a aoman who is herself the sovereign ruler of a kingdom (queen regnant); the widow of a former reigning sovereign is a queen donager, and, when the mother of the reigning sovereign, a queen mother. For the position of the queen consort in English constitutional law see CONSORT, and for her household see HOUSEHOLD, ROYAL.

QUEEN ANNE'S BOUNTY, the name applied to a perpetual fund of first-fruits and tenths granted by a charter of Queen Anne and confirmed by statute in 1703, for the augmentation of the livings of the poorer Anglican clergy. First-fruits (*annates*) and tenths (decimae) formed originally part of the revenue paid by the clergy to the papal exchequer. The former consist of the first whole year's profit of all spiritual preferments, the latter of one-tenth of their annual profits after the first year, but the First Fruits and Tenths Measure, 1926, made provision for the extinction of *annates* and *decimae* in most cases and for their redemption in the remaining cases. *See* TITHES.

QUEEN ANNE'S LACE: *see* WILD CARROT.

QUEENBOROUGH, a municipal borough in the Faversham parliamentary division of Kent, England, in the Isle of Sheppey near the junction of the Medway and Swale, 2 mi. S. of Sheerness. Pop. (1951) 3,137. Area 1.7 sq.mi. In 1339 the marshes were drained and the town's foundations laid. In 1361 Edward III replaced a nearby Saxon fortress by the castle, designed by William of Wykeham, which, from 1582 until demolished by Cromwell! was the official residence of the lord warden of the Cinque Ports. Edward III named the town *Regina Burgia* when he stayed there with his queen in 1366 and granted it a charter with markets and fairs and built the parish church. The guildhall contains valuable old regalia. Queenborough was a wool staple town in Tudor times and prospered still more when, in 1579. Matthias Falconer started manufacturing chemicals. This industry is still going on, and others include glass bottles, sanitary pottery and the importation and distribution of coal.

QUEEN CHARLOTTE ISLANDS, a compact group lying off the northern part of the coast of British Columbia, form part of that province of Canada. Pop. (1956) 3.082 (including 949 persons living on Indian reserves). Land area 3,970 sq.mi. The islands were named after his ship by Capt. George Dixon who, in 1787, sailed through Hecate strait, which separates them from the mainland. The islands contain resources of minerals (coal, gold, silver and copper) and softwood timber. The surrounding waters support prolific fisheries (chiefly salmon; halibut, herring, crabs and clams), but comparatively little settlement has occurred. The largest community, Queen Charlotte, had 283 inhabitants in 1956. Logging and fishing are the main occupations, most of the output going to processing plants on the mainland. There are scheduled air and marine transport connections with Prince Rupert but bad weather often disrupts the service, especially in winter: The native Haida Indians possessed one of the highest cultures and art forms found among aboriginal peoples of northwestern America. (A. L. FY.)

QUEENS, the largest of the five boroughs of the city of New York, U.S. Located on western Long Island, it extends across the island from the junction of the East river and Long Island sound to the Atlantic ocean; Queens county is conterminous with the borough. In the early colonial period the area was part of New Netherland and the first settlement was made by the Dutch in 1636 near Flushing bay. Gradually towns were organized, including Newtown in 1642, Far Rockaway in 1644, Flushing in 1645 and Jamaica in 1656. These settlements along with the rest of New Netherland came under English control in 1664 when Peter Stuyvesant surrendered to an English force acting for the duke of York. In 1683 the English established Queens county as one of the 12 counties of the province of New York. It was named for Catherine of Braganza, queen consort of Charles II.

During the American Revolution the residents of Queens county were divided in their allegiance; when the English captured Long Island in 1776 many of the patriots fled, and at the conclusion of the struggle a group of the Tories migrated to Newfoundland.

Throughout the 19th century Queens continued to be primarily a rural community with a few small trading centres. Some of the shore communities began to attract large numbers of summer vacationists and such popular resorts as the Rockaways became well known. In 1898 Queens borough was formed as a part of greater New York and at the same time assumed its present size (126.6 sq.mi.) when the three eastern towns of Hempstead, North Hempstead and Oyster Bay opposed joining New York city and were chartered as Nassau county. Pop. (1960) 1,809,578.

Queens experienced rapid development after the opening of the Queensboro bridge in 1909 and the Long Island Railroad tunnel the next year. This development continued and Queens became the fastest growing borough of the city, still retaining for the most part its residential character. *See* also LONG ISLAND; NEW YORK (CITY). (D. L. D.)

QUEEN'S BENCH, COURT OF, is descended from the court held *coram rege* ("before the monarch") when it was part of that undifferentiated *curia regis* which was still performing legislative and executive as well as judicial functions. It was a court to hear cases which concerned the sovereign, or cases affecting great persons privileged to be tried only before him. If he was absent abroad, such cases were heard *coram consilio nostro* ("before our council"). It was also a court to correct the errors and defaults of all other courts, and after the close of the civil wars of Henry III's reign was mainly occupied with the trial of criminal or quasi-criminal cases. In 1268 it obtained a chief justice of its own, but only very gradually did it become a separate court of common law. Thus it was not until a century after the court of common pleas (q *v.*) had become a distinct court of common law that the court of king's bench attained a similar position. It exercised a supreme and general jurisdiction. which comprised (1) criminal jurisdiction; (2) civil jurisdiction; and (3) jurisdiction over the errors of inferior courts including those of the court of common pleas, until by the act of 1830 the court of exchequer chamber became a court of appeal intermediate between the three common law courts and parliament. It also heard appeals from the court of king's bench in Ireland until 1783, and exercised jurisdiction over officials and others by means of the prerogative writs; *e.g.*, habeas corpus, certiorari, prohibition, mandamus, quo warranto and ne exeat regno.

By the Judicature act, 1873, the court was merged in the queen's bench division of the high court. It consists of a chief justice — now lord chief justice of England — and not less than 17 out of the total number of subordinate judges authorized by the High Court and County Court Judges act, 1950, as amended by the Restrictive Trade Practices act, 1956; there are 24 judges assigned to this division. Appeals from inferior courts come before a divisional court. composed of tno or three judges of the division. For appeals from the divisional court to the court of appeal *see* PRACTICE *AND* PROCEDURE. (H. H. L. B.; W. T. Ws.)

QUEENSBERRY, EARLS, MARQUESSES AND DUKES OF. The Queensberry title, one of many associated with the Scottish house of Douglas (*q.v.*), originated in the creation of SIR WILLIAM DOUGLAS (d. 1640) as earl of Queensberry in 1633. He was the eldest son of Sir James Douglas of Drumlanrig (d. 1616) and a direct descendant of Sir William Douglas, who obtained the barony of Drumlanrig in the 14th century.

His grandson WILLIAM, the 3rd earl (1637–1695), was created marquess of Queensberry in 1682 and duke of Queensberry in 1684; he held many high offices in Scotland under James II and VII until the earl of Perth contrived his dismissal.

His son JAMES DOUGLAS, the 2nd duke (1662–1711), was the royal commissioner to the Scottish parliament in 1700. Just after the accession of Anne in 1702 he was made one of the secretaries of state for Scotland and he was again commissioner to the parliaments of 1702 and 1703. In the latter part of 1703 he came under a temporary cloud through his connection with the Jacobite intriguer, Simon Fraser, Lord Lovat. Queensberry was deprived of his offices, but in 1706 he was once more commissioner to the Scottish parliament; in this capacity he showed great tact and ability in carrying through parliament the treaty for the union of the tno kingdoms. In 1708 he was created duke of Dover and marquess of Beverley in the peerage of Great Britain. In 1709 he was appointed third secretary of state.

CHARLES DOUGLAS. the 3rd duke (1698–1778), who had been created earl of Solway in 1706, was lord justice general from 1763 until his death in Oct. 1778. In 1720 he married Catherine, daughter of Henry Hyde, 4th earl of Clarendon, this lady, a famous beauty, although eccentric, was the friend of many of the wits and writers of her day, notably Gay, Swift and Walpole. Their two sons predeceased the duke, and when he died, his British titles became extinct, but the Scottish titles passed to his cousin, WILLIAM, 3rd earl of March (1724–1810).

This William Douglas, who now became the 4th duke of Queensberry, is best known by his sobriquet of "Old Q." On the turf he was one of the most prominent figures of his time, and his escapades and extravagances were notorious. From 1766 to 1776 he was vice-admiral of Scotland, and in 1760 he was made a lord of the bedchamber by George III; but later he mas an associate of the prince of Wales, being removed from his office in the royal household in 1789. He died unmarried, and the dukedom of Queensberry and some of his other titles, together with the Drumlanrig estates, passed to HENRY SCOTT, 3rd duke of Buccleuch, in whose family they still remain; but the marquessate of Queensberry and viscounty of Drumlanrig descended to SIR CHARLES DOUGLAS (1777–1837), the descendant of the first earl's second son, who became the 5th marquess. In his family the marquessate remains.

QUEENSLAND, a state of Australia occupying 670,500 sq.mi. in the northeast of the continent. A coastline of 3,000 mi.

— after that of Western Australia the longest of any individual state — bounds it on the north from the Gulf of Carpentaria and on the northeast and east from the Coral sea and the Pacific ocean respectively the 450-mi -long Cape York peninsula forming the only major irregularity in the coastal plan. In the west the boundary runs successively with that of Northern Territory along long. 138" E. and with that of South Australia along lat. 26° S and long. 141° E to the northwest corner of New South Wales In the south the boundary marches with that of New South Wales along lat 29" S , the Baruon-Macintyre-Dumaresq rivers and the crestlines of rhe Macpherson range to Point Danger.

The waters and islands of Torres strait nearly to New Guinea as well as the Great Barrier reef. are included within the political boundaries Maximum length (north-south) is 1,250 mi and maximum breadth (east-uest at lat 26° S) is 945 mi

Physical Features.—Queensland is characteristically an area of subdued relief Great plains occupy the heart of the state and, although they merge into higher country of sharper relief both to the easr and the northnest, there are relatively small tracts of country rhat are mountainous or where elevations exceed 3 000 ft

The Eastern Range, Plateau and Lowland Region.—This area occupies the eastern quarter of the state between the Main divide and the Pacific coast. It is underlain mainly by Palaeozoic rocks, folded into complex structures and invaded by widespread igneous intrusions between Devonian and Permian times. with a superposition of Mesozoic sediments in some central and southern basins and with Tertiary basalt-flow residuals capping'many of the higher areas. The two main components in the surface configuration pattern are the coastal ranges—a discontinuous and much-denuded series of low ranges and plateaus, often with cores of granitic rocks and flanks of metamorphics (considered by some to be the remnant of an early Tertiary watershed between east- and west-flowing streams)—and the present Main divide uhich follows generally the upwarped eastern rim of the Mesozoic rocks of the Great Artesian basin. Between these two structural swells is a series of extensive shallow interior basins and narrow near-coastal lowland corridors separated by ranges and plateaus, all with a marked north-northwest directional trend following the gram of the rocks.

The Main divide follows a course that is convex to the southwest so that the region has its greatest width (about 300 mi.) near the Tropic of Capricorn. In this central area, too, elevations are lowest. the great interior catchment basins of the Fitzroy and Burdekin river systems (occupying about 54,522 and 53,500 sq mi. respectively) with their markedly convergent tributary patterns being mostly undulating lowland westward oi the coastal ranges. The dominant structural feature of this central area is the huge Bowen syncline, a downwarp filled with sediments of Carboniferous to Triassic age including the most extensive bituminous coal measures in Queensland

Northnard and southward from the tropic the coastal and Main divide ranges become more conspicuous and continuous and converge to iorm the most striking ranges and highest plateaus in the state In the far north the Atherton tableland of about 12 000 sq mi everywhere exceeds 7,000 ft and rises irregularly southward to more than 3.000 ft. Pliocene basalt. weathering into rich red soils. covers much of its area and the Bellenden Ker range nith Queensland's highest peak. Mt Bartle Frere (5,225 ft) bounds it on the east In the far south. the rugged Macpherson range (Mt Barney 4 449 it) lies astride the state border inland from Tugun beach for 60 mi . merging thence into the highest part ot the Queensland Main divide (Mt Superbus 4 525 ft) which there presents a steep face to the edst but a lesser and more gentle descent westward toward the Darling downs The rivers in these mountainous arras have a more uniform flow than those of east-central Queensland The latter are classed as perennial. but considerable stretches of their courses dry out in winter.

Ihe Pacific coastline cuts transversely across the structural gram and is characterized by an alternation of rocky, north-facing promontories sheltering picturesque inlets and gently curving sandy beaches often backed by sdnd dunes and salt marsh The rivers generally How to the sea across deltaic plains those of the

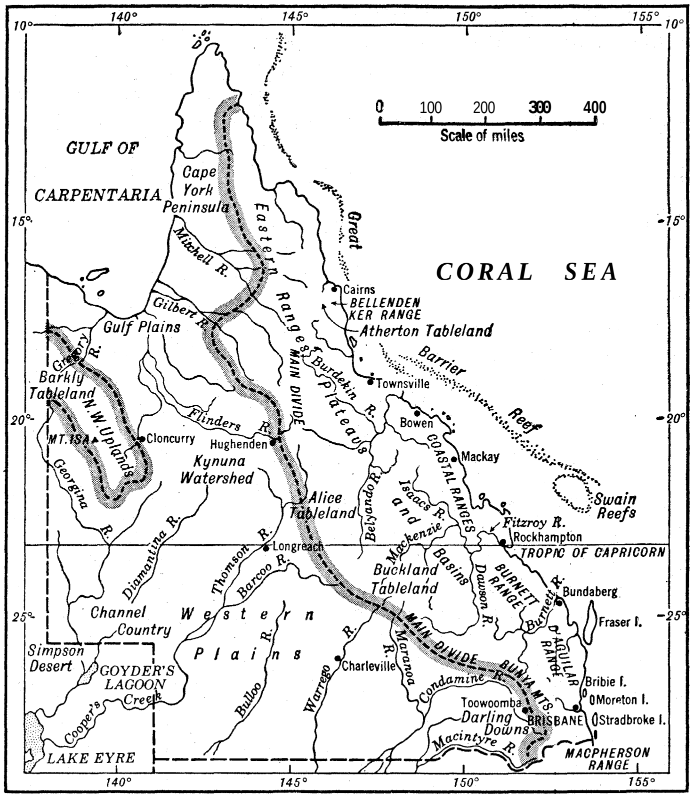


FIG. 1 —RELIEF AND DRAINAGE FEATURES OF QUEENSLAND. BROKEN LINES INDICATE THE LIMITS OF THE THREE PRINCIPAL PHYSIOGRAPHIC REGIONS

Burdekin and Fitzroy being of considerable size. The long, narrow islands close off the southern coast (Fraser, Bribie, Moreton and Stradbroke) are composed of sand dunes which are among the highest in the world The string of reefs and cays, collectively knonn as the Great Barrier reef that stretches for more than 1,100 mi from Torres strait to lat 24° S , lies along the seaward margin of the continental shelf (See BARRIER REEF) The Gulf coast oi Queensland is low-lying and mangrove-lined

The Western Plains—These plains occupy more than half the area of Queensland and form a great tract of lowland extending continuously from the Gulf coast to the southern border but constricted to a width of 280 mi in the low Kynuna watershed (lat 21° S) an upwarped structural and surface swell (600–1 200 ft , generally rising eastward) nith occasional low ridges. Northward and southward from this swell and westward from the hill country flanking the western side of the Main divide, there is a very gentle over-all slope northwestward toward the Gulf of Carpentaria and southwestward toward the Lake Eyre region, corresponding uith two great shallow sags in the thick Cretaceous sandstones and shales that underlie the plains These slopes are closely followed by the watercourses which form three systems converging respectively toward the Darling in the south the Lake Eyre flats of South Australia in the southwest and the Gulf of Carpentaria in the northwest Some of these watercourses are of considerable length but most flow only for short periods each year following the summer rains In floodtime, the Channel country of the far southwest is widely inundated. but nith the loss of water by evaporation and seepage the waters rarely reach Lake Eyre Of the western rivers, the Gregory alone has a perennial flow

West of the Channel country and astride the southnestern boundary of the state is a tract of fixed and partly vegetated sand dunes aligned generally along north-northnest axes

The extent of the western plains coincides fairly closely with that of the Queensland part of the Great Artesian basin with its underlying strata of water-bearing rocks

The *Northwest Uplands*—In the far northwest of Queensland is an outlier of the Pre-Cambrian rocks of the Australian shield trending north-northwest for 300 mi from near Selwyn and Dajarra to the state border west of Burketown. Especially in the south, the rocks are closely folded. intimately penetrated by igneous intrusions and locally mineralized. Dissected hill country with steep-sided rocky valleys following the north-south grain of the rocks characterizes this area. The Georgina plains west of Mt. Isa are floored by Cambrian limestones and rise gently northward to the Barkly tableland, the Queensland part of which is a watershed between the Georgina and Gregory river systems.

Climate.—Queensland is disposed with nearly equal proportions on either side of the Tropic of Capricorn and includes comparatively little high country, so that hot summers and mild winters are characteristic of the state.

The rainfall shows a well-marked summer maximum and varies widely. The heaviest falls occur in the northeast coastlands between Cooktown and Ingham and on the mountain slopes immediately to the westward (Tully 178.06 in.). The heaviest and most prolonged falls are from December to May. (R. H. G.; X.)

Vegetation and Animal Life.—Rain forest with strong Papuan floristic afhnities occurs in the higher rainfall districts, reaching its best development along the eastern coast in scattered areas. Inland it passes gradually into monsoon forest and disappears as a vegetation unit. The predominant vegetation type in a belt about 230 mi. wide along the eastern coast is eucalyptus forest. interspersed with extensive grasslands. The eucalyptus forests are the source of valuable hardwoods and the rain forests provide many important cabinet timbers. With increasing aridity the eucalyptus forests thin out. and the great pastoral areas such as the Mitchell and bluegrass downs, mulga and other scrubs, saltbush and bluebush stretch to the edge of the desert in the extreme west of the state. Extensive mangrove forests occur in the estuaries and on tidal mud flats.

Terrestrial mammals native to Queensland include 2 species of monotremes (echidna and platypus), 53 marsupials and 53 placental mammals. The echidna is common, and the platypus is more abundant in the southern part of the state than in the far north. Marsupials show the full present-day range in size from the great gray kangaroo (*Macropus* major) down to the two-inch pigmy mice (*Planigale ingrami*). Numbers of some species such as the koala have been greatly reduced as the result of settlement. Some, however, have adapted themselves to urban conditions, notably the brush-tailed opossum (*Trichosurus vulpecula*) and the short-nosed bandicoot (*Isoodon obesulus*). Two species of tree-climbing kangaroo (*Dendrolagus*) and two of the cuscus (*Phalanger*) in the north are examples of links with the marsupial fauna of New Guinea. Destructive carnivorous marsupials are few, but the native cat (*Dasyurus*), the largest of them. may cause considerable damage in poultry yards at night. Placental mammals include the dingo (*Canis* dingo), bats (including some destructive fruit-eating species, the Hying foxes) and rodents. Seals and dugongs are of species widely spread elsewhere. Of the snakes the largest authentic specimen is of *Python amethystinus*, 12½ ft. long, from north Queensland. Lizards are common, and among the turtles is included the edible green turtle. Emu, cassowary, four kinds of birds of paradise and four of bower birds are notable in the rich aviiauna. Marine fish species are numerous and of the freshwater species the lungfish (*Epiceratodus forsteri*) is of special interest. The corals and other marine life of the Great Barrier reef are of extraordinary richness, and a marine biological station was established at Heron Island. (D. A. Ht.)

HISTORY

By 1606 both the Dutch and Luis Vaez de Torres had found Cape York peninsula, but it was 1770 before Capt. James Cook discovered the east coast of Australia, the Torres strait itself, and removed the great south land from centuries of fireside speculation. At that time Cook noted signs that a great river might debouch on Moreton bay, which he named. Matthew Flinders, in 1799, denied it. hut in 1823 John Oxley, with the aid of castaways. discovered the Brisbane river and chose its neighhourhood as the new penal settlement that Sydney wished to establish in the remote north.

It was Allan Cunningham's discovery of the Darling downs (1827) that pointed the way to more flourishing settlement. This was already beginning overland from the south before the abolition of the penal colony in 1839 facilitated healthy development. The early squatters were followed in 1842 by the first free settlers and land sales. The main hindrances now became the remoteness of Moreton bay district, as it was called. the lack of understanding in Sydney, and the consequently tiny number of settlers, no more than 2,000 in the mid-1840s. The first emigrant ships from Britain did not reach Brisbane till the mid-19th century.

It was in 1859 that political separation from New Soufh Wales was achieved. when the population numbered 23,520, and before any industry had established itself. In the transition it was not always Brisbane that led the way. There was specific efforts to base the colony on Ipswich, and to make a main port of Cleveland, in Moreton bay. There was also an attempt (1846) to form a colony of north Australia, to be based on Gladstone ticket-of-leave men.

It might have been expected that the wide grazing lands would early tempt the sheep farmer, but it was 1840 before Patrick Leslie took the sheep to Warwick on the downs, and 1860 before there was any general migration westward. In that decade settlement was very rapid wherever there was water. The movement was encouraged in 1869 by act of parliament, which granted 21-year leases to those who had 25 sheep or 5 cattle to the square mile, Many of the early pastoralists failed. Wool had to be transported in drays by long trains of bullocks. the carriage of supplies to a station cost as much as the supplies themselves, markets were far away and uncertain. But by 1873 Victorian prosperity (in gold) began to be invested in Queensland and men of money came north. Studs were improved: fences replaced the shepherd. The first railways, from Ipswich to Dalby and Warwick, were operating by 1870. By 1900, 2.801 mi. of railway gave places like Longreach, Hughenden and Cunnamulla a link with the coast, and it was not till 1924 that the coastline from Brisbane to Cairns was completed.

In 1884 Dutton's act successfully encouraged the growth of a small squatting class. The great drought at the turn of the century when, between 1890 and 1902, 22.000.000 sheep were reduced to 7,250,000, made men turn energetically to the artesian boring that had been introduced in 1881 to open up land to sheep.

It looked at first as if the only impediments to cattle rearing were the distance from markets and the drought. The advent of refrigeration helped the first of these, though it did not change the trade and tradition of droving, bringing the cattle on the hoof from their pastures many hundreds of miles to the west. But in 1894 the cattle tick began to spread from northern Queensland, causing enormous losses, which with the drought of 1902 reduced the numbers from 7,000,000 to 3,500,000. Fluctuation continued, until World War II gave a fillip to prices and brought modern insecticides to combat the tick.

Apart from the Moravian missionaries at Nundah in the penal days, the first arable farmers were brought by John Dunmore Lang in the "Fortitude" in 1849. At once the farmer was resisted by the already settled graziers. Hewing out his farm by clearing the bush, attempting crops where none had been cultivated before, he won the contemptuous name of "cockatoo farmer." But, supporting himself, he advanced from maize and pumpkins to lucerne and sorghum, his livestock increased. and the plow, reaper and farmhouse supplanted hoe, scythe and sickle and bark hut. By the end of the century the government, spending over £1,000,000, had recovered much pastoral iand for the arable farmer; and by mid-20th century early pastoral settlement had become renowned for wheat or sugar cane.

After an early attempt, during the shortages of the American Civil War, to grow cotton (an attempt resumed in the 20th century), Queensland turned to sugar cane, introduced in the early 1860s by Louis Hope and now the state's largest product. The early growers, after the government's easy leases encouraged the industry, not only grew but manufactured the sugar in mills on their plantations. This system of many mills and few growers was later superseded by 8,000 small growers and by 32 central mills, encouraged by the government and often working as co-operative concerns. Cheap labour was scarce in Queensland, and the attempt to introduce Kanakas led to a prolonged political controversy, until in 1904 the federal government prohibited the traffic and ordered the deportation of those already in Australia.

Dairying did not flourish until there were sufficiently populous towns to give it encouragement. Up to 1888 Queensland imported much of its butter from the south, but in 1953 there were 100 factories producing butter and cheese, 20,000 dairy farms, and a production of £17,000,000 annually.

Although coal was discovered at Ipswich as early as 1827 and the first mine opened in 1846, it was the gold rush that really inaugurated Queensland's mining. From 1858 to 1873 the east and north of the state were invaded and opened up by diggers at Canoona, Peak downs, Gympie, Ravenswood, Charters Towers, Palmer river. Within a few months isolated spots in the bush became townships of 10,000 people. Here also the sensitive beginnings of the White Australia policy may be seen in the discrimination by act of parliament against Chinese and other Asian speculators (1877). Already by 1867 the population of the state had grown to 100,000. Even where the gold failed, as at Canoona, a town like Rockhampton could rise from the ruins; and a state with bank deposits in 1859 of only £287,000 became the possessor of mineral wealth that produced £222,420,264 in 1948. In 1882 came the discovery of a mountain of gold and copper, Mt. Morgan, and in the 1920s the process continued with the finding of the silver-lead-zinc deposits at Mt. Isa. But from 1880 the time of excitement was over, and it was replaced by the entry of capital, large-scale enterprise, road and railway, and the deepening of harbours.

Toward the end of the 19th century socialism began its advance in Queensland, and in 1899 the state had Australia's first Labour government, though a minority one. Labour's position, backed by strong trade unionism, became rapidly so powerful that after World War I it was almost continuously in office. In 1922 it abolished the upper house of parliament. but its early state enterprises largely reverted to private management, and its ardent socialism was modified by the practice of power. One of the most successful of its measures was the handling of agriculture through local co-operative boards of the producers themselves. (J. M. Cr.)

POPULATION AND ADMINISTRATION

Population. — At the 1961 census, the population of Queensland was 1,518,859 (excluding full-blooded aborigines, estimated at 9,579 in 1954). This represented 14.45% of the total for Australia, and an average density for the state of 1.96 persons per square mile. The vital statistics for Queensland compare favourably with those for other Australian states. The crude birth rate during the period 1956–60 was 24.17 per 1,000 of population per year. The crude death rate over the same period was 8.49 per 1,000 per year. The population of metropolitan Brisbane in 1961 was 620,121. The population (1961) in provincial cities, the largest of which are coastal or near-coastal in location, was: Rockhampton (44,102); Townsville (51,224); Toowoomba (50,107); Ipswich (48.668); Cairns (25,358); Bundaberg (22,791); Maryborough (19,136); Mackay (16,795). The greater part of the rural population is concentrated in the close hinterlands of these cities.

Education. — State education acts (1875 to 1948) established free and compulsory primary education to a leaving age of 14. In 1954 there were 1,522 primary schools (almost 1,100 of them one- and two-teacher schools) with an enrollment of 203.582 pupils. In 1951 there were 8,137 pupils in outlying parts of the state receiving education by correspondence. A pass in the scholarship examination entitles pupils to attend secondary schools (state or private) and to receive financial help. In 1954 there were 30 state high schools, 8 grammar schools and a system of private, denominational secondary schools. Teachers in state schools numbered 5,416 in 1954. Technical colleges provide apprentice training throughout the state together with a variety of other courses. There is a teachers' training college. Teachers for the state secondary service are trained at the university. The University of Queensland, established in 1911, now at St. Lucia, has faculties in arts, science, engineering, education, commerce, agriculture, law, dentistry, veterinary science, medicine and architecture. In 1954 its staff numbered 256 and its students 4,112 (of which about 1,406 were external students). (F. J. Sl.)

Administration. — The government consists of the governor. the executive council (*i.e.,* the governor and the ministers in office), and a legislative assembly of 75 members, elected by adult suffrage for a period of three years. There are four electoral zones, which are divided again into electoral districts as follows: 24 metropolitan districts of 10,795 electors each; 28 southeastern districts of 9,373 electors each; 13 northern districts of 7,696 electors each; 10 western districts of 4,613 electors each. Voting at elections is compulsory, as is electoral enrollment. The electorate consists of British subjects by birth or naturalization who have lived in Australia for six months, in Queensland for three and in an electoral district for one month.

Local authorities are classed as either city, town or shire councils, there being 12 cities of more than 7,000 persons, 10 towns and 112 shires. Councils are elected by adult suffrage and administer such services as public health and sanitation, roads, water, parks and amenities, and sometimes electricity and transport. (J. M. Cr.)

Social Services. — In 1954 there were 131 public hospitals. supplying free consultation and treatment, 110 public maternity hospitals, 205 maternal and child welfare centres, dental clinics and branches for free dental treatment. Advice is given to mothers in remote parts of the state.

The state department of health also administers a school health service and a scheme of mental hygiene and industrial hygiene. Maternity, child endowment and widows' pensions, which are financed by the commonwealth government, add to the social services available. (F. J. Sl.)

AGRICULTURE AND INDUSTRIES

Livestock Farming. — Pastoral industries have played a fundamental part in the economic development of Queensland, and the net value of pastoral production (£85,256.000 in 1951–52 including dairy products) was considerably greater than that of agriculture (£35,622.000) though less than that of manufacturing industries (£89,305.000). The relative importance of pastoral as compared with agricultural production is largely a reflection of the low and unreliable rainfall over a large part of the state and the concentration of rainfall mainly within four summer months. Bore water, indispensable for watering stock, is usually too highly mineralized for irrigating crops. Conditions on the savanna plains of western Queensland and on the less fertile ranges and basins of the east are thus most suited to extensive grazing.

Although sheep and cattle are run together on many properties, a belt of central Queensland extending from the southern border northward for 600 mi. through Charleville and Longreach to the Hughenden-Cloncurry downlands is mainly used for the raising of sheep and carries practically all the sheep grazed in Queensland. This corresponds with the plain country, receiving between about 10 and 20 in. of rainfall and lying south of latitude 20° S. Nearly all the animals (98.8%) are Australian merinos bred for their fine wool. Numbers fluctuate from year to year in relation to variations in rainfall and pasture growth. Stock losses through drought can be severe. Flocks totaled 16,163,518 (13.7% of Australian sheep) in 1952. The wool clip in the 1951–52 season was 138,-767,000 lb. (greasy), valued at £47.190.000 (12.9% of Australian production). Of the 4,504 properties carrying sheep in 1949–50, 1.811 (40.2%) were 10,000–50,000 ac. and 552 (12.3%) larger than 50,000 ac. In the far west, sheep stations up to 500 sq.mi. are not uncommon.

Queensland is the leading Australian beef-producing state, carrying half of the total herd and producing about 31% of the commonnealth's output of beef and veal. The raising of cattle for beef takes place under a wide variety of conditions and over a much greater total area of Queensland than sheep. About 40% are raised and fattened east of the Main divide where the higher total rainfall and the less meagre winter and spring fall create more

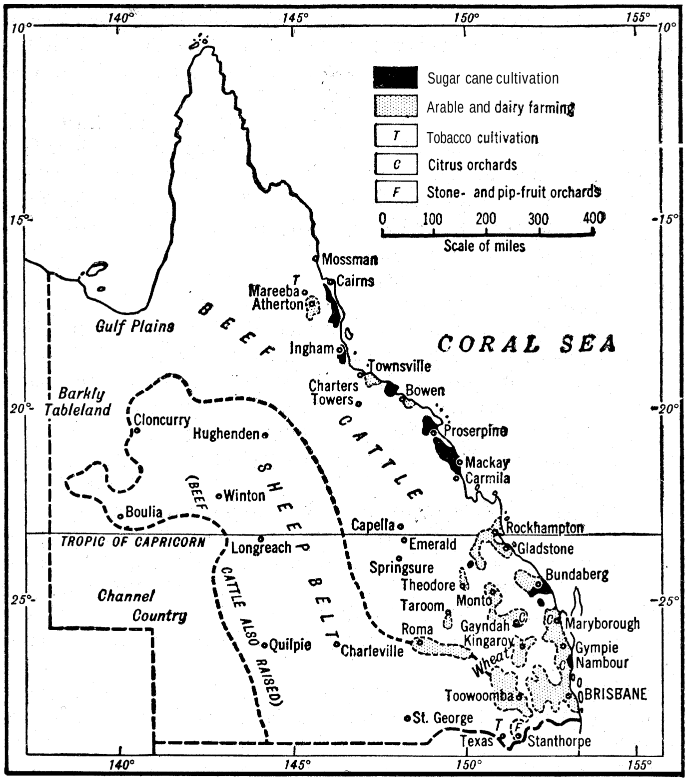


FIG. 2.— LAND USE IN QUEENSLAND

favourable year-round feeding conditions. About 20% are raised on the gulf plains and Barkly tableland. many of these being driven south to the Channel country where, together with the 5% that are raised in that area, they are fattened on the natural pastures that flourish for a short season after the late-summer floods. Most of the remaining 35% are reared on the broad belt of savanna country between the Main divide and the sheep belt. As with the sheep industry, drought and pests take serious toll of herds. Herds numbered 5,137,715 in 1952—49.8% of Australian beef cattle. Stations carrying cattle are generally larger than those carrying sheep, 44% of the stock being on stations of 100,000 ac. or more. Properties of 1,500 sq.mi. are not unusual in the remote north and west. The continued use of British breeds in a tropical environment is far from ideal. Zebu crossbreds. more tolerant of dry feed, water shortages and the cattle tick, were introduced experimentally on a number of stations.

Slaughtering and freezing works at the ports of Brisbane, Gladstone, Rockhampton, Bowen, Townsvilie and Cairns handle the bulk of the exported beef, the balance passing through New South Wales, Victorian and South Australian plants and the ports of Sydney, Melbourne and Adelaide. Production of beef and veal in the state in 1951–52 was 177,608 tons (30.5% of Australian production).

Dairy production is a major industry in three high-rainfall areas —the southeast coastlands as far north as Rockhampton, the Darling downs and the Atherton tableland. In 1951–52 the production of milk was 181,148,000 gal.; butter 28.211 tons (20.8% of Australian production); and cheese 4.700 tons (11.6%).

Pig raising is closely associated with dairy farming in the south; in 1952 there were 316,529 pigs (31%). Production of pork was 8,604 tons (24.6%) and bacon and ham 7,669 tons (20.9%).

Agriculture and Forestry.— The cultivation of crops is of major importance in the high-rainfall areas of the tropical east coast (sugar and fruit) and the Atherton tableland (maize), on the rich, moisture-holding soils of the Darling downs and south and central Burnett areas (wheat, lucerne, sorghum, maize and peanuts), and on the alluvial, volcanic and red-earth residua! soils of the southeast coastal region (maize, lucerne. fruit and vegetables). The total area under crops in 1951–52 was 2,022,400 ac.

Sugar cane is the leading crop in terms of value of production. In 1951–52, 5,005,172 tons (value £17,922,337) were cut, yielding 704,341 tons of raw sugar (94.5% of Australian production). Queensland's sugar industry was developed on a small scale during the second half of the 19th century with indentured Kanaka labour, but since 1906 has been operated exclusively by Australians of British or European descent, and its steady expansion under tariff protection has been the greatest single iactor in the peopling and development of tropical Queensland, 78.5% of the crop being, grown north of Carmila (lat. 22° S.). Cultivation is concentrated in areas with a combination of high rainfall and rich soil. Refineries at Brisbane and Bundaberg meet the needs of Queensland consumers, sugar being exported—both to other states and overseas—mainly in its less perishable raw state.

In respect of acreage under cultivation, wheat is Queensland's leading crop (454,543 ac. in 1951–52) though the value of the crop (£5,395,520 in 1951–52) is much less than that oi sugar cane. Production of wheat has increased markedly. In some measure this has been achieved by the more widespread use of drought-rcsistant varieties giving higher yields, but it has also been accompanied by a significant increase in area of cultivation. Production is concentrated mainly on the black soils of the Darling downs (Toowoomba-Dalby) and the chocolate soils of the South Burnett (Kingaroy) region. Cultivation and harvesting are highly mechanized and the size of holdings ranges up to 2,000 ac.

Maize is grown on many of the mixed farms of southeast Queensland to provide supplementary feed for stock. It is also the main crop of the Atherton tableland, a considerable surplus being shipped from Cairns to southern states and overseas. Total maize production in 1951–52 was 2,438,871 bu.

Peanuts are an important crop in the S. Burnett region and are becoming established on the Atherton tableland. Production of other oil crops such as linseed and sunflowers mas steadily increasing. but cotton growing declined aiter 1944 as a result of uniavourable seasons (dry farming methods are used), labour shortages and comparatively low profit margins. Tobacco growing has also undergone many vicissitudes.

A variety of tropical and subtropical fruits and vegetables is grown on smallholdings and mixed farms in coastal and near-coastal areas, the hulk of the production being within 100 mi. of Brisbane. Pineapples superseded bananas as the chief fruit crop, the gross value of the 1951 pineapple crop being £1,586,537, exceeded only by sugar cane, wheat and maize. 4 substantial proportion of this crop is canned for sale in southern and overseas markets. Papaws and mangoes are grown in coastal areas: citrus fruits are concentrated mainly in the Gayndah, Maryborough and Nambour areas of the southeast. The elevated "granite belt" around Stanthorpe, near the New South Wales border, is the only part of the state where apples, peaches and plums are grown commercially, and this is also the chief grape-producing area.

Queensland forests fall into three main types, the tropical rain forest (locally known as scrub or jungle) of the northeast coastlands and ranges, the rain forests of the southeast and the open forest covering most of the remainder of the eastern half of the state. Considerable areas of the tropical rain forest have been cleared for farming, but valuable reserves of silky oak, red cedar, Queensland maple and Queensland walnut remain. The southeastern forests provide a higher proportion of native pinewood, especially hoop and bunya pine, but natural reserves of these softwoods are becoming depleted, and the state government is steadily increasing the area of afforested country by the planting of exotic pines (especially North and Central American species such as Caribbean and Mexican pine) and the native hoop pine. The open forest of eucalypt hardwoods constitutes by far the greatest proportion of timber country despite ring-barking and clearing in many areas, and most of the state's building and constructional timber is obtained from ii. In 1951–52, 261,521,000 super.ft. of sawn timber, valued at £10,946,504, were produced by 650 sawmills. In addition, 110,028,000 sq.ft. of plywood and 47,139,000 sq.ft. of veneers were cut (£2,759,821 and £283,594 respectively).

Mining and Manufacturing Industries.— The metalliferous areas of Queensland are concentrated in the metamorphosed zones of the Pre-Cambrian rocks of the northwest and the Palaeozoic rocks of the northeast and southeast. With the gold rushes of the 1860s and 1880s, gold production rose steadily irom 2,738 fine oz. (worth £12,000) in 1860 to 676,027 fine oz. (£2,872,000) in 1900, but subsequent production declined. Production in 1952 was 84,642 fine oz., mainly from Mt. Morgan and Cracow, the total value (£1,375,465) being considerably less than that of lead (£6,564,910) and zinc (£4,471,637) production. The state's most extensive mineral workings are at Mt. Isa (in the far northwest) and Mt. Morgan (26 mi. southwest of Rockhampton). The Mt. Morgan cpencut is the state's main source of copper (j.650 tons, 90.6%), the smelters producing auriferous blister copper, A recent development is the extraction of zircon, ilmenite, rutile and monazite from south coast beach sands. Coal production was 2,742,236 tons in 1952 (a record figure). About half came from the 60 collieries of the West Moreton fields near Ipswich. The Big seam at Blair Athol is 70–80 ft. thick with only a thin (25–135 ft.) overburden—measured reserves of this seam alone amount to 112,500,-000 tons. The Callide open-cuts were developed extensively aiter 1950, most of the output being trucked or railed to Gladstone (80 mi.) for shipment to Victoria.

Manufacturing industries mere expanded considerably, the number of factories being increased from 2.882 in 1945–46 to 4,858 in 1951–52, and the net value of production from £29,105,442 to £89,304,791. The two major groups of factory industries are metal working-engineering and food processing. A little more than half (52.6%) of the total production was from factories in metropolitan Brisbane. Brisbane's industries range from shipbuilding (naval craft and cargo ships up to 10,000 tons), motor-vehicle assembly and furniture manufacture to sugar refinin , fruit canning and brewing. Developments after World War II included a cotton spinning mill and a tire factory. Two provincial cities are primarily industrial in function: Ipswich, with railway engineering shops and woollen mills, and Maryhorough, with railway engineering, sugar-mill and mining-machinery works and a small shipyard. Railway workshops are also maintained at Rockhampton and Townsville, and Toowoomba and Dalby manufacture agricultural machinery and implements. The generation and supply of electric power has also become a major industry.

External Trade.—External trade was valued at £325,243,000 in 1951–52. Of this. £142,867,000 related to trade with other Australian states and £182,376,000 to overseas trade. Total exports were valued at £144,233,000 and imports at £181,010,000, most of the balance being absorbed by invisible trade items. The chief items of oversea exports (1951–52 values) were: wool (£53,752,557), canned meat (£6,759,172), suear (£6,521,516), lead and silver-lead bullion (£5,672,224), zinc (£4,461,554) and frozen beef and veal (£4,045,763). The total value of pastoral-industry exports overseas mas £65,590,502, agricultural and dairy products £13,804,232 and mineral £12,005,113. Imports from overseas consist largely of manufactured goods, the main items being machinery and appliances (£14,481,826), hardware and metal manufactures (£11,775,123), textile? (£11,621,854), motor vehicles and parts (£9,257,070) and oil (£8,853,519).

TRANSPORT AND COMMUNICATIONS

With a comparatively small population dispersed over a wide area and with a large volume of primary commodities needing transport over great distances the provision of adequate public transport facilities—rail, road and air—has involved a high capital outlay in relation to returns. Standardization of the 3 ft. 6 in. gauge by the State Railway department was primarily a device to enable maximum railway mileage to be constructed and operated at minimum cost, and by 1924, when the Brisbane-Cairns coastal line was completed (1,043 mi.), the present system was substantially in operation, though the 69 mi. of standard gauge (4 ft. 8½ in.) line from Brisbane to Kyogle providing through running to Sydney was not completed until 1930. In 1953 rail mileage was 6,560. Five main lines, each having branching lines, serve interior districts. Air-conditioned trains with diesel power were introduced in 1953 on the Brisbane-Cairns ("Sunlander") and Townsville-Mt. Isa ("Inlander") lines. In 1951–52, 18,421,466 train-miles were run and 34,840,109 passengers carried.

A network of interstate and internal air services by the commonwealth government's Trans-Australia-Airlines, by Australian National Airways Pty., Ltd., and by several smaller concerns was established. Regular services are operated to New Guinea and New Caledonia and connections with other overseas air routes are made via Sydney and Darwin. Flying doctor aircraft are based at Charleville, Cloncurry and Charters Towers.

There are 133,987 mi. of roads in the state, of which 20,890 mi. are maintained by the Main Roads commission. Creek and river crossings form the main obstacle to road transport in country districts during the summer rains as it is uneconomic to build high-level bridges on lightly trafficked roads. An inland highway linking Brisbane and Townsville via Eidsvold, Emerald and Charters Towers provides an all-weather route from north to south. Passenger and cargo ships maintain regular services along the Queensland coast and to southern states, Thursday Island and New Guinea, and overseas shipping lines serve Queensland ports. (R. H. G.)

BIBLIOGRAPHY.—Australian and New Zealand Association for the Advancement of Science, *Handbook of Queensland* (1951); F. Hurley, *Queensland* (1950); Australian Institute of Political Science, *Northern Australia* (1954); *Queensland Yearbook, Queensland Chamber of Manufactures Yearbook* and *Australian Sugar Yearbook* (published annually); papers of specialized interest in such periodicals as the *Australian Geographer, Economic Record, National Development, Proc. Roy, Soc. Queensland, Queensland Government Mining Journal, Queensland Journal of, Agriculture* and *University of Queensland Papers;* C. A. Bernays, *Queensland Politics During Sixty Yeavs (1859–1919)* (1951); Government of Queensland publication, *Our First Half-Century* (1909); Annual Reports of Department of Public Instruction; F. M. Bailey, *Comprehensive Catalogue of Queensland Plants* (1909); W. D. Francis, *Australian Rain-Forest Trees*, 2nd ed. (1951); T. C. Roughley, *Wonders of the Great Barrier Reef* (1936; 1937; 1947); Ellis Troughton, *Furred Animals of Australia* (1941).

QUEENSLAND NUT, Australian nut and *Macadamia* are names applied to the edible fruits of two closely related trees of the silk-oak family (Proteaceae) native to Queensland and New South Wales. *Macadamia ternifolia* has stiff oblong-lanceolate leaves four to eight inches in length, with coarsely serrate margins; M. *integrifolia* has similar leaves, but with smooth margins. Under favourable conditions of growth (a climate about like that for the orange) and rather moist rich soil, the trees ultimately attain a height up to 60 ft. and are highly ornamental in appearance.

Hard-shelled, shiny round nuts, covered by thick husks and following the small white flowers, are abundantly produced on racemes six to eight inches long. The husks split open and release the nuts when the latter are fully ripe. The kernels are rich in oil and of unusually delicate flavour, which accounts for their popularity and the high prices they bring in food-specialty markets. They are used almost exclusively as a dessert nut.

Propagation is commonly by seed, but superior varieties (of which a number have been established in Hawaii and Australia) must be propagated vegetatively. Grafting is commercially feasible but rather difficult. Because of their eventual large size, trees in orchards are planted 35 to 40 ft. apart. There are numerous small commercial orchards in Hawaii and Australia, many trees in California and Florida and occasional ones in other tropical and subtropical regions. (W. Po.)

QUEENSTOWN, a town in the province of Cape of Good Hope. Republic of South Africa, in the upper valley of the Great Kei river, 154 mi. N.W. of East London by rail. 31° 53' S., 26° 52' E.; altitude 3,544 ft. Pop. (1960) 33.126, including 9,658 Europeans, 20.449 natives, 2,896 "Coloured" and 123 Asiatics. The town is the centre of a good wheat- and wool-producing area.

QUENTAL, ANTHER0 DE (1842–1891), Portuguese poet, was born in the Azores and studied at the University of Coimbra. After the publication of one volume of verse, he joined the revolt of the young men which dethroned Castilho, the chief living poet of the elder generation, from his place as dictator over modern Portuguese literature. He adopted socialist opinions, worked as a compositor in Paris though he had independent means, visited the United States and then returned to Lisbon where he worked actively for socialism.

Quental found his way through a series of disappointments to the mild pessimism, a kind of western Buddhism, which animates his later productions. His melancholy was increased by a spinal disease which, after several years of retirement, eventually drove him to suicide on his native island. Quental seldom attempted any form of composition other than the sonnet but few poets who have chiefly devoted themselves to this form have produced so large a proportion of really exquisite work. The comparatively few pieces in which he either forgets his doubts in inward conflicts or succeeds in giving them an objective form are among the most beautiful in any literature.

His friend, Oliveira Martins, edited the sonnets (1886), supplying an introductory essay; and an interesting collection of studies on the poet by the leading Portuguese writers appeared in a volume entitled *Anthero de Quental, In Memorianz* (1896). The sonnets have been turned into most European languages. They were translated into English by Edgar Prestage (*Anthero de Quental, Sixty-four Sonnets*, 1894) together with a striking autobiographical letter addressed by Quental to his German translator, Dr. Storck.

QUERCIA, JACOPO DELLA (*c.* 1374–1438), one of the most original Italian sculptors of the early 15th century, was born, probably at Siena, between 1370 and 1374. In *c.* 1406 he carved the tomb of Ilaria del Carretto in the cathedral of Lucca, a town with which his father, the goldsmith and sculptor Pietro d'Angelo, had long been associated. The effigy and sarcophagus from this tomb alone survive. In 1408 Quercia was employed at Ferrara on a statue of the Virgin and Child which still exists in the Museo dell' Opera del Duomo, and a year later he received the commission for the celebrated Fonte Gaia in the Campo at Siena (now replaced by a copy, original in the loggia of the Palazzo Pubblico). The scheme of this highly individual fountain was repeatedly modified, and effective work upon it seems to have been confined to the years 1414–19. Concurrently with the Fonte Gaia, Quercia was engaged on commissions at Lucca which included a statue of an apostle for the exterior of the cathedral (1413), the tomb slabs of Lorenzo Trenta and his wife in S.

Frediano (1416) and the Trenta altar in the same church (1416–22). These are strongly northern in character. In 1417 Quercia agreed to undertake two gilt bronze reliefs for the baptismal font in S. Giovanni in Siena; the contract for one of these was later transferred to Donatello, but the second, "Zacharias in the Temple." was completed in 1430 and is still on the font. Between 1427 and 1430 he also designed the hexagonal tabernacle in the centre of the font and carved the reliefs of prophets in the niches with which five sides of it are filled. In 1425 he had signed a contract for the central doorway of S. Petronio at Bologna: work on this occupied him until his death on Oct. 20, 1438. In its present form the doorway consists of ten scenes from Genesis set in the pilasters at the sides, five scenes from the early life of Christ across the architrave and a lunette surrounded by reliefs of prophets containing statues of the Virgin and Child and SS. Petronius and Ambrose (the latter an addition by Domenico da Varignana). The Genesis scenes are Quercia's most inspired and expressive works. In 1435 Quercia was appointed superintending architect of Siena cathedral for which he was employed on the decoration (unfinished) of the Cappella Casini. To the same late phase belongs the Vari-Bentivoglio monument in S. Giacomo Maggiore. Bologna (after 1433). Quercia also carved in wood, notably an Annunciation group in the Collegiata at San Gimignano (1421). Though his work is exceptionally fully documented, Quercia is a mysterious artist and his ambivalent style fits less easily than that of his more conventional contemporary Ghiberti into the context of Tuscan early Renaissance sculpture.

"THE VIRGIN AND INFANT JESUS" BY JACOPO DELLA QUERCIA. IN THE LOUVRE, PARIS

BIBLIOGRAPHY.—P. Bacci, *Jacopo della Quercia. Nuovi documenti e commenti* (1929) ; G. Nicco, *Jacopo della Quercia* (1934) ; L. Biagi, *Jacopo della Quercia* (1946). (J. W. P.-H.)

QUERCITRON BARK is the inner bark of *Quercus velutina*, the black oak, a native of the middle and southern United States. The exterior bark is removed from the tree by shaving and the inner portion, which contains the colouring matter, is detached and ground. The colouring matter of quercitron bark is quercitrin, $C_{21}H_{22}O_{12},H_2O$, a glycoside which by hydrolysis with acid yields quercetin, $C_{15}H_{10}O_7$, and the sugar rhamnose, $C_6H_{12}O_5$. When quercitron bark is exhausted with hot water under pressure, the extract deposits a crude quercitrin which is known commercially as yellow flavine. A second variety known as red flavine, prepared by digesting an extract of the bark at the boil with dilute acid, is in reality a crude quercetin. These products dye wool mordanted with aluminum and tin bright yellow and orange shades; they were at one time used with cochineal for obtaining especially vivid scarlets. (A. G. P.)

QUERCY, a former county of France which derived its name from the Gallic tribe of the Cadurci and corresponds to most of the present *départements* of Lot and Tarn-et-Garonne. In the middle ages it was divided into Upper or Black Quercy and Lower or White Quercy, the capital of the former being Cahors and that of the latter Montauban. Its two other chief towns were Figeac and Moissac.

Early in the 6th century Quercy passed under the authority of the Franks and in the 9th century it was part of the Frankish kingdom of Aquitaine. At the end of the 10th century its rulers were the counts of Toulouse and it fell to the French crown with the inheritance of Alphonse de Poitiers (1271). In the 13th and 14th centuries it was in dispute between the kings of England and France. In 1259 some rights over Lower Quercy were ceded to England; in 1360 the treaty of Brétigny assigned the whole county to Edaard III but in 1440 the English were finally expelled. In the 16th century Quercy vas a Protestant stronghold and the scene of savage warfare. During the reign of Louis XIII, Montauban was again the centre of activity.

QUERÉTARO, a central plateau state of Mexico. Pop. (1950) 286,238; (1956 est.) 314,034; area 4,432 sqmi. On the semiarid mesa and traversed at the north by a spur of the Sierra Madre known as the Sierra Gorda, Querétaro is about evenly divided between mountainous mineralized areas and the rolling plains and fertile valleys of the south which form part of Mexico's granary or *bajío*. The state has good air connections and is traversed in a southeasterly direction by the trunk highway from Nogales to Mexico City and the National Railways of Mexico. The climate is generally dry and temperate except in the northwest portion which is hot. Rainfall is moderate and frosts are few and light.

With soil 10 to 15 ft. deep in the southern lowlands, the state produces a large variety of crops. fruits, grain, medicinal plants and a notable sweet potato or camote. Though deposits of gold, copper, lead, tin and other metals occur, the chief products are opals and mercury especially in a compound (sulphoselenide of mercury) known as onofrite, from Cerro San Onofre. The breeding of fighting bulls is also an important activity.

The area was inhabited by the Otomi-Chichimec Indians who were conquered by the Spaniards in 1531. Colonization took place in the 1550s and Querétaro was administered with Guanajuato before it became a state in 1824. (J. A. Cw.)

QUERÉTARO, a city of Mexico and the capital of the state of Querétaro, is 167 mi. by rail and 162 mi. by highway N.W. of Mexico city, and located at the foot of the Cerro de las Campanas. Elevation 6,168 ft., pop. (1950) 49,209; (1958 est.) 53,114. Querétaro is considered an excellent example of a Spanish colonial city. It was founded by the Otomie Indians and was incorporated into the Aztec empire in 1446 and henceforth served as an outpost against the warlike tribes to the north until it was brought under Spanish control in 1531. Throughout most of the colonial period Querétaro was important primarily as a way station and supply centre serving the rich mining districts of Guanajuato and Zacatecas. Colonial buildings include the cathedral (restored several times), the federal palace and the churches of Santa Rosa, Santa Clara and San Augustin. Water is brought to the city by an aqueduct (built 1726–1738) approximately 5 mi. long, vith 74 arches, 50 ft. high and upborne by piers 46 ft. thick. The main products are textiles, pottery and agricultural produce. The city has one of the largest and oldest cotton factories in Mexico.

Querétaro has witnessed many fundamental changes in the evolution of modern Mexico. In 1810 it was the scene of a plot against Spain ahich led to the uprising headed by Miguel Hidalgo y Costillo in September of that year. In 1848 the treaty of Guadalupe Hidalgo terminating the U.S.-Mexican War was signed there. The forces of Benito Juárez defeated those of Emperor Jlaximilian at Querétaro in 1867; and on a nearby hill Maximilian and his generals Miguel Miramón and Tomás Mejía faced the firing squads. The Mexican constitution of 1917 nas written in Querétaro which was also the birthplace of the National Revolutionary party of Mexico (1929). the dominant political force in the republic. (J. J. J.)

QUESNAY, FRANÇOIS (1694–1774). French economist and leader of the first systematic school of political economy (see PHYSIOCRATIC SCHOOL), was born. perhaps at Méré, near Paris, on June 4, 1694. He studied surgery, graduated as a doctor of medicine (1744) and eventually became consulting physician to Louis XV. He did not publish anything on economics until the age of 60 and then mainly anonymous articles. But at Versailles, where he enjoyed the support of Mme. de Pompadour. there gathered around him and Jean C. M. V. de Gournay (1712–59) the secte des *économistes,* notably Victor Riqueti de Mirabeau, Nicolas Baudeau, P. P. le Jlercier de la Riviere. G. F. le Trosne and P. S. du Pont de Nemours, who looked to Quesnay as their leader and enthusiastically propagated his doctrines, A. R. J. Turgot was partly associated with the group; Adam Smith got to know

Quesnay and had a great respect for his ideas. Quesnay died at Versailles on Dec. 16, 1774.

Quesnay's peculiarities of expression and his extreme emphasis on agriculture as the sole economically productive activity-yielding a *produit net,* as contrasted with the "sterility" of industry and commerce, should not be allowed to conceal the great importance of his contributions to economic thought. He contributed, above all, to that systematization of economic analysis which introduced the classical period in Britain and France; only Richard Cantillon preceded him in this. Quesnay's system is summed up in his *Tableau économique* (1758), which displays diagrammatically the interdependence of the different economic classes and sectors and the flow of payments between them. In his *Tableau* Quesnay develops the assumption of a state of stationary economic equilibrium! a fundamental simplifying concept from which so much subsequent economic analysis departed. The general equilibrium analysis of Léon Walras and the input-output analysis of modern economics developed by W. W. Leontief are descendants of Quesnay's *Tableau.* Especially important was his analysis of capital as *avances,* or a stock of wealth which had to be accumulated in advance of production, and his classification of these *avances* in a manner which developed the distinction between fixed and circulating capital. Quesnay's analysis of savings as possibly harmful, in that if they are not invested but hoarded they may disturb the equilibrium of the flow of payments. is closely similar to that of J. M. Keynes. However, Quesnay's ideas on saving represent a line of thought which was to be supplanted immediately in orthodox economic thought for a century or more by the theory of Turgot and Smith, according to which saving is unconditionally beneficial.

The methodology of Quesnay's system and his principles of policy start from an extreme form of the doctrine of natural law which led him to proclaim that laissez-faire in economics—plus the single tax on net income from land—represented the divinely appointed economic order. Quesnay, in fact, is one of the originators of 19th-century doctrines of the harmony of class interests and of the related doctrine that the maximum social satisfaction occurs under free competition. He also developed the *a priori* method, often employed subsequently, of attempting to demonstrate these doctrines. In their day his principles of policy represented an active campaign against monopolies and privilege, requiring a strong government based, as Quesnay advocated, on a powerful monarchy.

Quesnay's *Oeuvres économiques et philosophiques* were edited by A. Oncken (1888).

See M. Beer, *An Inquiry Into Physiocracy* (1939) ; J. A. Schumpeter, *History of Economic Analysis,* pp. 223–243 (1954). (T. W. H.)

QUESNEL, PASQUIER (1634–1719), French Jansenist theologian and author of the *Réflexions morales,* was born in Paris on July 14, 1634, and joined the French Oratory in 1657. His Jansenist sympathies led to his banishment from Paris in 1681, and three years later he was expelled from the Oratory. Fearing further measures of persecution, he fled to Brussels where he lived with Xntoine Arnauld. In 1703 he was arrested, but soon escaped to Amsterdam, where he lived until his death on Dec. 2, 1719.

After Xrnauld's death in 1694 Quesnel was generally regarded as leader of the Jansenist party *(see* JANSENISM). His *Le Nouveau Testament en français avec des réflexions morales* (1692) played almost as large a part in its literature as Jansen's *Augustinus.* The bull *Unigenitus* (1713) condemned 101 sentences from the *Réflexions morales.* Quesnel, who had never admitted that his opinions were heretical, received the last sacrament on his deathbed.

See A. Le Roy's edition of Quesnel's correspondence, 2 vol. (1900) ; A. Vacant, *Dictionnaire* de *théologie catholique,* vol. xiii, col. 1460–1535 (1937). (N. J. A.)

QUÉTELET, (LAMBERT) ADOLPHE (JACQUES) (1796–1874), Belgian mathematician, astronomer and statistician, was born on Feb. 22, 1796, in Ghent and educated there in the lyceum and new university. He later studied astronomy at the Paris observatory and the probability theory under Pierre Simon Laplace. He lectured at the Brussels athenaeum, military college and museum; became head and founder in 1828 of the Royal observatory; and perpetual secretary (1834–74) of the Royal academy. He made important contributions to the study of meteoric showers.

Quételet was a prime mover in the development of methods for simultaneous observations of astronomical, meteorological and geodetic phenomena at scattered points throughout Europe. His outstanding contributions to statistical organization and practice included many aspects of governmental statistics, notably census taking; organization of the first international statistical conference; the development of uniformity and comparability in international statistics; and the application of probability theory to anthropology and sociology. His *Sur l'homme* (1835) developed the concept of the "average man" as the central value about which measurements of a human trait are grouped according to the normal probability curve. His studies of the numerical constancy of such voluntary acts as crimes stimulated extensive studies in "moral statistics" and wide discussion of free will versus social determinism in human behaviour. He died on Feb. 17, 1874, in Brussels. *See* also MEDICINE, HISTORY OF: *Beginning of Vital Statistics.* *(F.* H. Hs.)

QUETTA, a city in West Pakistan. which was formerly capital of Baluchistan, is the headquarters of the Quetta district and also of the division of the same name. The population (1951) was 83,892 including 28,094 in the cantonment area. It rose to prominence in 1976 when Sir Robert Sandeman founded a residency there. The name Quetta (Kawatah) is a variation of the word *kwat-kot,* signifying a fortress, and the place is still locally known as Shal or Shal Kot. Quetta is the southernmost point in the line of frontier posts and in the system of railways on the northwest frontier of West Pakistan, 536 mi. N. of Karachi. The cantonment and civil station of Quetta stand in an open plain about 5,500 ft. above sea level, within a ring of mountains. North of Quetta is the open plain leading to Pishin. During the last quarter of the 19th century Quetta grew into a strong fortress and an army station. A trade mart for western Afghanistan, eastern Iran and much of central Asia, Quetta's population had grown to 84,343 by 1951, despite a disastrous earthquake which practically destroyed the city in June 1935. Its importance as a summer resort increased after the establishment of Pakistan.

QUETTA DISTRICT has an area of 5,310 sq.mi. Pop. (1951) 212,885. The actual line of valley which contains Quetta and the Bolan pass was originally rented from the Khan of Kalat. This perpetual leasehold was afterward extended so as to include Nushki and give the British government the command of the trade route to Seistan. (K. S. AD.)

QUEVEDO Y VILLEGAS, FRANCISCO GÓMEZ DE (1580–1645), one of the greatest Spanish poets and prose writers. Born in Madrid on Sept. 17. 1580, he studied arts and theology at the universities of Alcalá and Valladolid from 1596 to 1606. In 1613 he became a counselor of the duke of Osuna, viceroy of Sicily and later of Naples, who entrusted him with diplomatic missions in Italy and Spain. Accused by the Venetian government of being one of the ringleaders of the conspiracy of 1618, he is said to have escaped from the city disguised as a beggar. Compromised by the fall of Osuna, Quevedo was imprisoned in 1620 but released in the following year. After refusing the post of ambassador in Genoa, he was given the honorary title of king's secretary in 1632. In 1639 he was arrested and confined in the monastery of San Marcos at León. This downfall has been traditionally attributed to a poem denouncing the political conduct of affairs, which was placed upon the king's table, but the incident may be apocryphal and Quevedo's authorship of the poem is not certain.

He was released from the monastery in 1643 and died at Villanueva de los Infantes on Sept. 8, 1645.

Quevedo is an outstanding figure in the European literature of his age. Of brilliant intellect and strong passions, he reveals his complex personality in the extreme variety of tone in his life and work. His learning and wide culture impelled him to write works of high moral seriousness; but he shows familiarity with low life and he kept a mistress by whom he had several children. The enormous range of his work, from the obscene to the devout, shows a capacity to live intensely on every level of experience but not to unify its extremes. The tension underlying his work reveals pent-up bitterness. traceable to sincere self-reproach. His humour is never far from the'sardonic. By itself much of his satire would seem splenetic, but in association with his serious poetry and prose treatises it discloses anguish at his failure to reconcile the defects of the world and of himself within it with the standards set by his own intelligence and conscience.

As a poet, Quevedo is supreme. His large output ranges from verse in the cant of the underworld through lampoons and parodies to meditative poems on time and death. His love poetry includes both poems showing an obsession akin to disgust with the crudely physical, and sonnets that transform the conventional Petrarchan tradition by their intensity of feeling. The keynote is his feeling that the divine calls the mind to a love which is torture to the body, that passion shows the light of life while consuming itself in darkness. There is no sensuous prettiness or emotional softness in Quevedo's poetry: his intense feeling is conveyed with dignity of expression and intellectual strength.

Though an opponent of the Latinizing innovations introduced by Luis de Góngora, whom he parodied unmercifully, Quevedo was adept in the new Baroque style. The greatest exponent of *conceptismo (see* SPANISH LITERATURE), he shows as masterly a use of the metaphysical conceit as does John Donne. In his satires his linguistic ingenuity and audacity are unbounded, and as a virtuoso of language he is unequaled in Spanish literature. The *Sueños* (1627), mostly visions of hell written at intervals from 1606 to 1622, show his development in the technique of satire: the conceits grow from mere puns into scintillating images that transpose the identities of objects and invert their functions. This culminates in his masterpiece, *La hora de todos* (written 1635–36). Here transposition and inversion produce a picture of a world where commercialism, imperialism, racialism, slavery and international politics have turned values inside out. No less masterly is the picaresque novel, *La vida del Buscón* (1626). Its verbal wit and often grotesque exaggeration have tended to obscure the acuteness of its psychological insight: the son of disreputable parents, the protagonist carries a burden of shame and guilt from which he seeks escape in illusory fantasies that lead to a life of roguery and deception.

In his nonsatirical work, Quevedo's *conceptismo* produces a terse and dignified style. His precision in the association of disparate concepts gives, in such works as *La política de Dios (I,* 1626; II, written 1634–35) and *La providencia de Dios* (written 1641), an original and powerful expression to a thought that is mainly conservative and traditional. His *Marco Bruto* (1644) is an interesting defense of monarchy against democracy. For Quevedo social and political issues resolve themselves into questions of personal morality. This made him promulgate in Spain the Stoic doctrines which Justus Lipsius had popularized throughout Europe. He translated Phocylides. Epictetus and Seneca and wrote Stoic treatises of his own of which the chief are *La cuna* y *la sepultura* (1634) and *Virtud militante* (written 1634–36). Their originality consists in presenting the subject in terms of the 17th-century preoccupation with the paradoxes of human nature and life. Quevedo's Stoicism is neither priggishness nor indifference, but a concern for one's own integrity that does not exclude compassion for one's neighbour, but does exclude the desire to judge, rebuke and punish him.

BIBLIOGRAPHY.—*Obras Completas,* ed. by L. Astrana Marín *(En prosa,* 3rd ed. 1945; *En verso,* 3rd ed. 1952; *Epistolario,* 1946). L. Astrana Marín, *La vida turbulenta de Quevedo,* 2nd ed. (1945); A. Papell, *Quevedo: Su tiempo, su vida, su obra* (1947); A. A. Parker, "The Psychology of the Picaro in 'El Buscbn'," *Modern Language Review,* vol. xlii (1947); T. E. May, "Good and Evil in the 'Buscbn'," *Modern Language Review,* vol. xlv *(1950)*; D. Alonso, *Poesia española,* pp. 531–618 (1950); A. Mas, *La Caricature de la femme, du mariage et de l'amour dans l'oeuvre de Quevedo* (193'7). (A. A. P.)

QUEZAL, QUETZAL or QUESAL, one of the most beautiful of birds, an inhabitant of the mountains of Central America. This bird, *Pharomacrus mocinno,* is one of the trogons (*q.v.*), and in body is about the size of a turtledove. The plumes of the tail, which may measure 33 ft., are golden green and before the Spanish conquest could be worn only by chiefs. The rest of the plumage is green above and scarlet below. In the female the tail is short. The eggs are a pale bluish green.

QUEZALTENANGO is a department in western Guatemala. Its surface elevations range from near sea level to more than 12,000 ft. at the peak of the volcano Santa Maria; its mountain valleys lie at altitudes of about 8,000 ft. It has some industry and a diversified agricultural production which includes grains, coffee, bananas and livestock. Area 753 sq.mi. Pop. (1957 est.) 222,498, chiefly Indian or mestizo descendants of preconquest Quiché stock.

The capital city Quezaltenango, pop. (1957 est.) 33.726, the second city of the republic, is connected with Guatemala city by paved highway and air transportation. It stands at the foot of the volcano Santa Maria near the site of the battle in which the Spaniards under Pedro de Alvarado and their Indian allies from Mexico decisively defeated the native Quiches in 1524. Before the conquest it had been the capital of a Quiché kingdom known as Xelajú. It is a marketing and processing centre important for textile factories, mills and breweries, and the seat of two university faculties.

An electrified railway, built in 1930 to connect with the coastal line, ceased operation in 1933 after extensive flood damage, but the Santa Maria hydroelectric plant continued to operate and in the early 1960s was capable of supplying power in excess of demand.

The name Quezaltenango means "palace of the quetzal," a native bird which had great symbolic importance among the Mayas and is now the national symbol of Guatemala. (W. J. G.)

QUEZON, MANUEL LUIS (1878–1944), Philippine statesman, was born at Baler on the island of Luzon, and studied law at Santo Tomas university in Manila. He joined the insurrectionist movement of Aguinaldo, but later swore allegiance to the territorial administrators and became a provincial prosecutor. He was a member of the Philippine assembly 1907–09, resident commissioner to the U.S. congress 1909–16, and president of the Philippine senate 1916–35. He was elected first president of the Commonwealth of the Philippines Sept. 17, 1935. He died Aug. 1, 1944, at Saranac, N.Y.

QUEZON, a long narrow coastal province of Luzon Island, Philippines, is 270 mi. long and varies from 5 to 35 mi. in width. Area 4,616 sq.mi. Formerly called Tayabas, the name was changed in 1946 in memory of Pres. Manuel Luis Quezon. The northern two-thirds of the province is mountainous and sparsely inhabited but excellent cabinet and plywood timber is produced near Infanta and Baler. Southern Quezon contains some of the largest coconut plantations in the world. Provincial population (1960) 656,892. Lucena, on Tayabas bay. is the capital and major copra centre; Tayabas, 8 mi. N. of Lucena, is also a trading and copra centre. (R. E. HE.)

QUEZON, CITY OF, capital city of the Republic of the Philippines named for Pres. Manuel Luis Quezon, is located immediately east of Maniia on Luzon. Area 28 sq.mi. Pop. (1960) 397,374. Much of the city lies at an elevation about 100 ft. above downtown Manila, which is slightly above sea level. Temperatures are lower than in Manila; because Quezon is further from the bay,'humidity is lower.

The city of Quezon officially replaced Manila as the Philippine capital in 1948 and in the second half of the 20th century construction of government buildings was underway. Most functions of the national government however remained in Manila. The University of the Philippines is located in Quezon as well as Ateneo de Manila and a veterans' hospital. The city is bisected by the Circumferential highway along which light industry began to develop.

San Francisco del Monte and Kamuning are first-class residential sections, while the Cubao section is an important transportation junction and bazaar area. (R. E. HE.)

QUIBERON, CAMPAIGN AND BATTLE OF. Several plans were made for the invasion of the British Isles by the French during the Seven Years' War, and in 1759 an army was assembled at Vannes in Brittany, with its transports lying in the Morbihan, the landlocked waters inside Quiberon bay. To protect this force while undertaking the invasion, the French planned to unite their fleets at Toulon and Brest; but these ports were blockaded by Adm. Edward Boscawen and Adm. Sir Edward Hawke respectively. During July 1759, Boscawen was compelled to take his squadron to Gibraltar for provisions and refitting, and Adm. de la Clue led the Toulon fleet through the straits of Gibraltar with the idea of reaching Brest. But he was pursued from Gibraltar by Boscawen, and in the running fight which finished in Lagos bay his force was completely disorganized and defeated.

Meanwhile Hawke continued the blockade of Brest with the utmost pertinacity, but on Nov. 9, 1759, he was forced to run into Torbay by lack of stores and exceptionally bad weather. Adm. Conflans took the Brest fleet to sea on the same day that Hawke left Torbay (Nov. 14), and headed south. Hawke also headed south. On the morning of Nov. 20 both fleets were about 30 mi. off Belle-Ile. Conflans, seeing a few English ships under Commodore Duff watching Quiberon bay, stood in close to capture them, but on sighting Hawke's fleet to the northwest, he changed his mind and determined to run into the bay itself.

On sighting the French, Hawke signaled "line abreast" in order to concentrate his force, and followed this up by "general chase" and "line of battle ahead." Hawke's leading ships soon began to overhaul the French. At 2:30 p.m., just as Conflans was rounding Belle-Ile, his rearmost ships began to be attacked and soon afterward both fleets swept into the bay. There were 21 of the line in each fleet, but the French had a great advantage in carrying pilots who knew the coast. Two French ships were sunk and another was captured before Hawke made the signal to anchor. Next morning, Nov. 21, the French fleet scattered; seven ships ran up the Vilaine river and nine ran out to sea for Rochefort, one sinking on the way. Conflans' flagship, the "Soleil Royal," ran herself ashore on Nov. 21 and was burned by her own crew. An attempt to burn the ships in the Vilaine by a boat attack was abandoned, because of bad weather and the strong defenses of the river mouth. Nevertheless, the French Brest fleet was now quite useless as a tactical combination, and "had we had but two hours more daylight," wrote Hawke, "the whole had been totally destroyed or taken; for we were almost up with their van when night overtook us." With both their fleets defeated, the French were now compelled to abandon their invasion project, and cease all major naval operations for the rest of the war.

(G.A. R.C.; W. C.B.T.)

QUICHÉ, the most important Indian nation in Guatemala at the time of the Spanish conquest. Today the Quiché tongue, a Mayan dialect, is spoken by about 275,000 pure-blooded natives throughout the departments of Quiché, Quezaltenango, Totonicapán, Retalhuleu and Sacatepéquez.

Quiché history and tradition are preserved in a book known as the *Popol Vuh* written by a native shortly after the conquest. It relates four attempts to create a satisfactory world and people it. On the last attempt the gods made four men: Balam-Quitze, Balam-Agab, Mahucutah and Igi-Balam: of these the first three became the ancestors of the Quiché. As first constructed these men had too many divine attributes to suit the gods, so their wits were dulled, but in compensation they were given wives. At this time the other Indian tribes were created and they all went to Tulan Zuiva to receive their household gods. The Quiché god, Tohil, then made the first fire by striking it from his sandal, while the other Indians learned the art from the Quiché. To gain this end, with one exception, they were tricked into giving human hearts in sacrifice. All then started to migrate to Guatemala and when they arrived the first sunrise took place. Then the four leaders withdrew to the woods and after the Quiché had successfully fought a war, these holy men died. They were succeeded by their sons who immediatelv departed on a mystic journey to the east where they received fhe insignia of temporal power at the hands of the great king, Nacxit, who also taught them the secret of writing.

Upon the return of their leaders the Quiché settled in stone wrought cities and from this point the *Popol Vuh* assumes a definitely historical character. It describes the reigns of many kings and pictures in detail their wars with neighbouring nations. The apogee of Quiché power was reached under Kicab who made tributary all his neighbours, but these conquests were never consolidated into a kingdom. Fighting continued with varying fortunes until the arrival of the Spaniards.

In 1524 Pedro de Alvarado, the lieutenant of Cortés, entered Guatemala. The Quiché had received warning of his coming and of the strength of the Spanish arms from the Aztec emperor Montezuma. They had hastily made peace with warring neighbours but were unable to unite them in a common defence. Their preparations to repel Alvarado were impeded by the death of their king, Tanub. His successor, Tecum Umam, met the Spaniards with a huge army upon the plains of Zelahuh near the modern Quezaltenango. There followed a series of desperate actions in which the Indians failed to withstand the Spanish cavalry and artillery, backed by a force of native allies. Finally Tecum Umam personally attacked Alvarado and after unhorsing him was slain. Then the Quiché retreated to their capital, Gumacaah, leaving innumerable dead along the banks of a stream to this day known as Xiquiguel, the river of blood. However, the Quiché were not yet conquered and the new king, Chignauivcelut, endeavoured to entice Alvarado into his capital so that he might burn the houses over the Spaniards' heads while his men cut off their retreat over the narrow causeway by which the city was entered. Alvarado discovered this plan, captured the Quiché by stratagem and hanged the king: thus the opposition was broken.

At the time of the conquest a king ruled the Quiché in regal style. He was surrounded by 24 councilors who gave the ruler their advice and acted as judges and revenue collectors. The principal touns were governed by appointed lieutenants who, however, had no jurisdiction over the nobility. Each governor had his council organized in the same fashion as the king's. All these officials and others down to the rank of doorkeeper of the council were drawn from the nobility who took great care to preserve the purity of their blood.

Today the Quiché live in small villages in the highlands of Guatemala, for the most part on various coffee plantations where the Indians are held in a state of peonage. Some of the towns, however, particularly Chiquinula, Nahualá and Chichicastenango, have maintained a semi-independence and run their affairs with little interference from the central government. Chichicastenango is of peculiar interest because its inhabitants claim descent from the Quiché nobility and recognize one of their number, Manuel Ajanel, as king.

BIBLIOGRAPHY.—Domingo Juarros, *History of the Kingdom of Guatemala* (1823); J. L. Stephens, *Incidents of Travel in Central America* (1841); Brasseur de Bourbourg, ed., *Popol Vuh* (1861); Karl Sapper, "Der gegenwartige Stand der ethnographischen Kenntnis von Mittelamerika," *Archiv. für Anthropologie,* iii. band (Heft) (1901); S. K. Lothrop, *Note on Indian Ceremonies in Guatemala* (Indian Notes, vol. iv. No. 1) (1927). (S. K. L.)

QUICHERAT, JULES ETIENNE JOSEPH (1814–1882), French historian and archaeologist, was born in Paris on Oct. 13, 1814, the son of a working cabinetmaker from Paray-le-Monial. He was educated at the college of Ste. Barbe and at the École des Chartes. Inspired by Jules Michelet's pages on Joan of Arc in the *Histoire de France,* he published the text of the two trials of Joan, adding much contemporary evidence on her heroism in his *Procès de condamnation et de réhabilitation de Jeanne d'Arc* (5 vol., 1841–49), as well as half a volume of *Aperçus nouveaux sur l'histoire de Jeanne d'Arc* (1850).

He published, in the *Bibliothèque de l'École des Chartes,* a full biography (1840) of Jean Castel, an obscure chronicler of the reign of Louis XI, and another (1842) of Thomas Basin, bishop of Lisieux, whose writings he also edited (4 vol., 1855–59). In 1849 he was appointed professor of diplomatics at the École des Chartes. He died at Paris on April 8, 1882.

BIBLIOGRAPHY.—After his death his unpublished papers were printed as *Mélanges d'archdologie et d'histoire,* vol. i, *Antiquités celtiques, romaines, gallo-romaines,* ed. by A. Giry and A. Castan, with a biographical notice of the author by R. de Lasteyrie (1885); and vol. ii, *Archdologie du moyen âge,* ed. by R. de Lasteyrie (1886). Quicherat's *Histoire de la laine,* on which he was occupied for many years, was missing from his papers, and only the introductory chapters (up to the 11th century) of his lectures on archaeology were found. Among

his lectures published in contemporary reviews are *La Formation française des anciens noms de lieu* (1867); *De l'ogive et de l'arckitecture dite ogivale* (1850); *L'Age de la cathédrale de Laon* (1874); and *Histoire du costume en France* (1875; 2nd ed., 1877) a popular work. *See* also J. Berthelé, *Jules Quicherat, sa vie et son oeuvre* (1884).

QUICKSAND, a state in which saturated sand loses its supporting capacity and acquires the character of a liquid. Once considered, especially by construction men, to be a special type of sand, quicksand is now recognized as a condition that may be assumed by any sand if its effective weight is temporarily or permanently carried by interstitial water. Some natural sands are in a condition so loose that minor disturbances caused by a footstep may collapse the loose structure and produce a "quick" condition. Under these circumstances a person may become engulfed as in a fluid, but since the density of the sand-water suspension exceeds that of the human body, the body cannot sink. Struggling may lead to loss of balance and drowning. This possibility has no doubt led to the superstition. prevalent in literature. that quicksand has the ability to draw a person to his death. (R. B. P.)

QUICKSWOOD, HUGH RICHARD HEATHCOTE GASCOYNE-CECIL, Baron (1869–1956), English Conservative politician, prominent layman in the affairs of the church assembly and youngest son of Robert Cecil. 3rd marquess of Salisbury and prime minister, was born in London on Oct. 14, 1869. He was educated at Eton and at University college. Oxford. becoming a fellow of Hertford college in 1891. His interests turned to politics and he became assistant private secretary to his father. Cecil sat in the house of commons as Conservative member, first for Greenwich (1895-1906) and later for Oxford university (1910–37). He took a vigorous part in the stormy debates on the Balfour education bill (1902), opposed tariff reform and resisted the parliament act of 1911.

During World War I he served in the Royal Flying Corps (1915–18) and afterward took a less active part in politics but generally supported his brother, Lord Robert Cecil (afterward Lord Cecil of Chelwood), in adopting an independent attitude toward David Lloyd George's coalition government. With him, too. he supported the enabling bill (1919). and he became a prominent member of the church assembly set up in accordance with its provisions. In the conflict which arose over the revision of the prayer book in 1928 he gave energetic if unsuccessful support to the new proposals in the house of commons and in the assembly. He also had a long dispute with the bishop of Liverpool in 1933-34 over permitting Unitarians to preach in Anglican churches.

Cecil's political career never fulfilled its early promise. In the early 20th century his independence and ability temporarily attracted a group of young and able Conservatives, but it was perhaps this very independence which kept him out of the cabinet. His reputation as an orator, gained early in his career, rarely persuaded, although it was impressive and often witty. He was created a privy councilor in 1918 and made a baron in 1941. He was also. from 1936 to his retirement in 1944. provost of Eton. a position which necessitated his withdrawal from the house of commons in 1937. He died at Bournemouth on Dec. 10, 1956,

QUIDDE, LUDWIG (1858–1941), German historian, politician and pacifist! was born in Bremen on March 23, 1858. During 1889–96 he was editor of the *Deutsche Zeitschrift fur Geschichtswissenschaft* and in 1890 became professor and secretary of the Prussian Historical institute in Rome. In 1892 he returned to Munich and joined the German Peace society. In 1894 he wrote a satire, *Caligula,* against William II, which brought him three months' imprisonment for lese majesty. During 1907–19 Quidde was a liberal member of the Bavarian diet and member of the Interparliamentary union. From 1914–29 he was chairman of the German Peace society. During World War I he urged peace without annexations. In 1919 he joined the Democratic party and was a member of the national assembly, where he fought for a proportional electoral system and against the treaty of Versailles. In 1920 the party did not send him into the *Reichstng,* but he remained a member until 1932. He was chairman of the German peace cartel, 1921–29, representing the right wing of pacifism. He believed in securing peace "from above." rejected the war resistance movement, compromised on war guilt and fought against such radical pacifists as F. W. Foerster. Quidde was arrested in 1924 in Munich after writing in *Welt am Montag* against illegal military training. In 1927 he received the Nobel peace prize. Defeated by the left, he resigned in 1931. In 1933 he emigrated to Geneva, where he died on March 5, 1941. His books include *Studien zur Geschichte des rheinishcn Landfriedensbundes von 1254* (1885), *Der Fortschritt der Rechtsidee der Kulturentwicklung* (1911) and *Die Schuldfrage* (1921). (H. Jr.)

QUIDOR, JOHN (1801–1881), U.S. painter, was born at Tappan, K.Y., on Jan. 26, 1801. A pupil of the portraitist John Wesley Jarvis, he enjoyed limited success as a painter in New York city from about 1828 to 1868, subsisting mainly by commercial work. In 1868 he retired to a daughter's home in Jersey City. N.J., where he died, Dec. 13. 1881. His animated grotesque paintings. chiefly based on Washington Irving's tales of Dutch New York, were rediscovered in the 20th century and highly praised for their style and emotional intensity.

See John I. H. Baur, *John Quidor* (1942). (D. H. W.)

QUIETISM, a complicated religious movement that swept through France, Italy and Spain during the 17th century. Its chief apostles were Miguel de Molinos; a Spaniard resident in Rome, Fénelon, the famous French archbishop and his countrywoman. Jeanne Marie Guyon. Quietism was essentially a reaction against the bureaucratic ecclesiasticism always latent within the church of Rome. though it had come more especially to the front during the struggles of the Counter Reformation carried through by the Jesuits. Like their contemporaries the French Jansenists and the Quakers and Anabaptists of northern Europe, the Quietists fell back on a doctrine of immediate inspiration of the individual conscience. To the many God spoke only in general terms through the church; but to the few He made His will directly known. But how did He do so? How distinguish the voice of God from the vagaries of our own imagination? Quietism offered an easy test: The less "sense of proprietorship" a man had in his own good actions—the more they came from a source outside himself—the surer might he be that they were divine. If, on the other hand, they were the fruit of his deliberate thought and will, that was enough to show that they did not come from God. but from his sinful self. Hence the first duty of the Quietist was to be "passive."

The Spanish monk, Juan Falconi. who is generally reckoned as the father of Quietism, died in the odour of sanctity in 1632; about 30 years later his fellow countryman, Molinos, transported his doctrines to Rome, where they gained unbounded popularity with bishops and cardinals and even with Pope Innocent XI. In 1675 Molinos published the *Guida Spirituale,* the great textbook of his school. But his success soon aroused the suspicion of the Jesuits, the great champions of militant ecclesiasticism. "Passivity" accorded ill with a zealous frequentation of the confessional, their chief centre of influence. Failing to turn public opinion against Molinos in Rome, they brought pressure to bear on Louis XIV through his confessor. Père La Chaise. At the instance of the French ambassador Molinos was arrested (1685); his papers were seized, and his chief disciples examined by the Inquisition. Two years later he was convicted of heresy and sentenced to imprisonment for life.

The later stages of the Quietist drama were played out in France. There Quietist ideas had long been spreading under the leadership of enthusiasts like François Malaval (1627–1719), a blind layman of Marseilles. A more romantic figure was Jeanne Marie Guyon (1648–1717), a widow of good family and remarkable personal charm, who devoted her life to missionary journeys on behalf of "passivity." In 1688 fate brought her to the French court, where she made a great impression on Mme. de Maintenon and other persons of quality. But her most illustrious convert was Fénelon, then tutor to the duke of Burgundy, eldest son of the dauphin. Mme. Guyon and Fénelon made Quietism famous.

In 1697 Jacques Benigne Bossuet was at work on an *Instruction sur les états d'oraison,* which was intended to distinguish once for all what was true in Quietism from what was false. Fénelon, feeling sure that Bossuet would do the Quietists less than justice, determined to be beforehand with him. While Bossuet's book was still in the press, he suddenly brought out an *Explication des maximes des saints*. The little volume raised a violent storm. For two years Fénelon was at feud with Bossuet; he was banished from Versailles; finally, he was censured by the pope (1699), although in very measured terms. This condemnation, and Fenelon's bitter controversies with Bossuet, proved the deathblow to official Quietism.

See also the articles on BOSSUET, JACQUES BENIGNE; FÉNELON, FRANÇOIS DE SALIGNAC DE LA MOTHE; GUYON, JEANNE MARIE BOUVIER DE LA MOTHE; and MOLINOS, MIGUEL DE.

BIBLIOGRAPHY.—H. Heppe, *Geschichte der quietistischen Mystik* (1875), covers the whole subject. On the place of Quietism in the history of religious thought *see* W. R. Inge, *Christian Mysticism* (1899); on its psychology *see* H Delacroix, *Etudes sur le mysticisme* (1908); J. Denis, *Mémoires de l'Académie de Caen (1894)*; W. James, *The Varieties of Religious Experience* (1902).

QUILLER-COUCH, SIR ARTHUR THOMAS (1863–1944), English writer (pseudonym "Q"), born in Cornwall on Nov. 21, 1863. He was educated at Clifton college and Trinity college, Oxford, where he was afterward appointed lecturer in classics (1886–87). While he was at Oxford, he published (1887) his *Dead Man's Rock* (a romance in the vein of R. L. Stevenson's *Treasure Island).* following it up with *Troy Town* (1888) and *The Splendid Spur* (1889). Gaining some journalistic experience in London, mainly as a contributor to the *Speaker,* in 1891 he settled at Fowey in Cornwall and wrote several Cornish tales, including *The Blue Pavilions* (1891), *The Ship of Stars* (1899), *Hetty Wesley* (1903), *The Shining Ferry* (1905). He published several volumes of critical articles, *Adventures in Criticism* (1896), *On the Art of Writing* (1916), *Studzes in Literature* (1918; 2nd series, 1927; 3d series. 1929) and *Shakespeare's Workmanship* (Bristol, 1918). In 1898 he completed Stevenson's *St. Ives*. From his Oxford days he was known as a writer of excellent verse; most of his poetical work is contained in *Poems and Ballads* (1896). In 1895 he published a delightful anthology from the 16th and 17th century lyrists, *The Golden Pomp;* the invaluable *Oxford Book of English Verse 1250–1900* (1900); the *Oxford Book of Ballads* (1910); the *Oxford Book of Victorian Verse* (1912); the *Oxford Book of English Prose* (1925); *Poems* (1929); *The Poet as Citizen and Other Papers* (1934); *Q's Mystery Stories* (1937); *Victors of Peace: Florence Nightingale, Pasteur, Father Damien* (1937). In 1910 Quiller-Couch was knighted. In 1912 he was appointed King Edward VII professor of English literature at Cambridge, and was elected fellow of Jesus college, Cambridge. He died in Fowey, Cornwall, May 12, 1944.

QUILMES, Argentine city and suburb of greater Buenos Aires, 12 mi. S.E. of the federal district on the estuary of the Rio de la Plata. Pop. (1960) 318,144. The Indians who gave the city its name were subdued and settled in the area by the Spanish in 1666. During the early 19th century it was twice the scene of hostilities: in 1806 when the first English invasion landed on its shores, and in 1827 when Argentine forces defeated the Brazilian fleet in the estuary. Quilmes is one of the important industrial centres of Buenos Aires and the location of large breweries and distilleries. (Js. R. S.)

QUILON, a seaport on the Malabar coast, in Kerala state, India. Pop. (1951) 66,126. The palace of the maharaja of Travancore stands on the bank of Quilon lake.

QUIMBY, PHINEAS PARKHURST (1802–1866), U.S. pioneer in the field of mental healing and generally regarded as the father of the New Thought movement, was born in Lebanon, N H., on Feb. 16, 1802. His active career was spent largely in Belfast and Portland, Me., and he died at Belfast on Jan. 16, 1866.

Professionally interested in hypnosis (*q.v.*), Quimby employed it for a time as a means of healing, but later discovered that he was quite as able to heal by suggestion. He came to believe that illness resulted from the patient's mistaken beliefs, and that its cure lay in discovering the truth. Not primarily religious in the orthodox sense, he believed that he had rediscovered the secret of Jesus' healing ministry. He wrote down his philosophy in the so-called Quimby manuscripts. Quimby became a controversial figure because Mary Baker Eddy (*q.v.*), who sought healing at his hands, and was at first a disciple and warm admirer, later denied, as it was thought by many, that she had been influenced by him. It is the official belief that her discovery of Christian Science (*q.v.*), a divine revelation, depended in no sense on Quimby.

The best source is *The Quimby Manuscripts,* ed. by H. W. Dresser (1921), the first edition of which contains a number of letters of Mrs. Eddy to Quimby and others not found in later editions. (C. S. B.)

QUIMPER, formerly Quimper-Corentin, a town of France, capital of the *département* of Finistère. 158 mi. N.W. of Nantes. Pop. (1954) 15,629. Quimper, or at least its suburb Locmaria on the Odet, was occupied in Roman times. Later Quimper became the capital of Cornouailles and the residence of its kings. It is said to have been Grallon Meur who brought the name of Cornouailles from Great Britain and founded the bishopric, first held by St. Corentin about 495. Hoel, count of Cornouailles, united the countship with the duchy of Brittany. Quimper suffered in the local wars of succession. In 1344 it was sacked by Charles of Blois. Monfort failed to take the town in 1345, but it opened its gates to his son John IV in 1364 after the victory at Auray. The cathedral of St. Corentin (13th to 16th centuries), with a fine façade (*c.* 1425), is a splendid example of the Gothic style in granite. Breton pottery is made there.

QUIN, JAMES (1693–1766), a leading English actor of his day, was born in London on Feb. 24, 1693. He made his first stage appearance at the Smock Alley theatre, Dublin, as Abel in Sir Robert Howard's *The Committee* in 1712. Engaged at Drury Lane theatre for small parts, his remarkable memory enabled him to deputize at short notice as Bajazet in *Tamerlane* with great success. Quin then went to Lincoln's Inn theatre and remained there for 14 years. A noted swordsman, he was convicted of manslaughter for killing another actor in a duel, and at Lincoln's Inn he defended the stage with his sword against rioters. He went to Covent Garden theatre in 1732 and became a leader of the stage, returning to Drury Lane from 1734 to 1741. His style was declamatory, very slow but impressive, and he always wore the same costume. In 1746 his supremacy was challenged by David Garrick (*q.v.*), the exponent of a new type of acting, and when the two played together in *The Fair Penitent* at Covent Garden, Garrick triumphed. Quin bore him no ill will; they became friends and acted together at Drury Lane. Quin was one of the finest Falstaffs the stage ever knew. He retired to Bath in 1757 and died there on Jan. 21, 1766, being buried in the abbey church with an epitaph by Garrick.

Although of poor education. Quin had great wit and warm-hearted generosity. He was also a great epicure, his appetite being as prodigious as his memory.

See *Life of Mr. Janzes Quin, Comedian,* anon., 2nd ed. (1887). (W. J. M.-P.)

QUINAULT, PHILIPPE (1635–1688), French dramatist and one of the collaborators with Lully in the creation of French opera, was born in Paris, where he was baptized on June 5, 1635. By 1666 he had written 16 comedies, tragedies and tragi-comedies. He later wrote librettos for Lully, creating with him the form of the *tragédie-lyrique* which became the model for French opera. Their first work in this form was *Cadmus* (1673) followed. between 1674 and 1683, by *These'e, Atys, Isis, Prosperpine, Persée* and *Phaéton* He was particularly successful in his later romantic works, *Amadis* (1684). *Roland* (1685) and *Armide* (1686). His librettos long survived him and were used by Gluck. J. C. Bach and others. Though his reputation later suffered by comparison with Racine, his plays were popular, providing a theatrical counterpart of the polite novel, and presenting an ideal world, less heroic than that of Corneille and less harrowing than that of Racine. He died in Paris on Nov. 26, 1688.

BIBLIOGRAPHY.—The best edition of his works is *Théâtre,* 5 vol. (1739). *See* also E. Gros, *Philippe Quinault* (1926); J. B. A. Buijtendorp, *Philippe Quinault* (1928); A. Adam, *Histoire de la littérature française au 17e siècle,* vol. ii (1951).

QUINCE, a fruit tree concerning which botanists differ as to whether or not it is entitled to take rank as a distinct genus, *Cydorzia,* or as a section of the genus *Pyrus* (family Rosaceae, *q.v.*). The name *Cydonia oblonga* is to be preferred to *Pyrus cydonia.*

Bailey gives five varieties of *C. oblonga,* namely. varieties *lusitanica, maliformis, pyriformis, marmorata* and *pyramidalis.* The quinces are much-branched shrubs or small trees with entire leaves. small stipules, large solitary white or pink flowers like those of the pear or apple. but with leafy calyx lobes and a many-celled ovary, in each cell of which are numerous horizontal ovules. The fruits may be round and flattened or somewhat pear-shaped, with large leafy calyx persisting on the mature fruit.

ROCHE
QUINCE (CYDONIA OBLONGA) BLOSSOMS

The common quince is a native of Iran and Anatolia, and perhaps also of Greece and the Crimea. By Franchet and Savatier *C. oblonga* is given as a native of Japan, with the native name "maroumerou." It is certain that the Greeks knew a common variety upon which they grafted scions of a better variety from Cydon in Crete. whence it was obtained and from which the later names have been derived. The fragrance and astringency of the fruit of the quince are well known, and the seeds formerly were used medicinally for the sake of the mucilage they yield when soaked in water. The quince is but little cultivated in Great Britain; in Scotland it seldom approaches maturity, unless favoured by a wall. The fruit has a strong aroma and in the raw state is astringent; but it makes an excellent preserve. and is often used to give flavour and sharpness to stewed or baked apples.

The Japanese quince. formerly considered in the genus *Cydoniu* but now known as *Chaenomeles lagenaria,* has been widely used as an ornamental plant in gardens as a shrub, particularly because of the beauty of its flowers that appear on the stems before the leaves open fully in late winter and early spring months. Some of the small shrubs bear large green fragrant fruits that are quite inedible in the fresh state but have been used in making preserves.

The quince was formerly grown in home fruit gardens and commercial plantings in the northeastern United States but later became the least esteemed of all tree fruits for orchards in that area. The fruit is almost inedible in the uncooked state. and other fruits are preferred in the fresh state for the diet. It thrives under the same systems of cultivation as do apples and pears and does fairly well along fence rows, where it may be given little care. The quince is susceptible to a bacterial disease called fire blight, which is also a serious hazard to pear growing in the United States. Trees that are not forced into strong vegetative growth by pruning and fertilization are less susceptible to the fire blight disease. The trees are subject to the same scale insects that attack apples and pears and should receive the same dormant spray treatment for the control of these pests. The fruits are golden yellow in colour and the flesh takes on a pink colour when cooked, giving an attractive colour to jellies and conserves made from this fruit. Orange and Champion are the more commonly grown varieties. Quince stocks are used on which to graft the pear to dwarf the tree and hasten early bearihg. The Angers variety, imported from France, is the most important stock used for dwarfing pears. (F. P. C.)

BIBLIOGRAPHY.—W. W. Robbins, *Botany of Crop Plants* (1924); L. H. Bailey, *Standard Cyclopedia of Horticulture* (1914–27) and *Manual of Cultivated Plants* (1924).

QUINCY, JOSIAH (1744–1775), American patriot, son of Josiah Quincy (1709–84), was born in Boston on Feb. 23, 1744. Between 1767 and 1770, he contributed several papers to the *Boston Gazette* that were flaming tirades against British oppression. After the Boston massacre he and John Adams defended Captain Preston and the accused soldiers and secured their acquittal. From this time on he wrote repeated letters to the *Boston Gazette* and published several books in which he urged opposition to England. In Sept. 1774 he left for England where he consulted with leading Whigs as to the political situation in America; on March 16, 1775 he started back, but he died on April 26 in sight of land. (B. B. K.)

QUINCY, a city of Illinois. U.S., on the Mississippi river, 110 mi. N.W. of St. Louis. First settled in 1822. it became the seat of Adams county, March 4. 1825, the day Pres. John Quincy Adams was inaugurated, and was named in his honour. Incorporated as a village in 1834 and chartered as a city in 1839, Quincy had a population of about 7,000 and was second in size to Chicago when the sixth Lincoln-Douglas debate was held there in John's square (non Washington park), Oct. 13. 1858. A prosperous river town, Quincy declined with the passing of the steamboat era in the latter part of the 19th century but after 1920, with the development of industry, population again increased. Among the manufactures are agricultural and industrial machinery, automotive parts, clothing and footaear, food products, chemicals, office supplies, paper products and heating equipment.

Most of the city occupies the upland about 150 ft. above the valley floor where the blississippi river flows against its steep left bank. A navigational dam and lock impound the water in Quincy bay. Riverview, Sunset and Gardner parks north of the business section and Indian Mounds and South parks to the south line the river bluffs. Quincy. a Roman Catholic coeducational college established in 1860. is in the residential part of the city Illinois Soldiers and Sailors home (founded 1887) occupies more than 200 ac. at the northern city limits. For comparative population figures *see* table in ILLINOIS: *Population.* (J. H GD.)

QUINCY, a city of Norfolk county, Mass., U.S., located on Boston harbour, about 8 mi. S.E of Boston (*q.v.*). A part of the Boston standard metropolitan statistical area, it is a manufacturing city and a centre of retail trade. Pop. (1960) 87,409. (For comparative figures *see* table in MASSACHUSETTS. *Population.*) Manufacturing is diversified (gears. confections, dairy products, detergents, electronic tubes and machinery for riveting, packaging and materials handling) but it is dominated by shipbuilding. The Fore River shipyards are among the most important in the country. The city was formerly famed for its granite quarries, which supplied granite for King's chapel and the Bunker Hill monument in Boston. Retail sales per capita are substantially above the average for the Boston metropolitan area and for the state, with sales of lumber. building materials, hardaare and farm equipment constituting nearly 10% of the total. Quincy's residents are distinguished by the high proportion with origins in Scotland, Sweden and Finland and by the predominance of craftsmen, foremen and clerical workers in the labour force. Prior to 1792, when Quincy was incorporated as a town, the area was part of the town of Braintree. It became a city in 1888. The birthplaces of two presidents, John Adams and John Quincy Adams, are preserved in Quincy. The two buildings. the Quincy homestead (built about 1636) and the Adams National Historic site, are open to visitors except in the winter season. (E. E. M.)

QUINET, EDGAR (1803–1875), French historian. philosopher and poet, a supporter and theorist of the republican movement. Born at Bourg-en-Bresse (Ain), Feb. 17. 1803, of a Protestant mother and a soldier in the army of the Rhine, he was greatly affected in his youth by Napoleon's defeat which he later recalled in his poems *Ahasvérus* (1833) and *Napoléon* (1836). After studying law in Paris he published a satirical work, *Tablettes du juif errant* (1823), but he first won recognition by his translation of J. G. Herder's *Philosophie der Geschichte (Ide'es sur la Philosophie,* 1827) which was admired by Goethe. Victor Cousin and Jules Michelet, with whom he formed a lifelong friendship. In 1829 he visited Morea on a government mission and on his return published *La Grèce moderne* (1830). Though attracted to German philosophy. he was critical of German political ambitions, which he denounced as "Teutomania," in his pamphlets *L'Allemagne et la Révolution* and *Le Système politique de l'Allemagne* (1831). Later he traveled in Germany nhere in 1834 he married Mina Moré. In 1838 he was appointed professor of foreign literature at Lyons and in 1842 became professor of literature at the Collège de France. There his views on the Jesuits and papal supremacy antagonized the clergy and in 1846 his lectures were banned by Guizot.

Quinet took part in the revolution of 1848, and was returned for Ain to the legislative assembly, where he supported the extreme radical party. An opponent of Bonapartism, he was banished after the coup *d'état* of 1862 and settled in Brussels where, after the death of his first wife, he married Hermione Asaki, daughter of the Rumanian poet. Georges Asaki. During the first years of his exile he wrote Philosophie de *l'histoire* de France (1855), *Révolution* religieuse *du 19e siècle* (1857) and *Histoire* de mes iddes (1858). In 1858 he moved to Veytaux in Switzerland where he wrote historical, political and philosophical works including La Rkvolution (186j), La Morte de la conscience *humaine* (1867) and La *Création* (1870), which was inspired by Charles Darwin. After the fall of the Second Empire in 1870 he returned to his professorship at the Collège de France. In the following year he was elected to the national assembly and opposed the peace terms after the Franco-German war of 1871. His last work, *L'Esprit* nouveau (1874) is a summary of his theories. He died at Versailles, March 27, 1875.

Quinet's complete works were published in 30 vol. (1877–81). His Lettres *d'exil* were published in 4 vol. (1885).

BIBLIOGRAPHY.—Mme. Edgar Quinet, *Memoires d'exil* (1868–70), *Edgar Quinet avant l'exil* (1887), *Edgar Quinet depuis l'exil* (1889) and *Cinquante ans d'amitid: Michelet et Quinet* (1899); Henri Monin, "Étude critique sur le texte des *Lettres d'Exil*" in *Revue d'histoire littdraire de la France* (1907–08, 1910); P. Gautier, *Un prophdte, Edgar Quinet* (1917); H. Tronchon, *Le Jeune Quinet ou l'aventure d'un enthousiaste* (1937).

QUININE is the most important alkaloid of cinchona bark; its chief use is in the treatment of malaria. In the 300 years between its introduction into western medicine and World War I, quinine was the only effective remedy for malaria. As a specific for this disease, quinine benefited more people than any drug ever used for the treatment of infectious diseases. The treatment of malaria with quinine marked the first successful use of a chemical compound in combating an infectious disease.

Like the other cinchona alkaloids, quinine is a large and complex molecule, and its total laboratory synthesis by Woodward and Doering in 1945 is one of the classical achievements of synthetic organic chemistry. However, commercial synthesis of quinine is not economically feasible.

Quinine acts by interfering with the growth and reproduction of the malarial parasites inhabiting the red cells of the blood, probably by preventing them from oxidizing glucose, their chief source of energy. Administration of quinine dramatically improves the condition of a person suffering from malaria; the parasites promptly disappear frorn the blood, and the symptoms of the disease are quickly alleviated. However, when quinine treatment is terminated, many recovered patients suffer another attack of malaria several weeks later. This is because quinine does not kill the malarial parasites iiving in cells of the body other than the red blood cells. These parasites persist and, after a time, reinvade the red blood cells and precipitate the second malarial attack, or relapse.

Because quinine fails to produce a complete cure in malaria, better antimalarial drugs were long sought for. At the beginning of World War II, two new synthetic antimalarial drugs, pamaquine naphthoate (Plasmochin) and quinacrine hydrochloride (Atabrine), had already been developed in Germany. They were definitely effective but not clearly superior to quinine. When the Allies' supply of East Indian quinine was cut off by the entrance of Japan into World War II, the search for new and more effective antimalarial drugs was greatly intensified. Although Atabrine remained the mainstay of Allied forces throughout the war, wartime research produced a number of antimalarial drugs that later almost completely replaced quinine. Some of them, such as chloroquine and paludrine, are more effective than quinine in suppressing the growth of the blood forms of the malaria parasite; while others, such as primaquine and daraprim, act upon both the blood and tissue stages of the parasite, thus producing complete cures and preventing relapses. All! the newer antimalarials, unlike quinine, may be completely synthesized in the chemical laboratory on a commercial scale.

In addition to its specific use in malaria, quinine is sometimes used as a nonspecific remedy for fever and pain. It probably reduces fever by dilating the small blood vessels of the skin, while its analgesic effect may result from depression of certain centres in the central nervous system.

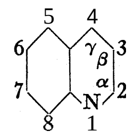
Prolonged administration of quinine may produce toxic symptoms such as deafness, disturbances in vision, skin rashes and digestive upsets. See also CINCHONA; CINCHONA BARK, ALKALOIDS OF; MALARIA. (J. W. MR.)

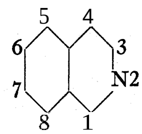
QUINNAT (Oncorhynchus tschawytscha), most important salmon (*q.v.*) of North American Pacific coast, frequently weighing upward of 50 lb. It has been naturalized in New Zealand.

QUINOA (Ckenopodium quinoa), a small annual herb of the goosefoot family (Chenopodiaceae). very similar to the common lamb's quarters (*q.v.*), native to Bolivia, Chile and Peru, where it has long been cultivated as a food plant by the native peoples of the Andean plateau. The plant produces a great profusion of very small seeds, which are ground intq meal and made into cakes or gruel or boiled like rice; the green parts are used as a pot herb like spinach.

See CHENOPODIUM.

QUINOLINE is an organic compound of formula C_9H_7N which in general chemical behaviour resembles pyridine (*q.v.*) very closely. It is, in fact, a benzopyridine, bearing the same relation to pyridine as naphthalene does to benzene. The benzene and pyridine rings are fused together in the 2,3 position, the other possibility, fusion in the 3,4 position, giving isoquinoline which is discussed below.


Quinoline


Isoquinoline

The positions of substituents in derivatives of the two compounds are indicated by numbers as shown above. The prefixes N, α, β and γ were also used formerly for the pyridine ring of quinoline.

Quinoline itself was first isolated from coal tar by F. F. Runge in 1834. The modern commercial product is obtained from that source or is made synthetically. It also occurs in bone oil. C. F. Gerhardt in 1842 obtained quinoline by heating the alkaloid cinchonine with potassium hydroxide and this was the first evidence of the occurrence of the quinoline nucleus in certain of the natural alkaloids; quinine similarly heated gives 6-methoxyquinoline.

The first synthesis of quinoline was achieved by W. Koenigs in 1879 by passing the vapour of allylaniline over hot lead oxide. A large number of further synthetical methods are available for the preparation of quinoline and its derivatives. Of these, the best known is probably the Skraup reaction (1880), which is of exceedingly wide application; it is employed for the formation of quinoline itself and for that of the derivatives substituted in the benzene ring. A primary aromatic amine is heated with glycerol, sulfuric acid and a mild oxidizing agent, nitrobenzene or arsenic acid being often used. Aniline is converted into quinoline in good yield by this method which can also be applied to practically all aromatic amines.

As was mentioned above, the natural alkaloid, quinine, contains the quinoline nucleus. Several synthetic antimalarial drugs, which are like quinine in being derivatives of 4-aminoquinoline, have also been prepared; of these, quinacrine (Atabrine) has found the widest use. (See MALARIA.)

Quinoline is a colourless, highly refractive oil boiling at 239° C. and with a characteristic smell. It is almost insoluble in water but miscible with organic solvents, and it behaves as a weak monoacidic base. Its salts are readily soluble in water except the bichromate which is sparingly soluble in the cold and can be used for the purification of quinoline. Since the pyridine ring is deactivated by the presence of the nitrogen atom, a substituting reagent such as nitric acid attacks the benzene ring and gives a mixture of the 5- and 8-substituted compounds. Further nitration gives the 5,7- and 6,8-dinitro derivatives. These nitro compounds can be reduced to amines which behave as true aromatic amines and can be diazotized and converted into other derivatives. Anionoid substituting reagents, such as sodamide, react with the pyridine nucleus in the 2 and 4 positions, and 2-aminoquinoline can be obtained directly by the action of sodamide.

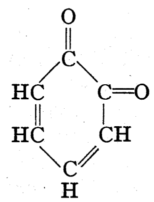
Quinoline and its homologues are tertiary bases and thus react with alkyl halides to give quaternary ammonium salts which show the normal behaviour of strong electrolytes. The quaternary hydroxides derived from these salts are not stable and tend to pass more or less completely into un-ionized forms, as with many other cyclic bases. The reactivity of these compounds is the basis for the preparation of dyestuffs of the cyanine class (isocyanines, pseudocyanines and carbocyanines) which are of great value as sensitizers of the photographic emulsion to wave lengths in the red and infrared,

Isoquinoline is found in coal tar and crude quinoline from that source contains about 4% of isoquinoline. It is a solid melting at 24° C. and boiling at 240° C. and with a smell quite different from that of quinoline. It is more strongly basic than the latter, since the nitrogen atom is not directly attached to the benzene ring, and its sulfate is not very soluble in cold water; separation from quinoline is based on these facts.

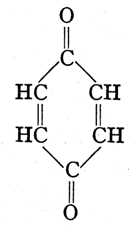
The isoquinoline nucleus is found in a number of important alkaloids; *e.g.*, papaverine, berberine, hydrastine and narcotine. A valuable reaction for synthesizing this nucleus is that of A. Bischler and B. Napieralski (1893). Acyl derivatives of β-phenylethylamines when heated with powerful dehydrating agents in boiling xylene or tetralin give 3,4-dihydroisoquinolines which can be dehydrogenated to isoquinolines with permanganate or catalytically with palladium. Many of the isoquinoline alkaloids have been synthesized by means of this reaction. (T. W. J. T.)

QUINONES, a group of coloured cyclic organic compounds containing two carbonyl groups, C = O (see ALDEHYDES AND KETONES) either adjacent (orthoquinone, I) or separated by a vinyl group, C = C, (paraquinone, II) in a usually six-membered unsaturated ring. All quinones have these features except a few in which the carbonyl groups are located in different rings: *e.g.* amphinaphthoquinone, III. The term quinone usually refers to the specific compound, parabenzoquinone (p-benzoquinone), II, but may also apply to some other compound having the required structural features.

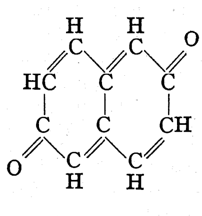
A similar ambiguity exists also for the terms hydroquinone and quinhydrone (see below). The general reactions of quinones are entirely analogous to the specific reactions of p-benzoquinone.



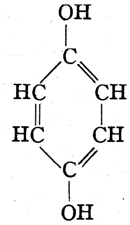
I



II



III



IV

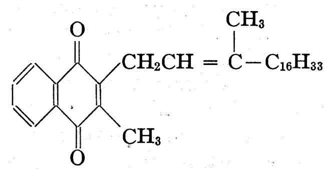
By a variety of reducing agents, p-benzoquinone is easily and quantitatively reduced to its corresponding hydroquinone IV. This change is readily reversed by oxidizing agents.

$$\underset{p\text{-Benzoquinone}}{C_6H_4O_2} + 2H^+ + 2e \rightleftharpoons \underset{p\text{-Benzohydroquinone}}{C_6H_6O_2} \text{ where } e \text{ is an electron.}$$

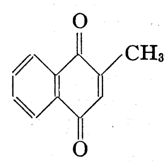
If a platinum electrode is put into a solution which contains equivalent amounts of some quinone and its hydroquinone, and which is saturated with respect to the addition compound of the two (the so-called quinhydrone), an electric potential is produced which is dependent on the hydrogen-ion concentration. By making connection through a suitable conducting solution with a reference half cell, this potential can be measured. A device, the quinhydrone electrode was developed to make use of the above principle in measuring the hydrogen-ion concentration of an unknown solution.

The ring of atoms in a quinone is said still to have a quinonoid (or quinoid) character if one of the sets of doubly bonded carbon and oxygen atoms is replaced by another doubly bonded atom pair, or even if both of those sets are so replaced. Quinonoid structures are important in theories concerning the relationship of chemical constitution to colour. Many quinones, among which one of the most important is anthraquinone (see ANTHRAQUINONE), are used as dyestuff intermediates. All vat dyes have quinonoid structures. An important feature in the use of vat dyes is the fact that the dye is placed on the cloth while in the hydroquinone state, and the oxidation to the quinone state takes place on exposure to air.

Many quinones occur in natural products. One of the most important of these is vitamin K_1, which possesses the structure V and is the antihaemorrhagic agent found in certain green plants. (See VITAMINS: Vitamin K.) Synthetic quinones, in particular 2-methyl-1,4-naphthoquinone, VI, have similar properties and are used in medical practice.



V



VI

A number of interesting naturally occurring quinones are described in Organic Chemistry by L. F. Fieser and M. A. P. Fieser, pp. 722–31 (1956). (M. S. N.; X.)

QUINSY, a common term for an abscess which develops around the tonsil, usually following acute tonsillitis (*q.v.*).

QUINTAIN, an instrument used in the age of chivalry in practising for the tournament (O. Fr. *quintaine,* from Lat. *quintana,* a street betaeen the fifth and sixth maniples of a camp, where warlike exercises took place), An early form consisted of the wooden figure of a Saracen armed with shield and sword: the object being to strike the figure on the forehead between the eyes.

As late as the 18th century running at the quintain survived in English rural districts.

QUINTANA, MANUEL JOSÉ (1772–1857) Spanish patriot and poet. was born in Madrid, April 11, 1772. A typical Spanish neoclassic, he wrote tragedies (El Pelayo), eloquent organ-voiced odes on large humanitarian themes, dared comparison with Plutarch—Vidas de *españoles célebres* (1807–33)—and wrote the best literary criticism of the century in his anthologies *Colección* de *poesías* castellanas and *Musa épica*. The national respect he earned for his clarion calls for unity against the French invaders never waned (Queen Isabel crowned him national poet in 1855), though his liberalism excluded romanticism and his pen was silent for half a century before his death in Madrid, March 11, 1857. (R. F. B.)

QUINTANA ROO, a federal territory of Mexico on the eastern side of the Yucatán peninsula, bounded by British Honduras and Guatemala. Pop. (1950) 26,967; (1956 est.) 33.434; area, 19,630 sq.mi. formed in 1902 from parts of the states of Yucatan and Campeche. The territory is hot, humid and heavily forested, with 50 to 60 in. of rain annually. Like the rest of the peninsula, Quintana Roo is a level, porous limestone plain through which water percolates to form underground grottos, caverns and wells.

The area is populated chiefly by descendants of Maya Indians who in 1847 rebeled in Yucatán and were eventually driven into these fastnesses by continuous military campaigns. Distrustful of Yucatecan Mexicans, they carry on sporadic trade in chicle nith British Honduras. Their main contacts with the outside world lie along the narrow-gauge railway that connects Felipe Carrillo Puerto (Santa Cruz de Bravo), to Vigía Chico on Ascension bay. Another penetration from the coast inland is by a rail line in the northern section from Leona Vicario (Santa Maria) to Puerto Morelos. Air strips at various points. and regular service to Belize, Brit.Hond., and Merida lessened some of the characteristic isolation of the territory, which for many years was used as a dumping ground for political prisoners.

Chicle and a small amount of copra, produced on the coast near Cozumel Island, are the main products. There are valuable stands of mahogany and other hardwoods which are largely unexploited. Sponge and turtle fishing is significant along the coast. The small Mayan hamlets are nearly self-sufficient.

The capital is Chetumal. The territory contains numerous important archaeological remains of the earlier pre-Spanish Mayan empire, notably those at Tulum.

In 1517, the first Spanish landing in Mexico was made at Cape Catoche. Hernán Cortés in 1519 landed first on the island of Cozumel alongside Quintana Roo. An airline links the island, now a tourist resort, with Merida. (J. A. Cw.)

QUINTESSENCE, according to some Renaissance philosophers (Paracelsus, Agrippa von Nettesheim, Rudolf Goclen), was the purest and most intimate nature of created things. Earlier the Latin term *quinta* essentia, "fifth essence" (equivalent to the Greek *pempte* ousia, which occurs in John Philoponus), was used to denote the thinnest and most divine material element surrounding the world of the four Empedoclean elements (fire, air, water and earth); the Pythagorean Philolaus (*q.v.*) spoke of a *pempton* soma or "fifth body"; and Aristotle described the ether as a primary substance distinct from the other four. (L. M.-Po.)

QUINTILIAN (MARCUS FABIUS QUINTILIANUS) (*c.* A.D. 35–*c.* 100), Roman writer whose work on rhetoric is one of the most valuable contributions of the ancient world to educational theory and to literary criticism, was born at Calagurris in Spain (the modern Calahorra in the Logroño province). He received at least part of his education in Rome; the orator Domitius Afer had a share in his training. He went back to Spain (not before A.D. 57). then returned to Rome in the retinue of Galba (68). There he taught rhetoric and was subsequently (c. 71?) appointed a public professor of that subject by Vespasian. The younger Pliny was among his pupils. At the same time he was a successful pleader in the law courts. After 20 years spent in these activities he retired (c. go) and devoted himself to writing; it took two years to compose his great work, the Institutio oratoria ("The Training of an Orator"), which was published *c.* 95. He achieved fame and wealth; ultimately Domitian made him tutor of his two grandnephews, prospective heirs to the throne, and awarded him the consular insignia. The preface to book vi of the Institutio expresses in tenderest terms his grief for the loss of his young wife (when she was 19) and of both his very young sons.

The Institutio oratoria was written at a time when, political life being no longer free, eloquence had lost its former power. But it had not lost its prestige. Rhetoric dominated education—in the form essentially of a training in liberal culture. The *Institutio,* in 12 books, provides a comprehensive course of instruction taking the student from infancy to the time when he has become a complete orator. Book i deals with the training prior to the study of rhetoric, book ii with the first rhetorical exercises and with declamation, and also with the nature and end of oratory. These two books contain the best Roman thought on education, much of it of enduring value for its practical good sense, sympathetic personal quality and insight into human nature. "Grammar" is considered in its two departments, the art of speaking correctly and the interpretation of literature. Books iii–xi are concerned with the five departments of rhetoric: books iii–vi with "invention" (iii discusses also the origin of rhetoric, and its kinds—of these the judicial receives most attention in the Institutio as a whole; in iv–vi invention is applied to the formal parts of a discourse; and vi includes a lively chapter on the arousing of laughter); book vii with arrangement; books viii–x with style (in viii and ix the elements of a good style are treated, and in x various practical methods of assuring command over them).

Book x contains the much-praised survey of Greek and Latin authors recommended to the orator for study. with neat summaries of their outstanding qualities. Often Quintilian gives us the established opinions of his time, but sometimes again he is independent, especially with respect to Roman writers; and his exposition is felicitous and interesting. He reproves certain stylistic abuses of his day (and the influence of Seneca) and would effect a return to the classical tradition of the Golden Age (his greatest admiration is for Cicero), but with concessions to the demands of changed conditions. The subjects of book xi are memory and delivery.

Quintilian's aim was to mold the character as well as to train the intellect (iv, preface, 3); and book xii delineates the ideal orator—taking the elder Cato's definition, "a good man skilled in speaking"—and offers advice for the employment of his gifts in public life. Since eloquence serves the public welfare, it must be fused with virtue; and philosophy is a component part of the rhetorical training. The moral power of this book makes it especially impressive and induces one to overlook the author's occasional lapses, as when he asserts with worldly wisdom that "Sometimes the public interest requires that the speaker defend what is not true" (ii, 17, 36) or accords fulsome praise to Domitian (iv, preface, 3–5).

Quintilian reviews and studies the principles of rhetoric in their fullest scope and variety, preserving what is valuable in the Greek and Roman tradition, but without slavish adherence to any one school; he applies discriminating judgment where the doctrines of his predecessors are contradictory, rejects them when they are absurd. He scorns superstitious conformity to rules as though they were immutable laws and particularly to such as are laid down without experience of actual battle in the courts. The work is everywhere marked by learning, wisdom and taste; and the engaging personality of the author, combining kindliness, sincerity and high principle, shines through it.

Quintilian's style exhibits some of the characteristics of the silver Latin, such as point, the use of rare and poetic words, and occasional looseness of structure, but no writer of his time departs less widely from the best models of the late republican period. The language is on the whole clear, unlaboured, energetic and dignified.

The Institutio exerted its greatest influence during the Renaissance and Reformation, after the discovery of a complete text by Poggio at St. Gall in 1416.

For the text of the *Institutio* oratoria see the edition by L. Radermacher, 2 vol. (1907–35); for the text with Eng. trans., that by H. E. Butler in the "Loeb Series," 4 vol. (1921–22). For commentary see Jean Cousin, *Études* sur *Quintilien* (1936) and the separate editions of book i by F. H. Colson (1924), of book x by W. Peterson (1891; new ed., 1903) and of book xii by R. G. Austin (1948). The text of Declamationes *majores* is ed. by G. Lehnert (1905), that of Declamationes minores by C. Ritter (1884).

Quintilian published one other rhetorical work, De *causis corruptae* eloquentiae, which has not survived; it probably dealt with the technical and educational aspects of the decline of oratory rather than the political and social. Of his speeches he published only one (now also lost), in defense of Naevius Arpinianus, accused of killing his wife. The other speeches that once circulated under his name he repudiated as having been corrupted by careless stenographers bent on profit (vii, 2, 24). He disowned also two books on rhetoric which kindly intentioned pupils had published from lecture notes without his authorization (i, preface, 7). Neither of the two extant collections of declamations ascribed to him (Declamationes *majores,* 19 in number; and Declamationes minores, 145 from a collection originally numbering 388) is regarded as genuine; both are of uncertain date. (HY. CN.)

QUINTUS SMYRNAEUS, Greek epic poet. probably flourished in the latter part of the 4th century A.D. He is sometimes called Quintus Calaber, because the only manuscript of his poem was discovered at Otranto in Calabria by Cardinal Bessarion in 1450. According to his own account (xii, 310), he tried his hand at poetry in his early youth, while tending sheep at Smyrna. His epic in 14 books, known as Ta meth *Homeron,* or *Posthomerica,* takes up the tale of Troy at the point where Homer's Iliad breaks off (the death of Hector), and carries it down to the capture of the city by the Greeks, their departure and dispersal in the storm. The poet has no originality; in conception and style his work is closely modeled on Homer.

See F. A. Paley, *Quintus Smyrnaeus* and the "Homer" of the Tragic Poets (1879); G. W. Paschal, *A* Study of *Quintus Smyrnaeus* (1904).

QUIPU, a knotted cord used by the Incas of ancient Peru and other Indians of the central Andes as a mnemonic aid and a recording device. The Inca type consisted of a heavy, central cord from which 1 to 100 variously coloured strings were suspended. A single knot or loop in a pendant string represented a number from one to nine, depending on the distance of the loop from the central cord. There also were positions for tens, hundreds. thousands and ten thousands. The quipus were used to record statistical information, in recording and reciting genealogies, in narrating legends and for recalling the proper order of complex ceremonial events. Apparently the quipu was not a calculating device. In the Guianas, knotted strings were used as timekeepers for ceremonial events.

QUIRINO, ELPPDIO (1890–1956), second president of the Republic of the Philippines, was born Nov. 16, 1690, in Vigan, in Ilocos Sur province. on the island of Luzon. He attended high school in Manila and took his law degree at the University of the Philippines. Quirino served in the Philippine house of representatives (1919–25) and in the senate (1925–31). He was a member of the Philippine independence mission which helped to obtain the passage in the U.S. congress in 1934 of the Tydings-McDuffie act under which the Philippines achieved independence on July 4, 1946. Also in 1934 he was elected to the constitutional convention. Thereafter he served as secretary of finance and later as secretary of the interior in the commonwealth government (1935–38). He was elected to the senate in 1941 and stayed in the Philippines during the Japanese occupation. After the war, Quirino again became secretary of finance in May 1916. As the candidate of the newly formed Liberal party, he became vice-president and secretary of foreign affairs of the new republic in July 1946. He succeeded to the presidency on the death of Pres. Manuel Roxas in 1948 and was elected president in 1919. During his term of office an intensive program of economic development was initiated with the assistance of the United States, the treaty of peace was signed with Japan and a new mutual defense treaty was concluded with the United States in 1951. The Hukbalahaps, or social dissidents in Luzon. were pacified primarily because of the efforts of his secretary of defense. Ramón Magsaysay. After being defeated for re-election in 1953 by Magsaysay he retired to private life and died on Feb. 28, 1956. See also PHILIPPINES: History. (C. A. B.)

QUIRINUS, a major Roman deity ranking close to Jupiter and Mars (*qq.v.*). Their *flamines* constituted the three major priests at Rome. His name is in adjectival form and would seem to mean "he of the *quirium,*" a word generally taken to signify the very ancient Sabine settlement which united with the Palatine community to form the original Rome. It has also been derived. however, from *covirium,* meaning "assembly of men." That the Quirinal, traditional site of Sabine settlement. was the seat of his cult there is no doubt. and the Sabine origin of the god is reilected in Ovid (Fasti II. 475). In spite of his importance rather little is known about Quirinus. He bears a similarity to Mars, and some believe that he is only another form of that deity. By the late republic he is identified completely with Romulus (*q.v.*), a confusion perhaps originally suggested by Quirites (*q.v.*). He had a festival. the Quirinalia. on Feb. 17; his temple on the Quirinal was one of the oldest in Rome. A cult partner Hora is spoken of, also minor deities, the Virites Quirini, of whom nothing else is known. Janus (*q.v.*) appears with the epithet Quirinus, but the relationship between the two is a matter of conjecture.

BIBLIOGRAPHY.—W. W. Fowler, Roman Festivals, pp. 322–324 (1899); G. Wissowa, Religion *and Kultus,* 2nd ed., pp. 153 ff. (1912); F. Altheim, History *of* Roman Religion, pp. 138 ff. (1938).
(R. B. LD.)

QUIRITES, earliest name of the burgesses of Rome (*see* QUIRINUS). In the phrase "*populus Romanus Quirites*" (or *Quiritium*), it denoted the individual citizen as contrasted with the community. Hence *ius Quiritium* in Roman law denotes full Roman citizenship. Whether the word ever had military associations is a point much debated, but if so it lost them at an early date and came to designate Roman citizens in their civil, as distinct from their military, capacity, and referred solely to Romans concerned in domestic affairs. Thus Caesar is said to have quelled a mutiny among his legionaries by the device of addressing them as "Quirites" (citizens). See ROMAN LAW.

QUIROGA, HORACIO (1878–1937), Uruguayan, short-story writer, became famous for his ability to portray man's futile struggle against the tropical jungle in Argentine territory of Misiones. Born Dec. 31, 1878, in Salto, he spent a good part of his life in Argentina, taking frequent trips from Buenos Aires to San Ignacio in the jungle province of Misiones. This primitive environment as well as his many personal experiences in the jungle furnished material for most of his *cuentos.*

His early period of literary apprenticeship. marked by his tendency to emulate the modernistic fashion, Los arrecifes de coral (1901). soon led him to realize that his talent was better suited to short stories. Some of his finest compositions. *Cuentos* de la selva (1918), El salvaje (1920), Anaconda (1921), El desierto (1924). Los desterrados (1926) and others, belong to this genre. *Más allá* (1935) reflects the depressed mood of his later years when he suffered from ill health and other misfortunes.

Quiroga took his own life in a charity hospital in Buenos Aires, Feb. 19, 1937. (H. Co.)

QUISLING, VIDKUN ABRAHAM LAURITZ JONSSON (1887–1945), Norwegian fascist, whose name became synonymous with "traitor." An army officer: he served as military attaché in Petrograd (later Leningrad) and Helsinki and later assisted Fridtjof Nansen in Russian relief. From 1927 to 1929 he represented British interests at the Norwegian legation in Moscow. He became Norwegian minister of defense in the Agrarian government, 1931–33. Resigning, he founded the fascist Nasjonal Samling (National Union) party. but never won a seat in the *storting.* Friendly to the Nazis, he visited Hitler in Dec. 1939 and collaborated in the German invasion of Norway in April 1940. The new regime proclaimed by him so incensed the Norwegians that it collapsed within a week, but he continued to lead Nasjonal Samling, the only party permitted by the Germans. On Feb. 1, 1912, Reichskommissar Joseph Terboven named him "minister president." Quisling's attempts to nazify the Norwegian church, schools and youth aroused bitter opposition. He persecuted the Jews, sending almost 1.000 to death in concentration camps. Despite difficulties with his party and the Germans, he held office until Norway was liberated in May 1945. Arrested, tried and found guilty of treason and other crimes, he was executed on Oct. 24. 1945. (HD. LN.)

QUITO, the capital of Ecuador and of the province of Pichincha. is situated about 114 mi. from the Pacific in a narrow Andean valley. Pop. (1950) 209.932. It was already an ancient city when the Spaniards arrived there in the 16th century. Before them there were the Incas, to whose empire it had belonged since 1487. Between that date and the year 1000 it was ruled by the Shyris, sovereigns of the Caras who are said to have come "by way of the sea." Prior to the Caras, it was the seat of the kingdom of the Quitus, the largest unit of an Indian tribal confederation that left no recorded history. Sebastibn de Benalcbzar, one of Pizarro's lieutenants, occupied it on Dec. 5, 1531. In the presence of his soldiers and 206 native inhabitants, he set up a municipal council (cabildo) and declared it in operation. He planned Quito as a typical Spanish city with streets running north and south, east and west from the central square or *plaza mayor.*

Quito lies on the lower slopes of the Pichincha (15,700 ft.) a volcano that last erupted in 1666. The central plaza, bounded by the cathedral, the palaces of the president and the archbishop and the municipal building, is only 15 mi. south of the equator, but because of its altitude of 9,350 ft. Quito enjoys a stimulating climate, the mean temperature at noon being 70°. Carved by two ravines spanned by masonry bridges, the city, oldest of all South American capitals, preserves much of its ancient atmosphere. The towers of numerous churches outlined against a circle of volcanoes, peaceful squares, fountains, balconied houses, steep streets, iron-grilled doorways and secluded gardens mark it as a place of charm.

Quito of the Spaniards was not a year old when the Franciscans established an art school, the first of its kind in South America. Thus began a celebrated religious art movement that flourished throughout the colonial period, leaving a wealth of polychrome sculpture in wood, and paintings without equal in the new world. Indian artists made of the churches, cloisters and old mansions of Quito veritable museums. The names of the sculptor Manuel Chili (Caspicara), and the painters Adrián Sánchez Galque, Miguel de Santiago and Gorivar González, among others, are noteworthy. Among the most admired Quiteiio churches and convents are La Compañía (Jesuit), whose baroque columns, ceilings and massive altars are covered with gold leaf; San Francisco, with its magnificent cloister; Carmen Alto, where the native Saint Mariana de Jesús lived and died; San Agustin, famous for carved ceilings, and Santo Domingo notea for a handsome façade; the Sagrario, where Ecuadorean independence was declared in 1809; and the 17th century cathedral, burial place of the hero of independence Antonio José de Sucre. Also worth mentioning is the church of the Merced convent, decorated in the Quiteiio style by the contemporary Ecuadorean artist Victor Mideros.

Although the city's convents and monasteries and its museum of colonial art indicate the deeply religious and contemplative character of its life, Quito is no longer an isolated capital, as in the past. There is a modern and busy airport meeting all international standards, including a 9,000-ft. runway required at that altitude. Quito has several daily newspapers and broadcasting stations, new housing projects for workers and athletic fields. Factories produce everything from textiles and soap to matches, shoes, hats, soft drinks, cosmetics, ready-to-wear apparel and pharmaceutical products. There are two institutions of higher learning, Central university founded in 1787 and the new Catholic university, offering facilities for the study of all the liberal and technical professions; also a technological institute, national library, astronomical observatory and conservatory of music. The city has several hospitals and a nursing school, two schools of social work, an American grade and high school, many modern residential developments and good public utilities.

Ecuadoreans are proud of the Casa de la Cultura, a cultural centre created in 1943 and financed with a share of the export duties. It acts as publisher and distributor of the works of Ecuadorean writers and organizes concerts, lectures, art exhibits and theatrical performances. In addition, it awards prizes for scientific research, literary and artistic excellence.

Among the characteristic sights of Quito are several outdoor markets or fairs operating once a week in different quarters of the city. Each one has a specialty—Santo Domingo, held on Saturday, is known for furniture and San Blas, for flowers, fruits and fowl. Only on Tuesdays, in the "24th of May" market, can one buy everything.

Equally typical are the countless diminutive shops where native craftsmen make silver jewelry, religious figurines, rugs, shoes, men's suits, furniture and other items. Although Quito is predominantly Roman Catholic there are a number of Protestant churches and a Jewish synagogue. (C. R. J.)

QUIXOTE, DON (in Spanish Don Quijote), the hero of Cervantes' (*q.v.*) romance (part 1, 1605; part 2. 161S), which was originally conceived as a satire of farcical incident directed against the romances of chivalry. (See SPANISH LITERATURE.) He has given his name in all European languages to a type of character which misses practical success by supposing that common humanity is governed by ideals as exalted or as imaginative as its own.

QUM, a district and city in the Central or Teheran *ostan* of Iran. The district produces abundant grain and cotton. Qum, the administrative headquarters, has a population (1956) of 96,463. It is a stronghold of the Shi'ite faith and has many tombs of saints and pious persons including the shrine of Fatima, sister of the imam Riza. Besides Fatima, at least ten kings and about 400 saints are interred in Qum and its precincts. Shah Abbas II, whose piety won him high favour with the ecclesiastical authorities, is buried in the shrine in a special mausoleum which is furnished with a set of 14 remarkably fine silk rugs, dated 1666. On the south side of the city is a group of five superb mausoleums (four of them of the 14th century) all distinguished by quite remarkable polychrome stucco ornament. The chief industries are glass, pottery and shoemaking.

QUOIN, in architecture, originally any vertical external corner of a building; more generally applied to large cut stones used either to form an accurate corner in a wall of rough rubble or brick or else to furnish a decorative termination to a wall surface of any material. Projecting stone quoins, frequently rusticated, or with the edges slightly recessed or beveled, are common decorative features in high Renaissance work in Italy, early 17th-century work in France and the Palladian style in England. In these styles they are used not only at the corners of a building, but also often at the edges of windows and doors. In much 18th-century work in Scandinavia. England and America, projecting quoin shapes are formed with brick.

In printing the term is applied to an expandable device used to tighten a form in its chase. See PRINTING.

QUOITS: see HORSESHOE PITCHING.

QUORUM, in its general sense, a term denoting the number of members of any body of persons whose presence is requisite in order that business may be validly transacted by the body or its acts be legal. The term is derived from the wording of the commission appointing justices of the peace which appoints them all. jointly and severally, to keep the peace in the county named, It also runs—"We have also assigned you, and every two or more of you (of whom [quorum], any one of you the aforesaid A. B, C, D, etc., we will shall be one) our justices to inquire the truth more fully," whence the justices so named were usually called justices of the *quorum*. The term was afterward applied to all justices, and subsequently, by transference, to the number of members of a body necessary for the transaction of its business.

QUOTA. Quotas, on imports or exports, are one type of quantitative or direct trade restriction. Quantitative controls are measures which directly limit the quantity—in exceptional cases the value—of goods (or services) that may be exported or imported. The opposite to quantitative controls are controls which operate by making imports or exports more expensive without fixing a limit on the quantity; of these, tariffs, which put a special tax on exports or imports, are the main type.

The principal quantitative trade controls are the quota, payments restrictions (exchange controls), licensing and monopoly systems. Under the monopoly system a governmental agency has an exclusive monopoly for the import or export of the restricted commodities. The distinction between the quota, exchange control and licensing system is riot so clear-cut. By exchange control is meant the complex of measures controlling and regulating international payments which enable a country to maintain the international value of its currency at a higher level than it would have in the absence of these controls. One of the most important of this complex of measures is the quantitative restrictions of imports by quotas and licences. There is a tendency to speak of quotas when the quantities are determined in advance and the rules for the distribution of the quota among countries of origin and traders are more or less clearly formulated; and of a licence system when the granting of import licences is left to the discretion of the administrative organs. This article refers chiefly to quotas, but much of what is said holds of exchange control and licensing and monopoly systems as well.

Quotas are fixed either by zutonomous action of a country or in agreement with other countries (autonomous v. contractual quotas). Another distinction is between import and tariff quotas. By a tariff quota is meant a regulation which permits the import of a certain quantity (quota) of a commodity duty free (or at a specially low duty), while quantities exceeding the quota are subjected to a (higher) duty. An absolute or import quota restricts imports absolutely.

Another type is milling or mixing quotas; this is a rule which requires that imports of, say, barley must be milled or mixed in a certain proportion with home-grown grain. In the following, reference will be made chiefly to absolute import quotas.

Throughout the last quarter of the 19th century and up to 1914 the predominant method of trade control was the tariff. In the 20th century quantitative restrictions on trade were first imposed on a large scale during and immediately after World War I. During 1914 to 1918 such controls were an integral part of mar economics. After the Armistice quotas were fairly rapidly abolished, except in central and eastern Europe. There the dislocations produced by the war were much more serious than elsewhere. Trade was resumed first on the basis of intergovernmental barter and then on that of general prohibitions modified by licences. During the 1920s quotas were progressively abolished and replaced by tariff protection. The next great wave of quota protection of trade came with the great depression in the early 1930s. Especially after 1931 one country after another introduced quantitative restrictions, first on cereals and certain other foodstuffs and then on a great variety of agricultural and industrial products. France was the first large country to introduce a comprehensive quota system (1931), but it was followed by practically all European countries. In 1935 to 1936 there was a slight relaxation, but this movement toward somewhat freer trade soon came to an end. Everywhere economies were being geared for the approaching war; and a tightly controlled trade is an integral part of a war economy. The United States was the only important country that made very little use of quotas during the 1930s. The only important U.S. quota was on sugar.

After the end of World War II quotas and other quantitative import restrictions were widely used to maintain equilibrium in the balance of payments. In the U.S. they were used more than before the war for the purpose of restricting imports of agricultural products, especially those supported by the agricultural parity price program. The draft charter for the proposed International Trade organization (ITO) contained extensive provisions on quotas which were incorporated into the General Agreement on Tariffs and Trade (G.A.T.T.).

Why did quotas become so popular and how does quota protection differ from tarifi protection? The increasing use made of quantitative trade controls is a phase in the trend toward autarky and protection observable irom about 1870. Tariffs went higher and higher, the last free-trade countries (Great Britain, the Netherlands, Denmark) introduced protective measures and eventually quantitative restrictions were piled on top of tariffs. But quotas are a much more effective device for restricting trade than tariffs and much more disturbing to the international trade mechanism. Under the tariff system volume and value of trade, although restricted, are still flexible. The flow of goods changes according to changes in demand and supply at home and abroad. Despite an import duty imports can rise, if cost of production and prices fall abroad and rise at home. Thus the effect of a tariff can be offset by a depreciation of the foreign currency or an export subsidy, while a quota constitutes a rigid bar to imports. This is one of the main reasons why during the great depression of the 1930s one country after the other switched from tariffs to quotas. Tariffs were no longer regarded a sufficient protection in the face of violently changing prices, unstable currencies and extensive utilization of export subsidies. Another related reason was that tariffs could in many cases not be increased at short notice without violating international treaties, while such treaties did not mention, and therefore were thought not to prohibit, the imposition of quotas. Quotas are a more poweriul weapon of discrimination between individual countries and traders. This makes them popular with economic nationalists and protectionists in all countries. In fact, it has been found practically impossible to find a method of quota allocation which could be called nondiscriminatory and in accordance with the most-favoured-nation principle, while under the tariff system nondiscrimination has a precise, generally accepted meaning. During the post-World War II period the principal motive for the use of quotas and other quantitative import restrictions was the balance of payments difficulties (dollar shortage) experienced by many countries. These problems stemmed irom inflation and overvaluation of currencies.

An important characteristic of the mode of operation of quotas differentiates them sharply from tariffs. If a quota is effective, *i.e.*, if it is smaller than the quantity which mould he imported in the absence of the quota, it creates a price differential between the importing and exporting country which is not covered by transportation cost plus duty. Under the tariff system, too, the price of the taxed commodity mill be higher in the importing than in the exporting country, hut (except if the tariff becomes prohibitive and imports cease altogether) the price difference tends to be equal to transportation cost plus duty; if it were greater, imports would increase; if it were smaller, imports would fall until the price differential was again equal to transportation cost plus tax. Under the quota system this mechanism is eliminated. It follows that the importation of the quota-restricted commodities becomes a very lucrative business. Under the tariff system the price difference flows into the coffers of the treasury; under the quota system it flows into private pockets, and in all countries with extensive quota systems fortunes have been made by importers. The consequence is that the government is forced to distribute the quota among individual traders. When quotas were first introduced in 1931, many countries made the mistake of fixing only global quotas and of letting everybody import until the quota was exhausted. Naturally every trader tried to import at once as much as possible, and the quota was exhausted within the first few days of the period (usually a month or a quarter of a year) for which it was fixed. Distribution of the licences to import within the quota must be made according to some principle. It should be remembered that the granting of an import licence under the quota system is equivalent to the granting of an unearned income. While under'the tariff system the selection of the actual importers is left to the automatic mechanism of the market and is no concern of the government, under the quota system the authorities have to decide how much each trader is allowed to import. The import function ceases to be a business activity where success depends on commercial efficiency and imagination, but becomes a sinecure handed out by government agencies. In the 1930s, the usual procedure was to distribute quotas among countries of origin and individual traders (usually importers but sometimes also foreign exporters) in proportion to the imports from the respective countries effected by the individual traders in some base period which was considered as "normal." It is easy to see that this is not a satisfactory solution and that it becomes less and less satisfactory as time goes on and the underlying situation changes. But the fact that quotas give rise to large profits made in connection with imports and exports has made the system popular with importers and exporters. This popularity is enhanced by the fact that quota restriction, much more than tariffs, facilitates monopolistic price policies by domestic producers.

All these unavoidable abuses, inefficiencies and inconveniences made it unlikely and undesirable that the quota system would replace the tariff system.

See EXCHANGE CONTROL; MOST-FAVOURED-NATION TREATMENT; TARIFFS.

BIBLIOGRAPHY.—F. A. Haight, *French Import Quotas* (1935); C. R. Whittlesey, "Import Quotas in the United States," *Quarterly Journal of Economics,* vol. 52, pp. 37–65 (Nov. 1937); H. Heuser, *Control of International Trade* (1939); M. S. Gordon, *Barriers to World Trade* (1941); *Trade Regulations of Commercial Policy of the United Kingdom,* National Institute of Economic and Social Research (1943); G. Haberler and M. Hill, *Quantitative Trade Controls — Their Causes and Nature,* League of Nations publication (1943); J. Viner, *Trade Relations between Free-Market and Controlled Economies,* League of Nations publication (1943); W. Diebold, *New Directions in Our Trade Policy* (1941); C. Wilcox, *A Charter for World Trade* (1949); W. A. Brown, *The United States and the Restoration of World Trade* (1950); Henry Chalmers, *World Trade Policies* (1953); Annual Reports of Secretariat of General Agreement on Tariffs and Trade (1951 *et seq.*).
(G HL.)

QUO WARRANTO, in English law, the name given to an ancient prerogative writ calling upon any person usurping any office, franchise, liberty or privilege belonging to the crown, to show "by what warrant" he maintained his claim, the onus being on the defendant. It lay also for nonuser or misuser of an office, etc. If the crown succeeded, judgment of forfeiture or ouster le main was given against the defendant. The procedure was regulated by statute as early as 1290 (the statute of *Quo Warranto),* which was superseded by the modern form of an information in the nature of a quo warranto. exhibited on behalf of the crown or a private person called the relator. The information will not be issued except by leave of the court on proper cause being shown. It lies where the office is of a public nature and created by statute, even though it is not an encroachment upon the prerogative of the crown. Where the usurpation is of a municipal office the information is regulated by 9 Anne ch. 25 (1711). Such an information must, in the case of boroughs within the Municipal Corporations act, 1882, be brought within 12 months after disqualification (s. 225); in the case of other boroughs, within 6 years after the defendant first took upon himself the office. Though nominally a criminal it has long been really a civil proceeding, and has recently been declared to be so.

In the United States, quo warranto is the proper remedy under the statutes of the various states to ascertain the right of a person to an office of a public nature or one in a corporation. It also is used to test the validity of a franchise held by a municipality or a public service corporation. Some states have substituted by statute information in the nature of quo warranto and other remedies, and where such substitution has been made, quo warranto is improper.

R THE letter corresponding to modern R in the ancient Semitic alphabet was 4 (resh), perhaps deriving from an earlier sign representing a head. Greek rho is found in a form practically unchanged in the early inscriptions from the island of Thera. The same form also occurs in early inscriptions from Attica and Corinth and in the Chalcidic alphabet. The most usual Greek form was rounded P; this is the form in which the letter occurs in the Lydian alphabet. A form D in which the loop is extended to the bottom of the vertical stroke also occurs in both the eastern and western alphabets. This was the form of the letter in the Umbrian and Oscan alphabets of Italy, while Etruscan had a form in which the loop reached nearly to the bottom. In the Chalcidic alphabet a form R with an additional oblique stroke occurred, and this must be the ultimate source of the Latin form, in which the oblique stroke was exaggerated.

The minuscule form has been subject to many variations. In cursive Latin of the 6th century occurred a form √ in which the loop has disappeared, the three right-hand oblique strokes, or the loop and oblique stroke. being reduced to a single stroke. The Irish form in the 7th century was ɼ in which a similar process had taken place, but the remnants of the loop and oblique stroke had become extended in a horizontal direction. On the basis of this was formed the Carolingian r, in which the vertical stroke was not extended below the line. The Carolingian form is the minuscule r of modern printing, but in handwriting it still contends with the form 𝓇, resembling the Latin cursive tradition.

The sound represented by the letter has been in general the liquid formed by contact between the tip of the tongue and the palate, but its precise quality differs considerably from one language or dialect to another. The trilled *r* produced by rolling the tip of the tongue, is found not only in several continental languages but in certain dialects of English as well. The back or uvular *r* is characteristic of standard French and is current in many parts of Germany. In southern England and the eastern United States the *r* is feebly pronounced and in final position is often dropped altogether. The spelling with initial *rh* is practically limited to words of Greek origin (*e.g.*, rhetoric), where it represents the classical Creek writing of *rho* with a rough breathing (῾) to indicate an unvoiced pronunciation. It has intruded itself incorrectly in "rhyme" (for "rime") and in "Rhegium," "Rhaetic." (B. F. C. A.; J. W. P.)

NAME OF FORM	APPROXIMATE DATE	FORM OF LETTER
PHOENICIAN	B.C. 1.205	4
CRETAN	1.100-900	4
THERAEAN	700-600	4
ARCHAIC LATIN	700-500	P
ATTIC	600	4
CORINTHIAN	600	4
CHALCIDIAN	600	P
IONIC	403	q
ROMAN COLONIAL	PRE-CLASSICAL AND CLASSICAL TIMES	R R R R
URBAN ROMAN		R
FALISCAN		4 Я Я
OSCAN		◁ D D
UMBRIAN		D a
CLASSICAL LATIN AND ONWARDS		R

DEVELOPMENT OF LETTER "R" FROM EARLIEST TIMES TO THE PRESENT

RA, the Egyptian solar god, one of the most important figures in the Pantheon. See EGYPT: Ancient Religion: The Pantheon.

RABAH ZOBEIR (d. 1900), the conqueror of Bornu (an ancient sultanate on the western shores of Lake Chad, included since 1890 in British Nigeria), was a half-Arab. half-Negro chieftain. He was originally a slave or follower of Zobeir Pasha (see ZOBEIR RAHAMA), and is said to have formed one of the party which served as escort to Alexandrine Tinne in her journeys in the Bahr-el-Ghazal in 1862–64. In 1879, Zobeir being in Egypt, his son Suleiman and Rabah were in command of Zobeir's forces in the Bahr-el-Ghazal. They persisted in slave raiding. and denied the khedive's authority, and Gordon sent against them Romolo Gessi Pasha. Gessi captured Suleiman and routed Rabah, who in July 1879 fled westward with some 700 Bazingirs (black slave soldiers).

He made himself master of Kreich and Dar Banda, countries to the south and southwest of Wadai. He finally established himself in Bagirmi, a state southeast of Lake Chad. In 1893 Rabah overthrew the sultan of Bornu. In his administration of the country he showed considerable ability and a sense of public needs. To the British. represented by the Royal Niger company, Rabah gave comparatively little trouble. Early in 1897 he began an advance in the direction of Kano, the most important city in the Fula empire. The news of the crushing defeat by Sir George Goldie of the Fula at Bida, induced Rabah to return to Bornu. He now turned his attention to the French. Émile Gentil had in this same year (1897) reached Lake Chad, via the Congo and Bagirmi, and had installed a French resident with the sultan of Bagirmi. As soon as Gentil had withdrawn, Rabah again fell upon Bagirmi. and forced sultan and resident to flee. In 1899 the French sent an expedition to reconquer the country, but it was only after a third encounter (April 22. 1900) that Rabah was slain and his host defeated. The chieftain's head nas cut off and taken to the French camp In this battle Major Lamy, the French commandant. also lost his life.

The French continued the campaign against Rabah's sons, two of whom were killed. Rabah had left instructions that if his army was finally defeated by the French. his successor should return to Bornu and make friends nith the British Rabah's third son, Fader-Allah. accordingly threw himself entirely upon British protection. But, in the later part of 1901 Fader-Allah, who had 2,500 riflemen, again made aggressive movements against the French. In retaliation, Captain Dangeville pursued him into British territory. A battle was fought at Gujba, Fader-Allah being defeated. He fled mortally mounded and died the same night.

RABAT, the capital of the kingdom of Morocco. North Africa, lies on the Atlantic coast, at the mouth of the Bou Regreg, 57 mi. N.E. of Casablanca and 174 mi. S.W. of Tangier Rabat. on the south bank. is separated by the Bou Regreg from the town of Salé opposite. Until March 2, 1956, when France relinquished its possessions in Morocco. Rabat was the capital of the protectorate and the seat of the French resident general. Pop. (1960) 227,445; (1952) 156,209. of whom 105.223 are Moslem, 10.239

Jewish and 40.747 non-Moroccan.

The old town, still surrounded by ramparts, lies near the coast, from which it is separated by a hill covered with extensive cemeteries. Within the ramparts are the medina, or Moslem town. and the *mellah*, or Jewish quarter. To the north stands an ancient fortress, the Kasba des Oudaya, on a cliff above the mouth of the Bou Regreg; it is entered by a splendid 12th-century gateway built during the dynasty of the Almohads (*q.v.*). Close to the Kasba is a charming Andalusian garden and in the adjoining medersa (college) there is a museum of Moroccan art. At .the southern edge of the old town, dominating the valley, is the 12th-century Hassan tower, a magnificent minaret of the Almohade period, at the foot of which are the ruins of the mosque of Al-Mansur. Intended to be the biggest in the world, it was never completed.

The European town of Rabat is partly enclosed within a great fortified wall which still stands along the greater part of its perimeter. As well as modern European quarters, the fortifications surround the Dar-el-Makhzen, or Sultan's palace, in front of which is the *Mechouar*, an immense walled courtyard, once bare, but laid out at the end of the 19th century with lawns. It was there that the sovereign received homage from his subjects. Various administrative buildings, among them the supreme court of justice, are in this part of the town, and nearby is Bab-er-Rouah, or the gate of the winds, a beautiful Almohade gateway.

Most of the government buildings are situated on the slopes of a hill around the former residency general, which is now the French embassy. The residential districts of Orangers and Aguedal, consisting of villas surrounded by gardens, extend far beyond the Almohade walls.

The harbour has never been busy because its approach is made difficult by the sand bar outside and by the constant silting up of the canal. The harbour has been abandoned and a bridge, completed in 1957, links Rabat with Salk, making it impossible for any merchant ships to enter the harbour.

History. — The town's history is inseparable from that of Salé. The first settlement was the Roman town of Sala Colonia, the remains of which were excavated in 1930 near Chella to the south of the city. These ruins adjoin the tombs of the Merinid (Beni Merin) dynasty (14th century). The present town of Salé was established on the north bank of the Bou Regreg between the 10th and 11th centuries and was founded by the Zenata Berbers, who were orthodox Moslems. to house the heretical Berghouata Berbers, whose domain stretched from the Bou Regreg west to the Oum-er-Rebia during the 10th and 11th centuries. The Kasba, later called "des Oudaya," was in the first place a bridgehead on the south bank for the occupants of Salk, and was for a long time called Salé-le-Neuf.

In the 12th century the first Almohade sultan, 'Abd al-Mumin, built a *ribāt* (camp), where he concentrated troops for his religious war in Spain. His second successor, Yakub al-Mansur, called it *Rībāt-el-Fath*, "the camp of victory," from which the town of Rabat takes its name. He erected the great fortified wall, within which the modern town has developed, as well as the tower of Hassan. In the 17th century numbers of Moors driven from Spain (the *Hornacheros*) settled in Rabat, which became with Salé a Corsair republic. (See BARBARY PIRATES.)

The Alaouite sultans, who stopped in Rabat on their way from Fez to Marrakesh, had a palace built there. Under the French protectorate (1912), Rabat mas made the capital of the country.

See Rabat et sa *région*, 4 vol. (Paris, 1918–20); H. Terrasse, *Villes impériales* du *Maroc* (Grenoble, 1937); J. Caillé, La *ville de* Rabat *jusqu'au* Protectorat *français*, 3 vol. (Paris, 1949). (A. AM.)

RABAUT, PAUL (1718–1794), French pastor of "the Church of the Desert" (see HUGUENOTS), was born at Bédarieux, near Montpellier, on Jan. 29. 1718. In 1738 he was admitted as a preacher, and after a year's study (1740–41) at the Lausanne seminary, received charge of the church of Nimes. In 1744 he was vice-president of the general synod. During the persecution of 1745–1752 Rabaut went into hiding, and in 1753 a price was put on his head. During the years that followed he sought, with Antoine Court and others, to place French Protestantism on a solid basis and to improve their legal position. In 1785, when he was visited by General La Fayette, it was arranged that Rabaut's son, Rabaut Saint-Btienne, should go to Paris on behalf of the Reformed Church. In Nov. 1787 Louis XVI's edict of toleration was signed, though it was not registered until Jan. 29, 1788. Two years later liberty of conscience was proclaimed by the national assembly, of which Rabaut Saint-Étienne was chosen vice-president, and it was declared that non-Catholics might be admitted to all positions. After the fall of the Girondists, however, in which Rabaut Saint-Btienne was involved, Paul Rabaut, who had refused to renounce his title of pastor, was arrested, dragged to the citadel of Nimes, and kept in prison seven weeks (1794). He died Sept. 25, 1794, soon after his release.

RABBI (Hebrew "my master" or "my teacher"), RABBAN or RABBENU ("our master" or "our teacher") and RAB. ("master" or "teacher") are titles applied to Jewish scholars or teachers. The title rabbi first came into general use toward the end of the 1st century A.D., although the heads of the Sanhedrin (*q* v.) had borne the title rabban since the time of Gamaliel I. Scholars who received their ordination in Palestine were called rabbi, while the Babylonian scholars who were not ordained in Palestine were called rab.

The title rabbenu was applied to Judah the Prince, the codifier of the Mishnah (2nd–3rd century AD.), and since then it has been a title designating the outstanding scholars of every generation.

There is no sharp distinction in religious status between the rabbi and the layman in Judaism. The rabbi is simply a layman specially learned in the Scriptures and the Talmud. To be recognized as a rabbi, however, a talmudic student has to be ordained. The custom of ordination is very old.

Joshua was ordained by Moses, the ceremony being as follows: Moses placed Joshua before Eleazar and the congregation and laid his hands upon him while giving him instructions. Symbolically. a portion of the spirit of Moses was transferred to Joshua through Moses' hands.

Moses also ordained the 70 elders who assisted him in governing the people. According to tradition the elders'ordained their successors, who in turn ordained others. so that there existed an unbroken chain of ordination down to the time of the Second Temple.

The practice of ordination in its Mosaic form ceased in Palestine in the second half of the 4th century when the Judaean academies were closed. (In the 16th century an attempt was made in Palestine to revive the ancient ordination, as well as the Sanhedrin. with all the power and authority that it possessed, but this attempt resulted in failure.) Down to the end of the 14th century, rabbinic ordination was purely a verbal ceremony. Later a new procedure was introduced whereby ordination was conferred upon a candidate in the form of a written statement awarded by a well-known and recognized scholar. Traditionally, the authority to act as a rabbi may be conferred by any other rabbi, but it is usual for students in theological academies to receive this authority from their teachers. In America the best-known rabbinical schools that ordain graduates are: the Hebrew Theological college, Skokie, Ill. (Orthodox); the Hebrew Union College-Jewish Institute of Religion. Cincinnati-New York city (Reform); the Jewish Theological Seminary of America, New York city (Conservative); and the Rabbi Elchanan Theological seminary, New York city (Orthodox). The main associations of U.S. rabbis are the Central Conference of American Rabbis (Reform), the Rabbinical Assembly of America (Conservative) and the Rabbinical Council of America (Orthodox).

In the middle ages there was strong opposition toward the chief rabbis, who usually were government appointees rather than persons chosen by the Jewish communities. The office of the chief rabbi exists today in some western European countries and in Israel. In England the chief rabbi of the United Hebrew Congregations of the British Commonwealth of Nations is elected by representatives of the congregations in Great Britain and the British dominions. He is thus recognized as the spiritual head of the majority of Jews in the British Commonwealth. The first chief rabbi of England was Rabbi David Tebele Schiff

(1765–92).

In France the office of the chief rabbi goes back to the Napoleonic consistorial system of 1808.

In Israel the chief rabbinate is based on the Religious Community ordinance of 1926, which conferred religious authority upon the rabbinical council headed by two chief rabbis, one belonging to the Sephardic, the other to the Ashkenazic section of the Jewish community.

See Louis Finkelstein, ***The*** *Beliefs* and *Practices of Judaism,* rev. ed. (1952). **(J. M.** RL.)

RABBIT, a well-known rodent, formerly called cony, The rabbit, *Oryctolagus cuniculus,* is a member of the family Leporidae *(see* RODENTIA). From the hare (*q.v.*) the rabbit is distinguished by its smaller size, shorter ears and feet, absence of black on the ears and gray colour; by the facts that the young are born naked and blind and that it lives in burrows in the ground. It breeds from four to eight times a year, a litter comprising three to eight young. It begins to breed at the age of six months and lives seven or eight years.

Originally inhabiting the western half of the Mediterranean basin, the rabbit spread, partly by the agency of man, throughout temperate Europe, and it is still extending its range. Introduced into New Zealand and Australia, where natural enemies were few. it increased beyond bounds until it became an unmitigated nuisance. The name rabbit is loosely used to include many members of the family Leporidae, especially in North America *(see* HARE).

The rabbit has long been domesticated, and the variations produced are greater than in any other mammal except the dog (*q.v.*). For not only has the weight been quadrupled and the structure of the skeleton modified, but the proportionate size of the brain has been reduced (cf. the domestic duck) and the colour and texture of the fur remarkably altered. The old English lop-eared breed may have ears 23 in. from tip to tip and 6 in. in width. The hardy and prolific Belgian hare resembles the true hare in colour and form. while a similar but larger variety is the (so-called) Patagonian rabbit. The Angora rabbit has very long fur, which is of commercial value; the most valued variety is the albino. The Dutch breed is small and particoloured, being dark posteriorly and white anteriorly. The silver gray is esteemed for its skin, while the Flemish giant is the biggest of all breeds.

Modern dressing and dyeing methods have developed rabbit fur (known to the fur trade as "coney") into the most satisfactory of low priced furs for wearing qualities. Because it lends itself readily to dyeing, it is used in great quantities in imitation of such furs as squirrel, seal, beaver, nutria, chinchilla, muskrat, ermine. leopard and still others.

Various tame varieties of rabbits, which are heavier and have a fur stronger and less liable to shed. are raised especially in Belgium and France, to supply the demand. Because of the excellent felting properties of rabbit fur it now forms the largest proportion of fur going into the manufacture of felt hats. Forty to fifty rabbit skins furnish material for a dozen hats. Rabbit fur is also in demand for upholstery purposes. The supply of rabbits for the hat industry comes chiefly from Australia (which for some years averaged 70,000,000 skins annually), New Zealand, Belgium, France and England.

RABBŪLĀ, a distinguished bishop of the Syrian church early in the 5th century. He was a native of Kenneshrin, a town some few miles south of Aleppo and the seat of a bishopric. He resided for some time in a monastery, and then passed to a life of greater hardship as a solitary hermit. On the death of Diogenes, bishop of Edessa, in the year 411–412, Rabbiila was-chosen his successor. On one occasion he visited Constantinople and there preached before Theodosius II. (who was then favourable to Nestorius) and a great congregation a sermon in denunciation of Nestorian doctrine, of which a portion survives in the Syriac version. He became the friend of Cyril of Alexandria, with whom he corresponded, and whose treatise *De recta fide* he translated into Syriac. The version survives in a British Museum ms.; ***see*** Wright's *Catalogue* p. 719. He died in August 435.

RABELAIS, FRANÇOIS (*c.* 1495–1553), French author, was born at Chinon on the Vienne in the province of Touraine The date of his birth is uncertain: it has been put by tradition and by authorities lonq subsequent to his death. as 1483. 1490 and 1495. It is said that he had four brothers and no sisters, that his father had a country property called La Devinière. and was either an apothecary or a tavern keeper. An indistinct allusion of his own has been taken to mean that he was tonsured in childhood at seven or nine years; and tradition says that he was sent to the convent of Seuilly. From Seuilly at an unknown date tradition takes him to the convent school of La Baumette near Angers. where he is supposed to have been at school with the brothers Du Bellay, with Geoffroy d'Estissac and others. He certainly entered the Franciscan monastery of Fontenay le Comte some time before April 5, 1519, by which date he held a position sufficiently senior to sign deeds for the community. Rabelais in all probability became disgusted with the cloister—indeed his great work shows this beyond doubt. In 1524 his friend Geoffroy d'Estissac procured from Clement VII an indult, licensing a change of order and of abode for Rabelais. From a Franciscan he became a Benedictine. and from Fontenay he moved to Maillezais, of which Geoffroy d'Estissac was bishop. But even this learned and hospitable retreat did not apparently satisfy Rabelais. In or before 1530 he left Maillezais, abandoned his Benedictine gdrb for that of a secular priest. For a time the Du Bellays provided him with an abode near their own château of Langey, but on Sept. 17, 1530. he entered the faculty of medicine at the University of Montpellier. becoming bachelor on Nov. 1, a remarkably short interval, which shows what was thought of his acquirements. Early in 1531 he lectured publicly on Galen and Hippocrates, and his stay at Montpellier, which lasted rather more than a year at first, was renewed at intervals for several years.

In 1532 he had moved to Lyons. He was appointed before the beginning of November physician to the Hôtel Dieu and lectured on anatomy with demonstrations from the human subject. He edited for Sebastian Gryphius, in 1532, the medical *Epistles* of Giovanni Manardi. the *Aphorisms* of Hippocrates, with the *Arr Parva* of Galen. and an edition of two supposed Latin documents, which happened to be forgeries.

At this time Lyons was the centre of an unusually enlightened society, and indirectly it is clear that Rabelais became intimate with this society. At this time probably appeared the beginnings of the work which was to make Rabelais immortal. The earliest known and dated edition of *Pantagruel* is of 1533, of *Gargantua* 1535. Besides this, 1533 saw the publication of an almanac, the first of a long series which exists only in titles and fragments, and of the amusing *Prognostication Pantagrueline.* Both this and *Pantagruel* itself were published under the anagrammatic pseudonym of "Alcofribas Nasier," shortened to the first word only in the case of the *Prognostication.*

On Oct. 23, 1533, *Pantagruel* was condemned by the Sorbonne. and in Jan. 1534 Jean du Bellay. passing through Lyons on an embassy to Rome, engaged Rabelais as physician. The visit did not last very long, but it left literary results in an edition of a description of Rome by Marliani, which Rabelais published in Sept. 1534.

In the spring of 1535 the authorities of the Lyons hospital. considering that Rabelais had twice absented himself without leave. elected Pierre de Castel in his place; but the documents do not imply any blame and the appointment of his successor was once definitely postponed in case he should return. In the summer of 1535 Rabelais once more accompanied Jean du Bellay, now a cardinal, to Rome, and stayed there till April in the next year To this period belong letters to Geoffroy d'Estissac and the bull of absolution which freed Rabelais from ecclesiastical censure, gave him the right to return to the order of St. Benedict when he chose. and to practise medicine. He took advantage of this bull and became a canon of St. Maur. In 1537 he took his doctor's degree at Montpellier and lectured on the Greek text of Hippocrates, and in July 1538 he was present in the capacity of *maître des requites* at the conference between Francis I and Charles V at Aigues-Mortes. In 1540 he was for the third time in Italy in the service of Guillaume du Bellay-Langey, elder brother of Jean, who was governor of Piedmont; and according to the letters of Pellicier, bishop of Montpellier and ambassador to Venice, Rabelais was then employed by him to collect manuscripts for the king's library. In Dec. 1540 he was compelled to return to France to clear himself of a charge of having revealed diplomatic secrets, but he rejoined Guillaume du Bellay at Turin in the following spring, and remained in hi5 service until he died on Jan. 9, 1543. Rabelais wrote a panegyrical memoir of Guillaume, which is lost. and the year before saw the publication of an edition of *Gargantua* and *Pantagruel,* book i, together (both had been repeatedly reprinted separately), in which some dangerous expressions were cut away. Nothing at all is known of his life, whereabouts, or occupations till the publication of the third book, which appeared in 1546, *avec privilège du roi,* which had been given in Sept. 1545.

Up to this time Rabelais, despite the condemnation of the Sorbonne referred to above, had experienced nothing like persecution or difficulty. Even the action of Dolet, who in 1542 reprinted the earlier form of the books which Rabelais had just slightly modified, seems to have done him no harm. But the storm of persecution which towards the end of the reign of Francis I was fatal to Dolet himself and to Des Périers, while it exiled and virtually killed Marot, threatened him. It is certain that he passed nearly the whole of 1546 and part of 1547 at Metz in Lorraine as physician to the town at the salary of 120 livres, and Sturm speaks of him in a contemporary letter as having been "cast out of France by the times," and says that he himself in another letter gives a doleful account of his pecuniary affairs and asks for assistance. At Francis's death on March 31. 1547, Du Bellay went to Rome, and at some time not certain Rabelais joined him. In 1549 a monk of Fontevrault, Gabriel du Puits-Herbault, made in a book called *Theotimus* the first of the many attacks on Rabelais. It is, however, as vague as it is violent, and it does not seem to have had any effect. Rabelais had indeed again made for himself protectors whom no clerical or Sorbonnist jealousy could touch. Rabelais was able to return to France, and in 1550 was presented to the livings of Meudon and St. Christophe du Jambet. There is very little ground for believing that the "curé of Meudon" ever officiated or resided there. He certainly held the living for less than three years, resigning it in Jan. 1553 with his other benefice, and at the episcopal visitation of 1551 he was not present.

Some chapters of Rabelais's fourth book had been published in 1548, but the whole did not appear till 1552. The Sorbonne censured it and the *parlement* suspended the sale, taking advantage of the king's absence from Paris. But it was soon relieved of the suspension. He died, it is said, on April 9. 1553, but actual history is quite silent save on the point that he was not alive in May of the next year, and the legends about his deathbed utterances—"La farce est jouée," "Je vais chercher un grand peut-être," etc.—are altogether apocryphal.

Ten years after the publication of the fourth book and nine after the supposed date of the author's death there appeared at Lyons 16 chapters entitled *l'Île sonnante par maistre François Rabelais,* and two years later the entire fifth book was printed as such. In 1567 it took place with the others and has ever since appeared with them although from the beginning of the 17th century its authenticity has been disputed.

Gargantua and **Pantagruel.**—Rabelais's works are so little read that some sketch of their contents is necessary. The first book, *Gargantua,* describes the birth of that hero (a giant. the son of gigantic parents), whose nativity is ushered in by the account of a tremendous feast. In this the burlesque exaggeration of the pleasures of eating and drinking, which is one of the chief exterior notes of the whole work. is pushed to an extreme. Early. however. the author becomes serious in contrasting the early education of his hero—a satire on the degraded schools of the middle ages—with its subsequent and reformed stage, in the account of which all the best and noblest ideas of the humanist Renaissance in reference to pedagogy are put with exceptional force. Gargantua is recalled from Paris, whither he had been sent to finish his education, because of a war between his father, Grandgosier, and the neighbouring king, Picrochole. This war is described at great length, the chief hero of it being the monk Friar John, an unclerical cleric in whom Rabelais greatly delights. Picrochole defeated and peace made. Gargantua establishes the abbey of Thelema in another of Rabelais's most elaborate literary passages, where all the points most obnoxious to him in monastic life are indicated by the assignment of their exact opposites to this model convent. The second book introduces the principal hero of the whole, Pantagruel, Gargantua's son, who goes through something like a second edition of the educational experiences of his father. Like him, he goes to Paris, and there meets with Panurge, the principal triumph of Rabelaisian character drawing, and the most original as well as puzzling figure of the book. Panurge has almost all intellectual accomplishments but is totally devoid of morality. This book, like the other, has a war in its latter part; Gargantua scarcely appears in it and Friar John not at all. It is not till the opening of the third book that the most important action begins. This arises from Panurge's determination to marry—a determination, however, which is halfhearted and which leads him to consult a vast number of authorities, each giving occasion for satire of a more or less complicated kind. At last it is determined that Pantagruel and his followers (Friar John has reappeared in the suite of the prince) shall set sail to consult the oracle of the *Dive Bouteille.* The book ends with the most obscure passage of the whole, an elaborate eulogy of the "herb pantagruelion," which appears to be. if it is anything, hemp. Only two probable explanations of this have been offered, the one seeing in it an anticipation of Joseph de Maistre's glorification of the executioner. the other a eulogy of work, hemp being on the whole the most serviceable of vegetable products for that purpose. The fourth and fifth books are entirely taken up with a description of the voyage. Many strange places with stranger names are visited, some of them offering obvious satire on human institutions, others, except by the most farfetched explanations, resolvable into nothing but sheer extravaganza. At last the Land of Lanterns, borrowed from Lucian, is reached, and the oracle of the bottle is consulted. This yields the single word "Trinq," which the attendant priestess declares to be the most gracious and intelligible she has ever heard from it. Panurge takes this as a sanction of his marriage, and the book ends abruptly. This singular romance includes the most bewildering abundance of digression, burlesque amplification, covert satire on things political, social and religious, miscellaneous erudition of the literary and scientific kind. Everywhere the author lays stress on the excellence of "Pantagruelism," and the reader who is himself a Pantagruelist (it is perfectly idle for any other to attempt the book) soon discovers what this means. It is, in plain English, humour, which may be said to consist in the extension of a wide sympathy to all human affairs, together with a comprehension of their vanity.

Moroseness and dogmatism are as far from the Pantagruelism of Rabelais as maudlin sentimentality or dilettantism. Perhaps the chief things lacking in his attitude are, in the first place,.reverence, of which, however, from a iew passages, it is clear he mas by no means totally devoid and, secondly, an appreciation of passion and poetry.

Interpretation and Criticism—In interpreting and criticizing Rabelais's works three questions must be discussed: What is the general drift and purpose of *Gargantua* and *Pantagruel,* supposing there to be any? What defense can be offered, if any is needed, for the extraordinary licence of language and imagery which the author has permitted himself? What mas his attitude toward the great questions of religion, philosophy and politics?

According to some expositors. Rabelais is a sober reformer, an apostle of sound education, of rational if not dogmatic religion, who wraps up his morals in a farcical envelope partly to make them go down with the vulgar and partly to shield himself from the consequences of his reforming zeal. According to others, Rabelais is all this but with a difference. He is not religious at all; he is more or less antireligious and his book is more or less oi a general protest against any attempt to explain supernaturally the riddle of the earth. According to a third class, the Rabelaisian legend does not so much err in principle as it invents in fact. Rabelais is the incarnation of the "esprit Gaulois," a jovial, careless soul. not destitute of common sense or even acute intellectual power, hut first of all a good fellow, rather preferring a broad jest to a fine-pointed one and rollicking through life like a good-natured undergraduate. But it is impossible to think that any unbiased judge reading Rabelais can hold the grave-philosonher view or the reckless-goodfellom view without modifications and aliowances which practically deprive either of any value Those who identify Rabelais with Pantagruel strive in vain to account for the vast ocean of pure or impure laughter and foolery which surrounds the few solid islets of sense and reason and devotion. Those who identify Rabelais with Panurge can never explain the education scheme, the solemn apparition of Gargantua among the farcical and fantastic variations on Panurge's wedding and many other passages; while, on the other hand, those who insist on a definite propaganda of any kind must justify themselves by their own power of seeing things invisible to plain men.

In only two points can Rabelais he said to be definitely polemic. He hated the monkish system as it existed in his time; he as certainly hated the brutish ignorance into which the earlier systems of education had suffered too many of their teachers and scholars to drop. At these two things he was never tired of striking, but elsewhere, even in the grim satire of the *Chats fourrés*, he is the satirist proper rather than the reformer. It is in the very absence of any cramping or limiting purpose that the great merit and value of the book consist. It holds up an almost perfectly level and spotless mirror to the temper of the earlier Renaissance. The author has no universal medicine of his own (except Pantagruelism) to offer, nor has he anybody else's universal medicine to attack. It is not indeed possible to deny that in the oracle of the bottle, besides its merely jocular and fantastic sense, there is a certain "echo," as it has been called, "of the conclusion of the preacher," a certain acknowledgment of the vanity of things; but it is little more than a suggestion, and is not strengthened by anything in the body of the work. Rabelais is, in short, if he be read without prejudice, a humorist pure and simple, feeling often in earnest, thinking almost always in jest.

If this general view is correct it will probably condition to some extent the answer to be given to the two minor questions stated above. The first is connected with the great blemish of *Gargantua* and *Pantagruel*—their extreme coarseness of language and imagery. Rabelais's errors in this way are of course, looked at from an absolute standard, unpardonable. But judged relatively there are several, we shall not say excuses, but explanations of them. In the first place, his comparative indecency has been much exaggerated by persons unfamiliar mith early French literature. The form of his book was above all things popular, and the popular French literature of the middle ages as distinguished from the courtly and literary literature, which was singularly pure, can hardly be exceeded in point of coarseness. Moreover, Rabelais's coarseness, disgusting as it is, has nothing of the corruption of refined voluptuousness about it, and nothing of the sniggering indecency which disgraces men like Pope, like Voltaire, and like Sterne. The general taste having been considerably refined since, Rabelais has in parts become nearly unreadable—the worst and most appropriate punishment for his faults. As for those who have tried to make his indecency an argument for his laxity in religious principle, that argument hardly needs discussion. It is notoriously false as a matter of experience.

This brings us to the last point—what his religious opinions were. He has been claimed as a freethinker of all shades, from undogmatic theism to atheism, and as a concealed Protestant. The last of these claims has now been very generally given up, but the accusation of freethinking, if not of directly anti-Christian thinking, has always been more common. Those who hold this opinion, however, never give chapter and verse for it, and it may be said confidently that chapter and verse cannot be given. The sayings attributed to Rabelais which colour the idea are purely apocryphal. Even a jest at the Sorhonne couched in the Pauline phrase about "the evidence of things not seen," was removed by the author from the later editions. It must be remembered that the later middle age, which in many respects Rabelais represents almost more than he does the Renaissance, was, with all its unquestioning faith, singularly reckless and, to our fancy, irreverent in its use of the sacred words and images. On the other hand, there are in the book expressions which either signify a sincere and unfeigned piety of a simple kind or else are inventions of the most detestable hypocrisy. For these passages are not, like many to be found from the Renaissance to the end of the 18th century, obvious flags of truce to cover attacks—mere bowings in the house of Rimmon to prevent evil consequences. They are always written in the author's highest style, a style perfectly eloquent and unaffected; they can only be interpreted (on the freethinking hypothesis) as allegorical with the greatest difficulty and obscurity, and it is pretty certain that no one reading the book without a thesis to prove mould dream of taking them in a nonnatural sense. There is absolutely nothing within the covers of Rabelais's works incompatible mith an orthodoxy which would he recognized as sufficient by Christendom at large, leaving out of the question those points of doctrine and practice on which Christians differ. Beyond this no wise man will go, and short of it hardly any unprejudiced man mill stop.

BIBLIOGRAPHY.—The first complete edition of Rabelais was published by Jean Martin (1567). By 1600 about 60 editions had been published (P. P. Plan, *Biblio. rabelaisienne,* 1532–1711, 1904). The first important critical edition mas that of Le Duchat (1711). Eloi Johanneau published an elaborate edition in nine volumes (1823–26). Later editions and commentaries have been numerous.

Monographs on Rabelais include those by E. Noel (1850); A. Mayrargues (1868); J. Fleury (1876); P. Stapfer (1889); H. Hatzfeld (1923);.Jean Plattard, *La vie de François Rabelais* (1929), Eng. trans. by Louis Roche (1930); L. Sainéan, *La langue de Rabelais,* 2 vol. (1922–23), *L'influence et la reputation de Rabelais* (1930); P. Villey, *Les grands écrivains du XVI siècle, Rabelais et Marot* (1923); J. Boulenger, *Rabelais à travers les ages,* with bibliography (1925); W. Nicati, *Rabelais notre maître; son oeuvre, sa doctrine, le Pantagruelisme* (1926); G. Lote, *La vie et l'oeuvre de François Rabelais* (1938); and P. Jourda, *La Gargantua de Rabelais* (1948). *See* also *Revue des études rabelaisiennes* (1903–12), continued after 1913 as *Revue du seizième siècle.*

Sir Thomas Urquhart translated the first two volumes of Rabelais into English in 1653; his work reproduced the spirit of the original with remarkable felicity, and was recognized by many as a masterpiece of translation. In 1693 Pierre Motteux republished the two volumes with a long commentary and added the third volume which Urquhart had not completed. Later Motteux translated the last two volumes of Rabelais. W. F. Smith made a new translation of the five books and minor writings in 1893; a second edition of this work appeared in 1934. Other English translations were made by Samuel Putnam, 3 vol. (1929) and by Jacques Le Clercq, 5 vol. (1942).

For biographies and criticisms in English, *see* A. F. Chappell, *The Enigma of Rabelais; an Essay in Interpretation* (1924); N. H. Clement, *The Influence of the Arthurian Romances on the Five Books of Rabelais* (1926); Samuel Putnam, *François Rabelais; Man of the Renaissance* (1928); A. J. Nock and C. R. Wilson, *Francis Rabelais; the Man and His Work* (1929); H. Brown, *Rabelais in English Literature* (1934); J. C. Powys, *Rabelais, His Life* (1948); and Mary P. Willcocks, *Laughing Philosopher* (1951).

RABI, ISIDOR ISAAC (1898–), U.S. physicist, invented in 1937 the atomic and molecular beam magnetic resonance method for observing spectra in the radio-frequency range. Subsequent development of several spectroscopic methods over a wide frequency range depended greatly on Rabi's pioneering work, for which he was awarded the Nobel prize in 1944. The importance of the work lies in the fact that a number of fixed mechanical and magnetic properties and the shape of a nucleus in an atom or molecule may be deduced from the observations of radio-frequency spectroscopy (*q.v.*). The observations also yield detailed information about the structure of atoms and molecules.

Born in Rymanow, Aus., on July 29. 1898, and raised in the United States. Rabi received a Ph.D. degree from Columbia university in 1927, joined its faculty in 1929 and became professor of physics in 1937. After he spent the year 1928 in Germany in the 'laboratory of Otto Stern, who had done important work with atomic beams, Rabi's continuing work in this field brought refinements in experimental technique and increasing insights into atomic phenomena. After 1940 he was active in research administration. and dealt with the relationships of scientific inquiry and its technological consequences to national and international affairs. From 1940 to 1945 he was associate director of the Radiation laboratory of the Massachusetts Institute of Technology, Cambridge, Mass., for the development of microwave radar. After World War II Rabi served on various government scientific committees, including the general advisory committee of the U.S. Atomic Energy commission. He was also a U.S. representative to UNESCO and was instrumental in arranging the 1955 Geneva conference on the peaceful uses of atomic energy, of which he was a vice president. (P. KH.)

RABIES (HYDROPHOBIA) is an acute, ordinarily fatal, infectious disease of the central nervous system caused by a virus and is, as a rule, propagated in domestic dogs and wild carnivorous animals such as the wolf, jackal, coyote, fox, mongoose and skunk. Rabies is propagated by vampire bats and insectivorous bats in some regions. Man and all warm-blooded animals are susceptible to infection with rabies.

History.—Rabies has been known in Europe and Asia since ancient times. The period of summer reckoned by the heliacal rising of the dog star, Sirius, has since antiquity been referred to as "dog days," when dogs are supposed to be especially liable to spells of madness. The people of ancient Egypt, Greece and Rome ascribed rabies to evil spirits because ordinarily docile and friendly animals developing this disease became suddenly vicious and aggressive without evident cause and, after a period of maniacal behaviour, developed paralysis and died. Aristotle (d. 322 B.C.) recognized the relationship of hydrophobia in man to rabies in animals and recommended cauterization of wounds produced by rabid dogs.

The transmission of rabies from a rabid dog to a normal dog by the inoculation of saliva was accomplished by Zinke (1804), by Griiner and by Salm-Reifferscheidt (1813). These experimental studies showed that the disease was infectious, and on the basis of this evidence it was assumed that destruction of stray ownerless dogs and quarantine of other domestic dogs would eliminate the disease. Sanitary measures including these provisions were adopted in Norway, Sweden and Denmark, and by 1826 these countries were free from rabies and remained so. Rabies was eliminated from some urban centres in continental Europe during the 19th century, but after a few years these areas frequently became reinfected, since rabies was established among the wild animals.

Nature of the Disease.—The disease often begins with such symptoms of excitation of the central nervous system as irritability and viciousness. During the early stages of the disease a rabid animal is most dangerous because it appears to be healthy and may seem friendly but will bite at the slightest provocation. Wild animals which appear to be tame and approach man or human habitation in daytime should be suspected of having rabies. The virus is often present in the salivary glands of rabid animals and is excreted in the saliva, so that the bite of the infected animal introduces the virus into a fresh wound. Under favourable conditions, the virus becomes established in the central nervous system by propagation along nerve tissue from the wound to the brain. When infection occurs, the disease develops most often between four and six weeks after exposure, but the incubation period may vary from ten days to at least eight months.

Bat Rabies.—A variety of rabies propagated by the vampire bat. Desmodus *rotundus murinus* Wagner, is known as paralytic rabies, paresian rabies, *mal* de *caderas* and derriengue. Although the disease symptoms produced by this virus differ from those of rabies contracted from dog bite, they are varieties of the same disease. One vaccine will protect against all types of rabies. In the vampire bat the rabies infection sometimes is limited to the salivary glands so that the animal can transmit rabies by bite for a period of several months without exhibiting symptoms of illness. This animal lives on blood alone and feeds by biting and lapping up the blood after inflicting a craterlike wound with its sharp incisor teeth. Therefore it does not need to become vicious in order to transmit rabies. Vampire bats are found only in Mexico, Central America and South America. The occurrence of epizootics of cattle rabies in Brazil, Trinidad and Mexico, in regions where dog rabies was rare or unknown, stimulated research on rabies during the period 1931–44 which resulted in the discovery that rabies exists as an enzootic disease of vampire bats in these countries. Rabies is found also in fruit-eating and insect-eating bats. Bats found flying in daytime or which try to attack and bite are likely to be infected with rabies.

Dog Rabies.—Dog rabies is commonly classified as furious rabies or dumb rabies, depending on the signs shown by the animal. In the former type the excitation phase is prolonged. while in the latter the paralytic phase is present from the beginning or develops early. Most infected dogs show some manifestations of each type. that is, a short excitation phase characterized by restlessness, nervousness, irritability and viciousness, followed by depression and paralysis. Sudden death from rabies, without recognizable signs of illness, is not uncommon. Dogs that develop the predominantly excited type of rabies invariably die of the infection, usually within three to five days after the onset of symptoms. Dogs developing the paralytic type of rabies without any evidence of excitation or viciousness may in rare instances recover from the infection. The symptom of hydrophobia or fear of water does not occur in dogs, but difficulty in swallowing is a common symptom of dog rabies. The paralysis of the muscles of phonation in rabid dogs often produces a characteristic change in the bark. There is no characteristic seasonal incidence of dog rabies.

Hydrophobia or Human Rabies.—Rabies in man is similar to the disease in animals. The excitation phase may continue until death occurs during a convulsive seizure. More often, symptoms of depression of the central nervous system develop before death. The hydrophobia symptom consists of repeated episodes of painful contraction of the muscles of the throat on attempting to swallow. This symptom may be elicited by the sight of water because of the association of water with the act of swallowing, hence the fear of water or hydrophobia. Rabies in man is uniformly fatal when associated with excitation of the nervous system and the hydrophobia symptom. Death ordinarily occurs within three to five days after the onset of symptoms. Abnormal sensations about the site of exposure are a common early symptom of rabies. Sometimes the disease is characterized by paralysis without any evidence of excitation of the nervous system. In such cases the disease may be prolonged to a week or more and recovery does occur on rare occasions. Human rabies contracted from the bite of vampire bats is uniformly of the paralytic type and the hydrophobia symptom does not occur. Rabies virus is often present in the saliva in human rabies and saliva specimens are examined for rabies virus by the mouse inoculation test.

Diagnosis.—Inclusion bodies, first described by A. Negri (1903), are found in the nerve cells of the brain of animals that die of rabies. They are not always present but a prompt diagnosis of rabies can be made in about 90% of the cases of furious rabies in dogs by demonstration of Negri bodies in the brain tissue after the animal dies. Negri bodies are found more frequently in those animals that show symptoms of viciousness for several days before they die of rabies. They are a specific reaction product and not a visible form or conglomerate of virus particles. Negri bodies are not found in the brains of animals infected with fixed varieties of rabies virus (see below).

The mouse test for rabies virus consists of intracerebral inoculation of mice with aqueous extracts prepared from brain tissue, salivary gland tissue or diluted saliva from cases of suspected rabies. Mice are uniformly susceptible to infection with rabies virus when thus inoculated and ordinarily sicken and die about one week after inoculation. The diagnosis of rabies is confirmed by demonstration of Negri bodies in the brain tissue.

Treatment.—Investigation by *Pasteur*.—The discovery by Louis Pasteur (1881) that the infective agent of rabies could be recovered in a relatively pure state from the brain of an animal that died of the disease opened the way for an extensive study of rabies. Since the infective agent as obtained from brains of rabid animals could not be identified by microscopic examination and could not be cultivated in nutrient mediums used for the growth of ordinary bacteria, it was called virus, from the Latin word for poison. The ultramicroscopic nature of some disease-producing organisms was first postulated by Pasteur. He was also the first to modify the pathogenicity of a virus for its natural host by serial intracerebral passage in another host. In an attempt to develop a variety of rabies virus which could be used safely for vaccination, he passaged the virus of rabies intracerebrally in rabbits. This resulted in the development of an infection characterized by a short, fixed incubation period; this modified virus was called fixed, to distinguish it from the natural, or so-called street virus. After 100 passages in rabbits, the fixed virus had little capacity to infect dogs when given by subcutaneous inoculation. By means of a series of ten daily subcutaneous injections of fixed virus, graded from no infectivity to maximum infectivity by drying infected rabbit spinal cord tissue at room temperature for various time periods, dogs were made resistant to experimental infection with the natural street virus. During 1885, a peasant boy who had been severely bitten by a rabid dog was taken to Pasteur, and, in view of the serious nature of the exposure and the plea that something be done, the boy was vaccinated in a manner similar to that used for immunization of dogs, the theory being that, if dogs could be immunized in a two-week period so that they would resist infection with the natural virus, the long incubation period of rabies in human beings would allow the development of a high grade of immunity before the potential onset of the disease. The treatment appeared to be without ill effect and the boy remained well, This became known and other persons were taken to Pasteur for treatment; soon the vaccine treatment for rabies was adopted as a routine procedure in medical centres throughout the world. The mortality from rabies was reduced from about 9% for all types of bites by rabid dogs to less than 0.5%. In rare instances the vaccine treatment will not prevent the onset of rabies, because the virus produces the disease before an adequate immunity is achieved by vaccination.

Vaccine Treatment (Active Immunization).—There have been many modifications of the Pasteur method of vaccination with live fixed virus vaccine. C. Fermi (1908) was the first to use chemical treatment—with phenol—of the fixed virus in the preparation of the vaccine. Later D. Semple (1919) showed that by incubation of the phenol-treated fixed virus at 37° C. it could be killed and still retain its capacity to immunize. A variety of chemical and physical methods have been used for inactivating fixed virus for the preparation of rabies vaccine. The commonly employed vaccines are the live fixed virus (Pasteur strain), the killed-virus vaccines of the Semple type and the U.V. (ultraviolet light treated) type. The vaccine treatment consists of 7 or 14 daily injections, depending on the severity of the exposure to rabies.

Serum Treatment (Passive Immunization).—V. Babès and Lepp (1889) introduced the serum treatment whereby animals are immunized with fixed rabies virus and the blood serum of these animals is injected into exposed persons to give them temporary immunity to rabies. This treatment is most effective if given within 24 hours after exposure. It has little value, if any. when given three or more days after exposure to rabies. A combination of serum and vaccine treatment is given in cases of severe exposure to rabies. Immediate treatment of animal bite wounds by cleansing with soap and water is important because much, if not all, of the virus can be removed thus. Chemical treatment is to be avoided before the wound is seen by a physician.

Control of Dog Rabies.—Dog rabies can be eliminated by enforcement of quarantine regulations for dogs, except in those regions where rabies is present in wild animals. Rabies has been kept out of Australia, Great Britain, Denmark, Norway, Sweden and the Hawaiian Islands by enforcement of quarantine regulations for imported dogs. The fact that dogs have developed rabies while under quarantine in these countries, and the development of rabies in dogs eight months after their arrival in Great Britain, makes it certain that the virus can remain latent in an exposed dog for at least this period of time. The eradication of rabies from Great Britain (1903) was accomplished with great difficulty and with much opposition from the dog-owning public because the quarantine regulations for dogs had to be maintained for several years before the disease disappeared. The vaccination of dogs, when combined with the collection of ownerless dogs, will eliminate dog rabies. The single-dose vaccination for dogs with Semple-type vaccine combines in one dose the amount of killed fixed virus ordinarily given in a complete course of vaccine treatment for persons bitten by rabid animals. The avianized live virus vaccine (Flury strain) is a fixed virus modified by serial intracerebral passage in one-day-old chickens and by prolonged cultivation in chicken embryos. This live virus vaccine is used for immunization of dogs and a single injection of the vaccine will produce good immunity for at least three years following vaccination.

BIBLIOGRAPHY.—Harald N. Johnson, "Rabies," in Viral and *Rickettsial* Infections of Man, 2nd ed., ed. *by* Thomas M. Rivers, pp. 267–299 (1952); "Rabies," Bulletin, World Health Organization, 10:703–866 (1954); WHO Expert Committee on Rabies, Second Report, World Health Organization: Technical Report Series, 82 (1954) (H. N. J.)

RACAN, HONORÉ DE BUEIL, MARQUIS DE (1589–1670), French poet, became page at the court of Henry IV. and then entered the army, seeing some active service. In 162j he published his most important work, Bergeries, a dramatic pastoral. Racan was a follower of Malherbe, and was one of the original members of the French Academy. He died in February 1670.

His Oeuvres *complètes* which include versions of the Psalms and sacred odes, were edited *by* Tenant de Latour in 1857, and the edition includes a biographical notice. See Sainte-Beuve, Causeries *du lundi.*

RACCOON, the typical representative of a family (Procyonidae) of American arboreal Carnivora (see CARNIVORE) The raccoon has a curious habit of washing its food in water before rating it The typical raccoon (Procyon *lotor*) is a thickly built animal about 3 ft. long, of which the tail is 10 in., with a coat of long coarse grayish-brown hairs, short ears and a bushy black-and-white-ringed tail. It extends over the whole of the United States and reaches northward to southern Canada and southward into Mexico where it attains its maximum size. The following are from C. Hart Merriam's The Mammals of the Adirondacks:

> Raccoons are omnivorous beasts and feed upon mice, small birds, birds' eggs, turtles and their eggs, frogs, fish, cray fish, molluscs, insects, nuts, fruits, maize, and sometimes poultry. Excepting alone the bats and flying-squirrels, they are the most strictly nocturnal of all our mammals. . . . They haunt the hanks of ponds and streams, and find much of their food in these places, such as crayfish, mussels, and fish, although they are unable to dive and pursue the latter under water. . . . They are good swimmers. . . . The raccoon hibernates during the severest part of the minter. . . . It makes its home high up in the hollow of some large tree, preferring a dead limb to the trunk itself. . . . From four to six young are . . . born at a time. . . . The young remain with the mother about a year.

The South-American species, P. *cancrivorus,* the crab-eating raccoon, differs by its shorter fur, larger size, more powerful teeth, and other minor characters. It extends over most of South America, as far south as northern Argentina.

RACE RELATIONS: see INTERRACIAL RELATIONS.

RACES OF MANKIND. The study of the varieties of the human race has occupied the attention of thinkers from early times. Two entirely different forms of classification have been employed, one based on the study of the skull, the second, and more generally used method, on superficial characters, such as skin and hair, which may be observed on the living man. To some extent these two methods have been combined in modern times.

Cranial Form.—Apart from Sergi, who elaborated a method of classification based on cranial *form,* the shape being estimated by viewing the skull from on top, most anthropologists have preferred to take measurements, especial importance being attached to the cephalic index—the percentage ratio of the length to the breadth—but numerous other measurements have been made, mostly of little value for classification. W. L. H. Duckworth suggested the combination of three characters on the skull, the cranial capacity, the cephalic index and the degree of prognathism (measured by taking the angle which the most projecting part of the jaw makes with the forehead). On the basis of the possible combinations of these criteria Duckworth divided mankind into seven groups.

Colour Groups.—The oldest grouping of mankind, still in popular use, is that of skin colour. It has been suggested that the degrees in pigmentation of the human skin are due to the effects of environment, either to sunlight or humidity or a combination of both, the evolutionary changes which took place at an earlier date having become part of the heritage of the races we know to-day. Although the darkest skins are to be found in the tropics, whereas the fairest occur in the temperate climate of western Europe, attempts to correlate skin colour and environment break down when specific cases are considered. Some exceptions can be explained by recent immigration, others again, especially in the individual, by racial admixture, for where races are mixed we may find members of the same family who are very ditferently pigmented. On the whole the average value of the skin colour in various groups is correlated with other criteria, which appear to be good bases for classification.

One of the most important of these is the cephalic index. Taking the length as 100, the proportion of the breadth seldom falls below 70 or over 90, and it is usual to describe those peoples with an index below 75 as *dolichocephalic* (long-headed), those above 80 as brachycephalic (short-headed), the intermediate group being *mesocephalic.* Taken by itself, either in the individual or the race, the cephalic index is by no means a certain guide. We find brachycephalic, mesocephalic and dolichocephalic groups in all the greater divisions of mankind.

Hair Form.—On the basis of the form of the hair, mankind may be divided into straight-haired (*leiotrichous*), woolly-haired (*ulotrichous*) and an intermediate group of wavy or curly-haired (cymotrichous). Certain types are difficult to define, but usually the distinction is clear-cut. All types of hair may occur in the same population, where racial admixture has taken place, but normally the variation is slight in the same group.

Straight-haired Groups.—The straight-haired peoples correspond to a large extent to the races called by some writers Mongol or Mongoloid, or "the Yellow-Brown Race." All these peoples possess cheek-bones of a greater or lesser degree of prominence. In most cases the face is flattened, often markedly so. The skin is usually yellow, shading into a coppery yellow or brown on one side, and on the other, especially in women, a pale almost white yellow tinge. In Asia the cephalic index tends to vary between mesocephaly and brachycephaly, with some marked cases of the latter form. In America the Eskimo are dolichocephalic and a wide range of mesocephaly and brachycephaly occurs among the other tribes.

Asiatic Groups.—There are three groups in Asia, a northern or Arctic group, a central group, the Pareoeans (the Dwellers beside the Dawn) and a southern or Proto-Malay, it being possible that the two latter groups, formerly included under the term Southern Mongoloid, should be classed together.

The northern group is rather indeterminate, and includes a number of tribes living in the circumpolar regions of Asia and extending even as far west as northern Scandinavia, where they are represented by the Lapps. Most of these peoples have mixed with other races, to which fact their diversity is due, but they certainly include a mesocephalic and a round-headed subdivision. In eastern Asia at least there is a more northerly group, living in the most easterly ,extension of the continent and a more southerly group, but the difference is probably due to racial admixture, consequent on the intrusion of the peoples who brought in the Turko-Mongol culture from the west and thus divided the northern and central groups of the straight-haired peoples.

In Korea there is a narrow belt which forms a connecting link between the northern and the Pareoean peoples. The latter differ most strikingly from their northern neighbours in having less prominent cheek-bones and a broadish nose. In the north of China they are often tall; in the south, where the type is found in greater purity, they are short and more stockily built. The Japanese represent a special variety of this type; they have mixed considerably with the Ainu, and this, at least in some cases, has altered their physical type.

The southern extension of these peoples, the Proto-Malays, are widely spread in south-eastem Asia and in the islands. They have been mixed with the various other peoples of this region and it is often difficult to distinguish them except by their broader heads.

The straight-haired peoples also extend into Central Asia, where they are known as Turks and Mongols. These terms are cultural and linguistic, and cannot be used in a racial sense. Great racial admixture has undoubtedly taken place in this region and much of the population is closely connected with the peoples of the west, but types occur with straight hair and other characters which show affinities with the Arctic group.

Most remote from the straight-haired peoples and showing certain relationships to them are the Polynesians, who live on the islands of the Pacific from Samoa to Easter I. and Hawaii to New Zealand. They probably represent an old mixture between the Proto-Malays and a group of the curly-haired people called Nesiots (islanders, see below), but other admixture has taken place and their position is difficult exactly to determine.

The *Amerinds*.—As regards the American aborigines, for whom the term *Amerind* has become conventionalised, it has been disputed whether they should be considered to belong to one race or not. The Eskimo, who to-day inhabit the Arctic coast of America, with a western extension into Asia, and an eastern into Greenland, once lived as far south as the coast of Massachusetts, and survived near Quebec till comparatively recent times. They differ from the other inhabitants of America in many respects notably in having extremely long skulls (the western Eskimo differ somewhat in this respect), which are compressed laterally and are very high-pitched. They have broad faces, an unusual feature in people with a long skull, and very narrow noses. The jaws are exceptionally well-developed and the individual teeth are very large, possibly owing to the nature of their food.

The Amerinds themselves vary considerably in most of those characters usually considered to be of racial significance. Hrdlicka, however, believes that they all belong to the same race. Verneau has recently affirmed the concurrence of types akin to the Melanesians, a view previously held by others also. Haddon suggests with every degree of probability that side by side with the straight-haired peoples there is a cymotrichous type, which he has called Palaeo-Amerinds.

The peoples of the north-west coast are most closely allied to the inhabitants of Asia, and are distinguished from the other Amerinds by their lighter skin colour. East of the Rockies and extending over the great plains and into the woodland area there is a group of tall tribes with mesocephalic heads, of whom the Sioux are a typical example. On the east coast in ancient times there was a different type with longer, narrower heads. On the American plateau and extending into central and southern America there is a round-headed type, of short stature and with straight noses, to whom the Maya of ancient times were akin. The Aztecs were more long-headed and their relationship with the more northerly peoples can be traced through some of the inhabitants of northern Mexico to-day.

The ethnology of South America is as yet not fully established, but several types can be distinguished, one akin to the Maya peoples and a different type, with a round head and tall stature, in Patagonia, of whom the Fuegians are a branch. Side by side with these straight-haired peoples there exist traces of a curly-haired race, both in ancient deposits and also among some modem tribes. With the exception of the Palaeo-Amerinds the distribution of the straight-haired peoples is continuous, the Bering Strait dividing the Asiatic and American branches.

Woolly-haired Groups.—The woolly-haired people have an extremely discontinuous distribution, namely, an eastern habitat which stretches from the continent of Asia to Fiji, and a western, the greater part of Africa. Attempts have been made to bridge this gap. Husing believes that in ancient times short dark curly-haired peoples occurred on the Persian Gulf in localities where negroes are still found. These negroes are, however, the descendants of imported slaves, and there is no information of a definite character to support Hüsing's contention.

In addition to woolly hair all these peoples have the following characters in common: dark skins sometimes almost black, broad noses, usually a rather small brain in relation to their size, especially among the taller members of the group, with forearms and shins proportionately long. In the skeleton there is a smoothness of contour which even in adults often recalls the bony form of a child, and among some members of the group the forehead has that prominent and smooth form which is so characteristic of the infant of our own race. In both eastern and western groups there is a division which includes some very small or pygmy peoples and another of medium or tall-statured tribes.

Eastern Group.—The eastern group may be divided on this basis into the pygmy Negritos and the taller Papuans and Melanesians. The former are all dark-skinned and have heads which are slightly rounded, the cephalic index varying from just under 80 to about 83. There are slight local differences due to the extreme isolation to which these peoples have been subjected. Four separate geographical groups occur, one in the Andaman Islands (the Andamanese), one in the central regions of the Malay Peninsula and eastern Sumatra (the Semang), a third in various parts of the Philippine Is., usually called after a well-known tribe, the Aeta and a fourth group called after a tribe in the western mountains of Dutch New Guinea, the Tapiro, who have left traces in other parts of New Guinea and probably also in parts of Melanesia. All these groups are isolated from one another and occupy as it were almost the circumference of a circle. The Andamanese occupy a very special position, both racially and geographically; they have been isolated for a long period and until recently were not in contact with any other race.

The Papuans and Melanesians are distinguished from the Negritos by their greater stature and narrower heads; the former probably represent the original stock. At one time they had a wide distribution throughout all Melanesia, probably to Australia, and the extinct Tasmanian aborigines seem to have been a variety of this stock. To-day Papuans are found in New Guinea and in some of the most easterly of the Indian Archipelago islands. They may be distinguished from their kinsfolk by their retreating forehead, prominent brow-ridges and the form of their noses, which are often prominent and rounded, with a down-turned tip.

The Melanesians are extremely variable and include a variety of racial elements, though the basis of the stock is Papuan. The racial mixing which has taken place will account for the fact that, although they are usually woolly-haired, all varieties of hair are found. Stature is equally variable, although the average height is under 5 ft. 3 inches. The prominent brow-ridges so characteristic of the Papuans is not common and the nose is usually smaller than in these peoples. The Melanesians have a wide distribution from the coastal regions of New Guinea and the neighbouring islands to the Pacific from New Caledonia to the Admiralty Is., and as far eastwards as Fiji; formerly they seem to have extended over most of the Pacific.

The Bushmen. — The Bushmen, who belong to the second group of the woolly-haired peoples, are also short, though not of pygmy stature; they differ from the other Ulotrichi in having yellowish skins. Now restricted to the Kalahari desert, they formerly ranged over the whole of south Africa and possibly over a much wider area. Their hair is short and curls into little tufts like pepper-corns, giving the appearance of bald patches. The head is small and low and there is little or no forward projection of the jaw. The most distinctive character of the Bushmen is a great development of the buttocks (*steatopygia*); this feature is specially developed in the women. The Hottentots are closely allied to the Bushmen and possess most of the characters already described. They represent a cross between the latter and other negroid stocks.

True Negroes. — The true negroes inhabit the Guinea Coast, but their original range seems to have been over most of tropical Africa. They are tall with black or dark brown skins, long narrow heads and retreating foreheads and prominent jaws. The lips are thickened and everted and the nose is very broad. They have mixed with other elements and have produced hybrid stocks. In the upper Nile valley numerous tribes, called Nilotes, are to be found; they are characterised by a very tall stature, a slender build and extremely narrow heads. There is also a more round-headed strain, due probably to an early admixture with some curly-haired people. Most, if not all, of the Nilotes have been considerably altered by contact with other non-negro peoples.

The Pygmies — In the equatorial forests certain pygmy tribes live. These Negrillos differ from the tall negroes not only in their stature but also in the lighter colour of their skin, which is often yellowish and covered by a light down, and in the more rounded form of the head; the nose is broader even than that of the negro.

Curly-haired Groups. — The third great division of the human race, the curly-haired or Cymotrichous, occupies in many ways an intermediate position between the other two groups. Its distribution is world-wide, and it includes both undifferentiated and highly differentiated groups of mankind. The white races belong to this class. The centre of dispersion of the group was probably somewhere in Asia, but the precise limits of this cradle land have not yet been determined.

The hair varies from wavy to curly, and, whereas in other races it is, with but few exceptions, black or dark brown, in this group every shade occurs from a dead black to a fair straw colour; the brown, however, predominates. The skin colour is equally variable.

Every degree of cephalic index is found, and this still remains the most convenient method of simple classification. The race, however, contains certain sub-races which appear to be more primitive than others and the division into primitive and more advanced groups brings out certain points which may otherwise be overlooked. The primitive which survive are the Proto-Nordics, the Proto-Indics and the Australian aborigines. The Palaeo-Amerinds also probably belong to this class. The more advanced peoples include a dolichocephalic group, a mesocephalic and a brachycephalic group.

Proto-Nordics. — The Proto-Nordics appear at one time to have had a wide distribution over northern Asia. Some of the present inhabitants of the Turkoman steppes present this type in an undifferentiated form, namely the Ainu, who have within comparatively recent times been driven out of the main islands of Japan, and who still inhabit the northern island (Hokkaido) Saghalien, and to the south the Ryukyu islands. This curious people are of medium stature, very stockily built, with large heads and a marked bar across the forehead. They have an abundance of hair on the head and body and long, wavy beards. Their eyes are straight as in Europeans and their general appearance contrasts very strongly with the Japanese who to-day live amongst them.

Proto-Indics.—The Proto-Indics may be classed geographically into three, possibly four, divisions: first, the jungle tribes of southern India (some of the more primitive tribes of northern India also have affinities with this stock); secondly, the Vedda, the most primitive of the inhabitants of Ceylon; and thirdly, some of the more primitive peoples of the southern part of the Malay Peninsula, of whom the best-known are the Sakai and Senoi. In Sumatra and Celebes and possibly elsewhere in the Malay Archipelago there survive tribes who may be considered as a fourth division of the Proto-Indics, but here they have for the most part been mixed with other stocks. In much of south-eastern Asia there is a racial background of Proto-Indics who have been overlaid by other invaders, but the stock has survived in a relatively pure state in the places enumerated above. The Proto-Indics have curly hair, very dark and often nearly dead black skins, a short stature and extremely broad noses.

The Australian Aboriginal. — The Australian aborigines almost certainly belong to the same stock, but they possess some special characteristics which may be due to the length of time they have been isolated from the parent stem. The skin is usually of a dark chocolate brown, the hair, which is somewhat variable but usually curly, is frequently very abundant on the face and body. The stature is medium, the nose very broad, and their most distinctive feature is the great bony development of the skull, including a great massing of bone over the eyes and a big development of the jaws and teeth. Whereas the Proto-Indics, notably the Veddas, have extremely small skulls, those of the Australians, though often containing an extremely small brain-case, are always massively built, and the beetling brows, low forehead and projecting lower part of the face give the males a very characteristic appearance.

Eastern Groups. —The most easterly representatives of these stocks in Asia are the Nesiots, who are found mixed with the straight-haired, round-headed Proto-Malays in the Malay Archipelago, in the Philippines, sporadically in southeastern Asia and in the interior of southern China; the exact extension of these peoples is not yet fully known. In southern India a large proportion of the population belongs to a second group, Chersiots (mainlanders, as opposed to Nesiots, islanders). They are here much mixed with Proto-Indics and round-heads. In the northern part of India the proportion of the round-heads is much greater, and in the northwest the round-headed element predominates. In Rajputana and in the Punjab there is another group of long-heads, to be distinguished from the Chersiots by their taller stature, fairer skins and narrower noses. These Haddon terms Indo-Afghans.

Western Groups. — Further west, in the horn of Africa and the desert between the Nile and the Red Sea, this stock is dominant in the population, though frequently mixed with negroes. These tribes represent the modern descendants of the Proto-Egyptian population. Among the groups of this stock with a white complexion severai varieties may be distinguished: one, the ***Eur-african,*** seems only to occur in isolated spots in north Africa and western Europe, including part of the British Isles, another is met with among the Bedouin Arabs, while the third or Mediterranean race forms the fringing population of the Mediterranean sea and the western Atlantic seaboard of Europe. In the eastern Mediterranean it is inextricably mixed with the Armenoid peoples.

Among the Mesocephals Haddon includes three groups; two, however, the Pyrenean and the Atlanto-Mediterranean are probably hybrids. The third, the Nordic, is more clearly marked and is characterised by fair skin and hair, blue eyes and a tall stature. To-day they form one element in the population of the British

Isles and northern France, Belgium and Holland, and northern Germany. They predominate in Scandinavia.

The Round-headed Group.—The great round-headed branch of the Cymotrichi is conveniently called Eurasiatic. It extends all along the great mountain chain from the central plateau of France on the west to the Himalayas on the east. The Alpine branch of the family is distributed along the central massif of Europe into central and even Eastern Asia, the Armenoid or Illprio-Anatolian has a more limited range in south-eastern Europe and western Asia. They may be distinguished by the extreme flatness and height of the head. In the Pamirs, in Persia, and extensively in central Asia and in India, a separate branch of this race, the Pamiri, is found, while locally in western Europe isolated examples of two early groups, the Prospectatores and the "Beaker Folk" still survive. They probably resulted from early crossing of round-heads with Mediterranean and Nordic man respectively.

All these peoples are marked by the roundness of their heads, their brown, auburn or black hair and somewhat sallow or olive skins. The eyes vary from brown to hazel, but blue eyes are found.

Most of the migratory movements which resulted in the present distribution of mankind took place to? far back in history for us to estimate their exact course, but in all probability human stocks were evolved near the places where we first find them recorded in historic times. Some migrations belong to the domain of ancient history, but it is very doubtful how far these movements have actually affected the physical type. In all probability ethnological history has consisted chiefly of the gradual extension of dominant types. (L. H. D. B.)

BIBLIOGRAPHY.—William Z. Ripley, *The Races of Europe* (1899); Bureau of American Ethnology, *Bull.* 30 (various authors); *Handbook of American Indians,* 1907–10; Augustus H. Keane, *Man, Past and Present* (1920); Clark Wissler, *The American Indian,* 2nd ed. (1922); V. Giuffrida-Ruggeri, *Homo Sapiens* (1923); Roland B. Dixon, *The Racial History of Man* (1923); Alfred C. Haddon, *The Races of Man and Their Distribution* (1925); L. H. D. Buxton, *The Peoples of Asia* (1925); British Museum, *Handbook to the Ethnographic Collections* (1925); J. Deniker, *Les Races et les peuples de la terre* (1926); R. Martin, *Lehrbuch der Anthropologie* (1928). *See* also articles on "Blood Tests" in *Man* (1928).

RACHEL, MLLE. (ÉLISA FÉLIX) (1820–1858), the great French classical tragedienne, was born at Mumpf, Switz., Feb. 28, 1820, the child of wandering peddlers. She sang on the streets of Lyons and Paris, where her acting ability was quickly discovered by Isidore Samson, who taught her all the technique he had learned from Talma. Rachel studied classical statuary for posture, practised vocal intonations and gestures, performed in many academy plays and at 17 made her debut at the Comédie Française as Camille in Corneille's *Horace.* Press and public acclaimed the new star, who although thin and less than five feet tall dominated the stage with her regal bearing, fiery glances and intense concentration.

Rachel was admired for her pantomime, the feverish excitement she brought to climactic scenes and the evil fascination of some of her characterizations. For 17 years she dictated the policy and program of the Comédie Française, bending its facilities and personnel to her will. Knowing that her genius and drawing power lay in classical plays, Rachel appeared in five by Corneille and seven by Racine, finding her greatest triumph in Racine's *Phèdre.* She was persuaded to join the popular romantic movement and appeared in plays by Hugo, Dumas *père* and De Musset, but of these only *Adrienne Lecouvreur* by Scribe and Legouvé was successfully received.

Rachel toured the provinces regularly and traveled to England, Austria. Russia, Italy, Germany and Belgium. Her United States trip in 1855 failed. Weakened from the constant struggle to maintain her artistic and social eminence, the strenuous touring and the vicissitudes of her notorious private life. Rachel died of tuberculosis on Jan. 3, 1858, and was buried at Pbre Lachaise in Paris.

BIBLIOGRAPHY —Joanna Richardson, *Rachel* (1956); Bernard Falk, *Rachel the Immortal* (1936); James Agate, *Rachel* (1928).

(E. P. K.)

RACHMANINOFF, SERGEI VASSILIEVITCH (1873–1943), Russian composer and pianist, was born on his father's estate Oneg, near Ilmen Lake. Government of Novgorod, on April 2, 1873. At nine he became a pupil of Demjansky's at the St. Petersburg conservatoire, going three years later to the Moscow conservatoire, where he studied piano under his cousin, Siloti. and composition under Taneiev and Arensky. In 1892 he won a gold medal with his opera *Aleko,* which was favourably received when produced at Moscow, 1893. Concert tours in Russia and elsewhere followed.

In 1899 Rachmaninoff appeared in London as pianist, conductor and composer, and in 1902 he had great success in Vienna. In 1903 he went back to Moscow where he remained for three years as piano professor at the Maryinsky institute, also conducting at the Imperial opera. Subsequently he lived for several years in Dresden where he devoted himself mainly to composition, varied by occasional concert tours.

In 1909 he paid his first visit to the United States, and in 1912–13 he conducted the Moscow Philharmonic Symphony orchestra. After the Russian revolution he escaped to Sweden, with his family, and in 1918 took up his permanent residence in the United States.

Among Rachmaninoff's many compositions, particularly notable are the Second Symphony in E minor, his piano concertos, op. 1, 18 and 30, *Rhapsody on* a *Theme by Paganini,* and *Etudes Tableaux.* His *Recollections,* dictated to his editor, Oskar von Riesmann, was published in 1934.

Rachmaninoff was internationally known for his creative ability as a composer, and for his technique and interpretation as a pianist.

He died in Beverly Hills, Calif., March 28, 1943.

RACINE, JEAN (1639–1699), French tragic dramatist, was born at La Ferté-Milon (Aisne), and was christened on Dec. 22, 1639. His father was a solicitor, and held the office of *contrôleur au grenier à sel* at La Ferté. Racine's mother died when he was little more than a year old and his father married again but himself died soon afterwards, whereupon the child went to his grandparents, who had strong Jansenist leanings. He was sent to the grammar school at Beauvais, and in Oct. 1655 was transferred to the school which the "Solitaires" had established at Port Royal. He was a diligent student, and wrote verse both in Latin and French, his Port Royal odes being far from despicable. In 1658 he was entered at the Collège d'Harcourt, and it is clear from his correspondence, which, as we have it, begins in 1660, that he was not at all of an austere disposition at this time, and that he was already given up irrevocably to literature. The marriage of Louis XIV. was the occasion of an ambitious ode, La *nymphe de la Seine,* which earned 600 livres, and in 1660 Racine finished one piece, *Amasie,* and undertook another, *Les Amours d'Ovide,* for the theatre. The first, however, was rejected by the actors of the Marais, and it is not certain that the other was ever finished. Racine's letters show that he was intimate with more than one actress at this time; he also made acquaintance with La Fontaine, and the foundations of the legendary "society of four" (Boileau, La Fontaine, Molibre and Racine) were thus laid. In Nov. 1661 he went to Uzbs in Languedoc to live with his uncle the Pbre Sconin, vicar-general of that diocese, whose attempts to secure a benefice for him were, however, in vain. Racine was back in Paris before the end of 1663, and an ode on the recovery of Louis XIV. from a slight illness secured him another grant of 600 livres in the summer of 1664. The ode in which he thanked the king for his presents, *La Renommée,* is said to have introduced him to Boileau, to whose censorship he was deeply indebted. Unfortunately there is a break in his correspondence after Nov. 1663, and from this time forward the gossip of the period, and the *Life* by his son Louis, who was only six years old when his father died, are our main sources.

The first but the least characteristic of the dramas by which Racine is known, *La Thébaide,* was played by Molière's company at the Palais Royal theatre on June 20, 1664. In Feb. 1665 the greater part of his second acted play, *Alexandre le Grand,* was read before a distinguished audience at the Hôtel de Nevers, and Molière's company played it on Dec. 4. But a fortnight afterwards *Alexandre* was played, "de complot avec hi. Racine," says La Grange, by the rival actors at the Hôtel de Bourgogne, and Racine's friendship with Molière ended in consequence. If, however, *Alexandre* was the occasion of showing the defects of Racine's character as a man, it raised him vastly in public estimation as a poet. He was now for the first time proposed as a serious rival to Corneille, and the contrast between the two was accurately apprehended and put by Saint Evremond in his masterly *Dissertation sur l'Alexandre,* still the best criticism of the faults of Racine, though not of the merits, which had not yet been fully seen. It may be added that in the preface of the printed play the poet showed the extreme sensitiveness to criticism which often accompanies a tendency to criticize others. These defects of character showed themselves still more fully in another matter. The Port Royalists detested the theatre, and in Jan. 1666 Nicole, their chief writer, spoke of dramatic poets as "empoisonneurs publics." Kacine immediately published a letter to the author, which, though very smartly written, is full of savage personalities. He had written a second pamphlet and was about to publish it when fortunately Boileau, who had been absent from Paris, returned and protested against the publication. It remained accordingly unprinted till after the author's death, and in later years he expressed bitter regret for having published the first.

After this disagreeable episode Racine's life, for ten years and more, becomes simply the history of his plays, if we except his liaisons with the actresses Mademoiselle du Parc and Mademoiselle de Champmeslé, and his election to the Academy on July 17, 1673. The series of his unquestioned dramatic triumphs began with *Andromaque* (Nov. 1667), and this play may perhaps dispute with *Phèdre* and *Athalie* the title of his masterpiece. It is much more uniformly good than *Phddre,* and the character of Hermione is the most personally interesting on the French tragic stage. Whatever may be thought of the *tragédie pathétique* (a less favourable criticism might call it the "sentimental tragedy"), it could hardly be better exemplified than in this admirable play, which owes its success to the application of the most delicate art to the conception of really tragic passion. *Andromaque* was succeeded, at the distance of not more than a year, by the charming comedietta of *Les Plaideurs* (printed on Dec. 5, 1668). At first it was a complete failure, though Molière is reported to have said on leaving the house, "Que ceux qui semoquoient de cette pièce meritoient qu'on se moquoient d'eux"; but the piece was suddenly played at court a month later; the king laughed, and its fortunes were restored. It was followed by a very different work, *Brttannicus,* which appeared on Dec. 13, 1669. This was much less successful than *Andromaque,* and seems to have held its own but a very few nights. Afteraards it became very popular, and even from the first the exquisite versification was not denied. But the complete nullity of Britannicus himself and of Junie, and the insufficient attempt to display the complex and dangerous character of Nero are not redeemed by Agrippina, who is really good, and Burrhus, who is solidly painted as a secondary character. Voltaire calls it "la piece des connaisseurs," a double-edged compliment. The next play of Racine has, except *Phèdre,* the most curious history of all. Henrietta of Orleans proposed the subject of *Bérénice* to Corneille and Racine at the same time, and both plays, but especially Racine's, were successful. *Bajazet,* first played on Jan. 4, 1672, has great technical merit, but it is impossible to imagine anything less oriental than the atmosphere of the piece, which is scarcely saved by its ingenious scenario and admirable style. This charge is equally applicable with the same reservations to *Mithridate,* which appears to have been produced on Jan.. 13, 1673, and was extremely popular. Racine's next attempt, *Iphigénie,* was a long step backwards and upwards in the direction of *Andrornaque.* Greek tragedy gave examples which prevented him from flying in the face of the propriety of character as he had done in *Bérénice, Bajazet,* and *Mithridate.* The date of its appearance is very uncertain. It was acted at court on hug. 18, 1674, but it does not seem to have been given to the public till the early spring of 1675.

The last and finest of the series of tragedies proper was the most unlucky. *Phèdre* was represented for the first time on New Year's Day 1677, at the Hôtel de Bourgogne. Within a week the opposition company launched an opposition *Phèdre* by Nicolas Pradon, who had been employed to write it by the duchess of Bouillon and other influential enemies of Racine. So well had their measures been taken that the finest tragedy of the French classical school was all but driven from the stage, while Pradon's was a positive success. The unjust cabal against his piece no doubt made a deep impression on Racine. But it is impossible to decide exactly how much influence this had on the subsequent change in his life. For 13 years he had been constantly employed on a series of brilliant dramas. He now broke off his dramatic work entirely and in the remaining 20 years of his life wrote but two more plays, and those under special circumstances and of quite a different kind. He had been during his early manhood a libertine in morals and religion; he now became irreproachably domestic and almost ostentatiously devout. No authentic account of this change exists; what is certain is that Racine reconciled himself with Port Royal, accepted their doctrine of the incompatibility of the stage and the Christian life. and on June 1 married Catherine de Romanet and definitely settled down to a quiet domestic life, alternated with the duties of a courtier. His wife had money, and he had possessed for some time the post of treasurer of France at Moulins. His annual "gratification" had been increased from 800 to 2,000 livres, and in the year of his marriage he and Boileau were made historiographers-royal with a salary of 2,000 crowns. Racine's labours brought him, in addition to his other gains, frequent special presents from the king, and in 1690 he further received the office of "gentilhomme ordinaire du roi," which afterwards passed to his son. He had two sons and five daughters.

The almost complete silence which Racine imposed on himself after the comparative failure of *Phèdre* tvas broken once or twice even before the appearance of his two last exquisite tragedies. The most honourable of these was the reception of Thomas Corneille on Jan. 2, 1685, at the Academy in the room of his brother. The discourse which Racine then pronounced turned almost entirely on his great rival, of whom he spoke even more than becomingly. But it was an odd conjunction of the two reigning passions of the latter part of his life—devoutness and obsequiousness to the court—which made him once more a dramatist. Madame de Maintenon had established an institution at Saint Cyr for the education of poor girls of noble family; the tradition of including acting in education was not obsolete, and the favourite asked Racine for *a* new play suited to the circumstances. The result was the masterpiece of *Esther,* with music by Moreau, the court composer and organist of Saint-Cyr. The beauty of the chorus, the perfection of the characters and the wonderful art of the whole piece need no praise. Almost immediately the poet was at work on another and a still finer piece of the same kind, and he had probably finished *Athalie* before the end of 1690. The fate of the play, however, was very different from that of *Esther.* The public cared very little for it, but the just judgment of posterity has ranked *Athalie,* if not as Racine's best work (and there are good grounds for considering it to be this), at any rate as equal to his best. Thenceforward Racine was practically silent, except for a brilliant *Histoire abrégée de Port Royal* and four *cantiques spirituels,* in the style and with much of the merit of the choruses of *Esther* and *Athalze.* The general literary sentiment was against him, and his weakness for spiteful epigrams cost him many friends. At last even the king withdrew his favour. He died April 21, 1699, and was buried at Port Royal.

Racine may be considered from two very different points of view,—(I) as a playwright and poetical artificer, and (2) as a dramatist and a poet. From the first point of view there is hardly any praise too high for him. Every advantage of which the Senecan trdgedy adapted to modern times was capable he gave it. He perfected its versification; he subordinated its scheme entirely to the one motive which could have free play in it,—the display of a conventionally intense passion, hampered by this or that obstacle; he set himself to produce in verse a kind of Ciceronian correctness. The grammar-criticisms of Vaugelas and the taste-criticisms of Boileau produced in him no feeling of revolt, but only a determination to play the game according to these new rules with triumphant accuracy. The result is that such plays as *Phèdre* and *Andromaque* are supreme in their own way But his greatest achievements in pure passion — the foiled desires of Hermione and the jealous frenzy of Phèdre — are cold, not merely beside the crossed love of Ophelia and the remorse of Lady Macbeth, but beside the sincerer if less perfectly expressed passion of Corneille's Cléopâtre and Camille. He had cut away from himself, by the adoption of the Senecan model, all the opportunities which would have been offered to his varied talent on a freer stage, though the admirable success of *Les Plaideurs* makes us regret that he did not experiment further in comedy.

BIBLIOGRAPHY.—The first collected edition of Racine's works appeared in 1675–76; the last appeared in the poet's lifetime (1697), perhaps revised by him. Among posthumous editions the most important is that of P. Mesnard in the *Grands écrivains* series, 8 vol. (1865–73). Louis Racine's *Life* was first published in 1747. Among English imitations are the *Distressed Mother* of Ambrose Philips (1712) and the *Phaedra and Hippolytus* of Edmund Smith (acted in 1707); and a complete verse translation by R. B. Boswell (1889–91). *See* Sainte-Beuve, *Portraits Littdraires*, vol. i, and for criticism the studies by G. Larroumet (1898) and J. Lemaitre (1908), and the *Life* by Mary Duclaux (1925). The case for and against Racine has been concisely stated by G. Lytton Strachey in *Books and Characters* (1922) and J. C. Bailey in *The Claims of French Poetry* (1907).

RACINE, LOUIS (1692–1763), French poet, second son and seventh child of Jean Racine, was born in Paris on Nov. 6, 1692. *La Grace* (1720) and *Religion* (1742), his most important work, are inspired by a sincere piety, and are written in verse of uniform clearness and excellence. His other works include epistles, odes, among which the *Ode sur l'harmonie* (1736) should be mentioned, *Mkmoires* (1747) of Jean Racine, and a prose translation of *Paradise Lost* (1755). Louis Racine died on Jan. 29, 1763.

His *Oeuvres complètes* were collected (6 vol.) in 1808. The *Lettres inédites de Jean Racine et de Louis Racine,* containing a notice on Louis Racine by the Abbé A. de La Rogue, were published in 1862.

RACINE, a city of southeastern Wisconsin, U.S., situated on Lake Michigan at the mouth of the Root river, 25 mi. S. of Milwaukee and 65 mi. N. of Chicago. It was founded in 1834 by a lake captain, Gilbert Knapp, and quickly obtained settlers in the first important American population movement into southeastern Wisconsin in the late 1830s. At first it was called Port Gilbert after its founder but in 1837 it adopted the French name of the river on which it stands and in 1848 it was incorporated as a city. Pop. (1960) city 89,144, of which about 10% mas foreign-born white (mainly from Denmark, Germany, Czechoslovakia, Italy, Russia. Poland and Lithuania); standard metropolitan statistical area (Racine county) 141,781. (For comparative population figures *see* table in WISCONSIN: *Population.*) Industry began to develop shortly before the American Civil War and Racine became an important centre for farm machinery at an early date. Its industrial development received a considerable impetus from World War II and was exceedingly diversified. Among its more important industrial products are tractors and farm machinery, automobile accessories, power tools, iron and, steel castings, electrical products, floor wax. malted milk, leather goods and furniture. The city is served by the Racine extension division of the University of Wisconsin, nhich provides two years of accredited college work. Racine possesses an extensive park system including recreational areas and Zoo park. (RE. H.)

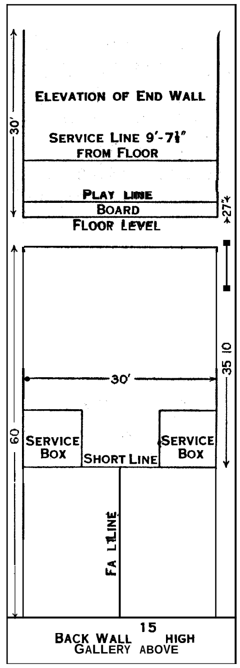
RACKETS (RACQUETS), a game played in an enclosed court with a ball and an implement called a racket, with which the ball is struck. The racket is about $2\frac{1}{2}$ ft. long and the head is tightly strung with catgut. No specific, standard dimensions are laid down. In the earliest days of the game, the head of the racket was inclined like a tennis racket; later it was pear-shaped. In modern days it is nearly circular and some seven or eight inches in diameter. The average weight of a racket is about nine ounces, and it is made of ash. Experiments have been made with metal frames but with no practical success. The balls are one inch in diameter and weigh one ounce. They are made of strips of cloth tightly wound over each other and then bound with twine, with a sewn covering of smooth white leather.

In England the floor of the rackets court is black or red in colour and the walls black. In India and some other places in the far east, where the floor and walls of the court are painted white, black balls are used.

The Court.—No standard size has been established for a rackets court, but the majority of courts are about 60 ft. long by 30 ft. wide. Both the single and the double or four-handed game are played in courts of this' size. Formerly there were several courts as large as 80 ft. by 40 ft. built specially for the double game.

Modern rackets courts have four walls and a roof, but in India some courts are left unroofed for the sake of coolness.

The floor, which must be perfectly level and smooth, is made of cement. The floor cannot be too hard since the faster the ball travels the better the game; similarly the walls, which should be built of masonry faced with cement and most carefully smoothed, cannot be too hard and fast The front and side walls are about 30 ft. high, the back wall being about half that height with a gallery for spectators (containing the marker's box) above it. The court is entered by a door in the centre of the back wall which, when shut. must be perfectly flush with that wall with no projecting handle. The court is lighted from the roof. The divisions and the markings of the court are shown in the figure. On the front wall is fixed a wooden board, the upper edge of which, 27 in. from the floor, constitutes the play line. and which usually fills the whole space from that height to the floor. At a height from the floor of 9 ft. $7\frac{1}{2}$ in. is a second line called the cut line or service line, usually painted red or green. At a distance of 35 ft. 10 in. (in a court 60 ft. by 30 ft.) from the front wall and parallel to it a line is painted on the floor from wall to wall called the short line. From the centre of the short line to the centre of the back wall is the fault line, dividing the space between the back wall and the short line into two equal rectangles. These lines again are usually red or green in colour.



PLAN AND ELEVATION OF

The rectangles are the service courts, called the right-hand and left-hand court respectively. Against the side walls outside these courts. but so that one side in each case is formed by the short line, are squares called the service boxes.

The Game. — Rackets is usually played by two persons (singles) or four persons playing two against two (doubles). The general idea of the game is the same as in lawn tennis and fives (*qq.v.*), the object of the player in all these games being to score a point by striking the ball either before it reaches the ground or on its first bound, in accordance with the rules of the game and in such a way that his adversary may fail to make a valid stroke in return. In the four-handed game one of each set of partners takes the right-hand court and his partner the left. The game consists of 15 points called aces. Aces can be scored only by the hand-in (the player, or side, having the service) and the hand-out must therefore win a stroke or strokes to obtain service before he or they can score an ace. In doubles each of the partners serves in turn; both must therefore be ousted before hand-out obtains the service; but the first hand of each game affords an exception to this rule (*see* below).

The right to serve first is determined by the spin of a racket, and the service must be made in the following manner. The server, standing with at least one foot inside one of the service boxes, must toss the ball from his hand and while it is in the air he must hit it with his racket so that it strikes the front wall above the service line and falls to the floor nithin the service court on the opposite side. After striking the front wall the ball may, but need not, strike the side wall, back wall or both; it may do so before or after touching the floor. The serve is a fault if the ball (1) strikes the front wall above the board but on or below the service line, in which case it is called a cut; or (2) touches the floor on the first bound, outside the proper service court, when it is called short or fault according to the position of its pitch (see below). If the hand-out player to whom the fault is served takes it (*i.e.*, if he plays at it), the fault is condoned and the play proceeds as if the serve had been good. If, however, the fault is not taken, the server must serve again from the same box; if he serves a second fault he loses his hand or innings and his partner or opponent, as the case may be, takes his place. Two consecutive faults thus have the same result as the loss of a stroke in the rally by the hand-in. In the United States only one serve is permitted and the server is retired by one fault. A serve that makes the ball strike the board, or the floor before reaching the front wall, or that sends it out of court (*i.e.*, into the gallery or roof of the court). counts the same as two consecutive faults: it costs the server his innings.

Skill in service is a most important part of proficiency in rackets; a player can seldom become first-rate unless he possesses a strong service. A great deal of cut may be imparted to the ball by the stroke of the racket which makes the ball in its rebound from the wall behave like a billiard ball carrying side when striking a cushion. When this cut is combined with great pace in the bound of the ball off the side wall, the back wall and the floor, at varying angles which the server has to a great degree under his control, it becomes exceedingly difficult for hand-out to get up the service (*i.e.*, to hit it on the first bound, sending it above the play line on the back wall) and still more so to make a good stroke which will render it difficult for his adversary to get up the ball and thus continue the rally. Rackets courts vary much in pace and conditions; in some. service is much easier to return than in others, but it not infrequently happens that a long sequence of aces. sometimes the whole 15 aces of a game, are scored consecutively by service that hand-out is unable to returri. To obtain first service is therefore an initial advantage, although in doubles it is limited by the rule that only one partner shall have a hand in the opening service.

The server may begin in either of the service boxes. When he has started, however, the service must proceed from the two boxes alternately until the close of the innings of the side, whether singles or doubles. When the other side obtains the innings they may also begin in either box nithout regard to where the last service of their opponents was delivered. In singles. harid-out changes sides in the court after each serve, answering to the change over of the server; in doubles the serve is taken alternately by the two hand-out players who permanently occupy the right- and left-hand courts, being allowed to change the order in which they receive the service at the end of any game or rubber. Except in the case of left-handed players, most of the play in the left half of the court, including the taking of service on that side, is backhanded; therefore the strongest partner in backhand play usually takes the left-hand court

The best position in the court lor the hand-out taking the serve depends entirely on the nature of the service; he has to use his judgment the instant the ball leaves the server's racket in order to determine where it will strike the floor and at what precise point in its course it will be best for him to attempt to take it. A strong fast service. heavily cut, that sends the hall darting around the corner of the court, leaving the back mall at an extremely acute angle or dropping almost dead off it, can only be got up by standing near the back wall a long way across the court and taking the ball by a wrist stroke at the last instant before it falls to the ground a second time On the other hand, nhen the server avoids the side wall altogether and strikes the hack wall direct and hard, whether he achieves a nick serve (*i* e., the ball striking precisely in the angle betneen the back wall and the floor) or hits the nall high up. hand-out will have little time to spare in changing position to get nithin reach of the ball Many good players make a practice uherever possible, especially in the case of heavily cut service. of taking the service on the volley (*i e.*, beiore the ball reaches the ground). sometimes taking the ball after it leaves the side mall and before it reaches the back wall. In returning the service or in playing any stroke during the rally, the ball may strike any of the other walls beiore the front mall. This boasted stroke is quite legitimate, often most valuable and sometimes indispensable

Good play consists for the most part in hard low hitting, especially as close as possible along the side walls into tho corners of the back wal?. One of the most effective and beautiful but difficuit, strokes in rackets is the drop that occurs when the ball is hit so that it just reaches the front wall and drops close to It. The half-volley, in nhich the ball is struck at the moment of its contact with the floor and before it has had time to rise. is employed with great effect especially in hard play, it makes the return much quicker than when the ball is allowed to rise to the full length of the bound and requires corresponding quickness on the part of the adversary

If hand-out succeeds in returning the serve, the rally proceeds until one side or the other fails to make a good return A good return mesns (1) that the ball is struck by the racket beiore its second bound on the floor, snd without its having touched any part of the clothes or person of the striker or his partner; (2) that it is hit against the front wall above the board without first touching the floor or going out of court; and (3) that it returns off the front wall into play (*i.e* , to the floor of the court or to an adversary's racket) nithout gomg out of court. If hand-in is the one to fail in making a good return. he loses his hand, and (in singles) hand-out goes in dnd proceeds to serve, in doubles one of the hand-in partners loses his hand and the second partner goes in to serve until he in turn similarly loses his hand, except that in the case of the opening service in the game there is (as already mentioned) only one hand in any event.

If hand-out fails to make a good return to the serve or to any stroke in the rally, hand-in scores an ace and the side that first scores 15 aces wins the game. When, however. the score reaches 13-all (*i.e.*, when each side has scored 13 aces), hand-out may, before the next serve is delivered, declare that he elects to set the game either to 5 or 3, whichever he prefers; and similarly when the score stands'at 14-all. hand-out may set the game to 3. He makes this declaration by calling "set-5!" or "set-3!" It means that 5 or 3 aces, as the case may be, shall be required to win the game.

It is the player's first duty to give the opponent full room for his stroke. but in the ccnfined space of a rackets court it is not always easy and sometimes, especially in doubles, absolutely impossible not to obstruct him. The rules. thereiore. carefully provide for lets (an old English word for "impediment" or "hindrance"). When in matches a let is claimed by any one of the players and allowed by the referee, or the referee and two umpires, the service or rally counts for nothing and the server serves again frorn the same service box.

In ordinary garnes, the marker makes the decision as to a let. It is the duty of the marker who occupies a box in the gallery to "call the game." As soon as the server serves the ball the marker calls "Play!" At the end of every rally he calls the state of the game, always naming the score of hand-in first: "One-love" (love being the term for zero) meaning that hand-in has scored one ace and hand-out nothing, "Two-love," "Five-all," "Five-ten," "Fourteen-eleven."

When the player reaches 14 it is customary for the marker to call "game-bail"; *e.g.*, "14–11 game-ball." When one side has scored 15, the marker calls "Game!"

The server in possession at the end of the game continues to serve in the new game, subject as before to the rule limiting the first innings of the game to a single hand. The usual number of games in matches is five for singles and seven for doubles. In matches where there are umpires and a referee, there is an appeal to them from the marker's decision except as regards those questions relating to the service, on which the marker's decision is final.

History. — Attempts have been made to trace rackets, like tennis, to an ancient origin; but although it is doubtless true that the striking of a ball with the hand or some primitive form of bat is one of the oldest forms of pastimes and that rackets evolved from such an origin. the game as now known can hardly be said to have existed before the 19th century. The first school that took to rackets was Harrow in the 1820s. It was about the middle of the century that closed courts of the modern pattern began to be built and the founding of Prince's club in 1853 increased the popularity and standing of the game in England. In modern times, largely because of the expense of the game, there is not so much play as previously, except at the British public schools. A number of courts went out of use in the 1930s, several being converted into squash rackets courts.

Rackets was first played on the North American continent in Canada, being well established in favour in the second quarter of the 19th century. The first court of which anything is known definitely was built in Montreal in 1836. One of the players there. Edward LaMontagne, took up residence in New York city and interested friends in playing the game shortly before the end of the first half of the century. He found that rackets already was known in New York and that there was a court in use just off the Bowery.

The first U.S. court of which there is a definite record was built in New York in 1850. The game was played in a few clubs in a half-dozen cities of the United States. The Racquet and Tennis club of New York was the game's main stronghold. The number of courts and players dwindled however, because of the expense.

See E. B. Noel and C. N. Bruce, *First Steps to Rackets (1925).*

(E. B. N.; A. DA.)

RACKHAM, ARTHUR (1867–1939), English illustrator, was born Sept. 19, 1867, in London. He studied at the Lambeth School of Art, London. Works he illustrated included *Rip van Winkle* (1905), *Peter Pan* (1906), *Alice in Wonderland* and the *Ingoldsby Legends* (1907). He won gold medals at Milan (1906) and Barcelona (1911). He was elected associate of the Société Nationale des Beaux-Arts in 1912 and in 1919 became master of the Art Workers' guild.

Rackham died Sept. 6, 1939, in Surrey.

Later illustrations include those to *Undine*, Grimm's *Fairy Tales*, Aesop's *Fables*, Dickens' *Christmas Carol, Comus, The Tempest, The Compleat Angler*, Poe's *Tales of Mystery and Imagination, The Rubaíyát* and *Peer Gynt*.

RADAR is an electronic device which provides man with the ability to detect and locate objects of a certain sort at distances and under conditions of lighting or obscuration which would render the unaided eye quite useless. Further, radar affords a means for extremely precise measurement of the range, or distance, to each of the objects it detects and locates—or "sees." It can also measure the speed of such an object toward or away from the observing station in a simple and natural way.

Radar is superior to the eye because it can "see" regardless of visibility conditions and because it affords an easy and accurate means for measuring target range and its rate of change. Radar is greatly inferior to the eye in the detailed definition of the picture offered. Largely because of the lack of detail in radar vision, the class of objects usefully seen by radar is smaller than the class distinguishable by the eye. Radar deals best with isolated targets in a relatively featureless background: aircraft in flight, ships on the open sea, islands and coast lines, and the like.

This article is divided as follows:

I. INTRODUCTION

How **Radar** Works. — Radar is a coined word, an acronym, derived from the initial letters of the phrase "radio detecting and ranging." Radio waves sent out from the powerful radar transmitter are reflected by objects within range of the set. A tiny fraction of the outgoing energy returns as an echo to the radar receiver, which is usually located, for convenience, at the same place as the transmitter. The properties of the received echo are used to form a picture or to determine certain properties of the object which caused the echo. As we shall see later on, there are several different forms of radar systems, making use of different properties of the received echo and involving different sorts of radio transmissions from the radar transmitter. The form employed in the majority of the sets is pulse radar. U'hen the word "radar" is used without qualification in this article, pulse radar will be meant.

Pulse radar is so called because the transmitter is keyed to send out short, very intense bursts or pulses of energy with a relatively long interval between pulses. The receiver is active during this interval. It receives echoes from the nearest objects soon after the transmission of the pulse, from objects at intermediate range later on and from the most distant objects near the end of the interpulse interval. When sufficient time has elapsed to permit the reception of echoes from the most distant objects of interest, the transmitter sends another short pulse. and the cycle repeats.

The delay between the transmission of the pulse and the reception of the echo is due to the fact that the radio waves used travel with the great but finite speed of light. In the units convenient in radar, the speed of light (about 186,000 miles per second, or 3×10^{10} cm./sec.) is 328 yd.[1] per millionth of a second, or microsecond. Since the radio energy from the radar transmitter must travel the distance from the radar to the target twice, once out and once back as an echo, each microsecond of delay between the transmission of a pulse and the reception of an echo corresponds to 164 yd. of range between radar set and target. If the delay corresponding to target range R is called T„ it will be given by

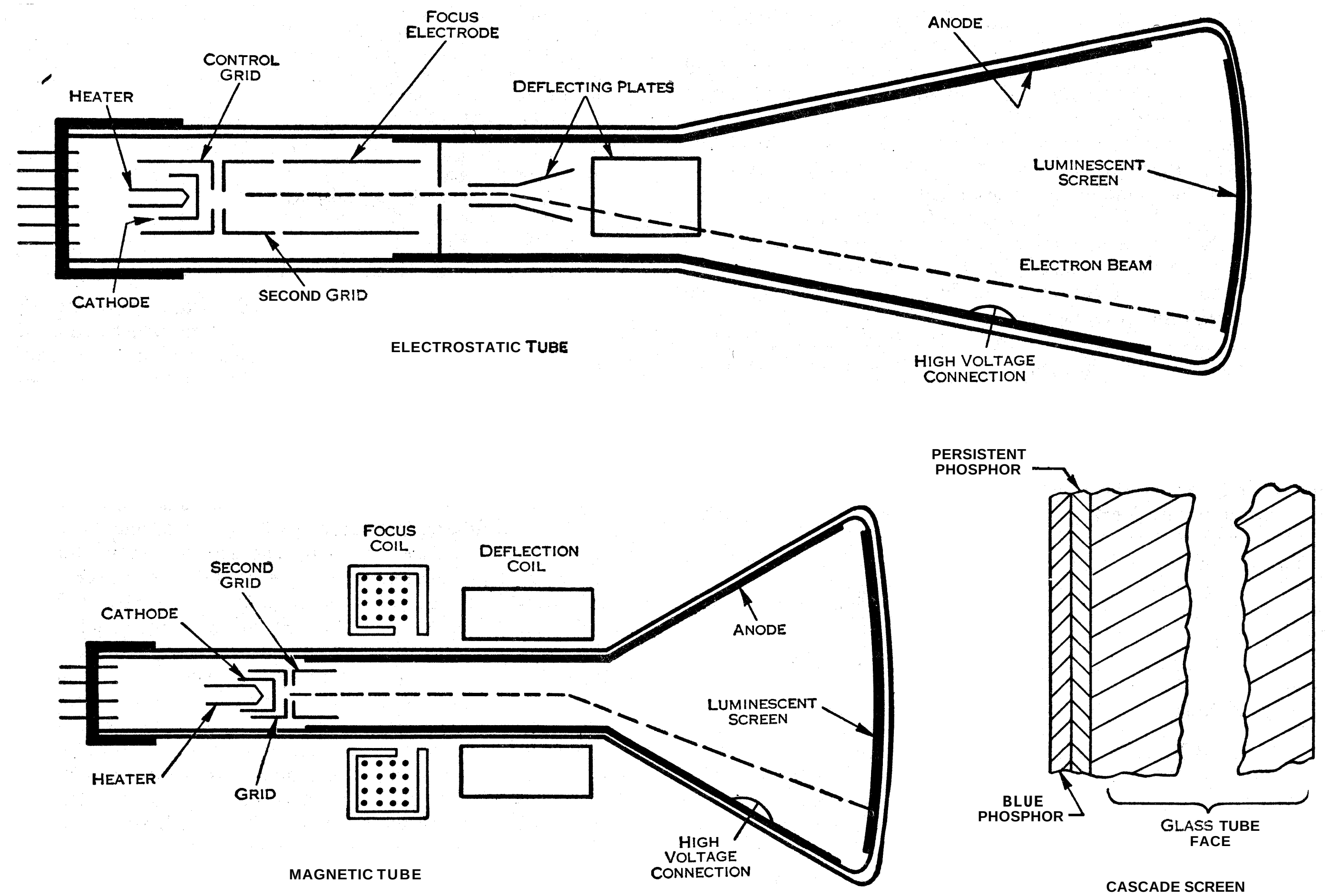
$$T_R = \frac{2R}{c}, \tag{1}$$

where c is the velocity of light.

This is the clue to the accuracy with which range can be measured by radar. Range measurement is reduced to the measurement of time, which can be performed more accurately than the measurement of any other basic quantity of physics. Very short intervals must be timed to get absolute precision in range, of course; if an error in range of only five yards can be tolerated, time intervals must be measured with an accuracy of one-thirtieth of a microsecond. Electronic timing and display techniques developed during World War II enabled such measurements to be made with great ease and convenience.

In 1945, for example, a serious map error was discovered by the use of bombing radar. This equipment enabled a bombing plane to find its position accurately by measuring the ranges to two fixed ground stations at which radar beacons (*see* below) were located. One beacon station was on the island of Corsica. A miss of about 1,000 yd., nearly 50 times the error expected, was scored on the first bombing mission carried out in Italy with this system. After an investigation of all possible sources of error, it was suggested that the reputed position of Corsica might be

[1]This is about 1,000 **ft.** (984) in one microsecond.



FROM RADIATION LABORATORY SERIES, MCGRAW-HILL BOOK COMPANY, INC

FIG. 1.— ELEMENTS OF A CATHODE-RAY TUBE

wrong A correction of about 1.000 yd in the position of the island was used on the next bombing run The results, and those of later missions that used the corrected position of the island, were indistinguishabie from those of optical bombing.

A cathode-ray tube (CRT) is almost always used for the display of radar signals This device, shonn schematically in fig 1, has an ' electron gun" at the base of its glass envelope, deflection plates or coils in the neck of the tube and a luminescent screen on the inside of the large, nearly flat face of the tube. The electron gun produces a narrow, accurately focused beam of electrons which is aimed toward the centre of the screen. This pencil of electrons can be deflected in its flight from gun to screen either by electric fields produced by voltages applied to deflection plates, or by magnetic fields produced by electric currents passing through deflection coils.

Means are almost always provided for producing two independent deflections of the beam at right angles to one another. When the beam of electrons strikes the screen covering the inner face of the tube, the impact of the electrons excites the luminescent material there and causes it to emit light.

Thus the CRT screen instantaneously displays a single small spot of light whose position depends on the deflecting voltages or currents effective at that instant. Because of the very small mass of an electron and the consequent small inertia of the electron beam the spot can be deflected at very great rates of speed "Writing speeds" (that is, speeds of CRT spot motion) of as much as 200 in per microsecond were used in laboratory test equipment during World War II. Writing speeds of 1/10 in. per microsecond were common in service radar equipment. Not only the position of the spot but also its intensity can be conttolled electrically

The voltage applied to a "control grid" in the electron gun determines the electron beam current to which the light intensity produced at the screen is proportional.

A simple way to display radar signals is in the form of a "one-dimensional" display. The signal beam of the CRT is swept across the face of the tube from left to right at a uniform rate of speed, beginning at the instant a pulse is sent out from the radar transmitter. Thus the distance the beam has traveled to the right from its initial position is a measure of the time that has elapsed after the transmission of the pulse, and the distance of an echo signal from the left end of the sweep is proportional to the range of the target causing the echo. The output signals of the radar receiver are applied to deflect the beam vertically, so that an echo appears as an upward deflection of the trace. To make sure that the weakest signals that are detectable at all are not missed, the over-all amplification of the receiver is great enough so that random electrical disturbances, called "noise," originating in the receiver, can be seen on the display. For example, in successful attempts to receive a radar echo from the moon, time exposures were taken of the CRT screen. The photograph showed the entire path traced by the spot of light on the CRT face, in this case, in $2\frac{1}{2}$ sec.

On the left could be seen the "tail" of the transmitted pulse leaking into the receiver. and, on the right, the echo signals from the target. The distance of the echo signals from the left side of the CRT screen gave the distance of the target, the moon, as about 250,000 mi.

The type of indicator just described has come to be called an A-scope. Besides being simple, it affords an easy and straightforward way of measuring range. It makes no use of alterations in the intensity of the CRT spot.

In addition to finding target range, it is usually necessary to determine also the direction in which each target lies as viewed from the radar station. This could be done, in principle, by triangulation, using two or more simultaneous range readings on the same target as seen from separate radar stations. From the standpoint of simplicity, it is far preferable to measure both range and direction from a single radar station.

This is possible if the radio energy sent out from the radar can be confined to a narrow beam, like that of a searchlight. Echoes will then be received only from targets which lie in the direction in which the beam is pointing. If the radar beam is swept or scanned around the horizon, the strongest echo will be received from each target when the beam is pointing directly toward it, weaker echoes when the beam points a little to one side or the other of the target and no echo at all when the beam points in other directions. The bearing of a target can thus be determined by noting the direction in which the radar beam must be pointed to give the strongest signals from that target.

This can be done in several ways, some of which are highly precise. None is more graphic than the radar display called PPI, for plan position indicator. The PPI shows the range and angular disposition of all targets seen by a radar set which is scanning the horizon. In the PPI, the radar echo signals from the receiver are applied to the control grid of the CRT indicator tube in such a way that the screen will be dark in the absence of a signal, and a bright spot will appear when a signal is received.

The electron beam executes a sweep of uniform speed beginning at the instant each pulse is transmitted. just as in the A-scope, but in the PPI each of these sweeps commences at the centre of the tube and goes radially outward. Target bearing is indicated on the PPI by making the direction of each radial sweep on the indicator correspond to the geographical direction in which the antenna (and hence the radar beam) is pointing at that moment. North can be chosen to be at the top of the tube, for example; when the radar beam is pointing north, the radial sweep is executed from the centre upward. When the antenna has swung around to point east, the sweep on the PPI will take place from the centre to the right, and so on. The result is a map, on which the direction of each luminous spot marking a radar echo, measured from the centre of the tube, shows the bearing of the target causing the echo, and the distance of the spot from the centre of the tube face shows the target range.

In addition to the A-scope and the PPI, many other forms of radar indicator have been devised for special purposes; some of these will be referred to later.

The Basic Radar Set.—A radar set is shown schematically in fig. 2, separated into the major components fundamental to its action. The operation of these components is as follows.

A cycle of operation is begun by the modulator, which spplies a high-power, high-voltage pulse to the magnetron, a type of transmitting tube developed specifically for radar use. For the brief duration of the modulator pulse, which may typically be one microsecond, the magnetron oscillates at a frequency of several thousand megacycles per second[1], usually abbreviated simply as mc., transforming the D.C. power applied to it by the niodulator into R.F. (radio frequency) power with an efficiency usually larger than 50%. The R.F. pulse thus produced travels down the R.F. transmission line shown by double lines in fig. 2, and passes through the two switches marked TR and ATR. These are gas-discharge devices in which the discharge is initiated and maintained by the high-power R.F. pulse produced by the magnetron. During this time, the TR (transmit-receive) switch connects the transmitter R.F. line to the antenna, and disconnects the mixer and the rest of the receiver, in order to prevent damage to these sensitive circuits by the high outgoing power. The ATR (anti-TR) switch, when operated, simply permits the R.F. pulse from the magnetron to pass through it with negligible loss. Between pulses, when these gas-discharge switches are in a quiescent state, the TR switch connects the mixer to the antenna, and the ATR disconnects the magnetron to prevent any of the feeble received signals from being lost.

The R.F. pulse, after passing through these two switches, travels down the R.F. line to the antenna, where it is radiated. As is usual in radar. a single antenna is indicated in fig. 2 as being used both for transmitting and receiving; this requirement gives rise to the need for the duplexing arrangements involving the TR and ATR switches. The antenna design depends on the shape of radar beam required to meet the functional demands placed on the radar. It is almost always mounted on a scanner arranged to sweep the beam through space in the manner desired, simple azimuth rotation is indicated in fig. 2.

After the pulse has been transmitted, the discharges in the TR and ATR switches cease and the system is ready to receive echoes. These are picked up by the antenna and sent down the R.F. line to the mixer. The mixer shown is identical with the usual mixer of a superheterodyne radio receiver; it is a nonlinear device which, in addition to receiving the signals from the antenna, receives power from a CW (continuous-wave) local oscillator operating at a frequency only a few tens of megacycles away from the frequency of the radar transmitter. The difference frequency that results from mixing the echoes with the local oscillator signals contains the same intelligence as did the original echoes, but it is at a sufficiently low frequency (typically 30 mc) to be amplified by more or less conventional techniques in the intermediate frequency (I.F.) amplifier shown. Output signals from the I.F. amplifier are demodulated by a detector, and the resulting unipolar signals, still containing the echo intelligence, are further amplified by a video-frequency amplifier similar to those familiar in television receiver technique.

Output video signals are passed to the indicator for display. The indicator shown is a PPI which must, in addition to receiving echo signals from the indicator, receive a timing pulse from the modulator to indicate the instant for the start of each sweep. It must also receive information from the scanner on the direction in which the antenna is pointing, in order that the radial range sweep be executed in the proper direction from the centre of the tube. The necessary connections are indicated in fig. 2.

Each of the components shown in fig. 2 presented a series of difficult new problems of design during the period of radar development in the years 1935–45. Broad problems of component design are treated later in this article.

II. THE DEVELOPMENT OF RADAR

1. Early History.— Radar was developed independently and nearly at the same time in the United States, England, Germany and France during the 1930s under various names, such as radio detection or radio location. In 1942 the U.S. Navy coined the term radar which became universal in all later applications.

The independent occurrence of almost simultaneous and very similar radar developments in all these countries should not be surprising. The ideas basic to radar principles had been repeatedly presented for many years preceding the development of radar. It is perhaps more surprising that practical radar systems were not evolved at an earlier date.

Of the two ideas basic to pulse radar. the echo principle and the pulse principle, the former dates from the pioneer work of Heinrich R. Hertz in electromagnetic waves. This German physicist in the 1880s. seeking demonstrable proof of theories on the nature of light and radiation that the English mathematician James C. Maxwell had published in the 1870s, produced radio waves in the laboratory. Hertz also demonstrated that these radiations could be reflected by metallic objects, as light is reflected by a mirror.

While Marchesc Guglielmo Marconi and others at once pursued the radio communications possibilities that Hertz had opened up. a German engineer, Christian Hiilsmeyer, developed a simple form of radar. or radio echo device, to prevent ship collisions He even obtained patents in 1904 in several countries. But therr was little interest in such a device at that time.

Meanwhile, the radio echo or reflection phenomenon was repeatedly observed, and comments were often made regarding its possible uses. Nikola Tesla wrote in Century *Magazine* (June 1900, lx, p. 208) that by means of radio a moving object such as a ship at sea might be detected and located. Marconi, speaking in New York city at a meeting of the Institute of Radio Engineers in 1922, elaborated upon this same application.

[1]The electromagnetic waves used in radar, like light and radio wales, can be characterized either by their wave length, λ, or by their trequency, ν These two quantities are related, since their product is the velocity of propagation of light, c,

$$\lambda\nu = c$$

Numerically, a wave length of 10 cm. corresponds to a frequency of about 3×10^9 cycles per second, or 3,000 mc. per second.

By the mid-1920s radio researchers were seeking to measure the height of the ionosphere, a layer of ionized gas near the top of the atmosphere that reflects high-frequency radio waves, making possible long-range radio transmission around the curve of the earth. In England, under the auspices of the British Radio Research board, Edward V. Appleton and Miles A. F. Barnett employed CW radiations in original experiments beginning in 1924 to determine the altitude of this reflecting layer. The method they used involved observation of the interference effect between the waves reflected from the ionized layer and the direct (or ground) waves radiated by the transmitter.

The second idea basic to radar is the pulse principle, which was developed in 1925 by Gregory Breit and Merle A. Tuve of the Carnegie institution, Washington. D.C., in ionospheric work. Their pulse-ranging method was soon adopted by ionospheric investigators all over the world.

2. Development Before World War 11.—In the 1930s radio detection research began to receive earnest attention in a number of countries. largely under military supervision and in secret, because of the urgent need to detect and locate enemy warplanes at night or in cloud.

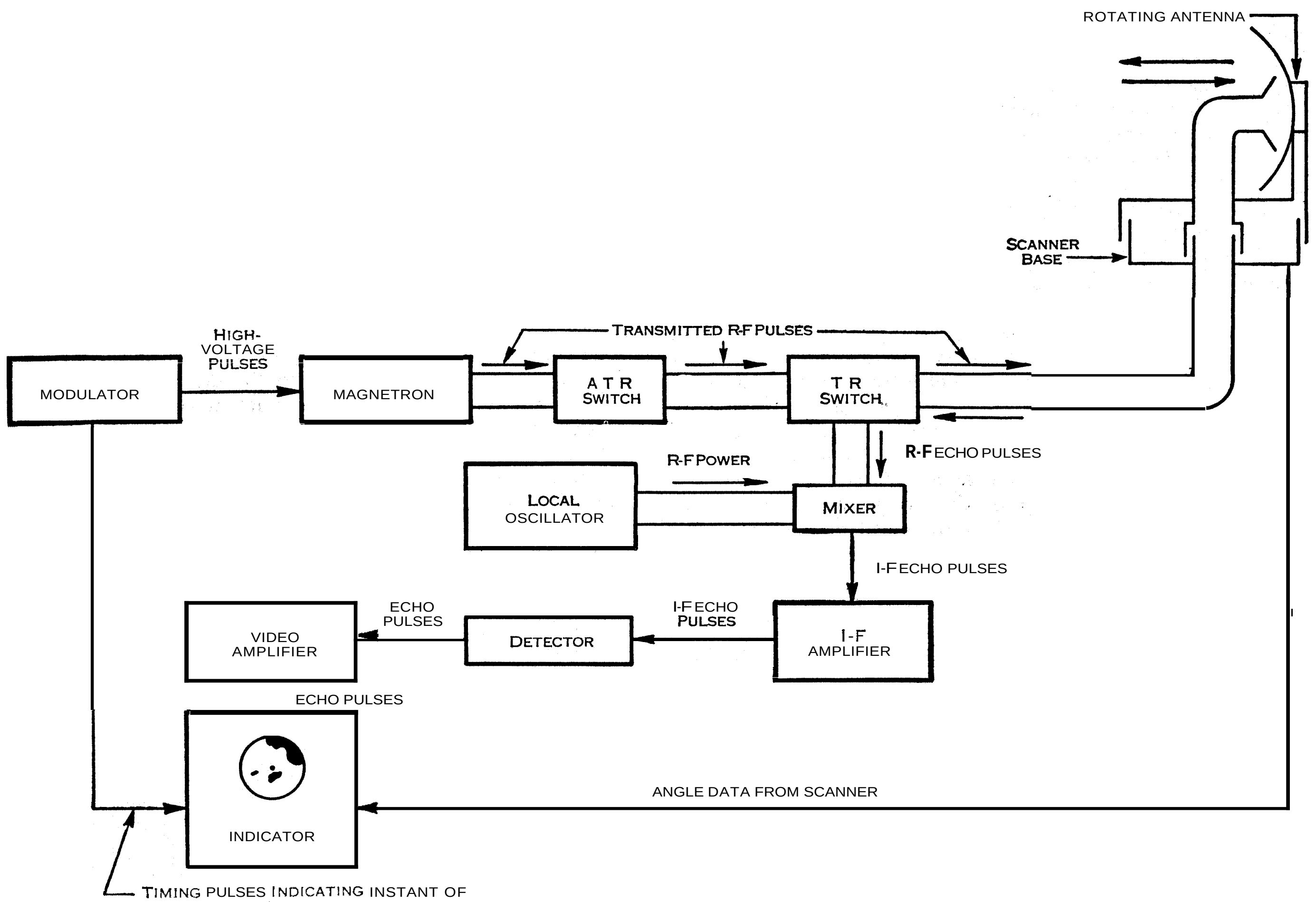
Germany.—German scientists, having begun development of a ship detector for the navy as early as 1933, soon concentrated their efforts on aircraft detectors. By Sept. 1939 a German ground set, the Freya, for early warning of approaching airplanes, was in production. The ship detector Seetakt went into production soon after. An especially excellent radar, the Wurzburg, its medium-length waves of 50 cm. (at 600 mc.) giving sufficient accuracy to direct effective antiaircraft fire against unseen planes, began to be employed in mid-1940 before any comparable precision position finder or gun layer (GL) radar had been developed by the Allies.

France.—The French, who had developed a simple obstacle warning set (an iceberg detector) for use aboard the ocean liner "Normandie" in the mid-1930s, also devised an aircraft warning system just before World War II. This was an interference-type radar using long waves (at 30 mc.) and requiring wide separation of the transmitter and receiver. The system was developed by Pierre David, chief engineer of the National Radio laboratories, who worked in great secrecy with army officers and civilian technicians. Not until about the time of an exchange of radar information with the British in 1939 did the French begin serious work on high-power pulse radar.

L'nrted States.—Scientists under A. Hoyt Taylor and Leo C. Young in the Naval Research laboratory and under Col. William R. Blair in the Army's Signal Corps laboratories made early progress in radio detection. Navy workers had devised an interference type of radio detector by 1930. Army scientists first worked on microwave radar types in the early 1930s, but the sets were failures militarily because they could not attain sufficient range. The output power of microwave oscillator tubes at that time was too weak.

Success came by 1936 when both the army and navy developed pulse radars on longer wave lengths generated by special high-power tubes. The signal corps demonstrated a model of the army's first radar, a searchlight control (SLC) set. in May 1937. This set was developed for the coast artillery corps to locate in darkness any airplane within searchlight range so that gun crews could trap the plane in searchlight beams and direct visual fire upon it.

The army air corps at once put in a priority request for a long-range aircraft detector for early warning (EW). This led to the development of a mobile set capable of detecting and locating aircraft well over 100 mi. distant. The signal corps completed development of both this set and a fixed version by the end of 1939, and contracts for their production were let by 1940. Both ,were in military use before the Pearl Harbor attack. U.S. navy radars



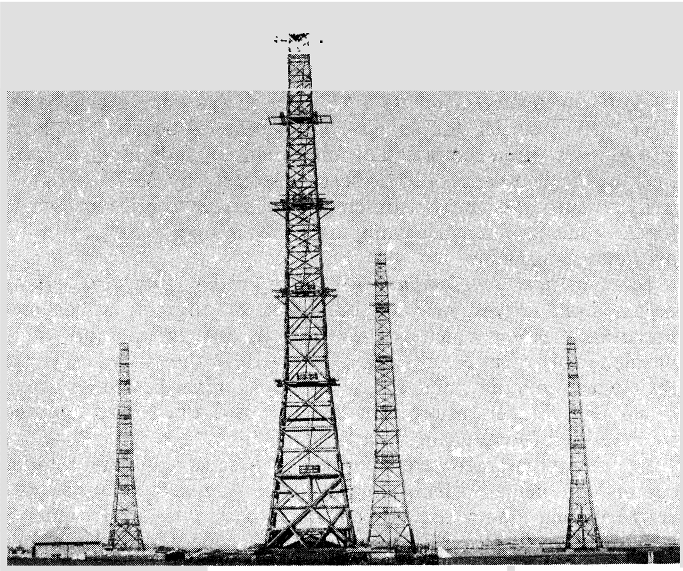
FROM RADIATION LABORATORY SERIES, MCGRAW HILL BOOK COMPANY, INC

FIG. 2.—BLOCK DIAGRAM SHOWING COMPONENTS OF A SIMPLE RADAR SET

were also in production and use by then, following successful ship-board tests in early 1939.

Great Britain.—British radar grew from the efforts of a committee that the air ministry set up in 1934 for the scientific survey of air defense. This committee received, among other suggestions, a carefully uorked out plan for the radio pulse-echo detection of aircraft. This was tested on Feb. 26, 1935, by a physicist then heading the radio department of the National Physical laboratory, Robert Watson-Watt.

The first experimental system of the type proposed by Watson-Watt was set up in the late spring of 1935 on the east coast of England. By that autumn the main features of a chain of warning stations to protect England had been worked out. By early 1338 the first five chain home (CH) stations, which protected the Thames estuary, were completed and in operation under Royal Air Force personnel. A chain of similar stations was erected around the borders of Great Britain in succeeding years.



WOODEN RECEIVING-ANTEYNA MASTS OF THE EARLIEST BRITISH RADAR, THE CH. THESE SETS WERE USED THROUGHOUT WORLD WAR II, HAVING BEEN USED IN 1944–45 TO DETECT GERMAN V.2 ROCKETS DIRECTED AT LONDON SET SHOWN IS AT SWINGATE, DOVER, FACING ACROSS THE ENGLISH CHANNEL TOWARD FRANCE

Development emphasis then shifted to air-borne radar equipment. Two types were designed: (1) a set for the detection of surface vessels or surfaced submarines by patrol aircraft (called ASV, for air-to-surface vessel), and (2) an equipment to enable night fighters to home on enemy aircraft (called AI, for aircraft interception).

An experimental ASV system was successfully demonstrated during British fleet maneuvers in Sept. 1938. Experimental AI equipment was demonstrated to the chief of R.A.F. fighter command in Aug. 1939.

The focusing of radar energy into sharp beams is especially important in the case of air-bcrne radar; for energy reflected when the radar beam strikes the ground or sea beneath the plane can mask entirely the much weaker echoes of the targets sought. Sharp beams can be obtained by the use of either very large antennas or very short radio wave lengths. Since large antennas cannot be carried in aircraft, short wave iengths are essential. The early British interest in military air-borne radar led to an intensive search for a type of radio transmitter which could give very high-power pulses at wave lengths of a few centimetres.

By early 1940, British researchers succeeded in developing just such a transmitting tube, the revolutionary multicavity magnetron, which gave about ten kilowatts of pulse power. The invention of this tube made microwave radar practical for the first time, and the history of modern radar can be said to date from the introduction of this device.

3. World War II Radar Development. — By the end of 1940 U S. and British radar work was being carried out on a basis of full mutual exchange of information. A British technical mission, headed by Sir Henry T. Tizard, visited the U.S. In September and October of 1940, bringing complete information on British radar developments and samples of the cavity magnetron. Arrangements were made for continuing exchange of technical information and for co-ordinating the development work of both nations.

In discussions with the microwave committee of the C.S. National Defense Research committee (NDRC), which had been set up a few months before, members of the British mission proposed that the U.S. undertake two specific microwave developments: a microwave AI radar and a microwave position finder or gun layer (GL), for antiaircraft fire control. To implement these proposals; the microwave committee arranged to create a radar development laboratory staffed principally by university physicists in a pattern originated by the British several years earlier.

United States.—The Radiation laboratory, as the new NDRC establishment was .. opened its doors at the Massachusetts Institute of Technology, Cambridge, Mass., early in Nov. 1940 Its director throughout its 62 months of life was Lee A. DuBridge, on leave from t University of Rochester, later president f California Institute of Technology, Pasadena, Calif. The U.S. army and navy looked to the new Radiation laboratory for tl development of microwave radar. Their own development agencies were already fully occupied with tl many problems connected with getting the long-wave ra ., already developed, through manufacture and into service use. At the end of 1940, the usefulness of microwave radar seemed highly speculative, and the army and navy laboratories quite properly felt it more important to on trate their effort on radar techniques which had already been worked

During 1941, though not a single microwave rad unit was delivered for service use, development work a the Radiation laboratory broadened far beyond the two specific e which had been s t l by the British mission. Microwave i ment was showing great promise f many different wartime uses, and a considerable amount oi army and navy interest was developing.

The t nendous expansion f the radar development program during the war years can e measured by tl personnel figures of the various t The t t personnel of tl Radiation laboratory was about 40 at the beginning of 1941; by the middle of 1945 it had risen to its peak of nearly 4,000. The radar section of the Naval Research laboratory increased its personnel to about 600 in the same period. The radar section of the Signal Corps laboratories grew into the Evans Signal laboratory, with a peak personnel of more than 3.000. A similar growth took place at the Aircraft Radio laboratory at Wright field, Dayton, Ohio.

Great Britain. — British research and production experience during World War II set a precedent for wartime radar development in the U.S. The Telecommunications Research establishment (TRE), located during the last years of the war at Malvern college, Eng., pioneered the path followed by the Radiation laboratory in the U.S. TRE originated five years earlier than its American counterpart, having begun with a nucleus of dedicated physicists and technicians who built the first CH station on the shore of the North sea in 1935.

By 1915 TRE personnel grew to number about 3,000. Throughout these years British government and military officials co-operated closely with university scientists and industrial engineers, providing funds and facilities while permitting great latitude and free play of imaginaiion to the end that complex but workable equipment might be devised and quickly brought to combat use. A new pattern of military-civilian co-operation and a spirited partnership of civilian scientists and military users was created with marked success, first in England and then in the U S., bringing revolutionary concepts and weapons to bear upon the enemy with devastating effectiveness and crucial timeliness. Experimental radar devices, hand-built at the laboratories, were often used in combat missions, the equipment being installed and maintained by civilian technicians who sometimes operated it as well.

The British and U.S. radar efforts together brought against the enemy increasing quantities of superior microwave radar. Notable examples were the precision position finders or GL sets that, by 1944. surpassed the German Wurzburg radars. Such too were the efficient air-borne microwave radars whose shorter wave lengths permitted use of smaller antennas and gave greater detail (higher resolution) of target reflections. The first of these was the British H_2S (wave length 9 to 10 cm.), used in 1943 in such effective raids as those on Hamburg. Next was the improved H_2X which employed still shorter waves (about 3 cm. long).

Increasing use of these and other microwave radars replacing long-wave sets such as the enemy continued to employ (for want of efficient microwave generators like the cavity magnetron) gave the Allies through the last two years of the war an overwhelming radar superiority. In particular, the Allies developed jamming devices that blinded all German radars, both ground and air-borne types, that were operating on medium or long waves. Meanwhile, the Allies freely employed their superior microwave sets (unaffected by medium- or long-wave jamming) to direct attacks upon enemy targets at sea, on land and in the air.

Germany.—German radar development during the war was much retarded, as compared with the Allied effort, by over-confidence at first and throughout by poor management and defective co-operation between the military services and civilian scientists. Particularly harmful was a cutback in research that Hitler ordered in 1940. But as Allied air attacks increased, German radar production was stepped up.

More than 2,000 Freyas were built during the war and thousands of other sets as well. Improved Wiirzburgs and other types were developed and organized into effective systems of early warning, target tracking. and fire control or gun laying. An effective AI set, the Lichtenstein, was hastily devised and placed in night fighters. All these efforts enabled the Germans to take an increasing toll of Allied aircraft over western Europe until a turning point in the radar war came in mid-1943.

When in Feb. 1943 the Germans salvaged an H_2S radar and its magnetron from a plane wreck near Rotterdam, they first learned that the Allies had developed microwave sets. (By the end of 1943 they learned of the still better 3-cm. radar when an H_2X set was recovered from a U.S. bomber that also crashed in Holland.) Desperately, the Germans hastened to set up the Rotterdam commission to develop cavity magnetrons and microwave radars, but only toward the very end of the war did they begin to produce the Berlin series of microwave sets, and these were too late to be of any help.

Japan. — Such radar as the Japanese had developed before World War II was of the continuous-wave type, utilizing interference or Doppler techniques. Not until 1940 did work begin on pulse-type radar.

Some types were strongly influenced by foreign radar design. For example, a Japanese version of the Wurzburg was developed by 1945, based on plans the Germans had sent via submarine. The army's Taichi-6 resembled a U.S. army set, and a type of naval ground-based radar for antiaircraft fire control, the S-3, was based upon another U.S. set, a number of which had been captured in the Philippines in 1942. More than a thousand sets of an ASV type, the Taki-1, were produced. Using waves a metre and a half long, at 200 mc.. the set was mounted in Japanese bombers that carried the necessarily large antennas mounted on the exteriors of their fuselages.

The Japanese also developed a 10-cm. magnetron. One of their best shipboard radars employed this type of tube. They did not, however, develop in World War II any radar comparable to the Allied microwave SCR-584 or the MEW (microwave early warning) radar set.

4. Use of Radar in World War 11.—The brilliant success of the early British chain home stations in countering the threat of the Luftwaffe demonstrated the usefulness of radar in its original military role — the detection and location of aircraft at ranges and under conditions of visibility that precluded locating planes in any other way. As the war continued. many other uses for radar were developed. The most important are described below.

Aircraft Warning. — The earliest sets used were 'those of the British home chain. These large installations used radio waves about ten metres in length, and gave their display on an A-scope. Target bearing was found by comparing the intensity of the target signal received on one fixed receiving array with the intensity of the echo from the same target received on another fixed array aimed in a different direction; the elevation angle of a target, and thus its altitude, was measured in a similar way. These CH radar stations, as they were called, remained the principal reliance of the British radar defense throughout the war, and were used in 1944 and 1945 for the detection of German V-2 rockets aimed at England.

Later aircraft warning sets used shorter radio wave lengths, usually about 1.5 to 3 metres. At this wave length, a relatively narrow beam can be produced by an antenna array small enough for installation on shipboard, or for use in a transportable ground equipment. At the same time, the use of a radar beam requires continuous scanning in azimuth in order to cover all directions from the station.

In early 1944, there was introduced a microwave early-warning radar, operating on a wave length of 10 cm., which was highly successful. The radar beam produced by this set was only 1° wide in azimuth; in consequence, the ability of the set to resolve closely spaced targets on its PPI display was very much better than that of earlier equipment having broader beams. In large R.A.F. raids, often comprised of more than 500 individual aircraft, most of the bombers could be seen separately by MEW radar.

In situations of heavy air traffic, or under conditions where precise control of aircraft is important, such high radar resolution is extremely valuable.

Identification *Equipment.*—When a radar indicator shows echoes from dozens, or even hundreds, of aircraft, it becomes important to know which of these aircraft are friendly and which hostile. This requirement was recognized by the British early in their work on radar, and they devised an identification system, called IFF (identification as friend or foe), which was adopted by the Allied forces during World War II.

All friendly aircraft were equipped with a transponder — a radar beacon (see below) which gave a coded response when the aircraft carrying it was in the beam of a radar set. Arrangements were made to display this response on a scope which was either that used by the challenging radar set, or a special scope associated with the radar. Aircraft showing an IFF response were taken to be definitely friendly; aircraft not showing such a response were doubtful. Either they were hostile, or they were friendly planes whose transponders were out of order or not turned on.

While IFF was extremely useful in the early days of the war when aircraft density was still low, it failed operationally in the enormously high aircraft densities of the latter years of the war. A means for rapid and secure identification was, therefore, one of the unsolved operational problems of radar at the end of World War II.

IFF equipment of the standard type was also used by Allied naval vessels in order to identify friendly ships both to aircraft and to other surface vessels. In this use, of course, the problem of high density seldom arose, and maintenance of transponders was easier than it was in aircraft. IFF in ships was, therefore, considerably more reliable than it was in aircraft.

Control of *Aircraft* Interception. — The observation was early made by the British that, since both a hostile plane and a friendly fighter can be seen on the indicator of a single radar, it might be possible for a ground controller, viewing the radar scope, to coach the fighter into position to make an interception. The development of the plan position indicator greatly facilitated such ground control of interception.

Special radar equipment, called GCI, was designed for this purpose in the earliest days of the war, and proved to be quite successful.

When the Germans abandoned daytime attacks on England at the end of 1940, the technique of ground control became much more exacting. It was no longer sufficient to bring the defensive fighters into the general vicinity of the enemy aircraft and then to rely on the pilot's vision to complete the interception. A skilful ground controller could, under favourable circumstances, bring a fighter close enough to his target to enable a visual contact to be made even at night; but this was so difficult that further radar aids to the interception were clearly needed.

AI Radar. — It was this reasoning which led to the development of radar for aircraft interception. Night fighters were provided with air-borne radar sets with a range of a few miles against other aircraft. The ground controller coached the night fighter into a position a mile or two behind the hostile plane, a little below and on the same course. He then instructed the radar observer in the night fighter to turn on his AI equipment. If the early phases of the interception had been successfully carried out, the hostile aircraft gave a signal on the AI radar, and the combat was joined on the basis of homing information made available by the night fighter's own radar.

By the time reliable microwave AI equipment had been developed by the Allies in World War II, they enjoyed such thorough air superiority that it did not play a major tactical role. The early British 1.5 metre AI equipment used in 1940 and 1941 had many drawbacks, but it was sufficiently effective to enable the R.A.F. to master the night-bombing campaign of the *Luftwaffe.*

Antiaircraft Position *Finders* or Gun Layers (*GL*).—The earliest radar set developed by the U.S. army signal corps was the searchlight control set, mentioned above, for determining azimuth, elevation and range of aircraft targets at night in order to direct searchlight beams upon them. These sets also were employed for control and direction of gunfire under conditions preventing visual tracking — at night or in cloud — although the set had not been designed for GL use. Such use of radar for fire control became a most important application in World War II, but neither early British nor U.S. sets, working at wave lengths of a metre or more: had sufficient accuracy to direct very effective blind gunfire.

The introduction of microwave sets, however, enabled the design of radar position finders whose accuracy was good enough to permit blind fire that was as effective as visually controlled fire. The most successful of all Allied types of such equipment was the SCR-584. This C.S. radar measured the azimuth and elevation angles of a target with an error of less than one-twentieth degree, and range with an error less than 25 yd. It was the first radar equipment which incorporabed automatic tracking; when the SCR-584 was pointed at a target, it could be "locked on" in such a way that servomechanisms actuated by the radar kept its antenna pointing continuously at that target.

Naval antiaircraft fire was controlled by radar of a similar sort, although no navy, Allied or Axis, had equipment for the purpose that was as effective or as satisfactory as the U.S. army's SCR-584.

Close Control of Aircraft.——The GCI techniques which were referred to above had as their aim the location of a friendly fighter in such a position that he could attack a hostile bomber, usually with the help of an AI radar carried by the night fighter. Minor errors in positioning the friendly plane were usually relatively unimportant, and the target with respect to which the friendly plane was being positioned was an aircraft moving with a speed comparable with that of the plane under radar control. Both these facts simplified the GCI problem.

As the position-finding precision of radar grew, it began to be clear that a ground controller could direct aircraft accurately into a desired position with relation to ground targets. Two principal problems presented themselves during the war, one of which is important in peacetime air operations.

First, the tactical air commands that accompanied the U.S. armies on the continent of Europe were composed, for the most part. of fighter bombers. These single-seat aircraft were much too small to carry radar equipment, and the pilot of such a plane was much too busy to interpret its readings even if he had had radar. Nevertheless, the TAC aircraft had to operate often in conditions of greatly restricted visibility. Controllers located at ground radar sets had considerable success in guiding TAC fighter bombers to their targets by radiotelephone instructions. Even entirely blind bombing was done by such aircraft, altogether on the basis of course and release-time instructions received from a controller at a ground radar. The SCR-584, suitably modified, was used for this work.

The second application of close aircraft control from the ground is that of coaching a plane in to a landing under poor visibility conditions. A special high-precision radar set, called GCA (ground controlled approach), was designed at the Radiation laboratory for this purpose. Though it emerged from production rather late in World War II, it was used quite successfully both in Europe and in the Facific. Its use had become common by the 1960s in both civil and military air operations.

Surface Search and Fire Control. — In addition to locating aircraft and directing fire against them, radar was used during the war to locate and direct fire against surface vessels, both from other ships and from coastal defense stations. As will be seen in the next section, microwaves enjoy a great superiority in search for targets near the surface of the sea, so that it often happened that the same radar was used for search and for fire control against surface vessels.

Such radar could also locate precisely the splashes caused by the fall of shot, thus permitting the spot correction of unseen fire. In naval engagements in the Pacific, on several occasions, ships of the U.S. fleet engaged and sank Japanese vessels without ever seeing them visually.

ASV Radar. —Of the several types of air-borne radar equipment used in the war, that employed by patrol aircraft for searching out and attacking surface vessels was one of the most common. A ship on the open sea is an ideal radar target, and even quite primitive equipment suffices to home on such an object. As the art of radar design advanced, ASV equipment developed from a heavy, bulky installation to a compact and effective unit.

ASV radar was most effective in the antisubmarine campaign. During much of 1943. German submarines were sunk at a rate not far from one per day, two-thirds of them by aircraft attack. Almost all of the aircraft attacks developed from radar sightings.

Means were also developed for bombing ship targets accurately on the basis of the radar display. In a single month, a single squadron of the U.S. 14th air force sank 110.000 tons of Japanese shipping in the China sea, entirely at night and entirely by radar.

Air-borne Radar for Navigation and Bombing. — During trials of AI and ASV radar, it was found that microwave equipment, with its narrow beams, could give a sufficiently good picture of the terrain beneath an aircraft to enable navigation by pilotage. Cities and built-up areas returned much stronger signals than open country, and hills, rivers and coast lines were especially well defined.

The British R.A.F. bomber command pioneered in using such radar to guide its pathfinder aircraft. These planes, manned by specially chosen personnel, dropped flares on the target at which the main force aimed by ordinary optical means. The U.S. strategic air forces, committed to daytime bombing, found by experience that target visibility was often so poor that in order to maintain full operation they also needed such radar aids.

Even on occasions when target visibility was good, the radar was useful in permitting the bombers to line up correctly on their approach to the bombing run. A medium-sized city is visible for about 50 miles on radar of wartime performance; it can rarely be seen as far as this with the eye. Of the 400,000 tons of bombs dropped by the 8th air force after Nov. 1943, when this equipment (called "Mickey" or "H_2S") was introduced, more than half was aimed entirely by radar.

Beacon *Bombing* Systems.-Mention has already been made of the use of radar beacons for identification. Since these beacons give an immediate response to a radar challenge, they provide an excellent means for measuring the range to a point whose nature is known. Two such measurements based on a single point enable the exact position of such a point to be found by triangulation. Since range can be measured so conveniently and so accurately by pulse-timing methods, every precise position can be determined.

Two different bombing systems were based on this principle during World War II. In one of them, called "Oboe," the aircraft carried a radar beacon. The beacon was challenged by two ground stations, and the range of the aircraft from each station measured. Signals were sent to the plane by radio to keep it on a circular course of constant range from one station, called the "cat." The other station, called the "mouse," sent signals to the aircraft indicating the exact moment of bomb release necessary to hit the previously chosen target.

The Oboe system was highly accurate; with good ground and air crews the operational errors were less than 250 yd. from an altitude of 30,000 ft. Its limitations were that. since it depended on the ability of ground stations to see the signals from a beacon in the bombing aircraft, it would not work over the optical horizon (about 250 mi, for an altitude of 30,000 ft.); and that it demanded a high degree of co-ordination between two widely separated ground stations. Even with this co-ordination, it could handle only one aircraft at a time.

Despite the limitations of the Oboe system, the British used it quite successfully to guide the pathfinder aircraft of R A.F. bomber command. The devastation of the Ruhr, which was just within Oboe range from the United Kingdom, was carried out almost entirely with the help of Oboe.

In the other type of beacon bombing system, called "H" by the British, beacons were placed on the ground at accurately located spots, and the interrogation and display equipment was carried in the bombing aircraft. A U.S. system based on this principle, called Shoran (for short range navigation), was highly successful during World War II.

Although Shoran was subject to the same horizon limitation as that affecting Oboe, it did not suffer from as severe a limitation in traffic-handling capacity. Each aircraft could challenge the ground beacons independently of all the other planes that might be doing so at the same time. It was with Shoran that the error in the map position of Corsica, already mentioned, was discovered.

Electronic Navigation *Systems.*—The beacon bombing systems and the air-borne radar for navigation that have just been described will be recognized as navigational equipment. They were rather specialized in nature, being designed for the exacting use of leading a bomber to its target. No such accuracy is needed to facilitate the ordinary navigation of aircraft from base to base. Radio-beam navigational aids to such navigation had been in use for years, but the development of pulse-timing methods for radar led to the development of navigational aids based on the pulse-ranging principle. Among the more important systems of this sort are the British Gee and the U.S. Loran.

Air-borne *Range-finding* and Gun-laying Radar. — The vigorous opposition of German fighters to Allied bombing in the early days of World War II led to the U.S. development of light, compact radar to aid in air-to-air gunnery, intended principally to contribute to bomber defense. One type was an automatic radar range finder for optically aimed fire by daylight. Another provided complete position-finding to protect bombers against night fighters under conditions precluding optical sighting. Both of these radars became available during World War II, but at such a late date that their operational usefulness was small. In the Korean War, however, they and successor equipment proved indispensable aids to air-to-air gunnery in jet aircraft combat.

Radar *Countermeasures.*—Use of radar by the Germans and the Japanese led to a considerable Allied effort in the field of countermeasures designed to mislead enemy radar or to render it ineffective. A similar effort was mounted by the Germans and the Japanese. These countermeasures took two forms: they consisted either of electronic "jamming" or "spoofing" of enemy radar by the transmission of suitably timed signals on the appropriate frequency; or, alternatively, they involved the dispersal of material which gave confusing radar reflections and thus hid attacking aircraft.

The second type of radar countermeasure was the most important single means of confusing enemy radar. Aluminum foil, cut into strips about a half wave length long at the enemy radar frequency, was the most commonly used form of material dispersed from aircraft to give false echoes. Such material was called "window" by the British, "chaff" by the U.S. army air force, and *Dueppel* by the Germans. Long-wave radar, with its broad beams, was the most readily confused by this means. The appearance on the scope of an Allied 10-cm. radar of "window" cut to confuse the German 60-cm. radar showed false echoes which were prominent but not hopelessly confusing. German radar, however, could see the aircraft targets under these conditions only with the greatest difficulty.

For about 18 months, both the Germans and the British refrained from using this deceptive trick, on the theory that the other side was ignorant of the possibility of doing it. Once it was introduced. however, the R.A.F. bomber command dispensed in the form of window, on each full-scale raid, a weight of aluminum sufficient to construct three heavy bombers. Loss figures showed that the protection afforded by this amount of window saved, on the average, seven bombers per raid.

5. Radar Development After World War II.—At the close of World War II the main outlines of radar system design had been reasonably well defined, and many of the operational applications had been completed. In the following years radar development included improvements of components and circuitry, electronic processing of received data, increasing use of solid-state transistors and masers. introduction of genuinely new components such as ferrite duplexers and new scanning methods, both mentioned below, and many new applications.

In civil uses commercial aviation and marine vessels increasingly employed radar aids to navigation. Highway police used a simple form of CW for the detection of speeding vehicles, the Doppler shift of the reflections from moving cars enabling instant and direct measurement of their speed. Astronomers and space researchers found that radar could help map the moon and could yield usable echoes from the sun and planets.

In U.S. military uses, remarkable attainments in transmitters of ever higher power and in receivers of greater sensitivity led to extremely long-range radars for early warning of ballistic missiles. Pulse-Doppler (PD) methods, utilizing such refinements as data processing and "memory" circuits, enabled the development of supersensitive radars for use in ground surveillance and personnel detection.

Military Developments. — Military radar equipment, as such, underwent little improvement in the period between the end of World War II and the beginning of hostilities in Korea in 1950. The Korean conflict made greatly increased military budgets available, but even then only detailed improvements in radar performance took place, resulting mainly from the development of improved components. This is well illustrated by the fact that radar sets differing only slightly from the SCR-584 (development of which was undertaken in 1941 with field use beginning in early 1944) were built for equipping the NATO military forces in the mid-1950s.

The most prominent postwar trend in the design of military radar systems was toward the elimination of human beings as links between a radar indicator and the controls of a weapon system. This general development was forced on military technologists by the astounding increase in aircraft performance, the development of nuclear weapons, the appearance of successful guided missiles and by the growth of commercial aviation.

In the years following World War II. the development of jet engines tripled the speeds of relatively conventional aircraft, thus putting unprecedented demands on air warning and control organizations and on air defense generally. The leisurely human plotting-and-telling organizations of World War II clearly had to be replaced by something faster and less fallible. If antiaircraft guns were to be useful at all, they would clearly have to be controlled entirely automatically to engage such high-speed targets. The performance of fighter interceptors had increased to the point where the reflexes of a human pilot were barely adequate to control an attack; a high degree of automatic control extending from the AI radar to the final weapon—gun or rocket — was clearly required for the best results.

In the case of guided missiles, the situation was even plainer.

An interceptor missile is a fighter aircraft without a human pilot. There can be no debate about the requirement for automatic control. The same is true of long-range missiles intended for a strategic bombing role, and indeed for missiles in general. In all these cases. radar is an important part of the system as a whole.

In addition, the development of nuclear weapons, to the point at which a single well-executed air raid might utterly destroy the capability of a great country to wage war, made it imperative to have an air-defense system that would be continuously alert and effective against a single unexpected raid. At the same time, the vast growth of civil aviation translated this requirement into the need for developing a system which could keep current track of thousands of aircraft, so that potentially hostile aircraft could be distinguished and investigated (counterattacked, if necessary) before they had an opportunity to attack. Any such system obviously would require a degree of automatic operation not dreamed of during World War II.

Fortunately, the development of high-speed digital computers. begun in the late years of the war, provided the basic techniques which made it possible to mechanize the use of radar data. The most ambitious undertaking of this sort in the 1950s was the development of the semiautomatic ground environment (Sage) system, designed to control weapons defending the continental United States against air raids.

In the Sage system, high-performance ground radar sets were placed in the U.S. and Canada at locations that gave reasonably continuous coverage of aircraft, except those at very low altitude. Signals from these radars were transmitted to central control stations, each equipped with a vast computer capable of establishing and maintaining aircraft flight paths from the intermittent radar data, performing partial identification of aircraft from flight-plan information filed by friendly aircraft before take-off, assisting in the assignment of defensive fighters to investigate unknown aircraft, and doing the GCI job for fighters and interceptor missiles ordered to the attack. In addition, such defense organizations as naval units and the antiaircraft missile batteries guarding important targets could be alerted and given information on the tracks of incoming hostile aircraft.

To increase the time available to ready defenses, long-range radar installations (the distant-early-warning. or DEW, line of radars) were constructed in the far north of the North American continent. Man-made islands (Texas towers) were built on the eastern continental shelf as far out as 200 mi, into the Atlantic. Ultra-long-range aircraft equipped with high-performance radar were flown as air-borne pickets as far out as 1.000 mi. at sea.

The DEW line was designed to detect and locate aircraft while they were yet a considerable flight time distant, even at supersonic speeds. But against much swifter long-range ballistic missiles, which began to present a threat by the mid-1950s, another radar system had to be developed. Called the ballistic missile early warning system. or BMEWS, this comprised two stations in North America and one in northern England.

The first BMEWS station! which began operation in Oct. 1960 at Thule, Greenland, under U.S. air force direction, cost nearly $500~000,000. Four antenna arrays, each standing 165 ft. high and 400 ft. long. were designed to emit the highest power radiations employed up to that time in military radar. The immensely powerful transmitters, generating several million watts at peak pulse, projected two fanlike beams over the north pole and far beyond. capable of detecting a missile 3,000 mi. distant when it attained an altitude of 600 mi. Two sets of echo data. which would be received as the missile passed first through the lower beam and then through the upper one, would enable electronic calculators at Thule to predict within moments the missile's course and impact area. Thus about 15 or 20 minutes could be provided for warning and countermissile action.

During the late 1950s there were many military applications of radar besides the advanced warning and interception efforts described above. Marked progress was made in radar range and accuracy. A variety of new applications appeared. Unprecedented demands for both offense and defense uses arose from the needs of military technology in support of radically new concepts of modern armed forces in the atomic and missile era. The needs and the applications involved navigation. meteorology, bombing, mapping, missile tracking and guidance, reconnaissance and surveillance.

Combat surveillance. to illustrate only one application, resulted in U.S army requirements for radar able to detect and locate such moving targets as a creeping soldier at short ranges and moving vehicles and troops at longer distances. The need for such "intrusion detectors" led to radar systems that combined certain characteristics of both pulse and CW techniques. The consequence became a type of radar system called pulse-Doppler. or PD, discussed near the end of this article,

Several types of PD radar, for detection and location of moving targets only, were developed for sensory and surveillance uses by ground troops. A small portable set called the "silent sentry," which used transistors instead of electron tubes and could therefore be readily powered by batteries, was able to detect moving tanks, trucks or troops up to 3 mi. distant, converting the pulse-Doppler echoes into audible sounds in the earphones of the radar operator. Differences in the sound made it possible to distinguish a walking from a running man up to a half mile away. Target location could be determined with an error of less than 25 yd.

A larger medium-range system indicated moving echoes, both audibly in headphones and visually on an oscilloscope, with a sensitivity so great that the audible signals differed recognizably for tanks. trucks or troops up to 10 mi. distant, and for a creeping man up to 2 mi. away.

Military needs for detailed surveillance of large areas of enemy terrain under conditions of cloud or night (preventing normal photography) and at considerable distances from one side (safely within friendly territory) led to a remarkable air and ground radar system developed by University of Michigan scientists and the US. army signal corps. The echo signals of the air-borne radar are recorded on film during the surveillance flight. This film is developed after the plane lands and is then processed by an analogue computer. The process yields a detailed presentation of the scanned area, which appears as if it had been viewed directly beneath the airplane, although actually it lay miles to one side. The entire system thus departs radically in its signal storage and delayed output aspects from radars that give an instant visual or aural indication of targets. The system also embodies a major innovation in its unique antenna treatment. Fine radar focusing and resolution, revealing great detail at long distances as well as in the foreground. would ordinarily require an immensely wide antenna, obviously impossible to mount in an airplane.

Yet the superior effects of such a huge antenna array are attained with a 5-ft. antenna (the size that is actually employed) by coupling its action to the forward flight of the plane. The forward motion. combined with the recorded reception of echo pulses and subsequent treatment in a computer. permits a scanning and focusing effect as though the short antenna were extended many times the length of the airplane. This circumstance requires exact navigation and automatic correction of inevitable flight aberrations. Therefore, a flight navigation system, including an automatic pilot, is included in the system design. As a result the radar is kept in accurate focus throughout the surveillance flight and is focused simultaneously at all ranges. The printed product turned out by the computer resembles a photographic map with better detail at greater ranges than previously possible—revealing, for example, the individual poles of a telephone line seen almost lengthwise many miles away.

Civil Developments.—Immediately after World War II several manufacturers in Great Britain and the U.S. offered simple radar equipment suitable for coastwise navigation. Ship-borne sets generally employ microwaves in the X band (3 cm.) in order to keep the antenna size small. The rotating antenna presents upon a PPI scope the echoes from the coast lines, obstacles and other ships. Shipboard radars steadily increased in number, coming into use even in small fishing and pleasure craft.

In some ports large radar surveillance sets have been installed ashore overlooking the harbour and approach waters in order to assist shipping when visibility is bad. The radar operator observing ship movements in the confined waters advises pilots of harbour traffic conditions from moment to moment by means of radiotelephone. A notable system at Liverpool, Eng., installed in 1948, guided ships through the narrow approach waters under adverse conditions of visibility. The system utilized six PPI scopes to cover in detail (discriminating within 40 yd.) the 14 mi. of the Mersey river channel and harbour front that are kept under constant surveillance.

Proposals were also made soon after World War II for the installation of radar navigational equipment in commercial airliners and for the establishment of ground radar stations along commercial airways and at airports. The U.S. Civil Aeronautics administration, which became the Federal Aviation agency (FAA) in 1958, promoted installation at major airports of GCA radar systems by means of which traffic controllers could observe airliners approaching in bad visibility or at night, guide them by means of radiotelephone and "talk" the pilots safely down to the field. GCA had not been provided at all airports in the early 1960s, partly because pilots preferred the instrument landing system, or ILS, a radio navigation and landing aid that has long been standard equipment at many airports over the world.

GCA in this application requires two types of radar. Airport surveillance radar (ASR) scans a circle 30 mi. or more in radius around the field and displays upon a PPI scope in the control tower all aircraft within range up to within about 5 mi. Within this smaller inner circle a precision approach radar (PAR) takes over, using a limited-angle PPI or B-scope and a range-height indicator. Airport surveillance sets employ pulse modulation, and all recent types also include MTI so that operators can switch to the MTI technique if necessary in order to distinguish moving echoes (airplanes) from fixed reflections in the area being scanned.

More GCA radar of an improved type was coming into use by the early 1960s as the FAA carried out a program of installing sets with longer range and greater refinement. A high-definition radar, known as airport surface detection equipment (ASDE), that gives almost photographic clarity (using very short 1-cm. waves) in distinguishing planes and motor trucks on the field, began to be used in 1960. The first two installations were made at the Idlewild, N.Y., and Newark, N.J., airports.

Meanwhile, air-borne radars, using wave lengths of about 5 cm., were being installed in increasing numbers of large modern air transports, primarily for storm detection, enabling pilots to fly evasive courses around dangerous turbulence. Frequencies corresponding to the wave lengths of about 5 cm. were found to be best for echo reflection from storm clouds.

Radar astronomy, the study (by means of radio reflection) of the moon and other bodies in the solar system, became possible with increased transmitter power, greater receiver sensitivity and the uses of electronic computers to discriminate the extremely weak echo signals from the stronger interfering signals of inevitable noise. The radar technique enables more accurate measurement of distance than optical methods permit, and it enables study of surface structure of bodies in the solar system. Radar astronomy is closely related to radio astronomy (*q.v.*), since the supersensitive radar receiver can be used alone to listen to the many active emitters of radio waves, such as those from heat and gaseous sources within the solar system and from innumerable other sources both in our galaxy and beyond it.

The first radar contact with the moon, about 250,000 mi. away, was made by the U.S. army signal corps in Jan. 1946, using a modified SCR-271 radar. This initial success was followed in 1958 with radar reflections from Venus, some 28,000,000 mi. distant, and in 1959 by radar contact with the sun, nearly four times as far.

Both the Venus contacts (by the Lincoln laboratory of the Massachusetts Institute of Technology) and the echoes from the sun (accomplished by researchers at Stanford university) required computer techniques for study of the echo patterns. The echoes, returning minutes after the transmission because of the enormous distances involved, were so weak that they could not be immediately distinguished from the radio noises, both those received from without and those generated within the receiver circuits. But by recording the received signals and processing them with an electronic computer, researchers were able to separate out the echo pattern. From it they could determine something of the nature and characteristics of the reflecting body. With improved equipment and techniques radar astronomers expected to be able to map the planets in considerable detail.

III. FACTORS AFFECTING RADAR PERFORMANCE

1. The Free-space Radar Equation.—A radar set must detect the weak signal returned from a distant reflecting object. The radar equation is important because it connects the various quantities that govern the strength of the signal so received. This relation will not serve to determine the maximum range at which the radar can detect a target unless the minimum power which gives a detectable radar signal, $S_{\min}$, is known. The value of this latter important quantity will be found to depend on many factors. not all of which are accessible to measurement.

In discussing the radar equation, we first assume the very simple case of free-space propagation of the radio waves used in radar. This corresponds to a situation in which (1) no large obstacles intervene between the radar antenna and the target, along the optical line of sight; (2) no alternate transmission path, via a reflecting surface, exists for the radio energy; (3) the intervening atmosphere which must be traversed by the radio energy is homogeneous with respect to index of refraction at the frequency used; and (4) no appreciable absorption occurs in the atmosphere.

These conditions restrict our attention to radar targets within the optical horizon, and in fact to targets high enough above the horizon to avoid important effects (see below) which arise from the reflection of an appreciable amount of energy from the surface of the land or sea. If the conditions of free-space propagation apply. the transmitted radio wave has spherical wave fronts (limited in extent by the directional properties of the antenna) which spread out in such a way that the intensity of the radio wave changes with the inverse square of the distance from the radar antenna.

If the transmitting antenna radiated energy uniformly in all directions, the power flow through unit area at a distance R from the antenna would be the transmitted power, P, divided by $4\pi R^2$. Most radar antennas are directive, however, and concentrate the energy in certain directions. so that the power flow observed at some distant point will differ by a factor G from that which would be produced by an antenna radiating uniformly the same total power. The quantity G is called the gain of the antenna in the direction in question. Its average taken over a complete sphere surrounding the antenna must clearly be unity. As radar antennas are ordinarily highly directive. we shall usually be interested in the maximum value of G, which we call G_o. When the radiating system, or antenna, can be regarded as an aperture of large area (measured in square wave lengths), over which a substantially plane wave is excited, we can write a useful expression for the maximum antenna gain. G_o. The maximum antenna gain is related to the antenna area A and the wave length λ by the following relation:

$$G_o = \frac{4\pi A d}{\lambda^2} \tag{2}$$

For actual antennas, the dimensionless factor d is usually about 0.6.

A second important property of an antenna is its effective receiving cross section. This quantity, whose dimensions are those of area. yields the total signal power available at the terminals of an antenna when an incident plane wave of unit power per unit area falls upon it. Effective receiving cross section is related to antenna gain as follows:

$$A_r = \frac{G\lambda^2}{4\pi} \tag{3}$$

In this equation. G has been written instead of G_o to emphasize that the applicability of eq. (3) is not limited to the direction of maximum gain or to beams of special shape. Once the gain of an antenna in a particular direction has been specified, its effective receiving cross section for plane waves incident from that direction is fixed.

To obtain a measure of the amount of power reflected by the target, we define the radar cross section of the target. σ, as follows: σ is to be 4π times the ratio of the power per unit solid angle scattered back toward the transmitter, to the power per unit area in the wave falling on the target. In other words, if the power falling on an area a located at the target position were to be scattered uniformly in all directions, the power received at the radar would be just the same as it is in the case of the actual target. Ordinarily, σ must be inferred by measurements on actual targets, since it depends in a complicated way on the wave length and on the angle at which a target is viewed.

We are now ready to formulate the radar equation. If S is the signal power received, P the transmitted power. G the antenna gain. λ the wave length, σ the radar cross section of the target, and R the range, or distance between radar and target,

$$S = \left(\frac{PG}{4\pi R^2}\right)\left(\frac{\sigma}{4\pi R^2}\right)\left(\frac{G\lambda^2}{4\pi}\right) \quad (4)$$

The quantity in the first parentheses gives the power density at the target; when we multiply by the second parentheses we obtain the power which returns to the radar antenna; the last factor is the receiving cross section of the antenna. Rearranging,

$$S = P\frac{G^2\lambda^2\sigma}{(4\pi)^3R^4} \quad (5)$$

This equation contains G, not G_o, and is thus valid for any direction. Usually we are interested in the return signal when the target lies somewhere along the direction the radar beam is pointing; G should then be replaced by G_o. If we then write G_o in terms of A, according to Eq. (2), we obtain

$$S = \frac{P\sigma A^2d^2}{4\pi R^4\lambda^2} \quad (6)$$

The received signal power is proportional to the power of the transmitted signals, to the radar cross section of the target and to the square of the antenna area. It is inversely proportional to the wave length squared. and to the fourth power of the range. If the minimum signal power required for detection, $S_{\min}$, is known. we can rearrange Eq. (6) to give the maximum range of detection, $R_{\max}$, for a target of given cross section, σ:

$$R_{\max} = \sqrt[4]{\frac{P\sigma A^2d^2}{4\pi S_{\min}\lambda^2}} \quad (7)$$

To help fix ideas. it will be useful to give a numerical example of the use of this equation, with values for the quantities involved which were not unusual in wartime pulse radar practice. Let $\lambda = 0.10$ ft. ($=3.0$ cm.), P $= 10^5$ watts, A $= 10$ ft.^{2}, d $= 0.6$, a $= 100$ ft.^{2} (the radar cross section of a small aircraft) and $S_{\min} = 5 \times 10^{-12}$ watts. We then obtain $R_{\max} = 155{,}000$ ft. or 29 statute miles.

A sixteenfold increase in transmitted power is required to double the maximum range. It would appear that $R_{\max}$ could be doubled by doubling the linear dimensions of the antenna. However. this change cannot be discussed so simply, as the decrease in radar beam width resulting from making the antenna larger indirectly affects $S_{\min}$. A change in wave length is also difficult to discuss, since it produces changes in $S_{\min}$, P and possibly σ as well.

2. The Minimum Detectable Signal.—The reason that $S_{\min}$ has a finite value. and cannot be made indefinitely small, is that an amplifier intended to increase the power of a feeble electrical signal always produces random electrical fluctuations, called "noise." As the true signal entering any receiver is made weaker and weaker. it subsides eventually into the fluctuating background of noise and is no longer discernible.

The limit of sensitivity of an ordinary low-frequency radio receiver is set, not by internal noise, but by similar random disturbances which originate outside the receiver. These disturbances enter the receiver by means of the antenna, so that the effectiveness of a desired signal in competition with such interference is the ratio of signal to the interference power at the antenna terminals. The absolute level of interference power throughout the conventional radio bands (down to a few metres wave length) is so high that internal noise in a reasonably well-designed radio receiver is negligible by comparison.

The situation is different in the microwave region, where external noise interference is almost wholly negligible. Great effort has. therefore, been put on reducing the inherent noise of microwave receivers.

Quite general theoretical considerations give the result that the mean square noise voltage unavoidably generated in a receiver is proportional to the width of the band of frequencies amplified by the receiver. This band width will be denoted by B. The excellence of a receiver in respect to its noise output is usually specified in terms of an over-all noise figure. N. This quantity is more or less arbitrarily defined as the ratio to the quantity kTB of the signal power at the antenna necessary to make the output signal power equal to the mean noise power. In this definition, k is Boltzmann's constant (1.38×10^{-23} joules/degree), and the temperature T is taken as 291" K.

Over-all noise figures of 10 were not uncommon for the best post ar microwave receivers. A noise figure of 10, at a bandwidth of 3 mc.. means that an input signal of 1.2×10^{-13} watts is sufficient to increase the receiver output by an amount equal to the average noise output.

When a receiver is designed to detect pulses of duration τ seconds. there will be a best choice for the band width B. As already remarked, the average noise power increases in proportion to B. However, this does not mean that B should be made as small as possible, for when B becomes much less than $1/\tau$, the output signal power resulting from each pulse will be proportional to B^2. Experiment has shown that the best value of B is about $B = 1.2/\tau$, but it can be changed by small amounts from this best value without serious effect on performance. In the mid-1950s, a value of B near $2/\tau$ was typical of pulse radar practice.

What has just been said does not yet constitute a specification for $S_{\min}$, the minimum detectable signal. The noise with which a signal must compete for recognition is statistical in character: that is. while the likelihood of large noise peaks is small, such large peaks do occur. For example, in the output of a receiver whose band width is 2 mc., there is better than an even chance that one noise peak having more than 20 times the power of the average will be seen in an hour's observation. About 100 noise peaks greater than 10 times the average will be observed each second. This random character of the magnitude of noise peaks makes signal detection largely a game of chance. It is a game of chance in which several factors favour an actual signal, however, A true radar echo is repeated at the same point on the indicator for each successive sweep. while noise peaks occur at random locations. This important difference between a signal and noise can either be used by the indicator directly—if the indicator screen shows a stronger signal for repeated excitation in the same place—or by the eye and mind of the observer. The latter means is astonishingly effective, as has been shown by experiment. The practical effect of this phenomenon of integration. whether it occurs in the indicator or in the mind of the observer, is to make $S_{\min}$ depend upon the pulse repetition frequency, n, of a radar approximately in proportion to $1/\sqrt{n}$.

The problem of actual signal detectability is much more complicated than has been indicated here. It should be noted. however. that the very strong dependence of signal power on range shown by eq. (6) illustrates the fact that most signals which are at all detectable will be very strong.

3. Propagation of Short Radio Waves.—We shall now examine the principal ways in which propagation conditions near the surface of the earth and through the atmosphere introduce effects which are not included in the free-space radar equation, Eq. (6). This is a vast subject, and only a few of the basic considerations can be mentioned here.

Effect of a Reflecting *Surface.*—If the transmission path between radar and target lies near a reflecting surface. energy may be able to reach the target (and scattered energy to return to the radar) by way of reflection from the surface, as well as directly ifig. 3). In the case of a flat, perfectly reflecting surface, the ratio. W, between the actual power at the point B of fig. 3 and the power which would have been observed at B for free-space conditions, can be readily computed. It depends on (among other things) the phase change produced in the reflected wave by the process of reflection. This phase change depends on the angle of incidence, θ, on the state of polarization of the incident wave and on the electrical properties of the reflecting surface. In radar. only grazing angles of incidence are practically important, and only the surface of the sea is sufficiently smooth to be an

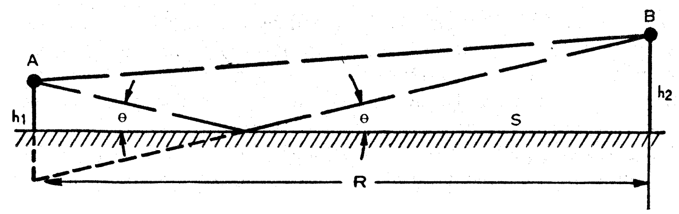


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FIG. 3.— WAVE PROPAGATION OVER A FLAT REFLECTING SURFACE. RADAR ANTENNA AT A, TARGET AT B

adequate reflector for microwaves. Under these circumstances, the ratio of the power actually reaching B to that which would reach it under free-space conditions is given by

$$W = 4 \sin^2 \left(\frac{2\pi h_1 h_2}{\lambda R}\right) \tag{8}$$

This ratio, as shown by eq. (8), varies between 0 and 4; the latter value being attained when the direct and reflected waves arrive at the target exactly in phase, as they will do when $4h_1h_2/\lambda R$ is equal to an odd integer. As the geometry of the problem is not afiected by interchanging source and target, the reflection must affect the return of the radar echo to the same degree as it affects the pulse transmission. Therefore the required modification of the radar equation is obtained by multiplying the radar equation for free-space propagation by W^2, giving

$$S = P\frac{G^2\lambda^2\sigma}{(4\pi)^3R^4} \cdot 16 \sin^4\left(\frac{2\pi h_1 h_2}{\lambda R}\right) \tag{9}$$

The effect of this modification is to introduce a strong dependence upon target height into the expression for the signal returned by a target to a radar which looks out over the surface of the sea. This is important for ship-based and coastal radar sets. Radar coverage under such circumstances shows a strong "lobe" pattern like that of fig. 4. At the maxima of the lobes, the received signal shows an increase by a factor of 16, leading to a doubling of the maximum radar range against a given target. An aircraft flying high enough to be well above the lowest lobe shown in fig, 4 will give a signal which flashes up and disappears repeatedly as the plane flies in toward the radar at constant altitude. Target height can be estimated by noting the ranges at which signal "fades" occur.

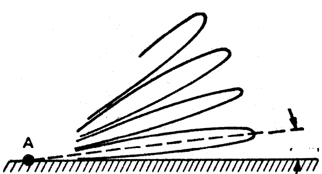

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FIG 4 —LOBES OF SIGNAL-STRENGTH PATTERN RESULTING FROM INTERFERENCE OF DIRECT AND REFLECTED WAVES

For targets at low angles (*i.e.*, in the region where $\frac{2h_1h_2}{R\lambda} < 1$) we can replace the sine in eq. (9) by its argument, obtaining

$$S = 4\pi P\frac{G^2\sigma(h_1h_2)^4}{\lambda^2R^8} \tag{10}$$

In this region of angles, the signal strength falls off as the inverse eighth power of the range, rather than as the inverse fourth power, if all other factors are held constant. Since the range at which this eighth-power dependence begins varies as the reciprocal of the radar wave length for fixed heights of radar antenna and target, the shortest radar wave lengths have a very considerable practical advantage when the primary task of radar is to search the sea for low-lying targets, the radar antenna itself being mounted at no great height.

Experiments have borne out this conclusion. and microwaves were commonly used for ship-based sea-search radar sets during and after World War II.

The *Round* Earth— Since beams of microwave radio energy travel substantially in straight lines, the distance at which a radar whose antenna is at height h_1 can see a target at height h_2 will be limited by the optical horizon. Actually, the diminishing density of the air with increasing height above the surface of the earth gives rise to a vertical gradient of atmospheric index of refraction. with the result that a slight downward curvature is introduced into all rays. The effect of this curvature is to extend slightly the practical horizon for microwaves. Due to a chance numerical relation between units, the following easily remembered formula gives R,,, the range to the horizon under "standard" conditions, for a height h above the surface of the earth:

$$R_h(\text{statute miles}) = \sqrt{2h(\text{feet})} \tag{11}$$

If we desire to find the greatest range at which a radar whose antenna is at height h_1 can see a target at height h_2, we must add the corresponding horizon distances, obtaining

$$R = R_{h1} + R_{h2} = \sqrt{2h_1} + \sqrt{2h_2} \tag{12}$$

Radio waves in the ordinary communication bands (down to a few metres wave length) are propagated over the horizon by either of two eifects. At the longest wave lengths, the energy is bent over the horizon by the phenomenon of diffraction; but energy can also travel around the curve of the earth, far beyond the horizon, because of the reflection of radio waves from the ionosphere, the ionized layer in the upper atmosphere. At radio frequencies around 100 mc. there is little reflection from the ionosphere; in the microwave region, from about 1.000 mc. up to higher frequencies, the ionosphere is transparent to radio waves. Thus neither diffraction effects nor ionospheric reflection can enable microwave radar to detect targets over the horizon, but there is some extension of range due to refraction in the lower atmosphere.

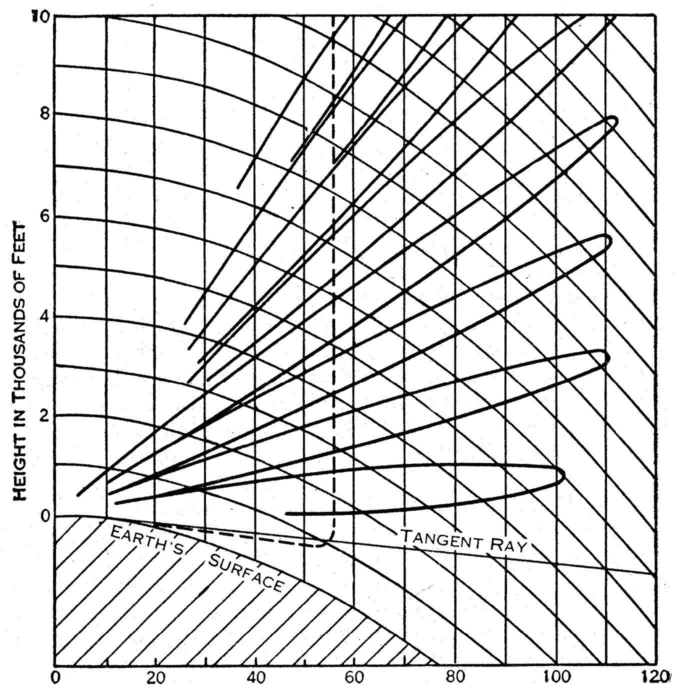

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FIG 5 — COVERAGE DIAGRAM FOR 2,600 MC RADAR WITH OMNIDIRECTIONAL ANTENNA AT HEIGHT OF 120 FT. SOLID CURVE FOR TOTALLY-REFLECTING EARTH. DOTTED CURVE FOR NONREFLECTING EARTH

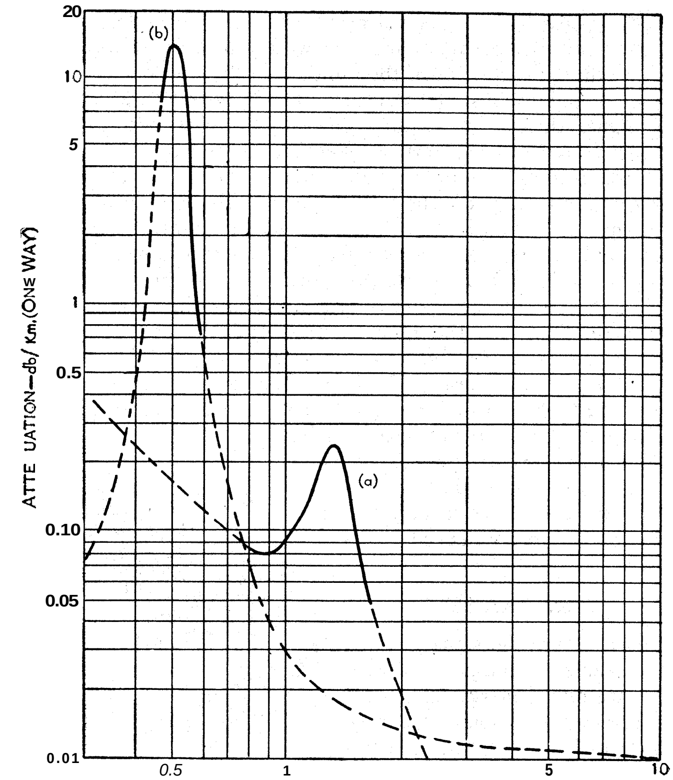

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FIG. 6.— ATTENUATION CAUSED BY WATER VAPOUR (CURVE *a*) AND BY OXYGEN (CURVE *b*) AS A FUNCTION OF WAVE LENGTH. CURVE a APPLIES TO AN ATMOSPHERE CONTAINING 10 GRAMS OF WATER VAPOUR PER CUBIC METRE. CURVE b APPLIES TO AN ATMOSPHERE WHICH IS 20% OXYGEN AND HAS A TOTAL PRESSURE OF 76 CM. OF MERCURY

Within the horizon. the curvature of the earth complicates somewhat the geometry of the interference problem involving reflection Eq (9) and (10) are not strictly applicable. for they were derived on the assumption of a flat reflecting surface The result of taking the earth's curvature into account can be shown by means of a coverage diagram (fig. 5). The curves of fig. 5 are contours of constant field strength. which means that the signal received from a given target will be the same no matter where it is located along a given contour.

Superrefraction.—It has already been mentioned that the atmosphere normally shows a vertical gradient of refractive index that results in a slight downward bending of rays of light or microwaves. Were this curvature only a few times greater, it would equal the curvature of the earth; under such conditions the "horizon" would vanish and a ray would bend around the earth aithout leaving the surface. Refractive index gradients of the magnitude necessary to produce such curvature amount to about five parts in 10^8 per ft. Under some conditions such gradients can be produced by temperature gradients alone, or, more commonly. by a vertical gradient in the concentration of water vapour in the atmosphere. Over the surface of the sea, the effects of evaporation of water into the air immediately above the surface and the diffusion of water vapour into still higher layers of air lead sometimes to the creation of a relatively shallow layer just above the water within which the vertical gradient of refractive index is negative and exceeds the critical value of five parts in 10^8 per ft.

In such circumstances, superrefraction takes place, and it is possible for microwaves to be propagated to distances many times the usual horizon distance. This phenomenon is specially common in certain parts of the world where climatic conditions favour its occurrence.

Atmospheric Attenuation —At the shortest microwave lengths, the earth's atmosphere is not entirely transparent, as it is for all practical purposes to waves of frequency lower than about 1.000 mc. The loss of energy, or attenuation, of a radar beam traveling through the atmosphere may be due to either of two causes: (1) direct absorption of energy in the gases of the atmosphere; or (2) absorption and scattering of energy by condensed matter such as raindrops. All such processes lead to an exponential decrease of energy in the beam with increasing distance from the source.

This exponential decrease is superimposed on the inverse-square decrease in energy with increasing range that was used in formulating the radar equation. Of the atmospheric gases. oxygen and water vapour absorb microwave energy in the frequency range experimentally used for radar. This absorption is due to the production thereby of a transition of the molecule of water vapour or of oxygen between two definite energy states. The observed absorption is thus characterized by "lines." such as those found in more familiar regions of the electromagnetic spectrum. Experimental results (solid lines) and their theoretical extension (dotted lines) are shown in fig. 6.

Energy is also absorbed and scattered by particles of solid and liquid in the atmosphere. Droplets of water, present as fog, cloud or rain. are practically the most important particles of this sort. The attenuation by water droplets is of little practical consequence at wave lengths of 10 cm. or more, although sufficient energy is scattered from storm areas to give radar echoes at all microwave lengths.

At wave lengths shorter than 10 cm., increasing attenuation is observed. Experimental results are given in fig. 7.

4. Target Properties. — Some useful things can be said about the radar cross section, σ, of various targets. In the case of the simplest single targets, σ can be calculated by electromagnetic theory; for other simple cases an approximate calculation will yield good results. A few values of radar cross section of such simple targets are collected.

(1) Dielectric sphere of radius small compared with wave length. Sphere radius a, dielectric constant ϵ, wave length λ.

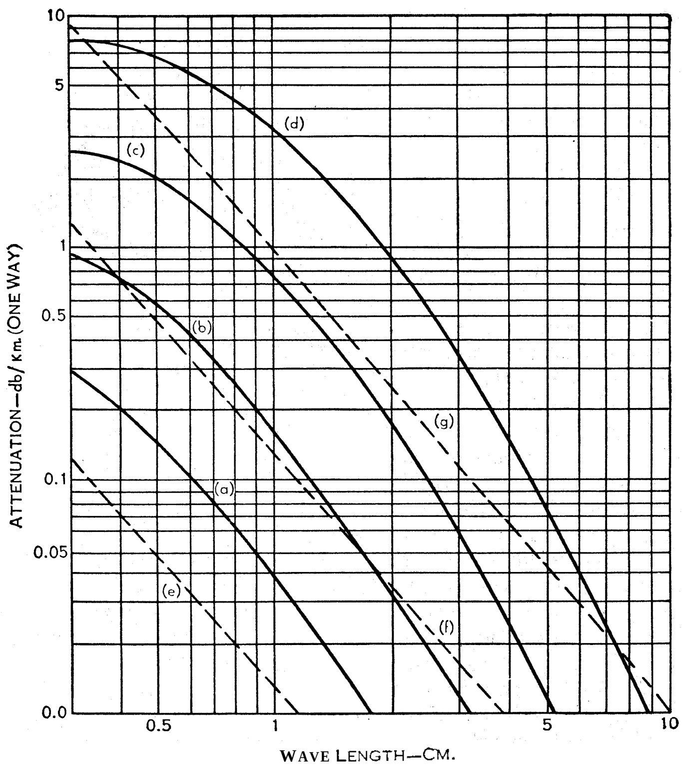

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FIG. 7.— ATTENUATION OF SHORT RADIO WAVES IN RAIN (SOLID CURVES) AND FOG OR CLOUD (DOTTED CURVES). CURVE a. DRIZZLE (0.25 MM./HR.). CURVE b, LIGHT RAIN (1.0 MM./HR.). CURVE c, MODERATE RAIN (4 MM./HR.). CURVE d, HEAVY RAIN (16 MM./HR.). CURVE e. FOR VISIBILITY ABOUT 2.000 FT. (0.032 GRAMS WATER PER CU. METRE). CURVE f FOR VISIBILITY ABOUT 400 FT. (0.32 GRAMS WATER PER CU. METRE). CURVE Q FOR VISIBILITY ABOUT 100 FT. (2.3 GRAMS WATER PER CU. METRE)

$$\sigma = 4\pi\left(\frac{2\pi}{\lambda}\right)^4 \left|\frac{\epsilon - 1}{\epsilon + 2}\right|^2 a^6 \qquad (13)$$

(2) Metal sphere of radius small compared with wave length.

$$\sigma = 9\left(\frac{2\pi a}{\lambda}\right)^4 a^2 \qquad (14)$$

(3) Flat metal sheet of area *A* placed perpendicular to radar beam. Dimensions of plate large compared with wave length.

$$\sigma = \frac{4\pi A^2}{\lambda^2} \qquad (15)$$

(4) Cylinder of radius R and length 1, both large compared wirh wave length. Cylinder is viewed perpendicular to axis.

$$\sigma = 2\pi\frac{Rl^2}{\lambda} \qquad (16)$$

(5) Segment of spherical surface of radius R, viewed either on concave or convex side. Diameter of segment, perpendicular to the incident beam, must be greater than λ.

$$\sigma = \pi R^2 \qquad (17)$$

Eq. (17) is also valid for a nonspherical curved surface, if the geometric mean of the two principal radii of curvature is used for R.

An important type of simple target is the corner reflector. This is used when a compact radar' target with a large cross section in any direction oi observation is desired. It consists of an arrangement of three planes intersecting at right angles. The law of optical reflection yields the result that a ray directed into the corner formed by three such planes will undergo triple reflection and be sent back in the direction from which it came (set: fig. 8). The maximum radar scattering cross section of such a corner, which it exhibits when viewed along the axis of symmetry of a single corner, is

$$\sigma_{\max} = \frac{4\pi a^4}{3\lambda^2} \qquad (18)$$

where a is the length of an edge of the corner and λ the radar wave length. The cross section remains large over most of the octant for which a single corner is effective; all directions can be covered by making a cluster of eight such corners (fig. 9).

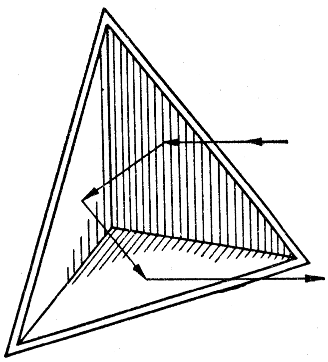

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FIG. 8.—PRINCIPLE OF THE CORNER REFLECTOR

Radar cross section can be reduced by the use of materials absorbent at. radar frequencies. Such materials are of two principal types. In the first kind, reflections occurring at the front surface of the absorber are cancelled by destructive interference with the wave that enters the layer and subsequently re-emerges. Such absorbers are similar to the anti-reflection coatings applied to glass. Absorbers of the second kind are designed so that no reflection takes place at the front surface and high attenuation in the material extinguishe's the entering wave. A continuous gradation from one kind of absorber to the other exists.

During World War II, the Germans produced a material of the first kind which was used for the camouflage of U-boats, to lessen the likelihood of radar detection of a surfaced submarine. An absorber of the second kind, which was never actually used. was also produced by the Germans. Its absorption was excellent uver the wave length range from 4 to 13 cm.

Complex Targets.—Most radar targets are much more complicated than the simple ones so far mentioned in this section. For such complex targets. the effect of interference of waves reflected frorn various parts of the target is extremely important in determining the strength of the received signal.

Ground "Painting" by Radar.— Air-borne radar equipment mas extensively used in military aircraft during World War II for navigation by piloiage under conditions of restricted visibility. Point-to-point variations in the radar reflection properties of the earth's surface enable the radar indicator to display a picture which, at best, shows a good relation with a map. Radar displays a marked contrast between land and water surfaces because of the greater diffuse scattering of the radio waves by the iormer.

Cities and groups of structures on the ground return a bigger signal than open country. possibly in part because of the retrodirectivity of the corner reflectors formed by building walls and the ground. Mountains and ridges can be distinguished by increased intensity on the near side and shadows cast beyond. The higher definition available with narrow-beam equipment using the shortest microwave lengths is important in giving a display which is easy to interpret. In all cases. however, experience and skill of the operator are important in making a good correlation between the radar picture and the ground beneath, especially inland in rather featureless country. Misidentification is so easy under these and other circumstances that air-borne radar must be regarded as an aid to dead reckoning, rather than a complete means of navigation in itself.

When the aircraft position is known to an accuracy of 20 or 30 mi., the radar display can hardly be interpreted incorrectly, even by an inexperienced operator.

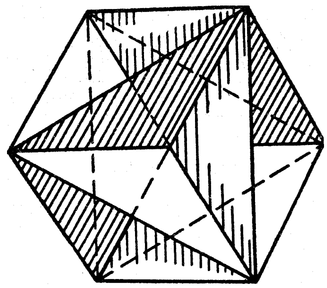

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FIG. 9.—CLUSTER OF CORNER REFLECTORS

IV. CW RADAR SYSTEMS

Since radar echo signals are so very feeble in comparison with the transmitted energy, they must be detected by some property which differentiates them from the transmitted signal in a readily measurable way. In pulse radar, this is done by turning off the transmitter for most of the time, so that signals received during the "off" time of the transmitter can be identified as echoes. It is possible to recognize echoes, however, even while the transmitter is working, on any of several schemes. Radio detection devices that involve a transmitter duty ratio of as much as 10% (in pulse radar this duty ratio is typically 0.1%) will be lumped here under the name CW radar. Devices of this sort have found important practical applications. (See NAVIGATION.)

If the targets of principal interest all have a radial motion relative to the radar. their echo signals can be distinguished by the frequency shift which is a consequence of the reflection of waves from a moving mirror. This frequency shift. f_d, is given by $(2v_r/c)f$, where v_r is the radial velocity, c the velocity of light and f the unmodified radar frequency. Numerically, with v_r in statute miles per hour and f defined by a wave length λ in cm. (equal to c/f), the frequency shift, which is called the "Doppler frequency," is given by

$$f_d = 89.4\frac{v_r}{\lambda} \qquad (19)$$

Thus at 10-cm. wave length. v_r amounts to about 9 c.p.s./m.p.h.

The Doppler-shifted return signal, when added to the transmitter voltage and rectified! gives rise to a voltage with small pulsations recurring at the Doppler frequency. The steady component can be removed by a high-pass filter (which may be simply a transformer or a series condenser) and the fluctuations then amplified and used to actuate an indicator. If the output signal is fed to ordinary telephone receivers, the ear can detect signals denoting the presence of a moving target over the range of World War II aircraft speeds. if the radar works at 10-cm. wave length.

CW radar systems of the type just described. with suitable technical modifications that do not affect the principle of operation, were built during World War II. 'Although they were not used in actual combat, they proved most useful in making precise measurements of the velocities of projectiles.

The system just described, though measuring the radial velocity of a target in a simple and accurate way, affords no information regarding target range. To measure range; the outgoing wave must be marked or modulated in some way, and the time re-

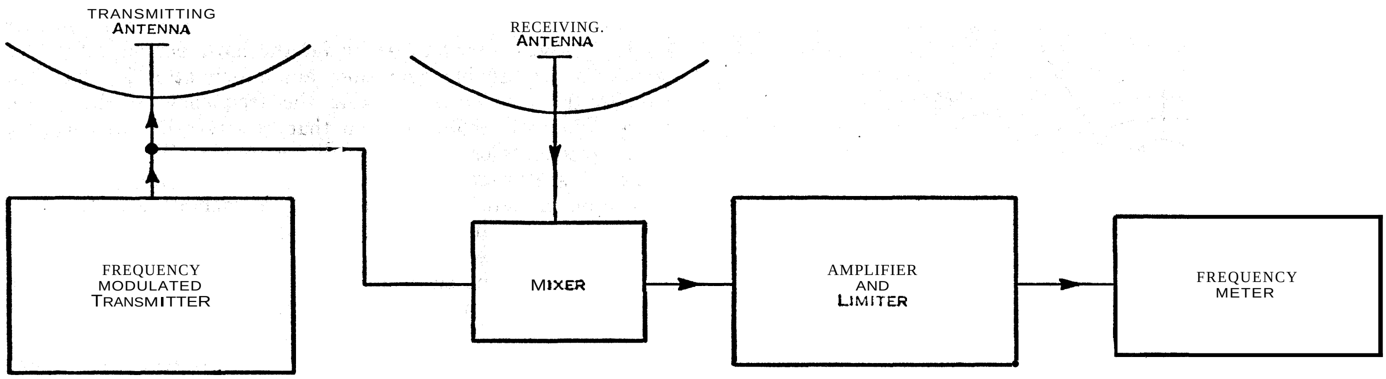

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FIG. 10.—SIMPLIFIED BLOCK DIAGRAM OF FREQUENCY-MODULATED CW RADAR SYSTEM FOR MEASURING RANGE

quired for the marks on the wave train to return as an echo must be measured. Either amplitude modulation (AM), or frequency modulation (FM), of the outgoing wave can be used.

The most familiar way of employing AM is that of pulse radar to determine the time delay between the transmission and reception of a pulse. However, we can also measure range by the use of two separate CW radar systems like the one described above, the transmitter frequencies of the two differing by an amount f_r. Let f_t be the frequency of one transmitter and $f_t + f_r$ that of the other. The Doppler frequencies developed by the two systems when they look at a single target moving radially will differ, since these Doppler frequencies involve the transmitter frequency, as eq. (19) shows.

If the target is very close to the system, the number of wave lengths in the distance from transmitter to target and back is very nearly the same for the two systems, since their frequencies differ only slightly. Thus the transmitter signal and the target signal will be in phase or out of phase with one another at the two receivers simultaneously, and the two Doppler outputs will be in phase for very short range. As the target gets farther away, one Doppler signal shifts phase more rapidly than the other, so that a phase difference between the Doppler outputs of the two systems is developed. When the target is far enough away so that the number of wave lengths to the target and back is one greater for $f_o + f_r$ than it is for f_r, the phase difference in the outputs is 2π. This phase difference, which is given by

$$\phi = \frac{4\pi f_r}{c} r \tag{20}$$

where ϕ is the phase shift, r the range, and c the velocity of light. is a linear function of range and can be used as a measure of range. It becomes ambiguous for targets so far away that the phase shift is greater than 2π.

1. Range Measurement by **FM.**—One of the most important applications of CW radar systems during World War II was their use for the measurement of the altitude of aircraft with reference to the earth or sea below. A system employing frequency modulation of the transmitted signal was developed for this purpose in the U.S., and independently a very similar system was worked out in Germany.

A schematic diagram of the system components is shown in fig. 10; the operating principle of the system is illustrated by the curves of fig. 11. The transmitter frequency varies linearly with time in the fashion shown. Energy arrives at the receiver both directly from the transmitter and by reflection from the target. Since the trip to the target and back takes time, the received frequency (indicated by the dotted line) is displaced along the time axis relative to the transmitter frequency. The two frequencies combine in the mixer to give a beat of constant frequency (except during the short crossover intervals when the sign of the FM is changing). The greater the target distance, the greater this beat frequency; its magnitude is a direct measure of the range. The beat signal between transmitter signal and echo is therefore amplified, and its frequency measured by a direct-reading frequency meter which can be calibrated in terms of range.

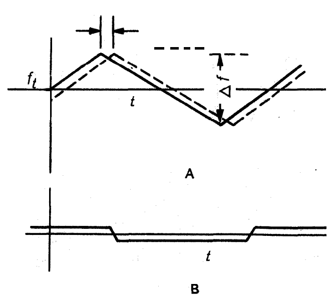

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FIG. 11—PRINCIPLE OF FM RADAR ALTIMETER

If it is desired to use this same principle for radar search, several targets may give return signals simultaneously. The receiver output will then contain several signals at different frequencies. These can be individually detected either by a frequency meter which will respond to and indicate several signals simultaneously, or by scanning a single-frequency meter over the frequency range corresponding to the target distances which must be covered. The vibrating-reed frequency meter will serve as an example of the first technique. In the second method, for example. a variable frequency can be added to the output signal and observations made when the beat frequency between the two signals falls in the pass band of a resonant circuit. Scanning devices are usually objectionable because they increase the time necessary to make an observation.

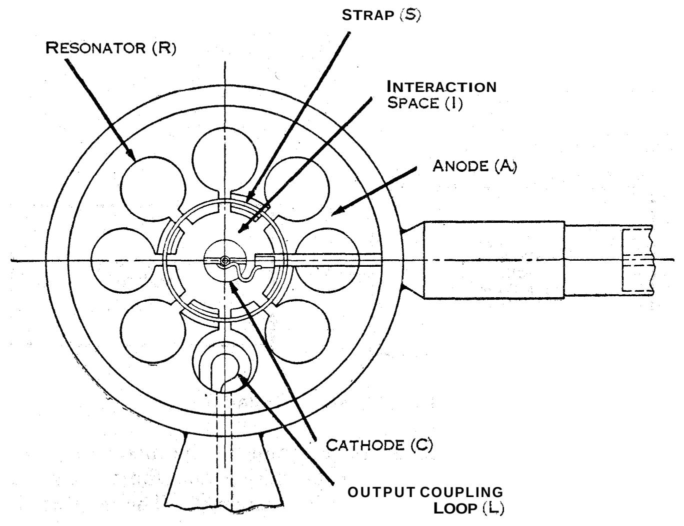
In addition to the CW radar systems whose operating principles have been sketched, there are many other types that involve different schemes of modulation of the transmitted signal and different techniques for handling the received echo. Though the amount of wartime development work which went into such CW systems was only a tiny fraction of that expended on pulse radar, there are applications for which CW radar is markedly superior.

For example, in accurate measurement of ranges as small as ten feet, a CW system is simpler than pulse radar. A system making use of the Doppler shift in frequency will measure the speed of a bullet in an easy and direct way and to any desired degree of accuracy. Or again, simple equipment may be desired, as in the familiar speed-detector radar employed in policing highway traffic, involving operation at short ranges (using microwaves of about 1 cm. in length).

V. RADAR COMPONENTS

1. The Multicavity Magnetron.— Beginning about 1938, the British made strenuous efforts to develop sources of high-power pulses at microwave frequencies, because of the importance of narrow radar beams in the air-borne equipment they were then attempting to develop. The modification of conventional tube types offered little promise; since to a first approximation, the electronic characteristics of a low-frequency tube are maintained at high frequency only if all tube dimensions are scaled in proportion to the wave length, λ. Near 1,000 mc., the practical consequences of this reduction in tube dimensions become serious. Electrode clearances become so small they are hard to maintain, while the reduction in cathode and plate areas (proportional to X^2) rapidly reduces peak emission and plate power dissipation.

An entirely new type of tube, the multicavity magnetron. was invented to serve the new requirement. By the 1950s, magnetrons had produced pulse powers as high as 10,000,000 watts at fre-



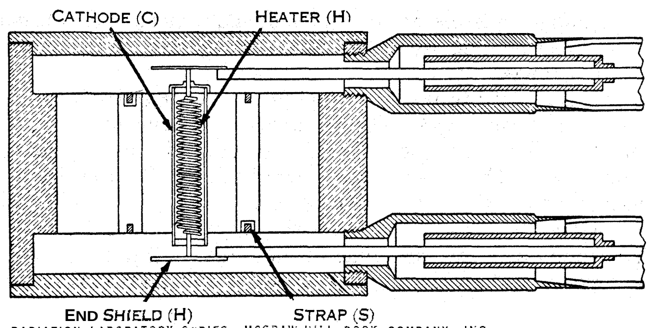


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FIG. 12.— CROSS SECTIONS OF A TYPICAL CAVITY MAGNETRON. MAGNETIC FIELD PERPENDICULAR TO UPPER FIGURE: VERTICAL IN LOWER FIGURE

quencies near 3.000 mc., and hundreds of kilowatts even at 24,000 mc. Klystrons are useful sources of continuous R.F. power at frequencies as high as 24,000 mc. and can also be designed to give high pulse power.

The magnetron is a self-excited oscillator capable of converting D.C. power into R.F. power with high efficiency. The main features of the design of a typical magnetron are shown in fig. 12. Between the indirectly heated cylindrical cathode C and the anode block A is an interaction space I, in which the conversion takes place. A constant! uniform, magnetic field is maintained in this interaction space in a direction parallel to the axis of the cathode. The anode block is pierced in a direction parallel to the field by a number of resonating cavities R, which open into the interaction space so that the inner anode surface consists of alternate segments and gaps. At the ends of the cavities are open "end spaces" which permit lines of magnetic flux to link one resonator to the next. Coupling between the resonators is increased by conducting bars called straps, S, which connect together alternate anode segments, An output coupling loop. L, extracts R.F. power from one resonator and feeds it to the output circuit.

Each of the eight resonant cavities shown in fig. 12 can be thought of as a simple oscillating circuit consisting of lumped inductance L_o and capacity C_r. When the magnetron is oscillating in the desired way, the capacities of the individual cavities are connected in parallel, and so are their individual inductances. The frequency of the magnetron as a whole is then about the' same as that of an individual cavity, since the frequency is proportional in either case to the product of inductance and capacity. The impedance of the oscillators, however, depends on L_o/C_o, and magnetrons of the same frequency but different impedance can be constructed by changing the shape of the individual resonators to keep L_oC_o constant while altering L_o/C_o.

Like all systems of coupled individual oscillators, the resonant systems of a magnetron can oscillate in different modes; in general these modes will have different frequencies. One of these modes has been found to be by far the most desirable from the standpoint of reliable operation, and much attention has been paid to the problem of making the frequency of the desired mode sufficiently different from that of any other to encourage the magnetron to oscillate in the desired mode. The straps shown in fig. 12 are primarily for this purpose of accomplishing mode separation in frequency; another way of achieving such separation is to make the alternate individual resonators of different natural frequencies.

Instead of a tube such as that of fig. 12, intended to be put between the poles of an electromagnet or a permanent magnet, a tube can be built in which the magnet pole tips are actually part of the construction of the magnetron proper. In this way, the air gap over which the magnetic field must be maintained is cut down, and as a result the required magnetomotive force (and the physical size of the magnet) can be greatly reduced. Permanent magnets are usually employed with magnetrons.

An electron in the interaction space is acted on by a constant magnetic field parallel to the cathode axis, a constant radial electric field resulting from the D.C. voltage applied between anode and cathode! and the rapidly-varying electric field extending into the interaction space from charges momentarily concentrated near the ends of anode segments. Such an electron is also part of a space charge subject to extreme variations in density. The very complex problem of the resulting electron motion has not been solved in detail, but a qualitative idea of the major processes responsible for magnetron behaviour can be given.

A simplified picture of the tnotion of individual electrons is offered in fig. 13. The distribution of charges shown on the anode segments is that appropriate to the desired mode of magnetron operation. The dotted lines with arrows show the resultant electric field. An electron located at point A at the instant shown will be speeded up by the R.F. field. The result of an increase in the tangential velocitv of an electron is. under the field conditions obtaining in the magnetron, to increase the curvature of the electron's path. The electron thus moves along the path shown, strikes the cathode, and plays no further role in the operation of the magnetron.

An electron at point B, however, is in a decelerating R.F. field; the curvature of its path will thus be decreased. If the frequency

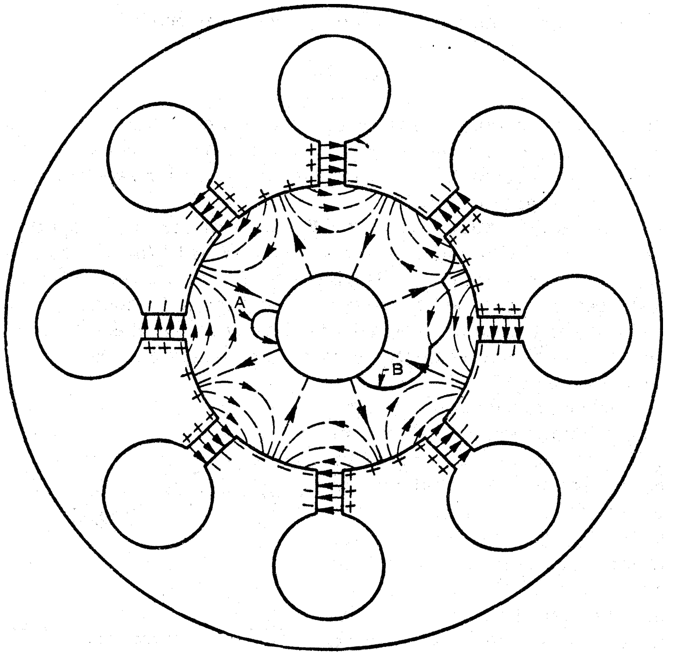

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FIG. 13.— PATHS OF ELECTRONS IN THE INTERACTION SPACE WHEN MAGNETRON IS OSCILLATING. ELECTRON AT A WOULD TAKE ENERGY FROM R.F FIELD BUT HITS CATHODE AS A RESULT OF SPEEDING UP AND IS THUS REMOVED FROM SPACE CHARGE ELECTRON AT B CONTRIBUTES ENERGY TO R.F. FIELD, THUS SUSTAINING OSCILLATIONS

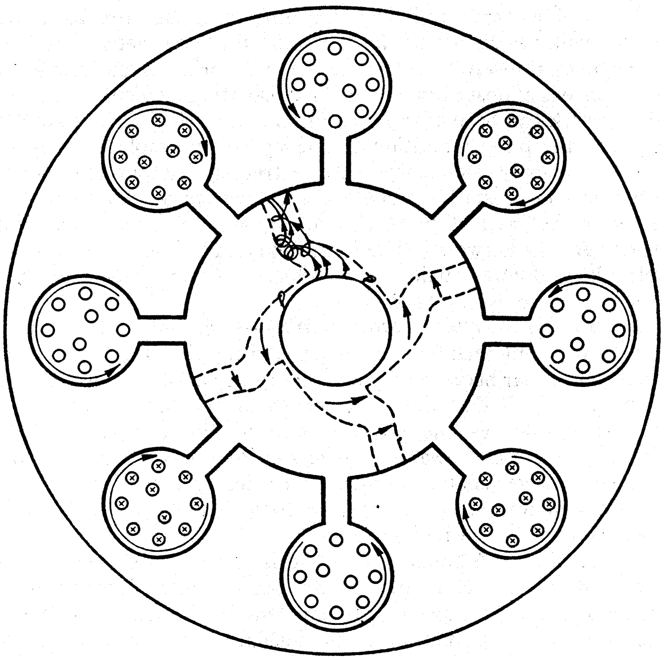

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FIG. 14.—SPACE-CHARGE DISTRIBUTION IN AN OSCILLATING MAGNETRON INSTANT SHOWN IS THAT OF ZERO R.F. ELECTRIC FIELD LINES OF R.F. MAGNETIC FIELD ARE INDICATED WITHIN CAVITY RESONATORS

of oscillation is appropriate to the motion of the electron, this electron will always be in a decelerating field as it passes before successive anode segments. It will then follow a path of the sort shown, and eventually strike the anode. Since the electron is always retarded by the R.F. field. it gives up to the R.F. field practically all of the energy gained in its fall through the D.C. field between cathode and anode. While this simple picture is qualitatively correct, the detailed operation of a magnetron is doubtless much more complicated. One experimental fact difficult to explain, for example, is that the anode efficiency of some magnetrons can be as high as 85%.

The behaviour of the space charge in the interaction space can be inferred from what has been said about the motion of an individual electron. The result is shown in fig. 14. Four spokes of high electron density contain those electrons which are in the proper position to be decelerated by the R.F. field. This configuration rotates about the cathode with an angular velocity which keeps it in step with the alternating R.F. charges on the anode segments. The R.F. current flowing in the oscillators is principally a displacement current produced by this rotating space charge. Fig. 14 shows the space charge at an instant when the R.F. electric field is zero; the lines of magnetic field in the resonators are shown.

The behaviour of a magnetron with changes of anode current and of pulse voltage can be displayed on a performance chart, which shows how these parameters affect frequency, power, magnetic field and efficiency under conditions of constant R.F. load.

The magnetron as it has so far been described is a fixed-frequency device. However, several different schemes have been worked out for tuning cavity magnetrons. In one way or another, each of these schemes involves loading the resonators so as to change their natural frequency of oscillation.

2. Pulse Modulators.—The modulator, or pulser, of a radar set is a somewhat unusual electrical device. It must supply, in the form of electrical pulses whose duration is in the range from 1/10 to 5 μ sec., currents of some tens of amperes at voltages as high as 50 or 60 kv. These pulses must be generated with a recurrence frequency of a few hundred to a few thousand per second, usually must be accurately spaced relative to one another and, since the magnetron is such a highly nonlinear load, they must be "flat" on top to better than 5% of the rated pulse voltage. In a typical case, a variation in pulse voltage of only 3 kv., will produce, in a magnetron operating at 25 kv. and 13.5 amp., a drop in anode current of 7 amp., which practically stops the oscillation of the magnetron.

In all pulsers, electrical energy stored in some circuit element is released rapidly during the pulse, and replenished during the interval between pulses. Energy can be stored either in the electrostatic field of a condenser or in the magnetic field of an inductance carrying a current. Pulsers employing electrostatic energy storage are far more common than those using an inductance as the storage element, largely because power losses in the latter type of pulser are ordinarily much greater for the same useful pulse output.

The following discussion refers to pulsers using electrostatic energy storage.

The basic circuit of a pulser is shown in fig. 15. If the energy-storage element is a condenser of capacity C, charged to a voltage V, the stored energy is $\frac{1}{2}CV^2$. At $t = 0$ the switch S is closed, and the condenser begins to discharge exponentially through the load resistance. If S is now opened suddenly at a time τ small compared with the time constant R_LC of the circuit, the voltage appearing across the load while the current is flowing is given by

$$V_L(t) = V(1 - \frac{t}{R_LC}), \qquad 0 \geqslant t \geqslant \tau \tag{21}$$

which is constant within a few per cent if $\tau < R_LC$.

In practice. vacuum tubes are the only switches that can be used to open the load circuit suddenly while it is still carrying a large current. The plate resistance of such tubes is always rather large, resulting in a high voltage drop across the switch during the pulse, and a corresponding loss in pulser efficiency. It would be desirable to use a very low-resistance switch, such as a spark or gaseous discharge, to eliminate this difficulty. However, all such devices have the property that the current flow through them, once started, cannot be interrupted until the voltage across the switch has fallen to an extremely low value. Thus, if such a low-resistance switch were used with a pulser having a simple condenser for an energy-storage element, the condenser would have to be completely discharged at each pulse. This is unsatisfactory, since the wave shape of the output pulse would then be exponential, instead of being substantially rectangular, as desired.

If, however, a transmission line is used as an energy-storage element instead of a condenser, its discharge properties under the appropriate load conditions are such that it will supply energy at constant current until it is completely discharged, This is exactly what is wanted for the generation of rectangular pulses. Elementary transmission-line theory shows that if a line of inductance L and capacity C per unit length is charged to a voltage V and then suddenly connected across a resistance R_L, a discontinuous current of magnitude $V/(Z_0 + R_L)$ will flow for a time $2t$, where Z_o is the characteristic impedance of the line $(= \sqrt{L/C})$ and t is its one-way transmission time. If $R_L = Z_o$, no current flows after a time $2t$, and a genuinely rectangular pulse has been generated. The time t is given by $l\sqrt{LC}$, where l is the physical length of the line.

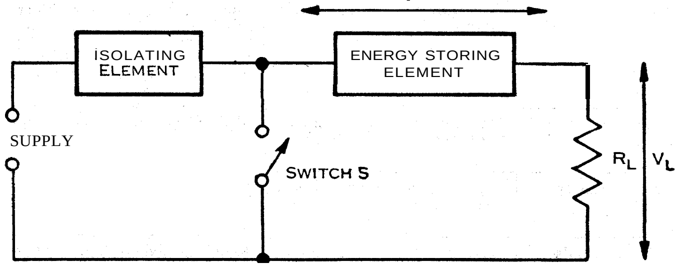

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FIG. 15.—BASIC CIRCUIT OF A PULSER EMPLOYING ELECTROSTATIC ENERGY STORAGE

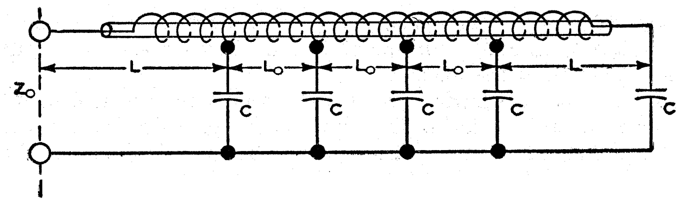

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FIG. 16.— SCHEMATIC DIAGRAM OF A PULSE-FORMING NETWORK. NUMBER OF MESHES REQUIRED DEPENDS ON DURATION OF PULSE

Since the pulse durations desired in radar are usually a microsecond or more, it is ordinarily impracticable to use actual transmission lines or cables in pulsers; a cable to supply a 1-μ sec. pulse would be about 500 ft. long. Instead, an "artificial line" (fig. 16) made up of properly chosen inductances and condensers is used. Such an artificial line is sometimes called a "pulse-forming network." A pulser employing a network as storage element is less flexible than one which uses a condenser and hard-tube switch, since the properties of the network itself fix the pulse duration and the load impedance. Components available for network construction make it desirable to give the network a low impedance; 50 ohms is typical. The magnetron load usually has a much higher impedance, in the neighbourhood of 500 ohms. Specially designed "pulse transformers" are used to match the load impedance to that of the network.

Devices used as the low-impedance gas-discharge switch in a network pulser include rotary spark gaps, fixed spark gaps in series, fixed gaps with an auxiliary electrode for triggering (called "trigatrons"), and thyratrons using either mercury or hydrogen as the filling gas. Hydrogen thyratrons were developed specifically for radar pulsers, and have the advantage over heavy-gas thyratrons in that they can pulse at much higher frequencies, because of the higher ion mobility in hydrogen.

The charging circuit used with either type of pulser so far considered—the "hard-tube" pulser which uses a single condenser as storage element, or the "network" pulser which uses a low-voltage switch—is an important part of the circuit. In the hard-tube pulser, the energy source must clearly supply direct current for recharging. The isolating element prevents excessive power from being drawn out of the energy source when the switch is closed (fig. 15), and must also permit sufficient energy to flow in the interpulse interval to replace that used during the pulse. In the hard-tube pulser, it can be either a high resistance, an inductance or a series combination of resistance and inductance.

In the case of the network pulser, on the other hand, the full energy of the charged network must be supplied by the recharging circuit after each pulse. This means that a resistance is a very inefficient isolating element, for as much energy will be dissipated in it, each time the network is recharged, as is usefully stored in the network. Accordingly, an inductance is almost always used as an isolating element. Further. the network can be recharged from an alternating-current source, provided the pulse repetition frequency is a multiple of one-half the A.C. supply frequency. An extremely simple high-power pulser can be made by mounting a rotary spark gap switch directly on the shaft of the A.C. machine supplying the recharging current for the network. The hard-tube and the network types of pulser have different fields of usefulness. A comparison of their properties is shown in Table I.

TABLE *I.—Comparison of the Two Pulser Types*

Characteristics	Hard tube pulser	Network pulser
Efficiency	Lower; more power required for auxiliary circuits and for dissipation in switch tube	High, particularly when pulse-power output is high
Pulse shape	Better rectangular pulses	Poorer rectangular pulse, particularly through pulse transformer
Impedance matching to load	Wide range of mismatch permissible	Smaller range of mismatch permissible (+ 20–30%). Pulse transformer will match any load, but power input to nonlinear load cannot be varied over a wide range
Interpulse interval	May be very short; as for coding beacons (*i.e.*, 1 μ sec.)	Must be several times the deionization time of discharge tube (*i.e.*, 100 μ sec.)
Voltage supply	High-voltage supply usually necessary	Low-voltage supply, particularly with inductance as isolating element
Change of pulse duration	Easy; switching in low voltage circuit	Requires high-voltage switching to new network
Circuit complexity	Greater, leading to greater difficulty in servicing	Less, permitting smaller size and weight

3. Radio-frequency Components.—A considerable body of new theory and technique grew up during the development of microwave radar because of the necessity of handling power at frequencies so high that the wave length of the R.F. energy is of the same order as the physical size of the circuit elements. The length of a microwave transmission line may be. and usually is, several wave lengths. For a fuller description of R.F. techniques at microwave frequencies, reference should be made to the works quoted in the bibliography.

***Coaxial Line.*—A** transmission line is characterized, as already remarked, by a characteristic iinpedance which depends upon the inductance and capacity per unit length of line, and is thus a function of the geometry of the insulators and conductors of which the line is made. In a coaxial line, a type frequently used for the transmission of high-frequency energy (fig. 17), the

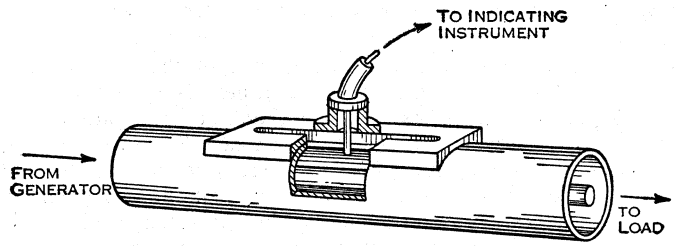

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FIG. 17.— SLOTTED SECTION OF COAXIAL LINE WITH PROBE FOR MEASURING STANDING WAVES

characteristic impedance, Z_o, is given by

$$Z_o = \frac{138}{k} \log_{10}(r_2/r_1) \text{ ohms} \tag{22}$$

where k is the dielectric constant of the material in the annular space between the conductors, r_2 is the inner radius of the outer conductor, and r_1 is the outer radius of the inner conductor.

A uniform line terminated at any point in a load duplicating its characteristic impedance behaves as if it were infinitely long; there is no reflection of energy from the termination. However. any impedance changes along the line (such as those introduced by dents. bends or obstacles in the line), or any departure of the load from the characteristic impedance of the line, will cause the reflection of energy. The reflected wave, which travels back toward the power source, interferes with the outgoing wave to produce standing waves in the line. These can be detected and measured by exploring the voltage along the line with a small movable probe, such as that shown in fig. 17. There will be voltage maxima spaced at half-wave length intervals with minima halfway between them. A line which is properly terminated and uniform, so that it exhibits no standing waves, is said to he "matched."

When a lossless transmission line a quarter wave length long and of characteristic impedance Z_o is terminated in an impedance Z_t, the input impedance of the line is

$$Z_i = Z_o^2/Z_t \tag{23}$$

This property enables two transmission lines of different impedance lo be matched to each other by joining them through a quarter-wave line whose characteristic impedance is the geometric mean of the impedances of the two lines. Such a quarter-wave section is called a "matching transformer." If a quarter-wave line is terminated by a short circuit, its input impedance is infinite; conversely, an open-circuited quarter-wave line appears at the input terminal to be a short circuit.

For a lossless line a half-wave length long,

$$Z_i = Z_t \qquad (24)$$

irrespective of the characteristic impedance of the line.

At microwave frequencies. the losses in the solid dielectrics used to insulate the inner from the outer conductor in a coaxial line are prohibitive at the power levels usually encountered. "Stub-supported" lines have therefore been developed (fig. 18), in which the "insulators" are short-circuited quarter-wave lines. Since the input impedance of such a quarter-wave line is infinite: it has no effect when placed in parallel with the main line. The stub is exactly a quarter-wave long only at one frequency, however, and it is often desired to make R.F. fittings which can work over a frequency band several per cent wide. In the stub support shown in fig. 18. this frequency sensitivity is compensated. over a band of $\pm 15\%$ of the base frequency. by the quarter-wave transformers formed by the fat sections of the centre conductor near the stub support.

Rotary joints which permit mechanical motion while transmitting R.F. power without reflection or mismatch are often required.

Standard coaxial line usually has a characteristic impedance of 50 ohms. this corresponding to a ratio of 2.3 for the radii of the outer and inner conductors. This is a compromise between a ratio of 3.6 (77 ohms) which, for a given outer diameter, gives the lowest attenuation due to conductor losses, and a ratio of 1.65 (30 ohms) which enables the maximum power to be carried at a given breakdown voltage gradient across the dielectric.

The size of a coaxial line is limited by the wave length of the radiation transmitted. The electric fields within a coaxial line have axial symmetry if the line is small enough. If, however. the mean circumference of the annular dielectric space between the conductors exceeds one wave length, a second "mode" of propagation of the R.F. energy can be excited. In this second mode, the field distribution has diametral symmetry. Since serious design complications arise if it is possible for two modes of propagation to be excited simultaneously in an R.F. line, the over-all size of coaxial line is always kept so small that only the axially symmetric mode of propagation can exist. The resulting limitation on power-handling capacity has restricted the use of coaxial lines to wave lengths of 8 cm. and more.

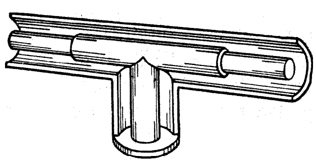

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FIG. 18.— BROAD-BAND STUB SUPPORT FOR CENTRE CONDUCTOR OF COAXIAL LINE

Wave Guide.—At shorter wave lengths, and for handling the highest powers even in the 10-cm. band. a ware guide is used. Though a metallic pipe of almost any shape will transmit or guide electromagnetic waves whose wave length is short enough. rectangular tubing whose internal dimensions have a ratio between 2.0 and 2.5 is ordinarily used to transfer micro ave energy. Though a detailed understanding of the propagation of R.F. energy in wave guide demands the solution of Maxwell's equations with the appropriate boundary conditions. we can get a picture of the mechanism of this propagation by considering the resemblance between a rectangular wave guide and a two-wire transmission line.

Fig. 19(A) shows a two-wire line with a single short-circuited stub support. analogous to the coaxial quarter-wave stub support already described. At the proper frequency, the input impedance of the stub is very high and the stub has no effect on the propagation of the wave on the line. In fig. 19(B) a great many stubs, extending both ways from the two-wire line. have been added, still without affecting the propagation of the frequency in question. In fig. 19(C) the stubs have been coalesced into a rectangular tube which looks like a wave guide. For a single stub, a slight

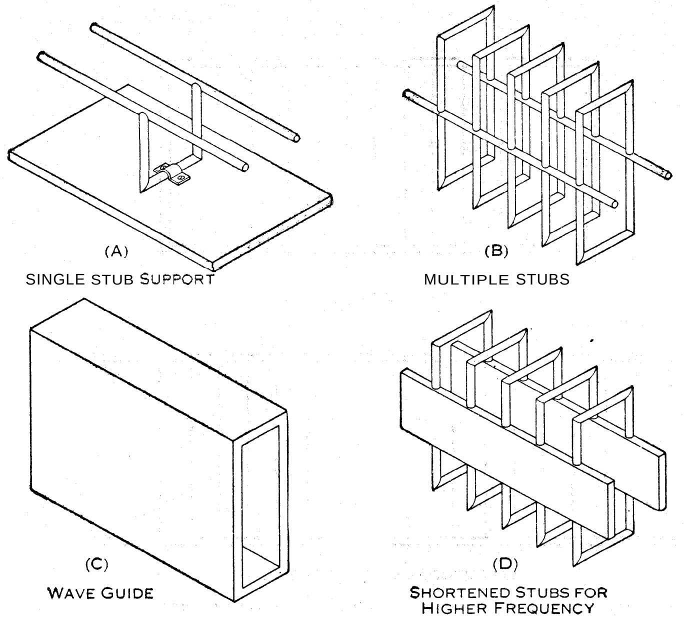

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FIG. 19.— TRANSITION FROM STUB-SUPPORTED TWO-WIRE TRANSMISSION LINE TO WAVE GUIDE. (A) SINGLE STUB SUPPORT. (B) MULTIPLE STUBS. (C) WAVE GUIDE. (D) SHORTENED STUBS FOR HIGHER FREQUENCY

correction to the length must be made to compensate for the inductance of the crosspiece, but when the stubs become a solid tube, no lines of force can link the narrow side, and the quarter-wave distance becomes exact. This also shows why the length of the narrow side of the rectangular tube is not critical.

All frequencies higher (wave lengths shorter) than that for which the quarter-wave stubs of our model were designed can be transmitted by wave guide. In such a case (fig. 19(D)) the two wires become broad bus bars with only as much of the wide side given over to stubs as is required by the now shorter wave length. Wave lengths greater than twice the broad dimension of the guide cannot be propagated because then the stubs become less than a quarter-wave long and shunt the line with a rather low inductive impedance which would extinguish the wave.

Fig 20 shows an instantaneous picture of the electric and magnetic fields in a rectangular wave guide whose wide dimension is slightly more than half the free-space wave length of the radiation being transmitted. Lines of current-flow in the walls are also shown. As the dimensions of the wave guide increase relative to the wave length of the radiation being transmitted, modes of propagation different from that illustrated (*i.e.*, having different space distributions of electric and magnetic field) can be excited.

As in the case of coaxial line, this is almost always objectionable, and the maximum size of the broad dimension of a rectangular guide is usually chosen to be less than 0.95 of the free-space wave length of the radiation to be transmitted.

Each type of wave guide has a cutoff frequency for propagation in the lowest mode. Waves of higher frequency are transmitted; those of lower frequency are rapidly attenuated. The wave length of the radiation inside the guide is longer than the free-space wave length and is given by

$$\text{Guide wave length} = \lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}} \qquad (25)$$

where λ is the free-space wave length and λ_c is the cutoff wave length. For the lowest mode in rectangular guide, as we have seen. the wave length corresponding to the cutoff frequency is twice the broad dimension. This sets a lower limit to the practical size of wave guide. Its broad dimension is usually chosen to be greater than 0.6 times the free-space wave length, because of design complications that ensue if the cutoff value of $0.5\ \lambda$ is approached too closely.

The narrow dimension of rectangular guide is chosen as large

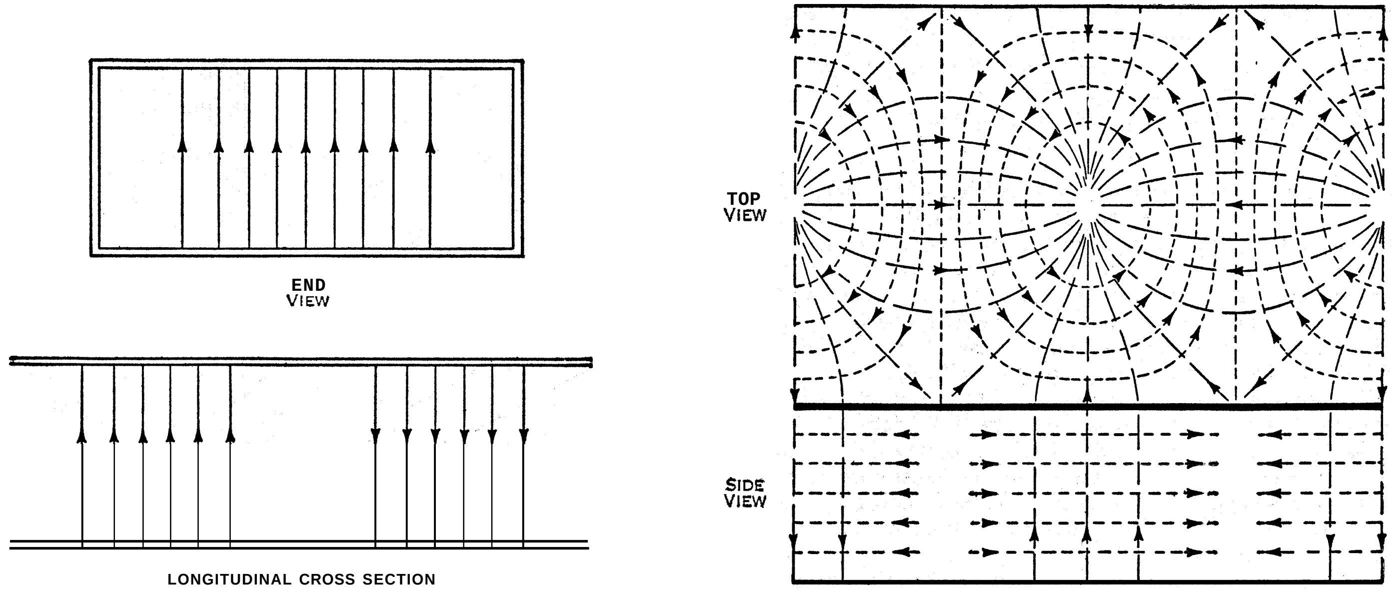

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FIG. 20.— FUNDAMENTAL MODE OF WAVE PROPAGATION IN A RECTANGULAR GUIDE. SOLID LINES ARE THOSE OF ELECTRIC FIELD: DASHED LINES SHOW CURRENT FLOW IN WALLS: DOTTED LINES SHOW MAGNETIC FIELD

as possible to raise the breakdown field strength (the electric field being across this narrow dimension); but it must be less than half a free-space wave length of the radiation to be transmitted, so that there is no possibility of transmitting a wave polarized at right angles to that shown in fig. 20.

Transitions between wave guide and coaxial lines usually take the form of a quarter-wave stub antenna on the coaxial line projecting into the wave guide at the proper distance from a reflecting end plate, as shown in fig. 21. Rotary joints make use of quarter-wave choke sections. The power-handling capacity of wave guide is more than double that which can be realized by the largest coaxial line it is practical to use; the attenuation in a given length of wave guide is about half that encountered in coaxial line. Mechanically. wave guide is superior, being easier to fabricate and more difficult to damage in use.

Resonant Cavities.—If both ends of a wave guide are closed by short-circuiting plates, and energy is introduced by a probe or through a hole so small that the properties of the enclosure are not affected, the resulting box is called a resonant cavity. When its length is an integral number of half-wave lengths of the radiation in the guide, the reflections from the end plates will reinforce one another and cause a resonant build-up of the energy in the cavity. Because the wave length in the guide differs from that in free space, as shown by eq. (25), the shortest resonant piece of a wave guide whose broad dimension is $1/\sqrt{2}$ free-space wave lengths is also $1/\sqrt{2}$ free-space wave lengths long. The narrow dimension of the cavity does not affect the resonant wave length, though it should be less than $\lambda/2$ to avoid the possibility of exciting the cavity in a mode polarized at right angles to the one desired.

The sharpness of resonance exhibited by a resonant cavity at microwave frequencies is very great. It is usually measured by a number called the Q of the cavity. If f_o is the resonant frequency and f_1 and f_2 are the two frequencies, one above resonance and one below. at which the voltage in the cavity is 0.707 that at resonance, then

$$Q=\frac{f_0}{f_1-f_2} \tag{26}$$

The Q of a 10-cm. cavity made of copper is typically as great as 15.000. This is much higher than the Q of resonant circuits made of coil-and-condenser combinations, for use at lower frequencies, because of the great effectiveness of a resonant cavity as a device for the storage of energy.

TR and ATR Switches.—Resonant cavities are used in the construction of the TR and ATR switches needed to permit duplex operation of a radar transmitter and receiver on a single antenna. Fig. 22 shows schematically how gas-discharge switches, fired by the high-power R.F. pulse from the magnetron, can be mounted to perform the TR and ATR switching functions. Breakdown of the TR tube puts a low-resistance short circuit across the receiver line, thus protecting it: but since this short circuit is a quarter-wave length away from the junction with the antenna line, there is no attenuation of the wave traveling toward the antenna. Breakdown of the ATR closes the circuit from magnetron to antenna; when the pulse is over and the ATR discharge goes out, the impedance at the T junction looking toward the magnetron is infinite because there is an open circuit half a wave length away. Looking toward the receiver, there is a matched line, so that all the echo power goes into the receiver.

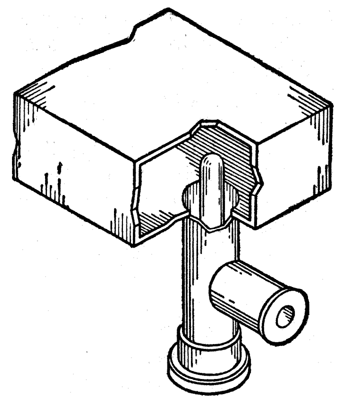

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FIG. 21.—TRANSITION FROM CO-AXIAL LINE TO WAVE GUIDE

To reduce the voltage necessary to break down the discharge gaps of the TR and ATR switches. they are filled with gas at a pressure of about 1/200 atmosphere. Further reduction is accomplished by mounting the discharge gap across a resonant cavity. to make use of the build-up in voltage accompanying resonance. Fig. 23 is a cutaway view of a TR tube used in the 3-cm. band. The resonant cavity is part of the tube envelope, and is made to be bolted between standard wave guide coupling flanges. Energy is coupled into and out of the cavity by means of round holes (filled with glass to retain the gas) in each side of the cavity. The discharge takes place between the two conical electrodes in the centre of the cavity; tuning is accomplished by moving one of them. mounted on a flexible diaphragm, toward or away from the other. To ensure rapid breakdown of the gap at the beginning of a pulse (within 0.01 μ sec.). a supply of ions is maintained in the gap by a discharge taking place constantly inside one of the cones.

ATR tubes are similar, except that they need have no output window, being mounted on the side of (*i.e.*, in series with) the R.F. line. Ordinarily they are made with lower Q, to reduce the chance of accidental maladjustment of tuning.

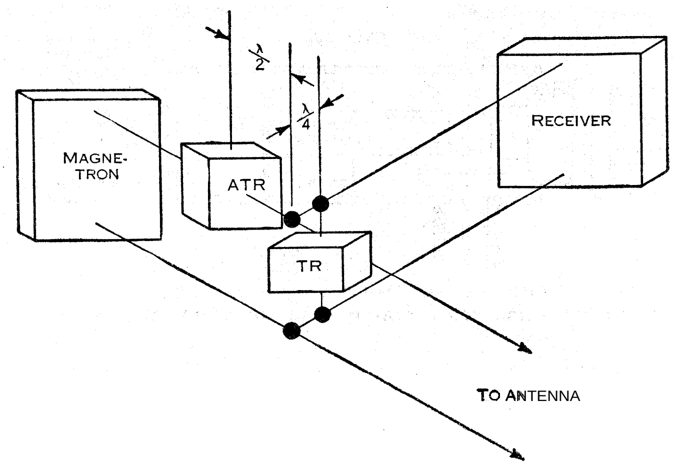

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FIG. 22.—PRINCIPLE OF A **DUPLEXING** SYSTEM SHOWN **IN** TERMS OF **TWO-WIRE R.F.** TRANSMISSION **LINE**

In the years following World War II, use of the newly developed ferrite materials. which exhibit a very pronounced Faraday effect at microwave frequencies, permitted the construction of circuit elements which were highly nonlinear, in the sense that they behaved differently for microwave energy traveling in opposite directions. This made possible the design of duplexing and isolating elements less complicated and more effective than the gas-discharge devices of wartime radar.

4. Antennas **and** Scanners. — The antenna of a radar set must radiate into space the energy fed to it as R.F. pulses, and must gather in the echo signals and send them down the R.F. line to the receiver. A good transmitting antenna is also a good receiving antenna; thus only the former function need be considered. Sharp beams are needed to make radar direction-finding possible: and a great deal of attention has been paid to the design of highly directional antennas that are capable of producing beams of the desired shape and dimensions. The nature of the beam wanted depends, of course, on the radar application.

Antenna Design.—The beam width, Θ, produced by an antenna is directly proportiona! to the wave length of the radiation used, and inversely proporiional to the width of the antenna. Beam width as usually defined is the full angular interval between the points at which the power radiated from the antenna has fallen to half its maximum value (fig. 24). Fig. 24 shows also the "side lobes," small subsidiary maxima unavoidably produced by a directional antenna. Their effects are usually objectionable, and attention is paid in antenna design to reducing the power in the side lobes. The beam width in degrees is given approximately by

$$\Theta = 70\lambda/D, \qquad (27)$$

where λ is the wave length and D the width of the antenna in the same dimension as that for which Θ is measured. D and λ should be given in the same units.

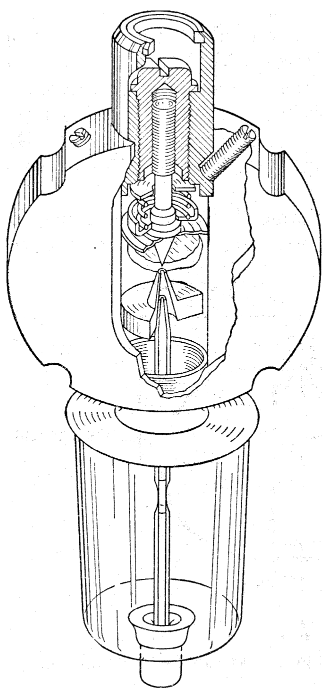

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FIG. 23.—CUT-AWAY VIEW OF 1B24 3-CM. TR SWITCH

Among the simplest microwave antennas is a reflecting paraboloid of revolution illuminated by a source of radiation, or "antenna feed," placed at its focus. Since the diameter of the reflector is several wave lengths, this antenna can be regarded from the standpoint of ray optics (fig. 25). Fig. 25 does not explain the side lobes or the beam width, but it does emphasize that the feed for such an antenna must itself be directive.

In accordance with eq (27). a paraboloid whose top and bottom have been cut off to leave a reflector wider than it is high will produce a fan-shaped beam whose vertical beam width is larger than its beam width measured horizontally. A "beaver-tail" beam wider in the horizontal than in the vertical direction can be produced by cutting off the sides of a paraboloid to leave a tall, narrow reflector. Further adjustment of the energy in the beam can be accomplished by altering the shape of the reflector without changing its over-all dimensions. Instead of a paraboloidal reflector with a feed at its point focus, a parabolic cylinder with a linear feed located along its line focus can be used as an antenna.

Mechanical Scanning.—In order to cover the necessary volume

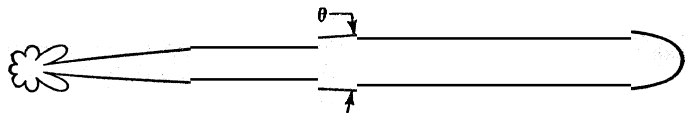

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FIG 24.—A TYPICAL ANTENNA PATTERN. **MAIN** LOBE HAS BEAM WIDTH *θ*. **SIDE** LOBES ARE SHOWN

of space with the narrow beam produced by a directional antenna, the beam must be swung around. or scanned In most cases, the permissible rates of beam motion, fixed as they are by the desirability of receiving several echo pulses from each target per scan, are so low that scanning can be accomplished by mechanical motion of the antenna array. The assembly of an antenna on its supporting structure, or pedestal, is called an antenna mount, or scanner.

Radar scanners are of many different sorts. the detailed design being dictated principally by the size of the antenna (this being determined by the wave length used and the beam width desired), and by the scanning pattern used to cover the volume being searched. A few simple scanning patterns are:

(1) *Azimuth* scan.—The beam is swung around the horizon at a uniiorm rate. The desired vertical coverage is obtained by fanning the beam in the vertical direction.

(2) Helical scan.—If information on the elevation angle of targets is wanted, a pencil beam can be used. uniform azimuth rotation employed and the elevation angle of ;he. beam altered constantly at a slow uniform rate (fig, 26). When the full elevation-angle range of interest has been covered, the motion in elevation angle is reversed.

(3) *Conical* scan.—For accurate direction-finding on a single target, a pencil beam can be rotated rapidly in- a cone whose angular opening is smaller than the beam width. Only when the axis of the cone is directly pointed at the target will the signals received in various phases of the rotation oi the beam have constant intensity. A change in signal strength will accompany conical scan when the axis of the cone is not quite on the target. The magnitude and phase of this change in signal strength as the beam rotates indicates the direction and the magnitude of the pointing error. The direction of the cone axis is changed to make the "error signal" zero. By the use of this scheme, radar direction-finding can be given a precision of about one-fiftieth of a beam width; this is far greater precision than can be obtained by noting the direction of maximum signal return when a beam is swept over a target.

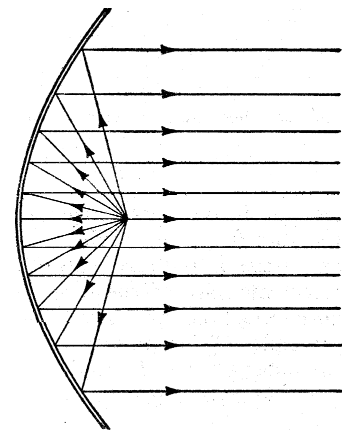

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FIG. 25.—RAY DIAGRAM OF A **PARAB-**OLOID ANTENNA

(4) Spival scan.—If a rapid axial rotation of a pencil beam, like that used in conical scanning, is combined with a siow change in the cone opening, a spiral scan (fig. 27) results. This permits rapid coverage of a fairly large area, with facilities for determining roughly both the azimuth and the elevation of targets.

Data *Transmission.*—In order to make use at the radar indicator of the directional information afforded by scanning, means must be provided for transmitting to the indicator a knowledge of the scanner position in all important co-ordinates. Only azimuth must be transmitted for an azimuth scan, azimuth and elevation for a helical scan, and azimuth, elevation and phase of rotation for a conical or a spiral scan.

This "data transmission," as it is called, is almost always accomplished electrically. The flexibility of mechanical means of data transmission is not sufficient to meet radar requirements. Self-synchronous generators and motors of the type used in other applications for transmitting position information are frequently employed. So are precision adjustable resistors. The latter have the advantage that they can be wound in such a way that the output voltage is any desired function of angle of rotation. Further, the applied voltage, to which the output voltage is proportional, can be varied in any fashion desired. Thus computation can be performed directly by the data transmission device.

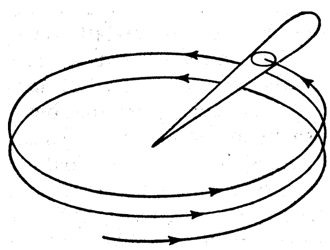

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FIG. 26.—HELICAL SCANNING PATTERN

For example, suppose it is desired to find target height, h, from a measurement of range, R, and elevation angle, ϕ; it will be given by

$$h = R \sin \phi \tag{28}$$

If the resistance card of the adjustable resistor used to measure elevation angle is so wound that its output voltage for an elevation

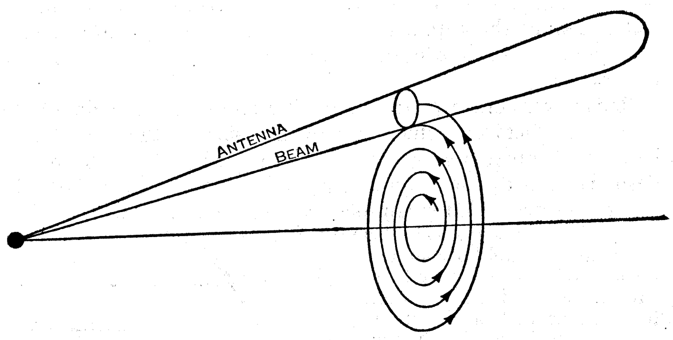

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FIG. 27.— SPIRAL SCAN

angle ϕ is proportional to sin ϕ, and the voltage applied to this resistor is developed from another adjustable resistor used to measure range and having an output linear with R, then the voltage at the output terminals of the elevation-angle resistor will be a direct measure of the height of the target. A highly successful antiaircraft computer was built during World War II on this principle. When used with radar, the data-transmission units of the radar actually formed part of the computing mechanism.

Rapid Scanning.—In some radar applications, such rapid scanning is desired that mechanical motion of a large antenna mount is not feasible. A number of devices have been developed to permit rapid scanning in one dimension by relatively subtle mechanical motions of parts of the antenna. These devices are sometimes referred to as "electrical" scanners, although rapid mechanical motion is almost always fundamental to the scanning.

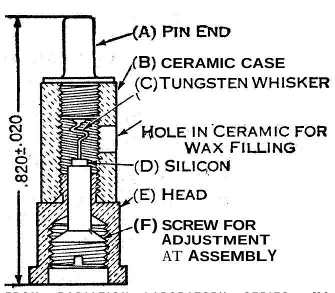

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FIG. PI.— STANDARD MICROWAVE MIXER CRYSTAL

Stabilization.—When a radar scanner is mounted on an unstable platform, such as a ship or an aircraft, readings of azimuth and elevation relative to the platform must be converted into readings

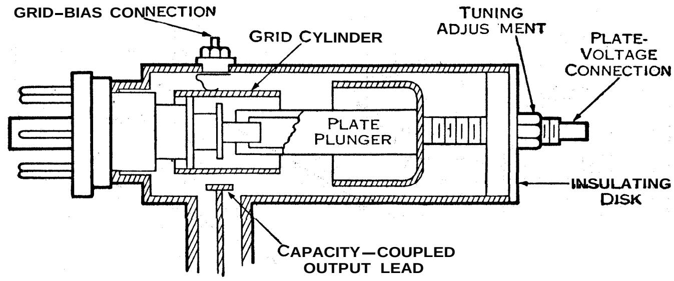

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FIG. 29.— LIGHTHOUSE TUBE MOUNTED IN A COAXIAL CIRCUIT

of these angles with respect to a stable set of reference axes. Compasses, directional gyros, and gyro stable verticals are commonly used as reference devices, and the stabilization of the radar data, as this conversion process is called, can be performed in a variety of ways.

5. **Radar** Receivers. — Under the term "receiver" is classed that part of the radar equipment which accepts the feeble echo pulses from the R.F. line, amplifies them, rectifies them and delivers to the terminals of the indicator or display equipment unipolar pulse signals at a level usually of several volts.

Most radar receivers are of the superheterodyne type, in which a local oscillator supplies CW signals at a low level to a mixer, where the echo signal and the local oscillator signal beat to give a signal at a frequency (called the intermediate frequency) equal to the difference between the frequencies of the signals mixed. This beat signal is modulated with the same intelligence as that conveyed by the R.F. echoes, and its frequency is chosen to permit fairly standard techniques to be used in the I.F. amplifier.

The I.F. amplifier is normally tuned to a fixed frequency, and the receiver tuning is changed by altering the frequency of the local oscillator. Arrangements, called AFC (for automatic frequency control), are incorporated in most radar receivers for keeping the local oscillator properly tuned with respect to the radar transmitter. Demodulation of the amplified I.F. signal is accomplished by a second detector followed by a filter for the intermediate-frequency signal. The resulting signals, called "video signals" because their frequency range is about that of television video signals, are further amplified and sent to the indicator.

R.F. Amplifiers.—Development of the idea that an electron stream can interact and exchange energy with a traveling electromagnetic wave led to the development soon after the close of World War II, of a type of vacuum tube called a traveling-wave tube. Some embodiments of this principle were useful for the hitherto impossible problem of amplifying energy at microwave frequencies.

By the early 1960s there were suitable R.F. amplifier tubes for all microwave frequencies in common use. They had not yet

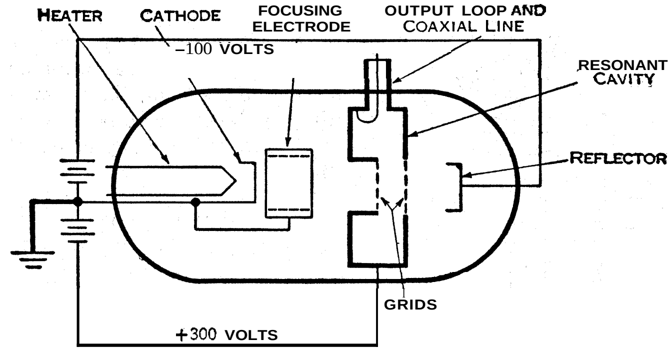

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FIG. 30.— SCHEMATIC DIAGRAM OF REFLEX KLYSTRON OSCILLATOR

altered the need for mixer crystals as first detectors in superheterodyne receivers used in radar, but they gave substantial promise of improving radar performance.

Microwave Mixers.—Conversion to intermediate frequency in the mixer at the low level of received signal power requires that' the nonlinear element used in the mixer be as efficient as possible and introduce a minimum amount of random noise. The most satisfactory element was the rectifying contact between a metallic point and a silicon crystal. The whole assembly was sealed up in a cartridge, referred to as a "crystal," for protection and stability. One standard form for this cartridge is shown in fig. 28.

The contact area between the metal and the silicon is only about 10^{-6} cm^2. High current densities are therefore produced even by lo currents, and a crystal can readily be burned out, especially by a pulse so rapid that heat cannot be conducted away from the contact.

The R.F. circuit in which the crystal is installed is called the "mixer." It has input terminals for the signal and for the power from the local oscillator. Its output terminals are connected to the first stage of the I.F. amplifier. Care is taken in mixer design to make the crystal appear as a matched load to the incoming signal; to prevent, as far as possible, loss of echo-signal power into the local-oscillator input line; and to provide a reasonably good match looking into the mixer from the local oscillator.

Local Oscillators.—The magnetron, although a very efficient source of high pulse powers, was not employed in wartime radar as a source of the low-level CW signal required from the local oscillator of a superheterodyne receiver. Quite satisfactory tubes of other types were developed for this purpose.

Some World War II radar sets used a special triode, called a "lighthouse" tube because of its construction, as a local oscillator. The lighthouse tube is designed with planar electrodes and extremely small interelectrode spacing to reduce electron transit time. External connections to its electrodes are provided in the form of disks and cylinders (fig. 29), so that a cylindrical R.F. circuit can be built directly around the tube. An average power output of a few watts can be obtained from a lighthouse tube, and the tube can also be pulsed to give peak power of about 1 kw. It has been used as a transmitter in some low-power radar sets.

Most radar sets used a reflex klystron as a local oscillator. Fig. 30 is a schematic diagram of such a tube. Integral with the tube structure is a doughnut-shaped resonant cavity with grids across its central portion. An "electron gun" focuses a stream of electrons through the grids. Upon arrival at the first grid, the electrons have a velocity corresponding to the 300 volts applied to accelerate them. If oscillations exist in the cavity, electrons will either be accelerated or decelerated by the R.F. field which they encounter as they pass through the space between the cavity grids. An electron which goes through just as the R.F. field is passing through zero will not have its velocity changed, and will be described as a reference electron. In the space just beyond the second grid there is a strong retarding field produced by a reflector electrode maintained about 100 volts negative with respect to the cathode, The path of the reference electron in this retarding field is similar to that of a ball thrown into the air. It will return to the grids after a time proportional to the retarding field. An electron that leaves the second grid earlier than the reference electron will have been accelerated by the R.F. voltage which then existed across the cavity, and, because of its higher velocity, it will spend a longer time in the reflection space than will the reference electron. By proper adjustment of the retarding field, the delay can be made to compensate for its earlier departure, so that it arrives back at the grids at the same time as the reference electron.

Similarly, an electron leavirig later than the reference electron has been decelerated by the R.F. field! has a lower velocity, and thus catches up with the reference electron because it spends less time in the reflection space. The net effect is that the electrons gather in a bunch which is formed about the reference electron. At certain reflector voltages, the bunch will return through the cavity grids in such a phase that the R.F. field retards the electrons, and thus receives from them energy to sustain the oscillations in the cavity. Oscillation is observed for more than one reflector voltage, since drift times differing by a whole R.F. period still produce satisfactory bunching.

The net energy given to the electrons during their first passage through the cavity is negligible when averaged over a whole R.F. cycle, being balanced between acceleration and deceleration. On the return passage, most of the electrons go through in a bunch at the most favourable phase to aid the oscillation. Very few electrons pass through on the return trip half a cycle later, when they would absorb energy from the R.F. field. Power is coupled out of thecavity through a loop feeding into a coaxial line. Power outputs in the range irom 20 to 50 mw. and efficiencies of about 1% were typical of such tubes produced in the postwar years.

Tuning over a wide range is accomplished by changing the size of the cavity mechanically; a small amount of tuning can be done by varying the reflector voltage.

Automatic Frequency Control.—The problem of keeping a radar set properly in tune consists in maintaining the difference between the local-oscillator frequency and the magnetron frequency constant at the value appropriate to the I.F. amplifier, with an accuracy of perhaps 0.5 mc. AFC is a practical necessity in scanning radar, for the magnetron frequency can be altered several mc. by changes in standing-wave ratio occurring in the R.F. system either in consequence of unsymmetrical rotary joints or because of strong reflections from nearby objects such as the masts of a ship or the engine nacelles of an aircraft carrying the radar. Further, variations in voltage, temperature and pressure all produce changes in frequency. Manual tuning is quite unsatisfactory, and AFC has come to be a standard part. of all radar.

In the AFC system, part of the local-oscillator power is mixed, in a crystal, with a small fraction of the magnetron power drawn out during transmission of the pulse. The resulting signal at the difference frequency is applied to a discriminator circuit similar to those used in a frequency-modulation receiver. The crossover or no-output frequency of the discriminator is set at the intermediate frequency of the radar. The pulses which come from the discriminator are integrated to produce a voltage that is applied to the reflector of the local oscillator in the proper sense to change the frequency toward that value which will bring the discriminator output to zero. It is desirable to use an AFC mixer which is separate irom the signal mixer, but it is possible to make an AFC system which obtains its information from the leakage power which inevitably reaches the signal mixer during the transmission of an R.F. pulse from the magnetron.

The I.F. *Amplifier.*—Because of the low power level of the input signal to a radar I.F. amplifier, the greatest attention must be paid to minimizing the inherent noise of the amplifier itself. Further, since strong pulses several hundreds of μ sec. in length may be followed immediately by weak signals which must not be missed, the transient response of the I.F. amplifier must be excellent. The amplifiers which resulted during World War II from attention to these requirements were rather different from anything which had previously existed.

The intermediate frequency is usually chosen in the range from 15 to 60 mc. The over-all gain of the I.F. amplifier is usually around 120 db. or 1,000,000 times in voltage. The desired over-all band width of the amplifier is ordinarily about 2 mc. Since the cascading of amplifier stages results in an over-all band width much less than the band width of an individual stage, it is very important to attain the highest possible product of gain and band width in the individual stages.

The design of the interstage coupling circuit used in an I.F. amplifier has an important effect on the gain-band-width product that can be achieved with given tubes. The characteristics of the tubes themselves are also of the greatest importance, the leading property being the ratio of transconductance to input and output capacity.

It is important that regenerative feedback of signals does not take place from later stages to earlier stages of the I.F. amplifier, or from plate to grid circuit in a single stage. Circuit layout and shielding must be carefully planned to avoid regeneration.

Second Detector.—The second detector produces a rectified voltage proportional to the amplitude of the I.F. waves. In most radio receivers it is important that this proportionality be exact;

in a radar receiver the response of the second detector may be proportional to a higher power of the I.F. amplitude, so long as reasonable efficiency is maintained. Either a thermionic diode or a rectifying metal semiconductor contact ("crystal") is used as the nonlinear rectifying element. Second-detector crystals usually employ germanium, instead of silicon, as the semiconductor, since germanium crystals can be made to stand a somewhat higher reverse voltage.

Video Amplifier.—The unipolar signals from the second detector, usually at a level of a few volts, are further amplified by a wide band resistance-capacitance-coupled amplifier called the video amplifier, because of its similarity to the video amplifiers used in television.

When the line from the radar proper to the indicator must be long, it is economical to drive the line at a low video-signal level and provide video amplification at each indicator. Since the standard dielectric-filled coaxial cable ordinarily used for the transmission of video signals has a low impedance—in the neighbourhood of 75 to 100 ohms—a "cathode follower" stage is frequently used to drive the line.

6. Radar Indicators.— The device which presents radar data in observable form is called the indicator. It is almost always a cathode-ray tube (CRT). The CRT presents a representation of electrical phenomena in terms of a picture painted on a phosphorescent screen by a sharply-focused beam of electrons controlled in position and intensity by electrical signals. The CRT is capable of using and displaying many millions of separate data per second, and the geometrical expression which it gives to radar data is particularly appropriate, since a geometrical situation involving the various radar targets is usually precisely what must be represented.

CRT Screens.—Both inagnetic and electrostatic CRT types are used, the terms referring to the means of deflecting the stream of electrons (fig. 1). The properties of the materials (phosphors) making up the luminous screen are of particular importance to the performance of the tube. If, as is usually the case, the scanning of the radar antenna interrupts the display in a given sector of the screen for longer than the retentivity time of the eye, it is desirable to introduce persistence into the screen—that is, to use a phosphor which will glow for some time after having been excited.

If little or no persistence is needed, the green willemite phosphor used in ordinary oscilloscope tubes and known as type P-1 is satisfactory. This material is extremely efficient in converting the energy of the electrons which strike it into luminous energy; it has an exponential decay with a time constant of a few milliseconds. If a rather short persistence is needed, a zinc-magnesium

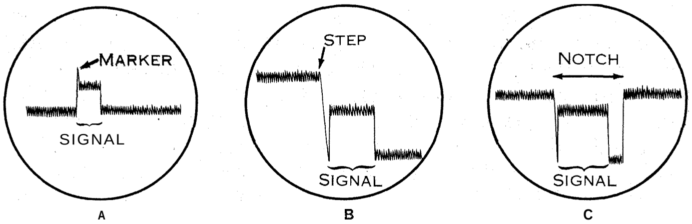

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FIG. 81.— RANGESCOPES: (A) PIP MARKER; (B) STEP MARKER; (C) NOTCH MARKER

fluoride phosphor designated as P-12 is used.

Most radar applications demand even a longer persistence. This can be achieved by a "cascade" screen consisting of two layers of different phosphors. The electrons strike and excite an inner layer of silver-activated zinc sulphide, which glows with a blue light. This blue light excites a layer of persistent phosphor, usually copper-activated zinc-cadmium sulphide. The zinc-to-cadmium ratio determines the decay characteristics.

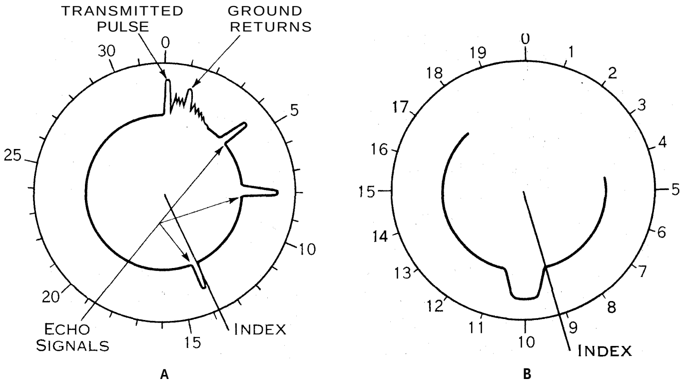

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FIG. 32.— J-SCOPE. ANOTHER TYPE OF RANGE SCOPE SHOWING READING IN (A) THOUSANDS OF YARDS: (B) HUNDREDS OF YARDS

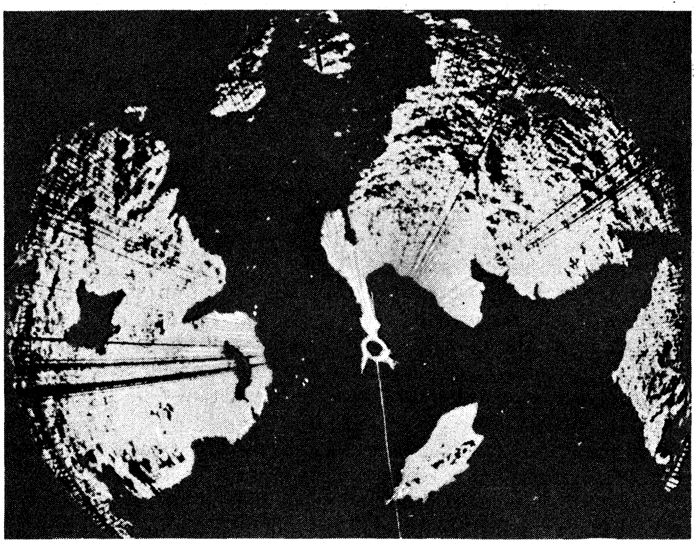
Because the long-persistence phosphor emits a predominantly yellow or orange light, an orange filter is used to remove the blue "flash" of the inner phosphor, which is annoying to the observer.

Radar Displays.—Because of the many special purposes that radar can serve, a considerable variety of different forms of display have been developed and used. The A-scope and the PPI have already been mentioned. These are typical of two general classes in which the radar echo signals are used either (1) to deflect the CRT electron beam, or (2) to alter its intensity. Displays of the first type (deflection-modulated displays) are useful for giving precise information on the strength and character of the signals delivered by the receiver, but leave only one dimension of the tube face free to represent a geometrical quantity. Displays of the second type (intensity-modulated displays) permit the presentation of a two-dimensional figure on which the signals appear as bright spots or patches, but the intensity response of CRT electron guns is so nonlinear that the brightness of each patch offers only qualitative information about signal intensity.

When a three-dimensional picture must be presented on the two-dimensional face of a CRT indicator, either more than one display must be used, or a formalized way of presenting the third dimension in an understandable, though unnatural, fashion must be devised.

The vast majority of radar displays use as one co-ordinate the value of slant range to the target. Range is displayed by causing the electron beam of the CRT to sweep across the tube at a uniform rate starting from a given point or line at a definite time in each pulse cycle. Distances on the tube face from the starting point are then proportional to increments of range.

The angle at which the scanner is pointing, either in azimuth or elevation. may enter the display (1) directly as a polar angle, (2) directly as a Cartesian co-ordinate, or (3) as the basis for resolving a range sweep in a particular direction.



BY COURTESY OF H M. STATIONERY OFFICE, REPRODUCED BY PERMISSION OF THE CONTROLLER;

AIR-BORNE RADAR DISPLAY SHOWING ECHOES FROM THE LAND AROUND THE IRISH SEA. THE ISLE OF MAN IS AT LOWER CENTRE (5 O'CLOCK)

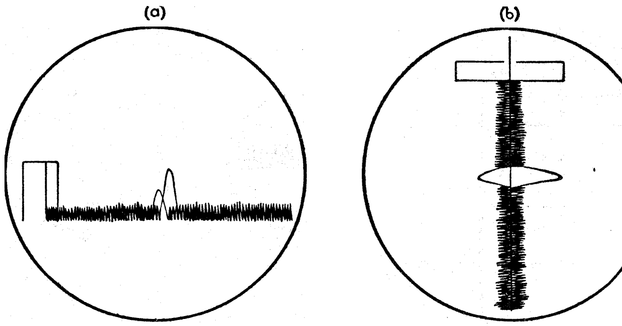


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FIG. 33.— DISPLAYS PERMITTING COMPARISON OF STRENGTH OF ECHO FROM A GIVEN TARGET ON TWO ANTENNAS. OR IN TWO POSITIONS OF A CONICAL SCAN. (a) SIDE-BY-SIDE PRESENTATION (K-SCOPE). (b) BACK-TO-BACK PRESENTATION (L-SCOPE)

Usually markers are employed to assist in making measurements of range or angle on a radar indicator. These may be "electronic" markers introduced into the signal channel as artificial video signals generated by a precision timing circuit (for range markers) or an angle-measuring circuit (for angle markers). Alternatively: they may be mechanical grids or markers placed over the face of the CRT.

A few of the most important radar displays are catalogued below, according to the spatial geometry represented.

One-dimensional Deflection-modulated *Displays.*—The simplest display of this type is the A-scope described earlier. Range is invariably the spatial co-ordinate presented on a display in this class. If it is desired to do accurate range-finding with the help of an indicator in this category, arrangements are made to delay the start of the range sweep by any desired amount, so that the interval displayed will include the target of interest. The sweep speed is then greatly increased to give higher resolution in range. Usually a movable electronic marker is provided for the precise measurement of range. Such a display is called an R- (range) scope. Fig. 31 shows R-scope displays with various types of movable range markers.

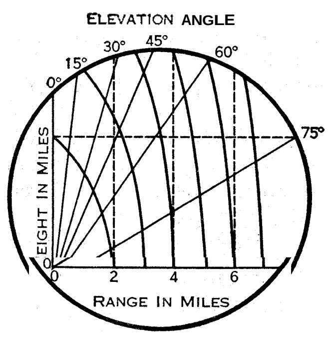

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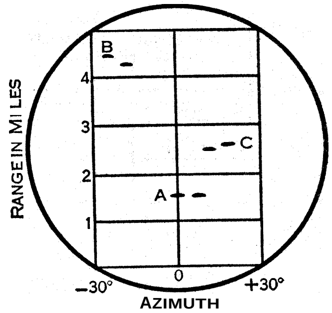
FIG. 34.— THE RANGE-HEIGHT INDICATOR (RHI). THIS IS A POLAR SCALE FACTORS ALONG THE TWO CARTESIAN CO-ORDINATES. THE VERTICAL STRETCHING IS SHOWN BY THE TWO-MILE GRID SHOWN DOTTED IN THE DIAGRAM. LINES OF CONSTANT ARE STRAIGHT AND HORIZONTAL ON THIS DISPLAY

Greater sweep length can be obtained by bending the range sweep into a circle on the face of the tube, and using the radar echo signals to deflect the beam radially from the centre of the CRT. Fig. 32 shows such a display called a J-scope.

Simple deflection-modulated range displays can be used for comparing the signal strength from two antennas whose patterns make a small angle with one another, or from a conically scanning antenna in two positions 180" apart. The K-scope is so arranged that the range sweeps to be compared start from different origins, so that the echoes to be compared are side by side. In the L-scope, signals from the two antennas produce deflections of opposite sign, the range origin being common (fig. 33).

Two-dimensional Intensity-modulated Displays.—The PPI is the most generally useful of the indicators in this category. For certain purposes, it is altered by moving the range origin (off-centre PPI), or by expanding the zero-range origin of the PPI into a circle (open-centre PPI), or by delaying the start of the sweep, so that a ring-shaped area is collapsed into a solid circle (delayed PPI).

A PPI can also be deformed by "stretching"; that is, by giving different scale factors to the two Cartesian co-ordinates of the display. Straight lines remain straight but, except for those parallel to the Cartesian axes, their directions are changed. If elevation, instead of azimuth. is the angular co-ordinate used on the scope, the resulting display is called a range-height indicator, or RHI. Lines of constant target height are horizontal and equally spaced. (See fig. 34.)



FROM RADIATION LABORATORY SERIES MC-GRAW-HILL BOOK COMPANY. INC

FIG. 35.—THE DOUBLE-DOT INDICATOR, A B-SCOPE IN WHICH EACH TARGET ECHO APPEARS TWICE. ANGLE OF LINE JOINING TWO SIGNALS SHOWS ELEVATION ANGLE OF TARGET RELATIVE TO AXIS OF RADAR SCANNER. TARGET A IS LEVEL SCANNER. 1.5 MI. AWAY. AND DEAD AHEAD. TARGET B IS 4.5 MI. AWAY, 25° LEFT AND SLIGHTLY BELOW TARGET C IS 2.5 MI. AWAY. 12° RIGHT AND

A plane surface can also be represented in a deformed manner useful for certain radar applications by presenting range and angle in Cartesian rather than in polar co-ordinates. This is accomplished by moving a range sweep laterally across the tube face in synchronism with the scanner motion so that the range origin is stretched out into a line. If the angular field shown by such a display is small enough, it can be "normalized" to reduce the distortion to modest limits. Normalization is performed by keeping the angular dispersion proportional to the range to the centre of the display.

Three-dimensional Displays.——As already remarked. no real three-dimensional display can be presented on the two-dimensional face of a CRT. However, certain formalized ways have been developed for indicating target elevation on a display which already shows target range and bearing. An example of this type is the "double-dot" display. On alternate range sweeps the origin of this modified Type-B indicator is moved to the right and left respectively by a fixed amount. On the sweeps occurring in the right-hand pattern the origin is simultaneously shifted vertically by an amount proportional to the sine of the elevation angle.

Any single echo then appears in two neighbouring positions, and the slope of the line joining the two dots is a rough measure of elevation angle. accurate to two or three degrees under the usual circumstances of use. (See fig. 35.)

A Simple Indicator.—The electrical means of achieving the rapid and accurate sweeps necessary for radar indicators are beyond the scope of this article, and the interested reader is referred to the works quoted in the bibliography. However, it will be useful to outline the functions of the important parts of a simple display system.

The parts of the indicator circuit concerned with the pulse repetition cycle are called the "timer." The timer provides a synchronization with the modulator, sweeps and markers for the display and measurement of range, blanking of the CRT during unused parts of the pulse cycle, and other related operatiocs.

In some cases; the timer exerts control of the firing time of the modulator by sending it a trigger pulse; in others it responds to a trigger from the modulator. The latter type of system is shown in fig. 36. Waveform b is used to turn the CRT on during the useful display cycle. The linearly increasing (or sawtooth) waveform *c*, is used to provide the uniform range sweep for the indicator.

Timing of this wave is controlled by waveform b. Electronic range markers (waveform d) are also generated by the timer and mixed with the radar video signals before they are sent to the CRT.

For illustrative purposes: fig. 36 shows provisions for either an A-scope or a R-scope display. For the former presentation. the range-sweep voltage is applied to one pair of deflecting plates and the mixed signal and range-mark voltages to the other pair. The square wave controlling the CRT intensity is applied to the cathode in the proper polarity to brighten the tube during the range sweep.

In the Type-B display, the range sweep is applied to one pair

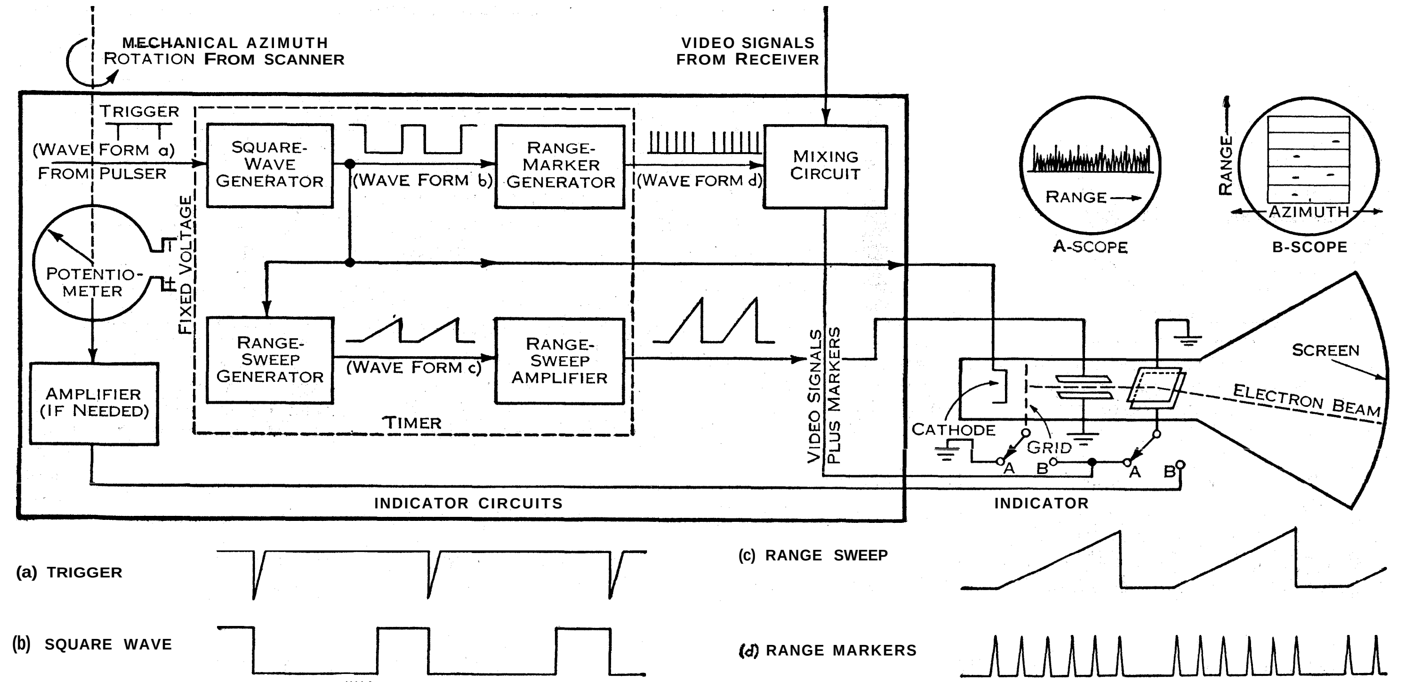


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FIG. 36.— BLOCK DIAGRAM OF A SIMPLE INDICATOR SYSTEM PROVIDING FOR EITHER A-SCOPE OR B-SCOPE DISPLAY. BELOW. WAVE FORMS IN CIRCUIT OF FIGURE

of deflection plates, as before. Signal modulation is applied to the control grid, and the second set of deflection plates receives a voltage which produces the azimuthal deflection. This voltage may be furnished. for example, by a linear potentiometer geared to the axis of rotation of the scanner.

The arrangement shown is equally applicable to a magnetic CRT, the only changes being in the deflection amplifiers.

VI. ACCESSORY DEVICES

1. Radar Beacons.—In nearly all cases where it would be advantageous if a particular radar echo could be made much stronger or more readily distinguishable from other confusing echoes, a radar beacon is indicated. By the use of a beacon, particular aircraft can be identified among heavy ground echo signals, or in the midst of a large formation of aircraft; the exact location of a specific point on the ground can be indicated, and so on.

A beacon is a repeater of radar pulses. It has an antenna and receiver that convert pulses of energy received at high frequency from a radar set or a special beacon interrogator into triggering signals. Each such triggering signal fires the transmitter in the beacon and causes it to radiate one or more pulses of radio energy that may have almost any desired characteristics in regard to power, frequency, number, duration and spacing. A short time is required for the beacon to reply to an incoming pulse, so that the first reply pulse is slightly delayed beyond the radar echo which would be received from an object at the beacon location. This delay can be made as small as a few tenths of a microsecond (a few tens of yards in range); if this small delay is still not negligible, it can be made extremely constant and allowed for in interpreting the beacon signals.

To permit the display of beacon signals alone, without radar echoes. the beacon transmitter frequency is ordinarily chosen to be different from the radar frequency. Beacon signals can be received at a radar set either by retuning the receiver to the beacon reply frequency, or by providing an extra independent receiver tuned to the beacon. Since the power of the beacon transmitter can be made as great as desired, there is no limit to the strength of the beacon reply. The range at which a beacon can be seen will then be limited only by the power of the radar transmitter and the sensitivity of the beacon receiver, which together determine whether the beacon will be triggered or not.

Since the beacon interrogation and reply links are independent, instead of being two paths for the same energy (as in the case of radar echoes), the range at which beacons can be challenged and their replies received is usually very great, and ordinarily limited only by the optical horizon. The interrogation signal at the beacon falls off as the inverse square of the range to the challenging radar; the reply of the beacon has a power at the radar which is the same function of range.

Beacons of the synchronous sort just described are variously called radar beacons, responder beacons, racons or transponders, there being no important distinction among these terms. Free-running beacons that are not triggered by a pulse challenge are seldom used in conjunction with radar sets, since from them only the bearing of the beacon can be determined. and not its range. Range is so useful a part of the data supplied by radar that beacons which enable its measurement are far preferable to those that do not.

In order to avoid overloading a beacon located where there are many radar sets. it is usually desirable to provide an interrogation coding arrangement whose purpose is to limit the beacon responses to only those interrogation pulses specifically intended to elicit such a response. The decoder is intended to serve this purpose. In the case of ground beacons serving as navigation check points for air-borne radar, it is customary to use pulse-width discrimination in the decoder. The usual radar pulses of an air-borne set are one microsecond or less in duration; the beacon decoder is arranged to produce a trigger for the beacon transmitter only if it receives a pulse whose duration is two microseconds or more.

The air-borne radar is then fitted with a control which lengthens the transmitter pulses and simultaneously retunes the receiver to the beacon reply frequency when it is desired to look at beacon signals instead of at radar echoes.

Reply coding is intended to identify the particular beacon whose response is seen. In the case of microwave radar beacons, this reply coding is usually "range coding," involving the transmission of a closely-spaced series of short pulses from the beacon transmitter.

Other possibilities for coding both interrogation and reply are numerous. Distinct frequencies can be chosen. Simultaneous challenge on two or more frequencies may be necessary to unlock the beacon and elicit a reply. Combinations of properly timed multiple pulses can be used. The beacon reply may be keyed on-and-off to send letters in Morse code. The particular coding system chosen will depend on the application.

Sometimes it is desirable to use, as the device intended to trigger a beacon and to display its replies, instead of a radar set,

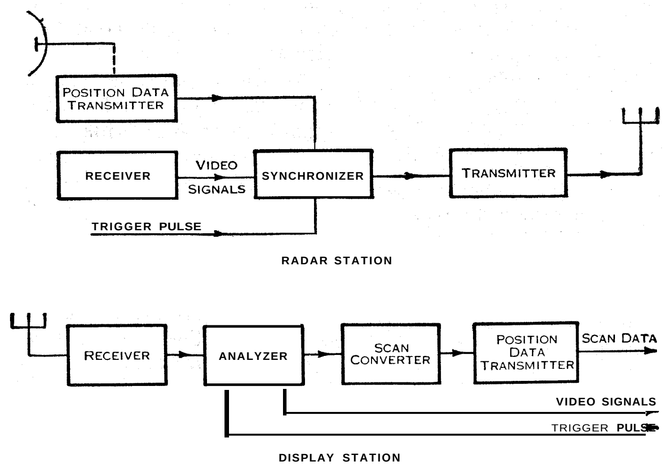

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FIG. 37.— ELEMENTS OF A SIMPLE RADAR RELAY SYSTEM FOR THE DIRECT TRANSMISSION OF RADAR INDICATIONS TO A REMOTE POINT BY RADIO MEANS

a much lower-powered device intended only to work with beacons. Such an equipment is called an interrogator-responsor. It is a radar set in all respects except that its transmitter power is so low that radar echoes cannot be obtained at useful ranges. This reduction in power output enables the equipment to be made much lighter and simpler than a radar set at the same frequency would be.

The interrogator-responsor can be especially small and light if only range information is wanted from the beacons, so that a scanner is not necessary and fixed antennas can be used. By providing two sets of fixed antennas aimed in slightly different directions, homing on a beacon can be done by turning the aircraft or ship carrying the interrogator-responsor until equal beacon responses are received on the two antennas.

By altering the interrogation and reply coding of a beacon to correspond with intelligence which it is desired to transmit, two-way communication using a radar-beacon link is feasible and has been accomplished.

2. Radio Relay of Radar Displays.— It frequently happens that the best site for a radar equipment is not the best location for the organization which is to make use of the information provided by the radar.

For example, in the World War II organization for fighter defense of the British Isles against. hostile air attack, the operating centre was maintained at Stanmore, north of London; information was sent there from radar sets located all around the coasts.

During World War II it was customary to transinit radar information from one point to another by "plotting and telling." The radar echoes seen were entered at the proper range and bearing on a map with a superimposed rectangular grid; this was plotting.

The letters and numbers comprising the grid reference for the location of the plot were "told" vocally over telephone lines or radio circuits to the control centre. where the targets were replotted.

This particular type of system has several drawbacks. Not only are there many chances for the introduction of errors in the target position, but also the speed and traffic-handling capacity of the system are severely limited. It has already been remarked that a radar indicator presents several million units of data per second. By no means are all of these significant, but in a situation involving hundreds of targets, which may not be at all uncommon, it is clearly impossible for even many tellers to give as useful a picture of the air situation as is available at the radar set.

For these reasons, methods were worked out during the war for transmitting, by a radio link, radar video information, synchronizing signals and signals giving the direction in which the radar scanner was pointing at any instant. At the receiving station, these data could be used to construct a radar indication whose quality was just as good as that of the indicators located at the radar set itself.

The problems are mainly those of any wide-band radio link, complicated by the fact that both pulses and long blocks of video signals must be transmitted and received. The elements of a system for accomplishing radar relay are shown schematically in fig. 37. Radar data are delivered to a "synchronizer" which arranges them in proper form to modulate the transmitter. At the receiving station, the receiver amplifies and demodulates the incoming signals and delivers its output to an "analyzer." The latter sorts out separately video signals, trigger pulse and scanner data. The video signals and the trigger are delivered immediately to the display system.

The scanner data must usually be modified in a "scan converter" before being used in display synthesis, because a code is ordinarily used for the transmission of scanner angle.

The scan converter uses the coded data to construct a duplicate of the scanner motion that can be used to drive a position-data transmitter connected to the indicators. The over-all requirements of the system are quite similar to those of television, since the band of frequencies which must be transmitted is about the same.

Comparative PPI photographs may be taken simultaneously at a transmitter and receiver several miles apart.

The direct relay of radar video signals is preferable to televising an indicator at the radar station and transmitting the information by television means, for the following reasons: (1) Persistent indicators do not televise well; their light is too far toward the red end of the spectrum. This leads to a loss in signal-to-noise ratio and in definition; (2) the display available at the receiving end must be identical with that scanned by the televison camera at the transmitting end. If video signals are transmitted directly, any desired type of indication can be synthesized at the receiver. The first, but not the second, of these objections can be removed by storing the radar information on an orthicon or other television pick-up tube directly, instead of viewing a CRT with a television pick-up.

3. Moving Target Indication.— "Ground clutter," the system of strong permanent radar echoes returned by hills and buildings in the vicinity of a radar set, is often a limiting factor on the performance of radar, especially in mountainous terrain. Similarly, the echo signals returned by waves to a radar set carried on a ship or located on the shore ("sea clutter") can be most troublesome. CW radar often makes use of the Doppler shift

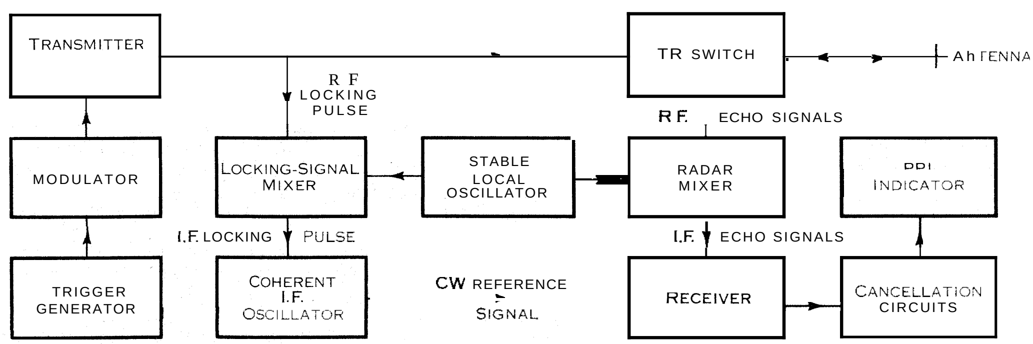

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FIG. 38.— SCHEMATIC DIAGRAM OF MOVING TARGET INDICATION (MTI)

in frequency of the signal returned from a target in radial motion relative to the radar, and thus responds only to moving targets. This same property can be conferred on pulse radar by special techniques, which will be described below, called MTI (moving target indication).

In pulse radar, the effect of the Doppler shift is to cause a phase shift from pulse to pulse of the echo from a moving target. If the radial velocity of the target is v, and the repetition period, or time between successive pulses, is T, each pulse travels a distance $2vT$ different from that traveled by the preceding pulse. This difference is $2vT/\lambda$ wave lengths, so that the phase change between each pulse and the one which follows it is $2\pi \times 2vT/\lambda$ radians. The Doppler frequency is $2v/\lambda$, in agreement with eq. (19).

The basic idea of MTI is to compare the phase of each echo on successive pulses. If there is no phase change, the target is stationary, and its signal is not passed to the indicator. If the phase changes from pulse to pulse, the target is moving, and its signal is displayed. The phase comparison is made in terms of a very stable oscillator which is adjusted, at the instant each pulse is transmitted. to have a standard phase with respect to the outgoing pulse. Beating the echo'signal with that of this "coherent oscillator" will give a signal whose amplitude depends on the relative phase of the echo and the output of the coherent oscillator. If the echo comes from a stationary target, the amplitude of the signal which results from beating the echo with the coherent oscillator output will not change from one pulse to another. If the echo comes from a moving target, the amplitude of the beat will change from pulse to pulse.

It is not important in principle whether the coherent oscillator used as a phase reference runs at radio frequency or at the intermediate frequency of the superheterodyne receiver, provided that the local oscillator of the superheterodyne is stable. Since it is easier practically to have the coherent oscillator run at intermediate frequency, this scheme has been used. A schematic diagram of a practical MTI system is shown in fig. 38.

A stable local oscillator supplies a signal to two mixers: one of which provides a "locking signal" for adjusting the phase of the coherent oscillator to its standard value with reference to the outgoing R.F. pulse. The other mixer is the signal mixer of the receiver. When the I.F. echo signals and the I.F. reference signal beat against one another, the phase of the receiver output signal depends on the number of cycles executed by the local oscillator and by the coherent oscillator during the out-and-back time of travel of the pulse. The result is shown in fig. 39(A). Four successive sweeps of an A-scope are shown, corresponding to four successive pulses.

It will be seen that four of the five echo signals seen on each trace are of constant amplitude from pulse to pulse, and thus correspond to stationary targets. The other echo signal shows a changing amplitude from pulse to pulse; this corresponds to a changing echo-signal phase, and indicates radial target motion.

The way in which stationary targets can be cancelled is shown in fig. 39(B). If the signals from successive pulse cycles are subtracted from one another. echoes of constant amplitude vanish, while echoes of changing amplitude do not.

The actual subtraction is performed by sending the receiver output to a "subtraction circuit" both directly and through a delay line which introduces an amount of delay exactly equal to the interpulse interval. Thus the subtraction circuit receives and compares echo signals from the immediately preceding pulse (direct from the receiver) and from the next earlier pulse (through the delay line).

The length of the usual interpulse interval is so long—some hundreds of microseconds—that electrical delay networks are impracticable for use in MTI. Instead. an ultrasonic delay device is often employed. Signals from the receiver output are turned into sound waves in a liquid or solid by a piezoelectric transducer, allowed to travel through the liquid or solid medium as ultrasonic waves for the distance necessary to introduce the required delay, and turned back into electrical signals by a transducer at the end of the medium.

The velocity of sound waves in such a medium as mercury permits the necessary delays to be produced by sonic paths of reasonable length (17.6 μ sec./in.). Alternatively, an electronic "storage tube," which works in a manner related to that of a television iconoscope can be used as a delay element.

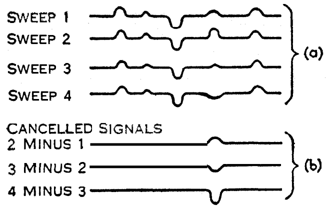

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FIG. 39.—PULSE-TO-PULSE CANCELLATION OF ECHO SIGNALS HAVING CONSTANT PHASE. (a) FOUR SUCCESSIVE SWEEPS OF AN A-SCOPE. (b) THE RESULT OF SUBTRACTING EACH SIGNAL FROM CORRESPONDING ONE ON THE SUCCEEDING PULSE

As the applications of MTI (and subsequent pulse-Doppler radar) came into wider use in postwar years, many advances were made. For example, mercury delay lines were replaced by quartz types that have a better signal-to-noise characteristic, entail smaller losses per unit of delay time and are more stable than the mercury lines they replace.

4. Pulse-Doppler. — The development of pulse-Doppler (PD) radar types in the 1950s for specific military needs (*e.g.*, ground surveillance) also made it possible to locate moving targets (distinguishing them from innumerable fixed objects on the ground and the resultant radar clutter) and to determine their range. CW emission is theoretically best for the discrimination of moving targets because of the frequency change, or Doppler effect, which is imparted to the reflected signals by the radial velocity of the target relative to the radar set. But since CW generators at centrimetre wave lengths tend to lack adequate power output, and since CW does not of itself enable range measurement to be made (unless frequency-modulated, as in the radio altimeter), PD radar employs powerful pulse transmission that also effectively measures the distance to the target.

The PD system employs the Doppler shift phenomenon that occurs within the pulse reflected from a moving object and enables the moving object to be detected in a background of fixed echoes.

The Doppler shift that denotes target motion can be detected in either of two ways. One method, called coherent MTI (described above), involves maintaining a stable reference frequency at the transmitter-receiver set to beat with the Doppler-shifted frequency of echoes received from targets in motion. The other method, termed noncoherent MTI, is used in military surveillance radars. It depends upon the presence of echoes from fixed objects in the same vicinity as the moving target under search. In this case the unchanged frequency of pulse-echo return from the fixed objects beats with the Doppler-shifted echo from the moving target to produce an aural or visual radar indication.

See ELECTRON TUBE; ELECTROMAGNETIC WAVES; NAVIGATION; RADIO; see also references under "Radar" in the Index volume.

BIBLIOGRAPHY.—*Historical:* Sir E. V. Appleton, "Radiolocation: An Account of its Development," *Electronic Engineering* (Sept. 1945), pp. 679 ff.; Sir R. Watson-Watt, "Radar in War and Peace," *Nature* (Sept. 15, 1945), pp. 319 ff., (*see* also Watson-Watt, *Three Steps to Victory* [1957], and a less complete version entitled *The Pulse oj Radar* [1959]); H. E. Guerlac, "The Radio Background of Radar," *Journal of the Franklin Institute* (Oct. 1950), pp. 28 ff.; *see* also Guerlac's thorough and detailed manuscript history "Radar," available in the Library of Congress; R. I. Wilkinson, "Short Survey of Japanese Radar," two parts, *Electrical Engineering* (Aug.–Sept. 1946), pp. 370 ff. (part i), and (Oct. 1946), pp. 455 ff.(part ii); L. Brandt, "German Radiolocation in Retrospect," *Interavia* (1950), pp. 315 ff.; A. E. Hoffman-Heyden, same title and same journal (1951), pp. 623 ff.; A. P. Rowe, *One Story of Radar* (1948); C. Bekker (pen name of H. D. Berenbrok), *Radar-Duell im Dunkel* (1958); D. Terret, *The Signal Corps: The Emergency* (1957).

General and Technical: L. N. Ridenour (ed.) and various authors, Massachusetts Institute of Technology Radiation Laboratory series, 28 vols. (1942–1953) (the Index volume is especially useful); J. F. Reintjes and G. T. Coate, *Principles of Radar*, 3rd ed. (1952); H. E. Penrose and R. S. H. Boulding, *Principles and Practice of Radar*, 6th ed. (1959); J. McQuay, "Principles of Modern Radar." two parts, *Radio-Electronics* (June 1960). pp. 42 ff. (part i). and (July 1960), pp. 34 ff. (part ii); I. Ritow, "Radar Fundamentals," *Electro-Technology* (Nov. 1960); pp. 107 ff.; *J. Instn. elect. Engrs.*, vol. 93 (1946) part iii A (Radiolocation) no. 1–10 (over 200 papers on all aspects of radar); E. G. Bowen (ed.), *A Textbook of Radar*, 2nd ed. (1954); D. Taylor and C. H. Westcott, *Principles of Radar* (1948); L. G. H. Huxley, *A Survey of the Principles and Practice of Wave Guides* (1947); S. S. Attwood and C. R. Burrows (eds.), *Radio Wave Propagation* (1949); L. A. Moxon, *Recent Advances in Radio Receivers* (1949); R. A. Smith, *Radio Aids to Navigation* (1947); F. J. Wylie (ed.), *The Use of Radar at Sea* (1952). (L. N. R.; G. R. T.)

RADAR METEOROLOGY generally signifies the use of radar to observe and study the state of the atmosphere. It may be considered a division of radio meteorology. which also includes the study of the effects of the atmosphere on radio and radar propagation; *i.e.*, bending and attenuation of electromagnetic waves. Radar meteorology comprises the study of radar echoes received from natural reflecting sources within the atmosphere and the relation of the echo characteristics to the nature of the atmospheric processes influencing the reflecting mediums. Some natural reflecting sources are hydrometeors (raindrops. cloud droplets, ice crystals and snowflakes), sharp invisible discontinuities in temperature and humidity, and the highly ionized paths of lightning discharges.

History. — The first verified report of a precipitation echo occurred on Feb. 20. 1941, when a 10-cm. wave length (3,000 mc. per second frequency') radar tracked a shower to a distance of seven miles off the English coast. Prior to that time the unavailability of the microwave magnetron restricted radar equipment to relatively low transmitted powers at the longer wave lengths. Under these conditions the relatively small precipitation particles could not be detected. although weak echoes were thought to be associated with storms as early as 1938 in England. The first detection of what are now believed to have been clear air echoes from the lower atmosphere was made by R. A. Watson-Watt. A. F. Wilkins and E. G. Bowen in England in 1935, using a 50-m. wave length pulsed system intended to explore the ionosphere. The earliest documented observation of lightning echoes was made by M. G. H. Ligda with a 10-cm. radar on July 20. 1949. in Cambridge. Mass. With the development of shorter wave length (1.25 cm.) radars toward the end of World War II. it became possible to detect some of the larger particles in nearby nonprecipitating clouds. while the increasing use of radar throughout the world brought with it the more widespread detection of both clear air echoes and lightning discharges.

Theory. — The radar transmits extremely short pulses of electromagnetic energy in a well-defined beam which is aimed by a parabolic reflector. When the beam is directed toward precipitation. a small fraction of the energy is scattered, a small fraction is absorbed and the remainder is transmitted through to be scattered and absorbed by particles deeper in the storm. The portion of the energy which is scattered or reflected back to the radar is amplified and displayed on an indicator in a position relative to the origin. This position depends upon the time taken for the energy to travel the round path between radar and target at the speed of light. If the beam is held in a fixed direction. the echoes are usually displayed on an A-scope (*see* RADAR: *How* Ruder *Works*) which shows their amplitude or intensity versus distance. If the beam is made to rotate in azimuth around a vertical axis, the echoes brighten a spot on a cathode-ray tube at a distance out from the centre (radar position) depending on the target range and at a direction determined by the direction of the beam. This display is known as the PPI scope or plan position indicator. Since energy is usually reflected from the entire depth of the storm, the geographical position and extent of precipitation may be mapped accurately on the PPI scope to ranges limited mainly by the earth's curvature. For example; a storm at a range of 200 mi. must extend above 20.000 ft. to be detectable above the radar horizon. With this restriction, the PPI display enables the meteorologist to watch the motion and development of precipitation areas. When the beam is made to scan in a vertical plane, the echoes are displayed on the range height indicator or RHI scope showing a vertical cross section of the storm. On this scope, the meteorologist determines the height and growth rate of the storm, and its physical nature such as snow or rain, in addition to other storm features.

When the wave length of the electromagnetic radiation is large with respect to the size of the scattering particle. the energy returned to the radar is given by the Rapleigh scattering law and is proportional to the 6th power of the particle diameter; *i.e.*, doubling the diameter of a drop increases the echo by a factor of 64. In addition, the echo power is inversely proportional to the 4th power of the wave length; *i.e.*, doubling the wave length decreases the echo by a factor of 16. Since a raindrop is roughly 100 times as large as a cloud droplet, its echo is about 1,000,000 times as strong as that from a cloud droplet. However. since there may be 1.000 times as many cloud drops as raindrops, the total rain echo is about 1,000 times as strong as that from a water droplet cloud. Cloud radars operate at wave lengths near 1 cm. while precipitation radars operate between 3 and 23 cm. Clouds comprised of ice crystals are more readily detected because the crystals are usually much larger than the cloud droplets.

Of course. at any instant the radar receives the energy scattered back from a large number of particles confined within a volume defined by the beam width and half the pulse length in space. This is called the pulse volume. A 1 μsec. pulse intercepts a 492-ft. depth of precipitation while a 1° beam intercepts a width of about 9,200 ft. at a range of 100 mi. Since there are roughly 100 raindrops per cubic foot of air. an individual echo from such a range may include the energy scattered from about 4,000.000,-000.000 (4×10^{12}) raindrops. At a particular instant, the drops may be so distributed as to cause their individual echoes to reinforce each other; at another time. their individual echoes may cancel each other. Because the drops change position with respect to each other as a result of wind shear and turbulence. the total echo received from such a group of particles fluctuates rapidly from one pulse to the next. However. since the drops are randomly distributed within the pulse volume. the average echo intensity over a number of pulses is the sum of those from the individual particles; *i.e.*, it is proportional to the sum of the 6th powers of the particle diameters. This quantity summed over a representative unit volume of space within the pulse volume has been designated by the symbol Z by radar meteorologists. When they measure the average echo power from a storm. they are interested in the Z or reflectivity factor of that storm.

For a small target such as an airplane, the incident and reflected energy both spread out and decrease in intensity as the square of the target range. Thus, the echo from such a target decreases as the 4th power of the range. However, storms usually intercept the entire area of the radar beam so that the total energy incident on it does not depend on its range: it is only the reflected power which decreases with distance. For this reason. the average echo intensity from a storm decreases only as the square of its range, provided its reflectivity or Z remains constant.

Water drops scatter microwave radiation about five times as well as ice particles of the same mass because of their higher index of refraction. Therefore. when snowflakes begin to melt as they fall into warm air with temperature above 32" F.. their echo suddenly increases by a factor of 5 over that of the dry snow above. When the particles melt completely. however. the resulting raindrops quickly begin to fall at an average of about five times as fast as the original snowflakes. decreasing the number of particles per unit volume and the echo intensity proportionally. This causes the echo from the melting particles to be about five times as strong as that from both the dry snow above and the completely melted raindrops below. The exact variation of echo intensity through the melting zone depends on a number of other factors. In any case, the echo intensification in that layer makes it appear as a horizontal "bright band" on the RHI scope. Such "bright bands" are characteristic of most widespread precipitation in temperate latitudes and indicates that the rain originates in the form of ice crystals aloft.

The storm reflectivity factor or Z has also been found to be related to the precipitation rate, R, in both snow and rain. and to the water content per unit volume in clouds. Although the exact relation between Z and R depends on the nature of the particle size distribution, and it is possible to have equal rainfall intensities comprised of a large number of small drops with small Z or a few large drops with large Z, under average conditions the storm Z as measured by the echo intensity can provide an estimate of the precipitation rate within a factor of about 2. If the echo intensity is averaged over long periods, the estimates of total rainfall can be made with greater accuracy. Since a calibrated radar can measure the average rainfall over an area approximately 50 mi. in radius (about 7,500 sq.mi.) with an accuracy comparable to that from a network of several hundred rain gauges, and can secure these data quickly, it has great value for flood warning purposes.

One of the facts which limits the use of radar for the quantitative measurement of distant rainfall is the attenuation of the radar energy by scattering and absorption in intervening rain. Attenuation reduces the echo power by an amount which is unknown or difficult to determine; the echo may then be a useless measure of rainfall. At wave lengths of 10 cm. and larger, the attenuation in normal rains is negligible. and such wave lengths are therefore preferable for quantitative measurements. As the wave length decreases below 10 cm., the losses due to both scattering and absorption increase so that 1-cm. wave length radars can only penetrate a few miles into moderately intense rains. Even at 3 cm., only the front edge of an intense rainstorm may be seen on the radar scope.

Attenuation in snow is due only to the scattering and is generally negligible except at the very short wave lengths and in the most intense snowstorms.

Echo Interpretation and Uses.—In addition to the measurement of average echo intensity, the radar meteorologist studies the rate of pulse-to-pulse fluctuation of the echoes as an indication of the turbulence and wind shear in a storm. This technique is believed to have promise in identifying severe storms and tornadoes since the violent winds move the particles about rapidly. Use is also made of circular polarization, a technique which permits the cancellation of echoes from spherical particles. Those echoes which are not canceled with circular polarization are due to large nonspherical raindrops and hailstones which also occur in violent storms, and to wet snowflakes in the melting layer. Aircraft echoes are also only slightly reduced by circular polarization. Such a radar can therefore detect aircraft when they might be obscured in the weather echoes on a linearly polarized radar.

The greatest use of weather radar is in the observation of the geometric structure and motion of clouds and storms. Widespread precipitation such as that associated with warm fronts in middle latitudes is generally seen on the PPI scope as a fairly uniform echo mass covering large areas of the scope. On the RHI, the advance deck of alto-stratus clouds and evaporating precipitation lowers slowly as the storm centre approaches until snow or rain finally starts at the ground. On the PPI, some pattern may usually be discerned within the larger echo masses associated with trails of ice crystals released from occasional discrete cloud cells; these trails twist and turn as the ice crystals fall into layers of different wind velocity. On the RHI scope, the trails frequently take the form of hooklike cirrus clouds such as may be seen visually in the sky on a clear day. Their slope on the RHI and pattern on the PPI are helpful in determining the variation of winds with height.

While individual trails or small precipitation areas move with the winds at the heights of the cloud cells from which the precipitation is released, the entire region of precipitation echo moves with the velocity of the large-scale pressure pattern or storm system.

The precipitation echoes associated with a cold front most frequently take the form of lines of shower or thunderstorm cells several hundred miles long oriented along the front. Individual cells tend to move with the mean winds or those near the 10,000-ft. level, and may be less than 10 mi. in diameter, although some lines fail to show any separation. On the RHI. the echoes appear as tall vertical columns with sharply defined edges and tops which may become diffuse as the water particles are transformed to ice crystals and form the anvils of cumulo-nimbus clouds. Such storms do not display the "bright band" except in their decaying stages. Similar echoes are associated with isolated showers and thunderstorms on hot days when the atmosphere is unstable. Their severity may be indicated on the radar by their height, sometimes exceeding 50,000 ft., their rate of growth which may exceed 2,000 ft. per minute, their strong echo intensity due to large raindrops and hailstones, and an attenuation shadow cast on other storms behind (at the shorter wave lengths). Tornadoes have occasionally been identified by a figure-6-shaped tail extending out from the edge of a larger thunderstorm echo.

The PPI pattern of a hurricane shows a number of spiral bands each perhaps several hundred miles long and 20 mi. wide which spiral into the vicinity of the hurricane eye or pressure and wind minima. The centre of spiral is readily identified making it possible to pinpoint and track the "eye" by radar with an accuracy of about $\pm$ 7 mi.

In the tropics where the storms generally move slowly the spiral bands may be more like complete concentric rings; however, as they move into middle latitudes the major precipitation tends to occur in the forward right sector. The outer bands are comprised of individual shower cells, while the inner bands are more continuous and display the "bright band" near the melting level.

Echoes are also detected from sharp discontinuities in moisture and temperature without the presence of particulate matter. These echoes, unidentified in the early days of radar, are called "angels." Isolated angels occur under a wide range of conditions though preferably in a turbulent atmosphere when moist parcels of air rise through a relatively dry environment into the bases of cumulus-type clouds. Widespread angel echoes have also been observed from the sea breeze front.

At wave lengths of 10 cm. and longer, the highly ionized columns produced by lightning discharges may also be detected. However, since the ionized path dissipates rapidly, the radar beam must be directed at the lightning region just at the discharge time. Cloud-to-cloud lightning is more readily discernible on the scope because of its greater horizontal extent than the cloud-to-ground variety; also it tends to occur in the upper and weaker snow regions of the storm so that its echo is not so easily obscured by the more intense rain echoes. Lightning echoes as long as 100 mi. have been observed.

For more information on radar theory, terminology and equipment, *see* RADAR.

BIBLIOGRAPHY.—R. Wexler and D. M. Swingle, "Radar Storm Detection," Bull. *Amer. Meteor. Soc.,* 28:159–167 (1947); M. G. H. Ligda, "Radar Storm Observation" in *Compendium of Meteorology,* ed. by T. F. Malone, pp. 1265–82 (1951), "The Radar Observation of Lightning," J. *Atmos. and Terr. Phys.,* 9:329–346 (1956); J. S. Marshall, W. Hitschfeld and K. L. S. Gunn, "Advances in Radar Weather" in *Advances in Geophysics,* ed. by H. E. Landsberg, vol. ii (1955); E. Kessler and D. Atlas, "Radar-Synoptic Analysis of Hurricane Edna," U.S. Air Force Department, Defense Department, *Geophysical Research Papers 50* (1956); V. G. Plank, "A Meteorological Study of Radar Angels," U.S. Air Force Department, Defense Department, *Geophysical Research Papers 52* (1956); J. S. Marshall and W. E. Gordon, "Radio Meteorology" in *Meteorological Research Reviews,* ed. by A. K. Blackadar (1957). (DD. A.)

RADCLIFFE, ANN (1764–1823), English novelist, only daughter of William and Ann Ward, was born in London on July 9, 1764. She was the author of four famous novels: *The Sicilian Romance* (1790), *The Romance of the Forest* (1791), *The Mysteries of Udolpho* (1794) and *The Italian* (1797). When she was 23 years old she married William Radcliffe, an Oxford graduate and student of law. He gave up his profession for literature, and afterward became proprietor and editor of the *English Chronicle.* After *The Italian* she gave up writing for publication. She died on Feb. 7, 1823. *Gaston de Blondeville* (1826) was published after her death, as were her *Poems* (1834). In the history of the English novel, Ann Radcliffe deserves at least the credit of originating a school of which she was the most distinguished exponent. She had a genuine gift for scenic effect, and her vivid imagination provided every tragic situation in her stories with its appropriate setting. Sir Walter Scott wrote an appreciative essay for the edition of 1824, and Christina Rossetti was one of her admirers.

RADCLIFFE, JOHN (1650–1714), English physician, born at M'akefield. a well-known physician in the reigns of William III and Anne. He left property to University college for founding two medical travelling fellowships and for building the Radcliffe observatory, hospital and library at Oxford, and enlarging St. Bartholomew's hospital in London. Radcliffe was elected M.P. for Bramber in 1690 and for Buckingham in 1713. He died at Carshalton on Nov. 1, 1714.

See J B Nias, *Life of John Radcliffe* (Oxford, 1918); A. B. Luckhardt, *Surg., Gynec. and Obst*, 72 674–677 (1941).

RADCLIFFE, a municipal borough (1935) in the Bury and Radcliffe parliamentary division of Lancashire Eng., on the Irwell, about 8 mi. N.N.W. of Manchester by road. Pop. (1961) 26,720. Area 7.7 sq.mi. In the church of St. Bartholomew the tower arch dates from the early 1jth century.

Industries include cotton, paper, chemicals and other manufactures and engineering.

RADCLIFFE-BROWN, ALFRED REGINALD (1881–19j5), British social anthropologist. whose great contribution was his systematic framework of concepts and generalizations relating to the social structures of simple societies, was born on Jan. 17, 1881, in Birmingham. After being educated at Trinity college, Cambridge, he took up the study of anthropology. In 1906 he went to the Andaman Islands! where his field work later won him a fellowship at Trinity college. In 1910 he carried out a second field expedition to Western Australia. concentrating on kinship and family organization. In 1916 he became director of education in the kingdom of Tonga and in 1921 took the chair of social anthropology at the University of Cape Town. In 1925 he accepted the chair of anthropology at Sydney university. where he built up a vigorous department for teaching and for research in both theoretical and applied anthropology. A brilliant lecturer and conversationalist, he became a well-known personality in Australian intellectual circles in spite of a somewhat aloof and critical temperament. Between 1931 and 1937 he was professor of anthropology at The University of Chicago, after which he held the chair of social anthropology at Oxford until his retirement in 1946. Among many academic honours he received were the Rivers and Huxley Memorial medals of the Royal Anthropological institute, of which he was president in 1939–41. He died in London on Oct. 24. 1955.

Together with Bronislaw Malinowski (*q.v.*), Radcliffe-Brown revolutionized the study of social anthropology in founding modern functionalist theory. His basic postulate was that every social system has a "functional unity" in which "all the parts work together with a sufficientdegree of harmony or internal consistency.'! He defined a social system as consisting of "the total *social structure* of a society together with the totality of *social usages* in which that structure appears and on which it depends for its continued existence." As his theory developed he laid increasing stress on the comparative analysis of social structure as the primary aim of social anthropology. Claiming social anthropology to be a natural science of society to which the conjectural history resorted to by older anthropologists was irrelevant. he sought to establish general tendencies or laws underlying the diversities of human social life. In the comparative sociology of kinship and juridical and political institutions. Radcliffe-Brown was an acknowledged master and his generalizations won wide support and inspired modern research in this field. He showed that the patterns exhibited by kinship systems, notably those that have a classificatory terminology, arose from particular combinations of the laws of the unity of the sibling group. the unity of the descent group and the separation of successive generations, in association with other specific variables such as distinctions of age and sex (*see* KINSHIP TERMINOLOGY). Applying these principles, he swept away the fog of pseudohistorical misunderstanding of the social basis of clans, totemism, alleged matrilineal survivals and other classical problems of anthropology.

Among Radcliffe-Brown's works are *The Andaman Islanders* (1922; new ed.. 1948) and *Structure und Function in Primitive Society* (1952).

See also ANTHROPOLOGY: *Analysis* of *Culture and Society.*

See M Fortes (ed.), *Social Structure: Studies Presented to A. R. Radcliffe-Brown* (1949); memoir in *Man*, vol lvi (1956). (M. Fs.)

RADEGUNDA, ST. (d. 587), Frankish queen, was the daughter of Berthaire, king of the Thuringians. Berthaire was killed by his brother Hermannfried, who took Radegunda and educated her, but was himself slain by the Frankish kings Theuderich and Clotaire (529), and Radegunda fell to Clotaire, who later married her. She left him when he unjustly killed her brother, and fled to Medardus, bishop of Poitiers, who consecrated her as a nun. Radegunda stayed in Poitiers, founded a monastery there, and lived for a while in peace. The queen died on Aug. 13, 587.

RADEK, KARL (1885–), Russian politician, was born in Lwów (Lemberg) and he was educated at the universities of Cracow and Berne. In 1904 he became a member of the Social Democratic party of Poland and Lithuania. During the revolution of 1905 he spent a year in prison, and subsequently became a member of the editorial staff of social democratic newspapers in Poland. Leipzig and Bremen which supported the left wing of the German Social Democrats. During World War I, after some months of illegal antimilitarist activity in Germany, he established himself in Switzerland where he wrote for the Berne *Tageblatt*. He took part in the Zimmerwald and Kienthal internationalist conferences in September 1915 and April 1916. After the Russian revolution of March 1917 he crossed Germany, together with V. I. U Lenin, G. E. Zinoviev, Julius Martov and others, and remained in Stockholm as the representative of the central committee of the Bolshevik party, issuing a weekly bulletin on the Russian Revolution in French and German. After the second revolution, in Nov. 1917, he took part in the Brest-Litovsk peace negotiations. When the German revolution broke out in 1918 he made his way illegally to Germany, where as a representative of the central committee of the Soviet Communist party he took an active part in reorganizing the German Communist party, working in its central committee after the murders of Karl Liebkneckt and Rosa Luxemburg on Jan. 16, 1919. He was imprisoned in Germany from Feb. to Dec. 1919. On his release from prison Radek returned to the U.S.S.R., where he became one of the leading members of the presidium of the Communist International. He returned illegally to Germany, however. and took part in the organization of the joint congress of German Communists and Left Independents. He was made a scapegoat for the failure of the German Communists to seize power in the autumn of 1923, and, on account of his support of the "right" groups of the German Communists, he lost his authority in the Communist International, losing his place in its executive committee and in the central committee of the Soviet Communist party. He was a prolific writer in the Soviet press on questions of international politics. Expelled from the Communist party in 1927, he was readmitted in 1930. In Jan. 1937, he was tried with 16 others for plotting against the Soviet Union and was sentenced to 10 years' imprisonment. He was released after serving only four years of his term in order that he might serve as a propagandist.

RADETZKY, JOSEF, COUNT OF RADETZ (1766–1858), Austrian soldier, was born at Trzebnitz in Bohemia in 1766, of an old noble family, originally Hungarian. He joined the army as a cadet in 1785. Next year he became an officer, and in 1787 a first lieutenant in a cuirassier regiment. He served as a galloper on Count Franz Moritz Lacy's staff in the Turkish War, and in the Low Countries during the Revolutionary War. In 1795 he fought on the Rhine, and next year with Beaulieu against Napoleon in Italy. His personal courage was conspicuous; at Fleurus he had led a party of cavalry through the French lines to discover the fate of Charleroi, and at Valeggio, with a few hussars, rescued Beaulieu from the enemy. Promoted major. he took part in Dagobert S Wurmser's Mantua campaign. As lieutenant colonel and colonel he displayed bravery and skill at Trebbia and Novi (1799), and at Marengo was hit by five bullets.

In 1801 Radetzky received the knighthood of the Maria Theresa order; in 1805 he was promoted to major general and given a commdnd in Italy under the archduke Charles, and thus took part in the successful campaign of Caldiero. Peace again afforded him a short leisure, which he used in studying and teaching the art of war. In 1809, now a lieutenant field marshal, he fought at Wagram, and in 1810 received the commandership of the Maria Theresa order and the colonelcy of the 5th Radetzky hussars. From 1809 to 1812. as chief of the general staff, he was active in the reorganization of the army and its tactical system, but, unable to carry out the reforms he desired because of the opposition of the treasury, he resigned the post. In 1813 as chief of staff to the prince of Schwarzenberg. he had considerable influence on the councils of the allied sovereigns and generals. He had a considerable share in planning the Leipzig campaign and as a tactician won great praise at Brienne and Arcis sur Aube. He entered Paris with the allied sovereigns in March 1814, and returned with them to the Congress of Vienna.

He then resumed his functions as chief of the staff, but his ardent ideas for reforming the army came to nothing in the face of the general apathy. His zeal added to the number of his enemies, and in 1829, after he had been for twenty years a lieutenant field marshal, it was proposed to place him on the retired list. The emperor, unwilling to go so far as this, promoted him general of cavalry and shelved him by making him governor of a fortress. In 1834. however, his services were again required in Italy. first under Frimont, and then in chief command.

In 1836 Radetzky became a field marshal. Apathy and parsimony caused the authorities again to neglect his many suggestions. and the outbreak of the wars of 1848 found the Austrian army in an unprepared condition through no fault of Radetzky's. Nevertheless. recalled to command. he conducted his famous operations in the Quadrilateral, leading up to the triumph of Novara on March 23, 1849. (See ITALIAN WARS.) To the soldiers of his army who idolized him, he was always simply "Vater Radetzky." He died on Jan. 5, 1858.

RADIATION (RAYS): see COSMIC RAYS; ELECTROMAGNETIC WAVES; PARTICLES, ELEMENTARY; RADIOACTIVITY, ARTIFICIAL; RADIOACTIVITY, NATURAL; X-RAYS; LIGHT.

RADIATION: BIOLOGICAL EFFECTS. All life is constantly being bombarded with various kinds of radiation—visible light, infrared, ultraviolet, radio waves, X-rays (from cosmic and terrestrial sources)—all of which are basically similar in that they are all transfers of energy from one place to another. In a wide sense any consequence of the transfer of radiation energy to a living organism is a biological effect of radiation. This definition includes both the normal effects on many life processes (*e.g.*, photosynthesis in plants and vision in animals) and the abnormal or injurious effects resulting from the exposure of life to unusual types of radiation or to increased amounts of the radiations commonly encountered in nature. This article, devoted chiefly to the discussion of the deleterious effects of radiation, is divided into the following sections:

I. DEFINITIONS AND CONCEPTS

For a better understanding of the later sections of this article a review of the two main types of radiation—electromagnetic waves and moving atomic particles—their measurement, sources and mechanisms, is in order.

A. TYPES AND MEASUREMENT OF RADIATION

1. Electromagnetic Waves.—Energy can be transferred through matter or through space by means of oscillatory variations in electric and magnetic fields originating at various sources. Electromagnetic wave radiation is classified into several types. depending on frequency and wave length. The various types (in order of decreasing wave length and increasing frequency) and their sources are summarized in Table I.

TABLE I.—*Electromagnetic Waves*

Wave type	Sources
Hertzian (Radio waves and Microwaves)	Radio transmitters
Infrared	Hot bodies
Visible	Hot bodies
Ultraviolet	Hot bodies; excited gases
X-rays and gamma rays*	Atoms struck by high-energy particles; radioactive materials; cosmic sources

*X-rays emitted during the disintegration of radioactive materials.

2. Particulate or Corpuscular Radiations.—Simply speaking, an atom consists of a nucleus (composed chiefly of neutrons and protons) surrounded by a cloud of electrons; in addition there are other special particles. When separated, either by natural radioactive disintegration or by artificial means (as in a cyclotron, for example), these particles, charged or uncharged, are capable of transferring their energy, wholly or in part, to any substance through which they pass. Streams of such particles constitute particulate radiations. The more important types of particle, the magnitudes and signs of their charges (relative to that of an electron, defined as the unit negative charge-), their masses (relative to the mass of a hydrogen nucleus. defined as the unit mass) and their main sources are summarized in Table II. The rate of transfer of energy by a particulate radiation depends on the mass of the particle, its velocity and, if charged, the magnitude of its charge.

TABLE 11.—Particulate ***Radiations***

Particle type	Charge	Mass	Sources
Electron*	−1	1/1843	Accelerating machines, radioactive materials
Protont	1	I	Accelerating machines
Alnha (α) particle‡ . . .	2	4	Radioactive materials
Neutron	0	1	Nuclear reactors, accelerating machines

*Electrons emitted by radioactive nuclei are called beta (ti) particles.
†Protons are the nuclei of hydrogen atoms.
‡Alpha particles are the nuclei of helium atoms.

3. Measurement of Radiation.—The physical quantity of a radioactive substance is measured in curie units (see RADIOACTIVITY. NATURAL). Radiation acts biologically by depositing energy within living cells through the process of ionization or excitation of some of their constituent molecules (see the following section).

Roentgen Unit—The original biological unit of X- (or gamma) ray exposure, the roentgen unit (r), is defined as that quantity of radiation that produces a given number of charged ions in a given quantity of air under standard conditions.

Rad.—A more general and more accurately defined measure of local exposure to all types of radiation is the rad, the radiation dose absorbed in tissue itself.

Rem.—The comparative unit called the rem (roentgen equivalent man) expresses the dosage of any radiation that produces biological effects in man equivalent to 1 rad of X-rays. The rem is the measure of the "relative biological effectiveness" (RBE) of radiations; *i.e.*, the ratio of doses of ionizing radiation from different sources that have the same biological effect.

For more technical definitions see RADIOLOGY. A detailed discussion of radioactivity may be found in RADIOACTIVITY, NATURAL, and RADIOACTIVITY, ARTIFICIAL.

B. MODE OF ACTION

1. Mechanisms of Energy Transfer. — There are several mechanisms by which energy is transferred from radiations to biological materials. Wave radiations yield up their energy through resonance. In general, the smaller a body, the higher its resonant frequency and therefore the higher the frequency of the radiation from which it will absorb energy. The energy of infrared and visible radiation is absorbed mainly by whole molecules and atoms and therefore appears mainly as heat. The energy of ultraviolet radiation is absorbed partly by the planetary electrons of atoms; an electron jumps to a higher-energy orbit. thereby bringing the atom into a state of excitation, in which it is chemically reactive. The energy of X-rays is also absorbed mainly by the planetary electrons of atoms, but the amount absorbed is usually great enough to produce ionization; *i.e.*, to induce an electron (or electrons) to escape altogether from the atom, which latter is thus ionized; an ionized atom is highly reactive, even more so than one in a state of excitation.

Particulate radiations yield up their energy through collision with the planetary electrons or atomic nuclei of the material through which they pass. Charged particles usually react with the planetary electrons and therefore leave the atom in an excited or, more commonly. ionized state. Neutrons, being uncharged, are able to pass through the orbits of the planetary electrons and collide with the nucleus of an atom. The nucleus may then recoil. or it may capture the neutron. In biological material neutrons yield up most of their energy through collision with hydrogen nuclei, which recoil as hydrogen ions (*i.e.*, protons). The neutron is eventually captured by some nucleus, and capture is usually followed by the ejection of one or more charged particles, often accompanied by a gamma ray.

2. Ionization and Penetrating Power. — Although all higher-energy radiations (*i.e.*, X-rays and particulate radiations) produce ionization in biological material, the spatial distribution of the ionization depends on the type and penetrating power of the radiation, the nature of the material irradiated and the spatial distribution of the radiation source or sources. High-energy X-rays produce ionization that is rather sparsely but uniformly distributed along the track of the radiation; alpha particles cause intense ionization along their tracks; in between these come neutrons, protons and beta particles. In general, the lower the speed of a particle, the denser the ionization along its track, so that all particles tend to be more densely ionizing toward the ends of their tracks. High-energy X-rays penetrate deeply (X-rays commonly used in medicine are less penetrating), but most beta particles penetrate only a few millimetres in biological tissues and alpha particles only a small fraction of a millimetre. Animal tissues such as bone and teeth which contain elements of fairly high atomic weight. such as calcium, absorb much more energy from a given radiation than do soft tissues, which are composed mainly of elements of low atomic weight. Ultraviolet radiation is of very low penetrating power.

3. Mechanisms of Biological Action. — The biological effects of the higher-energy electromagnetic radiations and of all the particulate radiations are mediated through the ionization (and, to a lesser extent, the excitation) that they produce in biological tissue. Thus all ionizing radiations have broadly similar biological effects; such differences as are found are the result of differences in the spatial distribution of the ionization. Ionization in biological tissues is largely intracellular. Therefore, an explanation of its mode of action must be sought at the cellular level; effects on the whole organism are likely to be secondary. Two main types of intracellular action have been distinguished: first, direct action through ionization of biological structures along the ionized track; and second, indirect action through the formation of reactive chemical substances that diffuse away from the ionized track and subsequently undergo further reaction elsewhere.

Direct *Action.*—Direct biological actions were studied in great detail in the period between 1927 and 1947. The leaders in this work included H. J. Muller in the U.S., N. Timofeeff-Ressovsky and K. G. Zimmer in Germany and D. E. Lea in Great Britain. A detailed quantitative theory was elaborated, the target theory or *Treffertheorie*, whereby a tissue undergoing irradiation was likened to a field traversed by the fire of a machine gun. It was supposed that to produce a given effect there must be one or more hits by an ionized track on a sensitive target, so that the probability of obtaining the effect was dependent on the probability of obtaining the requisite number of hits on the appropriate target. This theory was very successful in giving a quantitative treatment of many of the biological effects of radiations, particularly in the field of genetics

Indirect Action. — In the field of radiation chemistry, however, the target theory had little application, and from about 1940 the interest of radiation biologists tended to shift toward the indirect actions of radiations. This shift was given impetus by the discovery in 1947, by J. M. Thoday and J. Read, that the induction of chromosome breakage, which had until then been viewed as a target-theory effect par excellence, was enhanced if the tension of oxygen was increased in the material irradiated. This led on to the discovery of protective substances, such as cysteamine and cysteine, which reduce some of the biological effects of radiation exposure; Z. Q. Bacq (Belgium) and H. M. Patt (U.S.) were leaders in this field. Many other studies followed in which it became apparent that, although there certainly were indirect actions of radiations, the distances over which indirect action could occur were always small, usually no more than a few microns.

II. GENERAL BIOLOGICAL EFFECTS

The biological effects of radiations may conveniently be subdivided into somatic effects — short-term somatic effects (*i.e.*, short-term effects on the body of the individuai) and long-term somatic effects — and genetic effects. Historically, they were discovered in that order. But as the genetic effects are nearest to the cellular level, and the short-term somatic effects farthest from it, it is more convenient to consider them in the reverse order.

A. GENETIC EFFECTS

The genetic effects of radiations arise through damage to those intracellular bodies in the germ cells that are the material basis of heredity (*q.v.*). These are the chromosomes, with their constituent genes (see GENE). Genetic effects therefore occur only if the radiation reaches the germ cells. Thus in those animals (man is one) and plants in which the germ cells are fairly well covered by tissue, radiations of low penetrating power, such as ultraviolet light and alpha and beta particles, cannot produce genetic changes; however, radiations of high penetrating power. such as X-rays and gamma radiation, can induce genetic effects.

Radiation-induced genetic effects on animals and plants are probably not qualitatively different if consideration is given to the physiological variations between these two kinds of life. For obvious reasons, more research has been done on the changes induced in the genetic material of animals. However, mutations induced by irradiation of seeds have been of interest to plant breeders: many new varieties have been produced, some of which show improvement over the original stock in respect to hardiness, resistance to disease, etc. Genetic changes of two sorts are induced, namely, gene mutations and chromosome mutations They differ in important respects and will be considered separately.

1. Gene Mutations. — Radiation-induced gene mutations were first demonstrated by H. J. Muller in 1927. They are all of the same types that occur spontaneously in nature. Most gene mutations, whether spontaneous or radiation-induced, are harmful. They reduce the fitness of the organism in the sense that an individual carrying a mutated gene is less capable of surviving and leaving descendants than is an individual carrying the gene in its unmutated form. This is an empirical observation, but it may also be expected on theoretical grounds: any advantageous mutation that could occur spontaneously would probably have occurred at some time in the past and, being advantageous, would have spread through the species, thereby coming to represent the normal form of the gene; any mutation away from the normal form would therefore be a mutation to a less advantageous form.

Although the mutations induced by radiations are all of types that occur spontaneously, the relative frequencies with which any two particular genes mutate under irradiation may not be the same as the frequencies with which they mutate spontaneously; however, if whole classes of genes are considered, the mutational idiosyncrasies of particular genes are lost, and the over-all picture shows that exposure to radiation causes a proportionate increase in the mutation frequency of all classes of genes.

Experiments with animals and plants, notably by Muller and Timofeeff-Ressovsky and their co-workers, in the period between 1927 and 1935 established a number of factors influencing the induction of mutation by radiations. The yield of mutation is directly proportional to the amount of energy absorbed in the germ cells; *i.e.,* to the radiation dose. This linear dependence of mutation on dose, which is to be expected on target-theory considerations if gene mutation is the result of a single hit by an ionized track. has been demonstrated experimentally for doses down to a few r and is believed to be valid for all doses, though for statistical reasons it would be difficult to obtain experimental verification at doses much lower than this. The implication is that there is no threshold dose for the induction of gene mutation; *i.e.,* any dose, no matter how small, will induce some mutation.

Radiation quality has little effect on the amount of mutation induced, approximately the same amount of mutation being induced per unit dose, whatever the type of radiation, provided that the radiation intensity is the same.

Radiation intensity was originally thought to have no importance, the total amuunt of mutation induced being dependent only on the total accumulated dose. However, in 1958 it was shown by W. L. Russell that this does not hold good for mutation induced in immature germ cells (spermatogonia and oocytes) of the mouse, the amount of mutation induced by a dose accumulated at a rate of about 1 r per day being only about a third of that induced by the same dose accumulated at about 100 r per minute. If this is true of mammalian spermatogonia and oocytes generally, it holds important implications for man, whose germ cells are present mainly in the form of spermatogonia in the male and oocytes in the female.

The amount of mutation induced by radiation is usually expressed in terms of the mutation-rate-doubling dose, which is the dose that induces as much mutation as occurs spontaneously in each generation. This is merely a mathematically convenient way of relating the amount of induced mutation to that arising spontaneously; there is no special biological significance in a mutation rate twice the spontaneous rate. The more sensitive the genes to radiation, the lower the doubling dose. Doubling doses for high-intensity exposure of several different organisms have been found experimentally to lie between about 30 r and 150 r; for seven specific genes in spermatogonia of the mouse the doubling dose is about 30 r for high-intensity exposure and about 100 r for low-intensity exposure. Very little is known about the doubling dose for human genes: studies of the children of survivors of the atomic bomb explosions at Hiroshima and Nagasaki indicate that it must be higher than 10 r, but how much higher is not known; most geneticists assume that it is about the same as the doubling dose for the mouse.

The existence of a linear law relating induced gene mutation to radiation dose holds an important implication for populations: it implies that very small doses of radiation given to very large numbers of individuals may introduce into the population as many mutant genes as would be introduced through large doses to small numbers of individuals. Furthermore, it is necessary to take into consideration the probability that an exposed individual will contriburr to the next generation at some time after exposure. It follows that exposure of individuals below reproductive age (including unborn fetuses) is genetically of the greatest importance, and exposure of those above reproductive age is of no importance.

The effect on a population of a rise in its mutation rate depends on the role played by mutation in determining the characteristics of the population. Deleterious genes enter the population through mutation but, because they reduce the fitness of their carriers, they tend to die out; thus a genetic equilibrium is set up at a point where the flow of deleterious genes into the population through mutation is counterbalanced by the loss through reduction in fitness. At equilibrium a constant fraction of the population will be handicapped by deleterious genes. Increasing the mutation rate would increase the gene-handicapped fraction proportionately. However, the full increase would not be manifest immediately; this would occur only when genetic equilibrium had again been established, which would probably require several generations.

2. Chromosome Mutations. — Ionizing radiations not only cause genes to mutate but also may break the chromosomes in which the genes are carried. Chromosome breaks often heal spontaneously, in which case no damage becomes apparent. If a break fails to heal, a germ cell may be formed that lacks an essential part of the gene complement; such a germ cell may be capable of taking part in the fertilization process, but the ensuing zygote is usually incapable of full development and dies in an embryonic state. When two chromosomes in the same nucleus are broken, it sometimes happens that the broken ends join together, but in such a way that the order of the genes in the chromosomes is changed: for example, part of chromosome A may join onto part of chromosome B and vice versa. A germ cell carrying such a chromosome structural change may be capable of giving rise to a zygote that may develop into an adult individual, but the germ cells produced by the latter include many that lack the normal chromosome complement and so give rise to zygotes that are incapable of full development. An individual of this sort is called semisterile, and the number of his descendants is correspondingly lower than normal. Chromosome structural changes therefore usually die out of a population; for this reason they are of little importance in human populations. In some species, however, there are mechanisms that reduce the loss of fertility usually associated with chromosomal changes, and in them such changes may be present in the majority of individuals. They include the evening primrose, *Oenothera,* and some species of the fruit fly *Drosophila.* As would be expected from target-theory considerations, the induction of two-break chromosome changes is not dependent on radiation dose in a simple linear fashion. High doses, and doses given at high intensities, induce proportionately more changes of this sort.

B. Bodily (Somatic) Effects

Somatic effects due to radiation include all the injuries, long-term and short-term, to all the cells of the body of an organism—plant or animal.

1. Long-Term Effects. — Long-term somatic effects include damage to cells that are continually proliferating, so that the injury is passed on to succeeding cell generations. Such cells are found in embryonic tissues and in those tissues of the adult in which cell division normally continues throughout life; in vertebrates these include the blood-forming tissues, the basal layer of the skin, the intestinal mucosa and, in the male, the germ cells. Furthermore, the radiation may affect the rate of cell division: the cells may be killed or otherwise rendered incapable of further division; division may be slowed down; or, conversely, tissues in which cell division normally ceases in the adult may escape their normal biological control and cell division may continue. Mosaic sectors have been observed in many organisms exposed to radiations during embryonic development. They include humans who have been exposed in *utero* during diagnostic examination of the mother; in some fetuses there was a brown sector in the otherwise blue iris of an eye; in others there was a black patch in an otherwise blond head of hair. Unilateral arid nonheritable expression of a congenital defect of a type that is normally bilateral and heritable Is also believed to arise sometimes through somatic mutation. Sometimes the mutant region includes some of the germ cells, and the genetically mutant nature of the mosaicism can then be confirmed by a breeding test.

Slowing down or suppression of cell division, including radiation-induced cell death, may have important end results where embryonic tissues are exposed. This is because the rate of cell division is not uniform throughout an embryo; at any one stage of development the cells in some parts will be dividing rapidly, while in other parts there will be relatively little cell division. Exposure to radiation will affect the rapidly dividing tissues more strongly than the others. with the result that the pattern of development will be distorted and the individual, when adult, will have disproportionate parts. This phenomenon, which is well known in experimental plants and animals, is also known in man. (Among the persons exposed as early embryos to the atomic bomb radiations in Japan were a number with abnormally small heads and mental defect. Such children have also occurred following exposure *in utero* to medical X-rays.)

Radiation exposure of the blood-forming tissues leads to a reduction of cell division and therefore to a reduction in the blood-cell count which may, if sufficiently great, amount to clinically recognizable anemia (for this reason regular blood-cell counts used to be carried out on all radiation workers). Radiation exposure of the germinal tissues likewise leads to a reduction of cell division, which may be sufficient, if the dose is large enough, to induce sterility; a dose of 200 r to the gonads of the human male induces temporary sterility, lasting a few months; a gonad dose of about 500 r to either sex induces permanent sterility. Opacity of the lens of the eye. which may develop into a full cataract, has been observed following exposure to ionizing radiation, especially neutrons.

A further long-term effect of radiation exposure is a general shortening of the life span, not associated with death attributable to any specific cause. It is a phenomenon well established in laboratory animals, but evidence about its extent in humans is conflicting; the mechanism, whether through gene mutation in somatic cells, a reduction of cell division or some other cause, has not been established.

Loss of biological control over cell division, *i.e.*, the induction of cancer in animals and distortion of parts in plants, is one of the more serious long-term somatic effects of excessive radiation exposure. It may occur in any tissue. Cancer of the skin was the first long-term effect to be observed; it may result from exposure to ultraviolet as well as to ionizing radiation.

The nature of the dependence of the long-term effects of radiation on radiation dose, type and intensity is not yet established with certainty. Many authorities assume that the relationship is of a nonthreshold type, meaning that any additional exposure increases the probability of long-term effects occurring. It is a characteristic of the induction of cancer that there may be a long period of time between the causal exposure and the appearance of the effect: for some skin cancers in man induction periods of 40 years have been recorded.

2. Short-Term Effects.—A sufficiently large dose of radiation will kill any organism, but the dose required varies greatly from species to species; mammals are killed by less than 1,000 r, but fruit flies may survive 100.000 r, and many bacteria and viruses even higher doses.

This lethal action of radiation can be used as an alternative to heat treatment for sterilizing materials such as surgical sutures. It has found little application in the sterilization of foodstuffs, mainly because the high doses required induce chemical changes in the food that render it unpalatable.

BIBLIOGRAPHY.—D. E. Lea, *Actions of Radiations on Living Cells* (1947); A. Hollaender (ed.), *Radiation Biology* (1954); Medical Research Council, *The Hazards to Man of Nuclear and Allied Radiations* (1956); *Report of the United Nations Scientific Committee on the Effects of Atomic Radiations (1958)*; W. D. Claus (ed.), *Radiation Biology and Medicine* (1938). (T. C. CA.)

III. RADIATION AND HUMAN HEALTH

A. MAN'S RADIATION BURDEN

1. Natural Sources.—Throughout the ages man has been exposed to what is called natural background radiation. This includes radiation from cosmic as well as terrestrial sources. It has probably played the major role in evolution of life by providing mutations upon which natural selection has acted.

Cosmic rays (*q.v.*) rain down incessantly on the earth's atmosphere. Interacting with atoms in the air, such rays resolve themselves into various components—chiefly penetrating electrons, gamma rays and mesons (a class of atomic particles)—by the time they reach the earth. There is considerable variation in the intensity of cosmic radiation, both geographically and temporally, since sun spots and solar flares influence the primary intensity. For about every 5,000 ft. of altitude the intensity approximately doubles (*see* Table III). (Posing an obstacle to man's space travel is a belt of "trapped" radiation that surrounds the earth at a height of several thousand miles [*see* VAN ALLEN RADIATION BELTS].)

TABLE III.—*Cosmic Radiation Exposure at Different Altitudes*

Altitude	Mean dose in rads per year	Maximum variation due to solar flares
Sea level	0.021 to 0.010	50 ×
5,000 ft.	0.040 to 0.060	
10,000 ft.	0.080 to 0.120	
40,000 ft.	2.8	
30 km.–600 km.	7.3	1,000 X ?
22,000 km. (Van Allen belt)	about 8,800	very large ?

Man also receives external and internal radiation from natural radioisotopes, particularly radium and its daughters, members of the thorium series. potassium-40, carbon-14 and hydrogen-3 (tritium). The latter two are produced by cosmic rays. The greater part of external radiation comes from the radioactivity of minerals, whereas radioactive contamination of drinking water and food plays an integral part internally. Drinking waters vary by a factor of 10,000 in their radioactivity content. Among the foods, radium content of nuts and cereals is higher than that of milk or meat. Internal doses in normal persons from natural radioactivity are listed in Table IV.

TABLE IV.—*Internal Dose Due to Natural Radioactivity*

Isotope	Radioactivity in curies	Radiation	Dose in rads per year	Critical organ
Carbon-14	9×10^{-8} per g	Beta rays	0.0016	Gonads
Potassium-40	10.4×10^{-8} per g	Beta rays	0.0165	Gonads
Potassium-40	1.15×10^{-8} per g	Gamma rays	0.0023	Gonads
Radium and daughters	1×10^{-10} in body	Alpha, beta gamma rays	0.0380	Bones

2. Artificial Sources.—Since the discovery of radioactivity, man has substantially added to his natural radiation load. Medical X-rays are often necessary for the diagnosis or treatment of disease. In some countries almost the entire population is exposed to periodic diagnostic X-rays and a significant fraction to therapeutic doses. Therapeutic doses vary widely depending on. among other things, the disease being treated. Routine diagnostic doses, though they may vary somewhat depending on the apparatus and the operator, usually fall within certain limits (*see* Table V).

TABLE V.—*Typical Doses Received in Routine X-ray Diagnosis*

Examination	Dose per exposure
Chest X-ray	0.04–1 rad
Gastrointestinal X-ray	1 rad
Extremities	0.25–1 rad
Fluoroscopy	10–20 rads per minute
X-ray movie	25 rads per examination

High-voltage power supplies for radar or television. X-ray machines in shoe stores, dental X-rays, luminous-dial watches and phonograph static eliminators frequently give significant doses of radiation, often more than is warranted. A further contribution of man, one that has become of considerable concern, is fallout (see *Radioisotopes and Fallout*, below), the radioactive debris proceeding from atomic explosions. Unlimited nuclear testing may have serious consequences to world health.

B. INJURY FROM IONIZING RADIATIONS

Although all forms of radiation, if intense enough, may produce some adverse effects on man, the "hard" or penetrating ionizing rays, including X-rays and moving atomic particles, present the greatest hazard. Paradoxically, these same ionizing rays, when judiciously used in medicine, constitute a formidable weapon against cancer and an invaluable aid in diagnosis *(see* RADIOLOGY).

The concept of maximum permissible exposure to radiation is a much-debated point, subject to change as more information accumulates. Although the body may not be noticeably affected, genetic damage may occur and pass unnoticed for several generations, as was mentioned earlier. Maximum permissible exposures are proposed for persons who, by the nature of their work. are exposed to amounts of radiation beyond that to which the general population is exposed. (Recommendations vary somewhat in different countries; those given in Table VI are for the U S.)

TABLE VI.—*Maximum Permissible Exposures to Ionizing* **Radiations**

Organ exposed	Exposure
Whole body	3 rem in 13 weeks
Professional emergency dose (once in life)	25 rem
Accumulated dose under 18 pears	So professional exposure permitted
Accumulated dose over 18 years	Average of 5 rem per year less than 15 rem in any single year
Skin	6 rem in 13 weeks or 30 rem per year
Gonads	5 rem per year
Bone	3.8 rem per year

1. Historical Background.—In Dec. 1895 the German physicist Wilhelm Conrad Rontgen demonstrated the first X-ray pictures. among them that of the left hand of Mrs. Rontgen. Within a few weeks the news of the discovery spread throughout the world, and the penetrating properties of the rays were soon exploited for medical diagnosis without immediate realization of possible deleterious effects. The first reports of X-ray injury to various human tissues and to vision came from the Italian F. Batelli (1896). In that same year Elihu Thomson. the physicist, deliberately exposed one of his fingers to X-rays and provided accurate scientific observations on the development of roentgen-ray burns.

Also in 1896 Thomas Alva Edison discovered "fluoroscopy"; he was engaged in developing a fluorescent roentgen-ray lamp when he noticed that his assistant, Clarence Dally, was "poisonously affected" by the new rays so that his hair fell out and his scalp became inflamed and ulcerated. By 1904 Dally developed severe ulcers on both hands and arms; these lesions, which soon afterward became cancerous, caused his early death. During the next few decades many investigators and medical doctors developed radiation burns and cancer, and more than 100 persons died. presumably as a result of their exposure to X-rays. These sad early experiences eventually led to an awareness of radiation hazards for professional workers and stimulated development of a new branch of science, radiobiology.

Radiations from radioactive materials were not immediately recognized as being related to X-rays: In 1906 A. H. Becquerel. the French physicist and discoverer of radioactivity (1896). accidentally burned himself by carrying radioactive material in his pocket. Noting this. Pierre Curie. the co-discoverer of radium. deliberately produced a similar burn on himself. A few months later it was found that radium could be useful in medicine: this discovery led to the founding of the Radium hospital in Paris in 1906. It was soon recognized, however, that radium could also be very toxic. Beginning about 1925 a number of women in the painting industry who were exposed to luminescent paint containing radium became ill with anemia and lesions of the jawbones and mouth: some of these persons later developed bone cancer. The same thing happened to some patients who had received radium internally to relieve arthritis and other diseases. In the 1930s H. S. Martland and others called attention to these radium hazards and the practices were stopped.

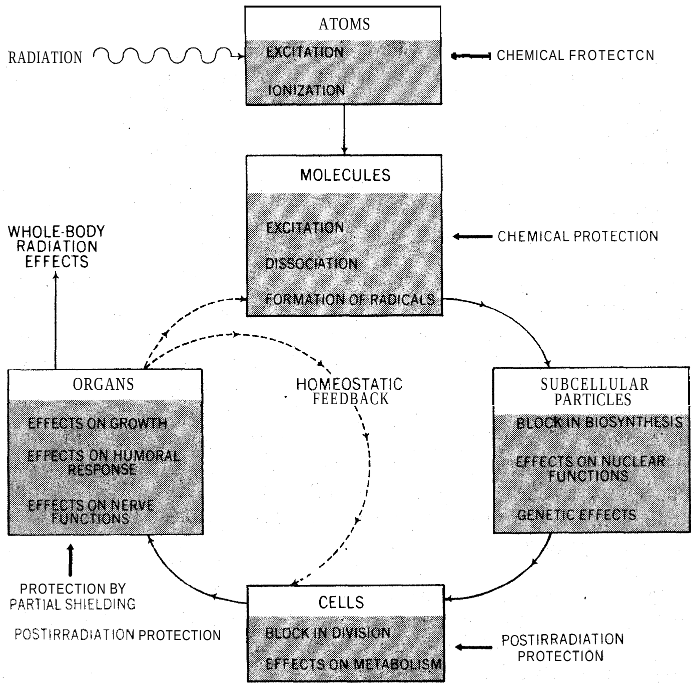
In 1933 Ernest Lawrence and his collaborators completed the first full-scale cyclotron, at Berkeley. Calif. This machine was a copious source of the neutron rays that had at that time just been discovered by Sir James Chadwick, in England. This time, however: human guinea pigs were spared. Ernest, his brother John Lawrence and Paul Aebersold exposed rats to the beam of the cyclotron; they found that fast neutron radiation was about $2\frac{1}{2}$ times more effective in killing power than were X-rays. These facts indicated the need for protection for investigators engaged in research with the cvclotron; thus a form of shielding mas devised for the machine. Since that time new and more powerful radiation sources have become available, and radiation health protection has become an elaborate discipline.

2. Exposure of the Embryo and Fetus.—Most of the information on effects of radiation in the human embryo has been based on results of studies on laboratory animals. From these data it has been concluded that babies, children and the aged are somewhat more sensitive to radiation than is the adult. In the embryo (the first eight weeks of pregnancy) radiosensitivity is greatest. Radiation delivered to the embryo can lead to miscarriage or stillbirth. Exposure of the fetus (eight weeks to birth) can lead to congenital malformations! stunted growth and premature aging. The embryo and the fetus are probably several times more radiosensitive than is the adult.

The developing nervous system is particularly sensitive. and even a relatively mild dose of radiation may have discernible effects. Pathological studies by S. P. Hicks (U.S.) have shown this in great detail. M. N. Livanov and his associates (U.S.S.R.) demonstrated the stunted development of the central nervous system using studies on induced reflexes.

3. Effects on Cells, Tissues and Organ Systems.—To understand radiation effects it is necessary to study the cellular and subcellular events that succeed a radiation insult and that give rise to gross effects. The work done in this area has already contributed a great deal to the understanding of normal and diseased states. How radiation may inflict biological damage is shown in the accompanying diagram.

The radiosensitivity of individual human cells in culture was first measured by T. T. Puck, in the 1950s. He used the progeny of



GENERAL SCHEME OF EVENTS IN RADIATION ACTION

Radiation acts on atoms, which in turn cause modification in molecules, cells and organs as shown. The existence of homeostatic regulation in the human body causes highly complex "feedback" interactions. The levels at which various protective agents act are also shown

human cervical cancer cells (of the strain named HeLa) kept alive in tissue culture. HeLa and other available human cells are so sensitive to radiation that half of them are killed by doses of 80 to 300 rem. The killing effect manifests itself when the cells attempt to divide but cannot do so since their chromosomes are broken and abnormally jointed as a result of radiation. Neuroblasts (nerve cell initials) and cells of the intestinal epithelium, of mucous membrane and of blood-forming organs exhibit the greatest sensitivity. Most resistant are adult nerve cells, which owe their resistance to the fact that they do not normally divide; specialized nerve endings and synapses (*e.g.*, in the retina), however, may exhibit great radiosensitivity. At sublethal doses human cells exhibit delay of cell division following radiation, perhaps as a consequence of a block in the synthesis of new genetic material ideoxyribonucleic acid or DNA). while the synthesis of proteins goes on. Such cells frequently turn into "giants," having several hundred times normal volume. Late effects, *e.g.*, the initiation of cancerous growth, no doubt have their origin in sublethally injured cells and are in part due to genetic and chromosomal alterations.

Inhibition of epithelial tissues with cellular breakdown and increased permeability leads to invasion by pathogens, inflammation, ulceration, loss of fluids, nausea and diarrhea.

Inhibition of blood formation leads. in the course of days or weeks, to leukopenia (reduction in the number of white cells), which lessens defense against infection: anemia (reduction in the number of red cells), which results in defective oxygen transport; lassitude; anoxia (reduction of oxygen in tissue) ; bleeding, due to a failure of platelet synthesis; and loss of immunity. None of these effects is as yet completely understood by medical science.

It is known that, because of the varied cellular effects of radiation, the function of individual organs can become imbalanced. Since the body has widespread humoral and neuronal interconnections. irradiation of a single organ can modify the functions of the rest of the body. A dramatic example of this effect is given by irradiation studies on the pituitary of animals and humans, as shown by C. A. Tobias and others. In the former pituitary irradiation can arrest the growth of a young animal and can affect his sexual development and metabolism. In humans irradiation of the pituitary can arrest proliferation of certain hormone-dependent cancer cells. thereby causing regression of this type of cancer wherever it may be located in the body.

Radiation effects due to whole-body radiation can be lessened by the shielding of particular parts of the body. L. O. Jacobsen and others demonstrated in mice that shielding of part of the blood-forming system, *e.g.*, the spleen, increases the radiation tolerance by a factor close to two. Shielding of other parts of the body also protects. but to a lesser extent. Least protection is afforded by head shielding.

In addition to the effects discussed in an earlier section (see *Long-Term Effects*, above), some investigators also claim a chronic deterioration of the central nervous system (although others have shown in experiments with monkeys that radiation doses up to lethal levels do not impair learning ability).

4. Acute Lethal Effects. — Prior to Xug. 6. 1945, there was no known case of widespread loss of human life due to penetrating radiation. On that day the first atom bomb used in warfare was exploded over Hiroshima, causing the death of ,about 66.000 persons. many of whom died of the effects of radiation. In persons exposed to very large doses of radiation painful, ugly and repulsive symptoms occur prior to a delayed death. The violence and combination of these symptoms is perhaps unmatched by any single known disease.

In the lethal radiation syndrome the greater the dose given, the sooner and more profound the radiation effects. Follo ing a single dose of 400–800 rem to the whole body. survival is improbable. Very high doses, 5,000 rem or more, cause immediate and discernible effects on the central nervous system. States of intermittent stupor and incoherence vary with hyperexcitability resembling epileptic seizures. Death is certain within several days. This syndrome has been carefully studied in animals; a human case has been described by S. G. Wilson (see *Bibliography*).

When the dose is between 600 and 1,000 rem, the earliest symptoms are nausea and vomiting, followed by prostration. watery and bloody diarrhea. abhorrence of food. and fever. The blood-forming tissues are profoundly affected, and in a few days the white blood cell count may decrease from about 8,000 per mm.3 to as low as 200 per $mm.^3$. The body loses its defenses against bacterial infection, and inflammation of mucous membranes and intestinal lining occurs. As a result of the reduction in blood platelets the blood loses its ability to clot, and spontaneous internal or external bleeding may result. Return of the early symptoms. often accompanied by delirium or coma, presages death. There can be great individual variation in the symptoms. At lower doses they may be delayed for a few days. Loss of hair within ten days has been taken as an indication of the lethal severity of the exposure.

As alluded to earlier, in the dose range 250 to 800 rem survival is possible (though in the upper range improbable), and the symptoms appear as above, but in milder form and generally following some delay. Nausea, vomiting and malaise may begin on the first day, then disappear. and a latent period of relative well-being follow. Anemia and leukopenia set in gradually. After three weeks internal hemorrhages may occur in almost any part of the body, but particularly in mucous membranes Susceptibility to infection remains a very great hazard, and some loss of hair occurs. Weight loss, lassitude. emaciation and fever may last for many weeks before recovery or death occurs.

Man is generally able to survive a single dose of less than 250 rem The symptoms are similar to those already described, but much milder and delayed A number of patients with advanced cancer have received doses in this range. In doses under 100 rem the discernible radiation effects-may be so slight that the patient is able to continue his normal occupation though there is a measurable depression of his bone marrow. Sublethal doses may have chronic sequelae many years later.

5. Protection Against External Radiation. — Great effort? have been made by scientists of many countries to find agents that will increase radioresistance of the body.

The findings by H G. Crabtree and W Cramer in 1933 that living systems deprived of oxygen are more radioresistant. and by A. Lacassagne in 1942 that newborn rats kept in carbon dioxide atmospheres were twice as resistant as their litter mates kept in air, went largely unnoticed until 1950. In that year H M. Patt demonstrated that large doses of the amino acid cysteine given prior to irradiation provided substantial protection against radiation effect Following this latter discovery many substances were found with some protective action. Although the matter is still under debate. it appears that all these substances act by producing anoxia or by competing for oxygen with normal cell constituents and radiation-produced radicals. Since anoxia is in itself a highly hazardous physiological state and all protective compounds tried thus far are toxic. it cannot be said that protection of humans by these drugs prior to radiation exposure is a practical matter

For many years it was held that cure of radiation disease was hopeless since events were thought to be irreversible once a person had received a lethal dose. It was historically important, therefore. when L. O. Jacobsen and E. Lorenz demonstrated in mice that ground substance of embryo spleen or bone marrow administered following irradiation allowed the animals to survive what would otherwise be a lethal dose of X-rays. It is hoped that detailed study of this finding will lead to the understanding of various physiological processes and disease control.

It has been shown that most of the effect of transfused bone marrow depends on the provision of intact. living cells which then migrate to the marrow of the irradiated host and proliferate there, repopulating the host's marrow with cells characteristic of the donor. Bone marrow transfusion between animals of different strains is successful in these cases because the irradiated animal loses its ability to develop antibodies against the injected "foreign" tissue. If the injected bone marrow proliferates rapidly enough. it may save the host from acute lethal effects of radiation only to develop another disease several months later. This latter syndrome, sometimes called "wasting disease" (or homologous disease). is due to development of antibodies by the proliferating donor cells against the irradiated host and is usually rapidly fatal

It is obvious that if bone marrow could be taken with ease (as blood is taken) from various normal human volunteers, cultured and preserved under refrigeration, then injected only into immunologically compatible individuals. it might prove to be a powerful therapeutic agent against radiation disease.

Transfusion of fresh normal human bone marrow has already demonstrated some worth in alleviating radiation effects. In 1958 an unfortunate accident occurred at a nuclear reactor in Yugoslavia in which five persons were exposed to near lethal doses of mixed neutron and gamma radiation. They were flown to the Radium hospital in Paris. where four of them. received human bone marrow transfusions. As judged by their recovery, these men were considerably benefited.

Bone marrow transfusion, as well as transplantation of other organs, may be of importance in future control of various seemingly incurable conditions; *e.g.*, leukemia. A special radiation technique has been applied in conjunction with bone marrow transfusion in some very desperate cases. Leukemia patients. usually in the terminal stages of their disease: first receive a whole body "lethal" dose of X-rays or some other form of radiation. This is presumed to kill all the cells in the marrow. including the leukemic ones. Somewhat later, compatible normal bone marrow is injected to repopulate the patient's bone marrow with normal cells of the donor, thus ending the leukemic condition. There is some hope that this treatment may be of benefit to some leukemia patients and that it may be used against other diseases; *e.g.*, hereditary anemia. (The clue to successful bone marrow transplantation is the complete understanding of immunological compatibility. Only when this knowledge is attained will transplantation of bone marrow [and also of essential organs such as the kidney] become established as a feasible medical practice.)

6. Radioisotopes and Fallout.'— Much of the present radiation hazard to man comes from radioactive isotopes. which usually emit electrons or positrons. alpha particles and/or gamma rays. or even characteristic X-rays. The exposure may be external, in which case penetration is an important factor. Alpha particles do not penetrate deeply enough in the skin to cause damage. Beta particles or X-rays over 30 kv. can be hazardous to the skin, causing redness, loss of hair or ulceration. (Large doses may cause skin cancer.)

Isotopes can also enter the body by ingestion, inhalation or injection. Their radiation effects then depend on their internal distribution, duration in the body. energies and rate of radioactive decay (half-life or half-value period). The problem is enormously complicated since isotopes have different and sometimes elaborate distribution patterns.

The definition "critical organ" has been assigned to that part of the body that is most vulnerable to a given isotope. The critical organ for plutonium, radium. strontium and many other fission products is bone and the adjacent bone marrow. For soluble fission products. which will distribute in the entire body (and also for some forms of uranium), the critical organs are the gonads or sometimes the kidneys. For iodine the critical organ is the thyroid gland. Insoluble air-borne radioactive dust often deposits in the alveoli of lungs, while colloidal particles of very small size can reach the bone marrow. liver or spleen. Table VII is an abbreviated list of the maximum permissible concentrations (U.S. recommendations'~for man of some radioisotopes. (Maximum permissible concentration is the greatest amount of a radioisotope that

TABLE VII.—*Maximum Permissible Concentration* (*MPC*) of *Some Radioisotopes*

Isotope	Chemical form	Critical organ	Microcuries in body
Tritium (Hydrogen-3)	Water		2,000
Carbon-14 . . .	Carbon dioxide		400
*Strontium-90 . .	Water soluble salt		40
		bone	4
Iodine-131 . . .	Water soluble		50
		thyroid	0.7
Cesium-137 . . .	Water soluble		30
†Radon-222 . . .	Gas		
‡Radium-226 . . .	Water soluble		0.2
		bone	0.1
Uranium . . .	Water soluble		0.2
		kidney	0.005
Plutonium-239 . .	Water soluble		0.4
		bone	0.04

*MPC in drinking water: 0.001 microcurie/litre.
†MPC in air: 0.00001 microcurie/litre.
‡MPC in drinking water: 0.0001 microcurie/litre.

can be accumulated in the body without producing noticeable damaging effects. Compare with maximum permissible dose. which is applicable to radiation received from external sources [see *Studies on Human Populations,* below].)

Since isotopes continuously deliver radiations to the surrounding tissue, one must distinguish between the effect of protracted continuous exposure and single acute or periodically repeated exposures. For beta. gamma and X-radiations, utilizing split dose delivery, it has been found that 15% to 40% of an acute radiation effect "disappears" within several hours; the body is, therefore, able to tolerate a greater total dose when the dose is protracted or when part of it is given at later times. For neutron and alpha radiation the recovery is less. (Neutrons are generally more effective than X-rays: for acute effects. by a factor of 2 or **3;** for chronic effects. by a factor up to 10.)

Fallout is the deposition of air-borne radioactive contamination on the earth. Radioisotopes may be produced naturally in the air by cosmic radiation or may enter the air from stack gases of atomic reactors following industrial accidents or from bombs or bomb tests. (Since 1954 bomb tests carried out by several nations have produced fallout measurable on the surface of the entire world. arousing great attention and controversy with respect to its health and genetic effects.)

Several of the radioisotopes contained in fallout are especially hazardous because they remain radioactive for relatively long periods (have long half-lives). Cesium-137 and strontium-90 may be the most important (*see* FALLOUT). On the ground fallout material can cover external surfaces and foliage and later be washed into the soil. From here plants incorporate strontium-90 along with the chemically similar calcium. and cesium-137 with potassium. Persons obtain these radioactive materials mostly from drinking water and from plant and animal foods, including milk. In the sea much of these materials can eventually lodge in the bodies or skeletons of fishes snd in plants near the coast.

Strontium-90 becomes concentrated in bone and remains there, in steadily decreasing amounts. for almost 30 years, producing local irradiation. Its actual concentration within the body is difficult to measure because of the softness of its rays. There is generally lower concentration of strontium-90 in man than in other animals or in plants or soil. Newborn babies who have actively growing bones retain relatively greater amounts of strontium-90 than do older persons.

7. Studies on Human **Populations.**—Several groups of persons have been exposed to large amounts of radiation. Among these arc the survivors of the atomic bombings of Hiroshima and Nagasaki, and some Marshallese and Americans exposed on Rongelap and neighbouring islands in the course of atomic bomb tests. In the former group the incidences of leukemia and cataracts are higher than in the general population. Fertility seems somewhat reduced and life span possibly shortened. These effects. which depend on the dose. thus far have not been noticed in the latter group.

Hundreds of persons have a measurable radium burden in their bodies. Many of them received the radium as a method of treatment for arthritis and other diseases in the early 1930s. By the use of modern counting methods the amount entrapped in the body of this long-lived alpha-particle-emitting isotope (half-life of over 1.500 years) may be determined and may eventually provide accurate information on the dose that can cause bone cancer.

Certain groups of persons receive considerable doses of X-rays during radiation therapy for various ailments. In England a survey indicated the late results of X-ray therapy to the lumbar spine of persons having ankylosing spondylitis (a rheumatic ailment). The incidence of leukemias and bone tumours among these patients was higher than that of the general population. In a separate study suggestive evidence was obtained that children of women given abdominal X-rays for diagnostic purposes during pregnancy may develop more leukemia than children whose mothers were not so X-rayed. Children who received X-irradiation to the thymus at an early age appeared to show greater than normal incidence of cancer and leukemia in subsequent years. As a result of these studies it seems prudent to limit radiation exposure for children and embryos as much as possible. Practices such as X-raying feet in shoe stores seem completely unwarranted. Attempts should be made to reduce the numbers of necessary exposures received in dental X-rays, in fluoroscopy, in chest X-ray procedures and in diagnosis with radioisotopes.

The possible effect of radiation on radiologists is a much debated question. An earlier study in the United States indicated that their life span may be several years shorter than that of other doctors and that they have more leukemia and more stillborn children. However. no significant differences were found between English radiologists and their colleagues.

Localities with higher radium content seem generally to have more congenital malformations. though radiation as a direct cause has not always been established. A study in New York state correlated the incidence of such malformations with radioactive mineral content of the soil and water of the locality. In Jachymov, Czech.. where for many generations miners have mined radioactive ore. lung cancer is quite prevalent; though the radioactive ore is undoubtedly involved. genetic factors (due to inbreeding) and silicosis of the lungs from inert ore may also be partly responsible for this high incidence of cancer. In Sweden many persons are constantly exposed to comparatively high radiation background due to the uranium in the building blocks of their houses.

TABLE VIII.—*External Dose Due to Natural Radioactivity*

Source	Dose in rads per year
Ordinary regions	0.025–0.160
Active regions	
Granite in France	0.180–0.350
Houses in Sweden (Alum shale)	0.158–0.220
Monazite alluvial deposits in Brazil	Mean 0.500 max 1.0
Monazite sands, Kerala, India	0.37–2.8

An entire segment of the coast-line state of Kerala, India, is composed of radioactive monazite sands. Since the inhabitants and their ancestors have lived in this same locality for many generations, India, with the help of the Cnited Nations, has initiated a study of the possible harmful effects of this long-term radiation exposure by comparing the health of this population segment with another group living on uncontaminated soil nearby.

As mentioned earlier. radiation with its deleterious effects causes a person to become "physiologically" older than his actual age would indicate. Using mortality studies of survivors of the Hiroshima blast, it appears that where very large doses are absorbed each rem received by the whole body physiologically ages a person 2 to 15 days. Statistical fluctuations, however, are very great and experimental results difficult to interpret. It is not yet known whether this concept of aging holds for doses smaller than 50 rem or for protracted radiation exposure.

8. Cancer and Radiation.— The role of large doses of radiation in increasing the incidence of cancer and leukemia cannot be questioned. It has been demonstrated in all animal species tested thus far. Exposure of the whole human population, even to minute doses in fallout. may lead to some thousands of new leukemia and cancer cases in the world. Thus far no data exist that would clearly demonstrate whether leukemia (or cancer) incidence is proportional to dose or whether a "threshold" dose level exists below which carcinogenic effects are negligibly small. In order to acquire adequate data, a population of several million would have to be studied for several years. There is a large school emphasizing that all good studies of the origin of cancer point to a number of factors, including genetic, hormonal and injurious factors (chemical or virus). that must act together before cancer is produced. The great majority of cancer and leukemia cases in the earth's population is probably not caused by radiation but by other agents. (See also CANCER; LEUKEMIA.)

C. EFFECTS OF HERTZIAN WAVES AND INFRARED RAYS

1. Hertzian Waves.—The effects of Hertzian waves (electromagnetic waves, radio waves and microwaves or radar waves) and of infrared rays are usually equivalent to the effect produced by heating. The longer radio waves induce chiefly thermal agitation of molecules and excitation of molecular rotations, while inirared rays excite vibrational modes of large molecules and release fluorescent emission as well as heat. Both types of radiation are preferentially absorbed by fats containing unsaturated carbon chains

Nikola Tesla in 1891 was the first to record the fact that heat production resulted from bombardment of tissue with high-frequency alternating current (wave lengths somewhat longer than the longest radio waves) and to point out the possibility of its utilization for medical purposes. At the same time J. A. d'Arsonval. using the same current, began to experiment on animals and human beings. In 1898 R. von Zeyneck used high-frequency current to produce heat within the organism. and was followed in this by Von Berudt and other workers. To this form of treatment F. Nagelschmidt applied the term "diathermy." This method of internal heating is beneficial for relieving muscle soreness and sprain. Diathermy can be harmful however. if so much internal heat is given that the normal cells of the body suffer irreversible damage. Since man has heat receptors only on his skin, he cannot be forewarned by pain when he gets a deep burn from diathermy. Sensitive regions easily damaged by diathermy are those having reduced blood circulation; e.g , bone or the lens of the eye. Cataracts of the eye lens have been produced in animals by microwave radiation applied in sufficient intensity to cause thermal denaturation of the lens protein.

In the radio-television industry and in the radar divisions of the military, persons are sometimes exposed to high-energy densities of microwave radiation. For occupational exposure, tolerance levels that have been set in the U.S. are summarized in Table IX.

The heating effect of high-frequency waves and currents has had some use in surgery. The first surgical use of short waves (8 megacycles) was made by L. H. Stiebock. who successfully destroyed a patient's tonsils without the necessity of giving an anesthetic. This procedure produces cutting by heat coagulation of tissue without producing bleeding. It has been used to cut certain structures (*e.g.*, the dura membranes) in brain surgery and in minor skin operations. Higher-frequency electromagnetic waves (about 10 megacycles) are also used in brain surgery for producing "heat lesions" in the treatment of Parkinson's disease and cerebral palsy.

TABLE IX.—*Maximum Permissible Exposures to Microwave Radiation*

Frequency (megacycles)	Part exposed	Single exposure level (watts/cm.^{2})	Continuous exposure level (watts/cm ^{2})
1,000–3,000	Whole body	0.3	0.01
3,000	Eye	17	0.15
3,000	Testes	1.3	0.005

Such heat lesions produced in certain parts of the brain may temporarily relieve the tremors accompanying these diseases.

2. Infrared Rays.—An important part of solar energy reaches the earth in the form of infrared rays. Absorption and emission by the human body of these rays plays an important part in temperature exchange and regulation of the human body. Principles of infrared emission and absorption must be considered in design of air conditioning and of clothing.

Overdosage of infrared radiation, usually resulting from direct exposure to a hot object (including heating lamps) or flame, can cause severe burns ("flame burns"). While infrared exposure is a hazard near any fire, it is particularly dangerous in the course of atomic chain reactions. In the course of an atomic detonation a brief but very intense emission of inirared occurs together with visible and ultraviolet light emitted from the fireball ("flash burns"). Of the total energy of nuclear explosion, as much as one-third may be in the form of thermal radiation, moving with the velocity of light (186,000 mi. per second). The rays will arrive almost instantaneously at regions removed from the source by only a few miles. Smoke or fog can effectively scatter or absorb the infrared components, and even thin clothing can greatly reduce the severity of burn effects. (See also BURNS.)

D. EFFECTS OF VISIBLE AND ULTRAVIOLET LIGHT

Life could not exist on earth without light from the sun. Plants utilize the energy of the sun's rays in the process of photosynthesis to produce carbohydrates and proteins, which serve as basic organic sources of food and energy for animals. The strong ultraviolet rays of the sun, which are hazardous, are effectively absorbed by the upper atmosphere. At high altitudes and near the equator the ultraviolet intensity is greater than at sea level or at northern latitudes.

Very short-wave ultraviolet light, below 2,200 Å, is highly toxic for cells; in the intermediate range the greatest killing effectiveness on cells is at about 2,600 Å (1 A = 1/10,000,000 mm.). The nucleic acids of the cell, of which the genetic material is composed, strongly absorb rays in this region. This wave length, easily available in mercury vapour, xenon or hydrogen arc lamps, has great effectiveness for germicidal purification of the air.

Since penetration of visible and ultraviolet light in body tissues is small, only the effects of light on skin and on the visual apparatus are of consequence. When incident light exerts its action on the skin without additional external predisposing factors, scientists speak of intrinsic action. In contrast, a number of chemical or biological agents may condition the skin for action of light; these latter phenomena are grouped under photodynamic action.

1. Intrinsic Action.—Light is essential to man because of its biosynthetic action. Ultraviolet light induces the conversion of ergosterol and other vitamin precursors present in normal skin to vitamin D, an essential factor for normal calcium deposition in growing bones. While some ultraviolet light appears desirable for formation of vitamin D, an excess amount is deleterious. Man has a delicate adaptive mechanism that regulates light exposure of the more sensitive deeper layers of his skin. The transmission of light depends on the thickness of the upper layers of the skin and on the degree of skin pigmentation. All persons, except albinos, are born with varying amounts of melanin pigment in their skins. Exposure to light further enhances the pigmentation already present and can induce production of new pigment granules. N. R. Finsen of Denmark realized the therapeutic possibilities of sunlight and ultraviolet light around 1900. He was an exponent of the idea that exposure of the whole body to sunlight promotes health.

The French physician J. M. Charcot in 1858 was the first to recognize that large doses of ultraviolet radiation caused "sunburn." The wave length of about 2,800 & is most effective. It induces reddening and swelling of the skin (due to dilation of the blood vessels), usually accompanied by pain. In the course of recovery epidermal cells are proliferated, melanin is secreted and the outer corneal layer of dead cells is thickened.

G. Findlay in 1928 was the first to clearly show that prolonged or repeated exposure to ultraviolet light leads to the delayed development of skin cancer. The fact that ultraviolet light, like X-radiation, is mutagenic (induces mutations) may explain its ability to cause skin cancer, but the detailed mechanism of cancer induction is not yet completely understood. There seems very little doubt, however, that skin cancer in man is in some cases correlated with prolonged exposure to large doses of sunlight. Among coloured persons who are protected by rich melanin formation and thickened corneal structure of the skin, incidence of cancer of the skin is several times less frequent than it is among white people living at the same latitude.

2. Photodynamic Action.—There are a number of diseases in man and animals in which light sensitivity is involved; for example, hydroa, which manifests itself in blisters on parts of the body exposed to sunlight. It has been suggested that this disease is due to a light-sensitive porphyrin compound found in the blood of certain persons.

Actually there are many organic substances and various materials of biological origin that make cells sensitive to light. When eosin is added to a suspension of human red blood corpuscles exposed to light, the red corpuscles will break up, or hemolyse. Other typical photodynamic substances are rose bengal, hematoporphyrin and phylloerythrin. All these are dyes capable of fluorescence. Their toxicity manifests itself only in the presence of light and oxygen.

Some diseases in domestic animals result from ingestion of plants having photodynamic pigments. For example, St. Johnswort's disease is caused by the plant *Hypericum*. Fagopyrism results from eating buckwheat. In geeldikopp (yellow thick head) the photodynamic agent is produced in the animal's own intestinal tract from chlorophyll derived from plants. In humans the heritable condition of porphyria is frequently associated with light sensitivity, as are a number of somewhat ill-defined dermatological conditions that result from exposure to sunlight. The recessively inherited rare disease xeroderma pigmentosum is also associated with light exposure: it usually results in death at an early age from tumours of the skin developing on exposed areas. Certain drugs (*e.g.*, sulfanilamide) sensitize some persons to sunlight. Many cases are known in which skin contact with a photodynamic substance was followed by increased light sensitivity.

3. Deleterious Effects on the Eyes.—The wave length of light that produces sunburn can also cause inflammation of the cornea of the eye. This is what occurs in "snow blindness" or after exposure to strong ultraviolet light sources. Unusual sensitivities have been reported. Ultraviolet light, like infrared or penetrating radiations, can also cause cataract of the eye lens, a condition characterized by denatured protein in the fibrous cells forming the lens. The retina is usually not reached by ultraviolet light, but large doses of visible and infrared can irreversibly bleach the visual pigments, as in "sun blindness." Numerous pathological conditions of the eye are accompanied by abnormal light sensitivity and pain, photophobia. The pain appears to be associated with reflex movements of the iris and refiex dilation of the blood vessels of the conjuntiva. In order to avoid injury to the eyes while working with ultraviolet light sources or while being exposed to atomic flashes, protective glasses are worn.

BIBLIOGRAPHY.—*Ionizing Radiation:* Otto Glasser, *Wilhelm Conrad Rontgen and the Early History of the Roentgen Rays* (1934); Percy Brown, *American Martyrs to Science Through the Roentgen Rays* (1936); A. Hollaender (ed.), *Radiation Biology,* vol. 1, 2 and 3 (1954); M. Errera and A. Forssberg, *Mechanisms in Radiobiology,* vol. 1 and 2 (1961); H. S. Martland, "The Occurrence of Malignancy in Radioactive Persons," *Amer. Jour. Cancer,* vol. 15, p. 2433 (1931); "Report of the International Commission on Radiological Units and Measurements (ICRU), "U.S. Department of Commerce, *NBS Handbook* 62 (1956); Charles L. Dunham *et al.*, "Atomic Bomb Injury: Radiation," *J.A.M.A.*, vol. 147, p. 50 (1951); Samuel Glasstone (ed.), *The Effects of Nuclear Weapons,* sponsored by U.S. Atomic Energy Commission (June 1957); H. C. Paxton *et al.,* "Nuclear Critical Accident at the Los Alamos Scientific Laboratory on Dec. 30, 1958," *Atomic Energy Commission Report LAMS 2293* (1959); S. G. Wilson, *Radiation Induced Central Nervous System Death,* U.S. Air Force School of Aviation Medicine Publication (1958–59); "Pathologic Effects of Atomic Radiation," National Academy of Science, *Nat. Res. Council Publication* ***452*** (1956); S. P. Hicks, "Acute Necrosis and Malformation of Developing Mammalian Brain Caused by X-ray," *Proc. Soc. Exptl. Biol. Med.,* vol. 75, p. 485 (1950); M. N. Livanov and D. A. Dirjukov, "Central Nervous System Changes Produced by Ionizing Radiation, Biological Effects of Radiation," *Second United Nations International Conjerence on the Peaceful Uses of Atomic Energy,* vol. 22, D9 (1958); T. Puck, "The Genetics of Somatic Mammalian Cells," *Advances in Biological and Medical Physics,* vol. 5, pp. 75–101 (1957); W. D. Claus (ed.), *Radiation Biology and Medicine* (1958); C. A. Tobias *et al.,* "Pituitary Irradiation With High-Energy Proton Beams: a Preliminary Report," *Cancer Research,* vol. 18, pp. 121–134 (1958); L. O. Jacobson *et al.,* "The Role of the Spleen in Radiation Injury," *Proc. Soc. Exptl. Biol. Med.,* vol. 70, p. 740 (1949); H. G. Crabtree, "Changes in Carbohydrate Metabolism Induced by Radium Irradiation of Tissues," *Scient. Rep. Imp. Canc. Res. Fund.* vol. 10, p. 33 (1932); H. M. Patt *et al.,* "Cysteine Protection Against X-Irradiation," *Science,* vol. 110, p. 213 (1949); R. Shapira, D. G. Doherty and W. T. Burnett, "Chemical Protection Against Ionizing Radiation," *Radiation Research,* vol. 7, p. 22 (1959), and *Science,* vol. 125, p. 1092 (1957); L. O. Jacobson *et al.,* "Further Studies on Recovery From Radiation Injury," *Jour. Lab. Clin. Med.,* vol. 37, p. 683 (1951); C. E. Ford *et al.,* "Cytological Identification of Radiation Chimaereas," *Nature,* vol. 177, p. 452 (1956); E. D. Thomas *et al.,* "Irradiation and Marrow Infusion in Leukemia," *Arch. Intern. Med.,* vol. 107, pp. 829–845 (1961); R. E. Zirkle, "Effects of External Beta Radiation," *National Nuclear Energy Series,* vol. iv, 22E (1951); J. G. Hamilton, "The Metabolic Properties of the Fission Products and Actinide Elements," *Rev. Mod. Phys.,* vol. 20, pp. 718–728 (1948); R. Zirkle (ed.), "Biological Effects of External X and Gamma Radiation," part i, *Nationl. Energy Series,* vol. iv, 22B (1954); H. A. Blair, *Biological Effects of External Radiation,* "National Nuclear Energy Series," vol. iv, 2 (1954); E. Teller and A. L. Latter, *Our Nuclear Future* (1958); "Radioactive Fallout—a 2-Year Summary Report," *U.S. Atomic Energy Commission Report TID 5550* (1959); "The Nature of Radioactive Fallout and Its Effects on Man," Hearings Joint Comm. on Atomic Energy, Congress of the U.S., parts 1, 2,3 (1957); W. B. Looney, "Effect of Radium in Man," *Science,* vol. 127, p. 630 (1958); W. M.

Court-Bronn and R. Doll, "Leukemia and Aplastic Anemia Treated With X-rays for Ankylosing Spondylitis" in *Hazards to Man of Nuclear and Allied Radiation* (1956); A. Stewart *et al.*, "Malignant Disease in Childhood and Diagnostic Irradiation in Utero," *Lancet*, vol. ii, p. 447 (1956); J. T. Gentry, E. Parkhurst and G. V. Bulin, "An Epidemiological Study of Congenital Malformations in New York State," *Amer Jour. Pub. Health*, vol. 19, no. 4, p. 1 (1959); H. B. Jones, "Demographic Consideration of the Cancer Problem," *Trans. N.Y. Acad. Sci.*, series 2, vol. 18, no. 4 (Feb. 1956); E. B. Lewis, "Leukemia and Ionizing Radiation," *Science*, vol. 125, p. 965 (1957); *Report of the United Nations Scientific Committee on the Effects of Atomic Radiation*, United Nations General Assembly Official Records, 13th Session, supplement no. 17 (A13838) (1958); "Safety Regulations by the National Committer of Radiation Protection," U.S. Department of Commerce. *NBS Handbook 41, 47–61, 63, 69; Atoms for Peace Manual*, presented by Alexander Wiley in United States Senate (1955).

Hertzian Waves, Infrared Ray and Visible and Ultraviolet Light: H. P. Schwan and K. Li, "Hazards Due to Total Body Irratliation by Ratlar." *Proc. of I. R. E.*, vol. 44, pp. 1572–81 (1956); J. E. Roberts and H. F. Cook. "Microwaves in Medical and Biological Research." *Brit. Jour. Appl. Phys.*, vol. 3, no. 2, pp. 33–40 (1952); E. L. Dobson and S. F. Warner, "Factors Concerned in the Early Staees of Thermal Shock," *Circulation Research*, vol. 5, pp. 69–73 (1957); Alexander Hollaender (ed.), *Ultraviolet and Related Radiations and Visible and Near Visible Light* (1956); H. F. Blum, "The Physiological Effects of Sunlight on Man," *Physiol. Rev.*, vol. 25, pp. 483–530 (1945), and *Photodynamic Action and Diseases Caused by Light* (1941); El. C. Dake and Jack DeMent, *Ultra-Violet Light and Its Applications* (1942). (C. A. T.)

RADIATION BALANCE OF THE EARTH. The earth receives from the sun 13 × 10^{23} cal. of radiant energy each year. Since the mean temperature of the earth and its atmosphere does not change perceptibly from year to year, and since solar radiation is the main source of energy received by the earth's surface and atmosphere, the same amount of energy must be radiated from the earth to space.

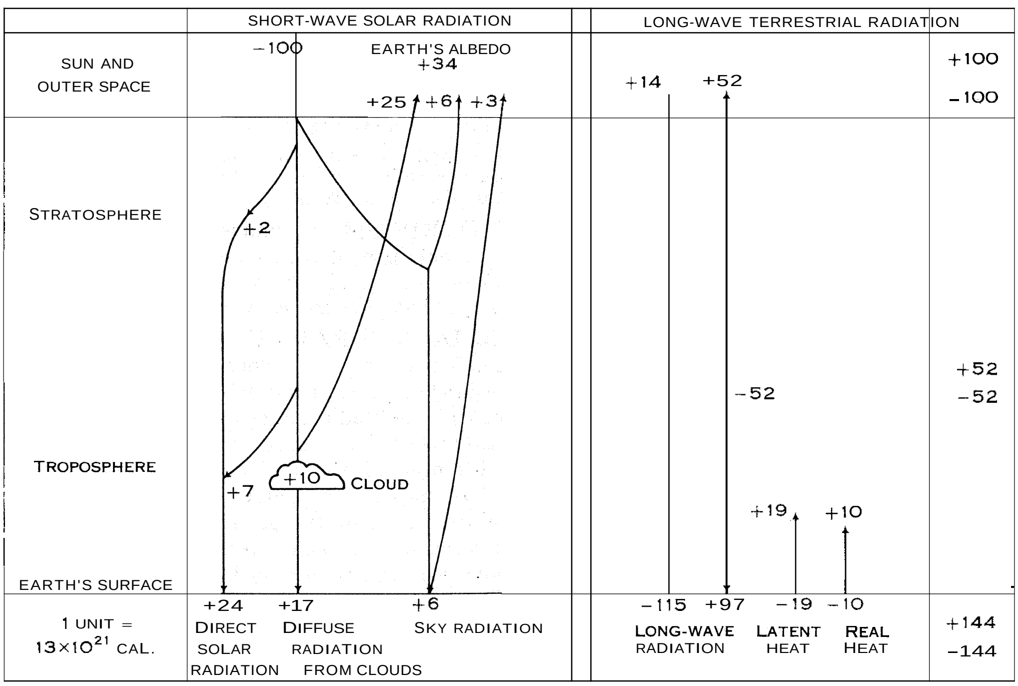
The visible and infrared spectral intensity of solar radiation is approximately that of a black body radiator at 6,000° K. The ultraviolet and X-ray regions of the spectrum differ from the 6,000° K. black body, and moreover become greatly intensified during some types of solar disturbances. The maximum intensity in the solar spectrum is found at 0.48μ (μ, the micron, equals 10^{-4} cm.), and roughly half the energy is contained in the visible band between 0.38μ and 0.77μ, the remainder is in the invisible ultraviolet and infrared bands. As the incoming solar radiation encounters the outer layers of the earth's atmosphere, some of the air becomes ionized, forming the stratified ionized region known as the ionosphere (50–300 mi. high) which reflects radio waves of broadcast frequencies. Farther down! in the stratosphere, certain bands in the ultraviolet are absorbed by oxygen. some of which form ozone, itself a strong absorber of ultraviolet radiation. Indeed. principally because of the presence of ozone. dangerous ultraviolet radiation of wave lengths below 0.3μ is not received at the earth's surface. Closer to the earth's surface (within three miles) water vapour serves as a powerful absorbing agent.

For simplicity in arithmetic let the earth's annual income of 13 × 10^{23} cal. of solar energy equal 100 units. Total absorption of the solar radiation as it passes through the atmosphere is 19 units. Because of reflection from clouds and the earth's surface and by scattering in the atmosphere 34 units (the "albedo" of the earth) are returned to space without increasing the energy of the earth and its atmosphere. The remaining solar radiant energy, amounting to 47 units, reaches the surface of the earth and is used primarily to raise the temperature of the surface layer of the land and ocean; a smaller fraction is utilized in evaporating water and in producing photochemical changes.

The earth. radiating as a black body at its observed mean temperature of 59° F., has its maximum intensity of 10μ and practically all of its radiation (the long-wave radiation) is contained between 4μ and 120μ. Because of the peculiar absorbing properties of water vapour, the normal atmosphere is practically transparent to the short-wave solar radiation but much more opaque to the long-wave terrestrial radiation.

Atmospheric water vapour and carbon dioxide absorb most of the energy emitted by the earth's surface. However, since the atmosphere radiates energy both upward and downward, it would undergo a net cooling were it not for the transfer of energy upward from the earth's surface by convection and evaporated water (latent heat).

In the figure there is presented a graphical summary of the various vertical streams of energy and their totals. This shows that clouds reflect about 25 units. the atmosphere and earth's surface reflect about 9. The clouds absorb 10 units. the clear atmosphere absorbs 9 and the earth's surface 47 units. One hundred fifteen units of long-wave (infrared) energy are radiated upward by the earth's suriace which, however, receives back 97 units irom the atmosphere. Eventually 66 units leave the "top" of the atmosphere to space, 52 of which are emitted by the atmosphere. Finally 19 units are released into the atmosphere from the latent heat of condensation released during the precipitation process, and 10 units are given to the atmosphere in the form of real heat by heat transport from the earth's surface. Note that there is a balance of incoming and outgoing energy at the outer limit of the earth's atmosphere, within the atmosphere. and at the surface of the earth. thus representing an equilibrium condition whereby the mean temperature of the earth's surface and its atmosphere remains essentially unchanged from year to year. at least within the period of systematic meteorological observations made over a large portion of the earth's surface. It is the lack of heat balance averaged over seasons that causes the seasonal variations in temperature and weather observed in extratropical latitudes. It is the lack of heat balance at various latitudes that causes the day-to-day weather changes.



ANNUAL HEAT BALANCE OF EARTH AND ITS ATMOSPHERE

Equatorward of latitude 38° there is a net radiative heating averaged over the year. poleward of this latitude there is a net radiative cooling. This lack of latitudinal radiative heat balance is counteracted by atmospheric and oceanic transport of heat between polar and tropical regions, resulting in a net transport of heat poleward.

The atmospheric transport is effected mainly by large moring cyclonic and anticyclonic eddies, which create alternate periods of stormy and fair weather. (H. WR)

RADIATION CHEMISTRY: see PHOTOCHEMISTRY.

RADIATOR. In practice. what is commonly referred to as a radiator consists of a heat exchanger used to heat enclosed spaces. A room radiator normally consists of a cast iron or steel. multi-section, heat exchanger through which steam, hot water or hot gases are circulated to heat its exposed surfaces. Heat is transferred from these hot surfaces to the relatively cooler room air by natural convection and to surrounding surfaces and occupants by direct thermal radiation. To the extent that the convective heat transfer from such a device often constitutes the major portion of the total heat transferred, it becomes evident that the conventional radiator acts also as an effective convector. Hence. in its everyday usage the word radiator as referred to a room or space-heating device is to some extent a misnomer. In room heating applications, radiators are located in a vertical position underneath windows whenever possible. Condensing steam or hot water is circulated from a central boiler through a number of such radiators interconnected in series, in parallel, or both. (See HEATING AND VENTILATION.)

With the increasing popularity of air conditioning and radiant panel heating and cooling installations after mid-20th century, the conventional radiator was rapidly being superseded in residential as well as commercial installations (*i.e.,* offices. hospitals. theatres, stores, etc.). As compared with the use of radiators. in radiant panel heating installations the practice is to use a lower panel surface temperature (about 140° F.) in conjunction with the much larger surface areas of ceilings, walls or floors to achieve the heating effects desired. This procedure allows a greater fraction of the total heat exchange to take place through direct radiation between these surfaces and occupants. Radiant panels are commonly heated by hot water circulated in serpentine copper tubing embedded in plastered ceilings, walls or concrete floors. (Y. S. T.)

RADIĆ, STJEPAN (1871–1928), Yugoslav statesman. was born at Trebarjevo, near Fiume (Rijeka), on July 11. 1871. He studied in Zagreb and Prague, being once expelled from the Lycée and twice imprisoned in Zagreb for Croatian and anti-Hungarian demonstrations. From 1897 to 1899 he studied in Paris and later lived for a time in Semlin as Balkan correspondent to various newspapers, coming into contact with Serb political leaders, and settled in 1902 in Zagreb. In the same year he began to publish the *Hrovatsko Misao,* in which he outlined the program of the Croatian Peasant party, which first entered the Croatian Sabor. with 9 seats, after the elections of 1910, but soon became the most powerful political force in Croatia. In 1911–12 Radii was again imprisoned by the Magyar Ban of Croatia. During World War I he became an Austro-Hungarian Legitimist, but on the collapse of Austria-Hungary converted his party. which followed him implicitly. to republicanism. In Feb. 1919 he demanded self-determination for Croatia, and union with Serbia and Montenegro "with equal rights." Disagreement with the Serbs; however, led him back to prison during 1919–20.

Radii then condemned his party to a long and singularly sterile period of opposition and parliamentary abstention. until, tiring oi this. he left Yugoslavia in July 1923 for a prolonged visit to London. Moscow and Vienna. He returned to Zagreb in Aug. 1924 with fresh ideas on Pan-Slavism and the co-operation of workmen and peasants, and was imprisoned in Jan. 1925. In March, however, his nephew Pavle Radii effected a reconciliation. Radii was released, his party entered the government, he himself became an enthusiastic supporter of King Alexander. and for a time was a member of the Yugoslav cabinet. His habit of embarrassing his colleagues as often and as much as possible led to his resignation. He returned to opposition, which he conducted with such verve that a government deputy named Račić shot him in the Skupština on June 20, 1928. On Aug. 8, 1928. he died at Zagreb from the effects of his wound.

RADIĆ, PAVLE (1880–1928), Yugoslav statesman, nephew of the above, was born at Trebarjevo, near Fiume on Jan. 1. 1880. He settled in Zagreb as a banker. The coalition of Serb Radicals and Croat Peasants which existed fitfully in 1926–27 was mainly his work; but when it broke down, he rejoined the opposition. On June 20. 1928, he was murdered in an unsuccessful attempt to save his uncle's life.

RADICAL, one who desires extreme change of part or all of the social order. The word (Lat. *radix,* "root") was first used in a political sense in England. and its introduction is generally ascribed to Charles James Fox, who in 1797 declared for a "radical reform" consisting of a drastic expansion of the franchise to the point of universal manhood suffrage. The term radical thereafter began to be used as a general term covering all those who supported the movement for parliamentary reform. After the passage of the Reform act of 1832, which extended the suffrage only to part of the middle class. a group of Radicals allied with the Whig faction in parliament continued to press for an extension of the vote to include even the working class. When the Reform act of 1867 further widened suffrage, the Radicals, notably in London and Birmingham. took the lead in organizing the new voters. helping to transform the Whig parliamentary faction into the Liberal mass party of the later Victorian era. Because of their efforts on behalf of the working-class vote the Radicals earned the loyalty of the trade unions; from 1874 to 1892 every trade unionist who sat in parliament regarded himself as a Radical.

In France before 1848, the term radical designated a republican or supporter of universal manhood suffrage; the open advocacy of republicanism being technically illegal. republicans usually called themselves radicals. After 1869, a self-styed Radical faction led by Georges Clemenceau began to drift away from the moderate democratic-republicanism of Léon Gambetta. These Radicals regarded themselves as the true heirs of the French Revolutionary tradition. In 1881 at Montmartre they adopted a platform calling for a wide range of social reforms, and at the turn of the century the Radical-Socialist party (*q.v.*) was formed.

The English Radicals of the 19th century were influenced by philosophical ideas assuming that men are able to control their social environment by collective action. a position held by the so-called philosophical radicals. These assumptions also underlying Marxist theories of social reform. in time the label "radical" was affixed to Marxists and other advocates of violent social change, thus becoming inapplicable to the gradualist reformers whom it had described previously.

In the United States, although the term is usually one of opprobrium. this was not always true in the postdepression years of the 1930s; and it is generally not true in less stable and prosperous societies. In popular U.S. usage, radicalism stands for political extremism of any variety. of the left or right. communism serves as an example of the former, fascism of the latter. See also LIBERALISM; MARXISM; SOCIALISM; ANARCHISM; COMMUNISM.

For a discussion of philosophical radicalism *see* Elie Halévy, *La Formation du radicalisme philosophique,* 3 vol. (1900–03; Eng. trans., *The Growth of Philosophical Radicalism,* 1928). (S. MR.; H. M. S.)

RADICAL EMPIRICISM, in philosophy, is the theory that experience is the only test of reality and truth. This is the view of William James (*q.v.*), and was so named by him.

Sre W. James. *Essays* in *Radical Empiricism* (1912).

RADICAL-SOCIALIST PARTY (PARTI RÉPUBLICAIN RADICAL ET RADICAL-SOCIALISTE; commonly called the RADICALS). one of the major political parties of modern France. Founded in 1901 on the reunion of the Radical-Socialists with the Radicals from whom they had broken away, this party dominated the third republic in the 20th century as the old Radicals had done in the 19th (see FRANCE: *History*). The party was loosely organized and drew its funds from a small number of subscriptions. being primarily representative of sectional interests. Its power was founded on the influence of local personalities (mayors and departmental councilors), of various committees (notably those of Freemasonry) and of provincial newspapers with large circulations (*e.g.,* La *Dépêche de Toulouse,* owned by the Sarraut brothers). Its supporters were mainly people of the urban middle class (*petit bourgeois* rather than business magnates), professional men (lawyers. doctors and teachers), farmers and craftsmen. It was strongest round Lyons and in the south of France, particularly in the southwest.

Radical ideology comprised (1) loyalty to the principles of the Revolution of 1789, with ready use of Jacobin slogans; (2) rationalism and anticlericalism; and (3) the systematic protection of group interests. particularly those of small tradesmen. small businesses, people with small private incomes and the lower ranks of the civil service.

Albert Thibaudet makes a distinction between the authoritarian, patriotic radicalism of such men as Clemenceau and the individualist radicalism of "the citizen against the ruling powers"—as propounded. for instance, in Alain's *Éléments d'une doctrine radicale.* There are. however, several other varieties of radicalism; *e.g.,* the technocratic (represented by Joseph Caillaux), the anticlerical (Émile Combes) and the presidential (Édouard Herriot—a statesman most adroit at combining heterogeneous elements).

Men of the centre, between the right and the Socialists. the Radicals were essentially the governing party of the third republic. A Radical. Édouard Daladier, was premier at the time of the Munich agreement (1938) and at the outbreak of World War II (1939). Immediately after that war the Radical party seemed just a relic of a past age: and in the elections of Oct. 1945, under a form of proportional representation, the Radicals won only 6.8% of the votes and 35 seats. whereas in 1936. under a single-member majority system of election. they had won 14.6% and 116.

Subsequently the party underwent three phases. First, its opposition to "three-party rule" by Communists. Socialists and Christian Democrats (M.R.P.) and. after the Communists had left the government in 1947, its holding of the balance between the parties enabled it to restore its fortunes (1945–53). The party itself was reconstituted. its newspaper propaganda revived and public confidence in it recovered. Thus several coalition governments were formed under Radical leaders (René Mayer, Henri Queuille, André Marie): and in the elections of 1951 the Radicals won 72 seats. Next followed the attempt (1953–56) by Pierre Mendès-France to consolidate the party, to attract more youth into it and to make its propaganda more cogent (*e.g.,* in the newspaper *L'Express*), identifying it moreover with a progressive economic policy and with a liberal attitude toward the countries of the French union. &lend&-France. however, was only partially successful in the elections of Jan. 1956 and was very adversely criticized by other Radicals, so that he had eventually to retire from leadership of the party. The parliamentary group splintered, and divisions within the party became more acute than ever before. In the elections of Nov. 1958. under a majority system again; the Radicals won 11.5% of the votes and 35 seats. which, however, had to be divided between four parliamentary groups. (J. TD.)

RADIN, PAUL (1883–1959), U.S.-Canadian anthropologist. was born April 2, 1883, in Poland and was taken to the U.S. as an infant. He was significantly influenced during his university years by James Harvey Robinson and Franz Boas. After work at the College of the City of New York, he received the Ph.D. in anthropology at Columbia university.

Radin was primarily interested in the folklore. religion and language of primitive peoples. contributing such works as *The Winnebago Tribe* (1915–16) and *Primitive Man as Philosopher* (1927). His view of anthropology as a branch of history and his emphasis on primary documentation are reflected in *The Road of Lije and Death* (1945), *Culture of the Winnebago: as Described by Themselves* (1949), as well as in his major critical-theoretical work, *Method and Theory of Ethnology* (1933). Radin pioneered in what later became important fields of anthropology (culture-personality studies, cultural contact) and in the use of autobiographical documents; see, *e.g., The Autobiography of a Winnebago Indian* (1920), republished as *Crashing Thunder* (1926). From the 1930s on. a growing interest in Marxian sociology led him to a reinterpretation of some of his earlier formulations; see *Primitive Religion* (1937).

Though not primarily active as a teacher, Radin at various times taught at the University of California. The University of Chicago, Cambridge university, Kenyon college, Gambier. O., and Brandeis university. Waltham. Mass. For many years he was field ethnologist for the geological survey of Canada. Radin died Feb. 21, 1959. (A. M. H.)

RADIO, the radiation and detection of signals propagated through space as electromagnetic waves to convey information. Radio is one of the chief branches of telecommunication. It embraces telegraphy, telephony and television without wires, and radar.

Wireless was the original term for radio and is still widely used in Great Britain. The word radiotelegraphy was substituted generally for wireless telegraphy (and similar terms in other languages, following international conferences on radio communication held in Berlin. Ger., in 1903 and 1906.

This article, in the sections outlined below. describes the historical development of radio technology and the theories of radio wave propagation. Basic material on the nature and behaviour of radio waves may be found in ELECTROMAGNETIC WAVES. The growth of the industry that produces scheduled programs of entertainment. news and educational material is traced in BROADCASTING. while the article TELEVISION describes the technical aspects of that subject as well as the production of programs. Additional material on telecommunication may be found in the articles RADIO RECEIVER; TELEGRAPH; TELEPHONE; and FACSIMILE TRANSMISSION. Examples of radio aids to navigation are given in the article NAVIGATION. The following article is divided into these sections:

I. FORMS OF RADIO COMMUNICATION

Any form of telecommunication by radio requires a transmitter to furnish the energy for transmission: an antenna or aerial from which the energy may be propagated; the medium of propagation. which is the same as that pervading free space outside the earth's atmosphere. although its electrical transmission properties are modified by the atmosphere and the proximity and character of the earth's surface; and, finally. the receiver. In the receiver. the weak signal is resonated (tuned), amplified and demodulated (detected) to recover the original signal, which is reproduced by a teletype printer, loudspeaker or television picture tube. The highest rate of information reproduction is about 10 bits per second for high-speed code. 10.000 bits for high-fidelity sound and 10,000,000 bits for high-definition television. (A bit, or binary digit, is the binary unit of information, capable of expressing such quantities as 0. 1;' yes, no; off. on, etc. *See* INFORMATION THEORY.)

These basic requirements are essentially the same for both radiotelegraphy and radiotelephony. The various forms of telecommunication are distinguished by the way that the continuous radio-frequency power generated in the transmitter (usually called the carrier wave) is interrupted or varied (that is. modulated) from moment to moment. In radiotelephony the primary controls to modulate the carrier in the transmitter are directly responsive to the human voice or to music and other sounds.' In radiotelegraphy the elemental modulation is led to the transmitter in the form of a signal unit, or pulse of power. successive combinations of which. in various time patterns and usually in opposite senses (such as on-off. present-absent, plus-minus, high-low, mark-space) are given either arbitrary language code meanings or various functions in the remote interconnection of machines. In television two simultaneous (multiplexed) modulations are employed. One modulation is radiotelephonic (audio) and the other consists of signals (video) representing a range of light values of successive elemental areas into which a scene can be divided by a process called scanning. In basic radar the transmitter is pulse-modulated in a continuous manner. but without information. The informational content of radar is supplied as modulation en route at a point or points of reflection.

The modern concept of radiotelegraphy does not confine it to the system of reducing messages to Morse code signals for the purpose of transmitting and transcribing them for delivery as telegrams. or even to the system of accomplishing the same end by use of remotely actuated printing telegraph machines, important though both systems are to the world-wide radiotelegraph business. In modern usage. all information to be conveyed—words to be typed. a speech to be reproduced, a song to be sung, a snitch to be operated. a card to be punched. a piece of Linotype text to be set. a television scene to be displayed or a calculating machine to be operated—can be reduced to a stream or succession of elemental units in a time domain. Radio telecommunication concerns itself with the collecting and processing of such information. if necessary its compression through codification. its propagation without wires. its detection, re-expansion or decodification and, finally. its dissemination and utilization for purposes of intelligence or control. Radiotelegraphy concerns itself with that portion of the radio telecoinmunication product which is a matter of record (hence often called record communication) or control. as distinguished from radiotelephony, radio broadcasting and television, in all of which the information is only momentarily made audible or visible. Generally speaking, the pulse-transmission techniques associated with radiolocation (radar), radio navigation (loran) and radio direction-finding are considered specialized branches of radiotelegraphy.

II. EARLY HISTORY

James Clerk Maxwell was the first scientist to foresee the propagation in space of electromagnetic energy from waves originating in wires and the first to show mathematically the laws of the transfer of such energy through space at the speed of light. Maxwell built upon and united the expressions of earlier mathematicians and physicists in his own equations expressing the relationship of electromagnetic forces within, and at the boundaries between. conductors and dielectrics.

In 1845 Michael Faraday was first to bridge the existing gap between light and electricity by observing the phenomenon of magnetic gyration. When he passed a beam of polarized light through transparent glass, application of a strong magnetic field was capable of rotating the axis of polarization of the light. Faraday's. experiment led him to conclude. with Thomas Young, that light waves represent transverse vibrations. Later. William Thomson. Lord Kelvin. calculated the oscillatory character of electricity in a condenser discharge (1853). Kelvin passed on to Maxwell the theory that these oscillations represented successive transformations of energy between magnetic and electrostatic fields much like the kinetic-potential energy transformations in the swinging of a pendulum or in surface waves.

George Green, an English mathematician, introduced the imperfect analogy of space as an elastic medium whose dynamic properties of compression, shear and rotation—in relation to the transmission of transverse and longitudinal waves—were mathematically determinable (1828). This idea later served Maxwell for an ether model, by use of which he was able to identify light and electricity as two forms of electromagnetic wave propagation occurring at the velocity of light.

Maxwell's equations are given with their derivatives and implications and discussed at length in the articles ELECTRICITY: *Electromagnetic Waves;* ELECTROMAGNETIC WAVES: *Maxwell's Field Theory;* LIGHT: *History.* Published in 1863 and 1873. they remain a working tool of radio and telecommunication research despite the questions raised by the relativity, electron and quantum theories. the wave-corpuscular controversy and the shortcomings of the ether model.

1. Experiments by Hertz.—Radio is a superb example of a phenomenon whose principles were known to mathematicians some time before they were demonstrated practically. Maxwell made no attempt to prove physically his thesis of the identity of light and electricity, and his writings were known only by other mathematicians. Among these was H. L. F. von Helmholtz. who held the chair of physics in Berlin and whose best-known work was on the resonance of sound (1862). However, his other work in electrical oscillations and electrodynamics involved his theories in controversy with Maxwell's (1874). Among Helmholtz's pupils was Heinrich Hertz. who in 1886–88 brought into electrical resonance, at a wave length of approximately 4 m. (or at a frequency of about 75,000,000 cycles per second [c.p.s.]), a pair of plates radiating electrical energy and a detecting loop of wire some feet away. A micrometer gap in the loop. by producing sparks that could be seen in the dark, revealed a transfer of energy as predicted by Maxwell (fig. 1).

Hertz had the benefit of the induction coil as a generator of radiation, besides laboratory types of electrical influence machines. Using these. he established that radiated electrical energy, like light. was emitted as transverse waves in all directions. Electrical waves, moreover. could be brought to a focus, reflected. refracted and polarized. Like sound. they could be set up as standing waves on wires. He also established. by measuring wave lengths and calculating frequency, that the velocity of electrical transmission through space was the same as the velocity of light, as predicted by Maxwell. He found that radio waves, because of the difference in frequencies between radio and light, would pass through certain

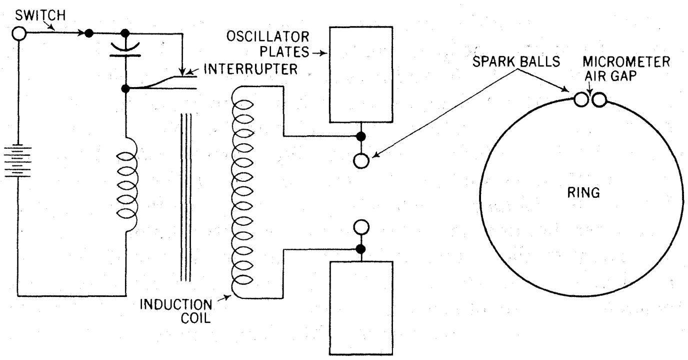


FIG. 1.—HERTZ OSCILLATOR. 1887

substances opaque to light but were stopped by metallic screens. However. Hertz had no interest in using his discoveries for actual communication.

2. Hertz to **Marconi.**—The decade between Hertz and Marconi was marked by the development of a great deal of interest in electrical waves. The commercial successes of the wire telegraph in the first half of the 19th century and of submarine cables and the telephone in the latter half, directed speculation toward wireless modes of operation. Experiments in conducting galvanic currents through earth and water without wires took place. Inductive devices requiring primary and secondary coils of very large dimensions were used. The principles of the first sensitive detector of faint signals—the coherer—were demonstrated, and radio signals were employed to convey intelligence for the first time.

3. The **Coherer-Decoherer.**—The coherence of dust particles in air when electrified was discovered by Pierre Guitard of France in 1850. In 1879 D. E. Hughes. an Anglo-American electrician. while investigating the resistance of loose contacts between carbon granules in his microphone transmitter, discovered the phenomenon on which the action of coherers depends. The coherence when electrostatically charged, and a resulting decrease in the resistance of loose brass and copper filings to the flow of a current, were noted by C. Onesti of Italy in 1884. E. Branly. a French physicist, published in 1890 his discovery that the resistance between loose iron filings in a glass tube decreases with the impact

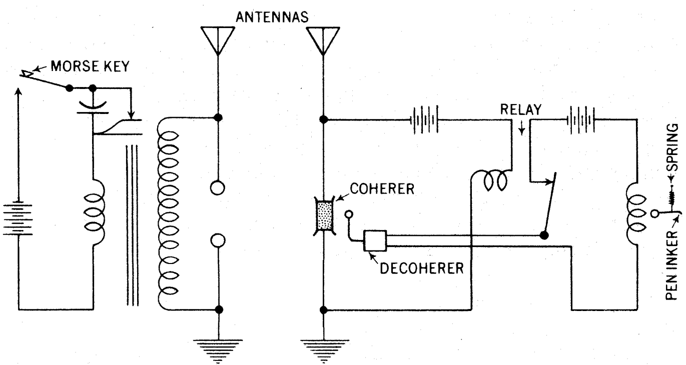


FIG. 2.—MARCONI-LODGE APPARATUS, 1896

of radiated electric waves. Branly did not apply his coherer to the reception of electromagnetic waves as communication signals, but he found it necessary to tap the cohering filings mechanically to make them "decohere." Sir Oliver Lodge. an English physicist, demonstrated improvements in Branly's coherer in 1894. He used the device, in place of a Hertz loop, for the detection and pen recording of Morse signals transmitted in a laboratory by radio. Included in the inker circuit was Lodge's "trembler" or decoherer, which automatically shook the filings to restore their high resistance, thus making the device responsive to no-current as well as to marking-current conditions in the dipole radio-frequency receiving circuit (*see* fig. 2). In 1895 A. S. Popov, a Russian physicist, in his study of distant lightning flashes, used Lodge's receiver with two improvements. One was the use of choke coils to nullify the effect of local sparking at the inker-decoherer circuit relay contacts; more important was the use of an external insulated wire and a ground (earth) connection, between which the coherer was inserted. He sent Hertzian signals into his receiver over a distance of 300 yd. in 1896. Further improvements in the coherer were made by Marconi.

4. Wireless by Conduction.—Practical wire telegraphy began more or less simultaneously in Germany, England and the United States during the decade 1835–45. and quickly spread. The use of the earth as one of the two needed guides for conduction currents flowing in extended electrical circuits was discovered in 1838 by K. A. von Steinheil of Germany. It was found that two separate remote paths through earth and water could be joined in emergencies to afford telegraph communication of sorts. Samuel F. B. Morse is said to have telegraphed across the Susquehanna river in 1842 without wires or cables, by means of two pairs of plates immersed in opposite banks, one upstream and another downstream. With the coming of the microphone and a sensitive telephone receiver in the late 1870s this method found other applications, especially when the combination used was a buzzer and telephone receiver. Thus, Sir William Henry Preece, electrician to the British post office, satisfactorily communicated across the Solent (1882). In 1889 the Indian Telegraph department employed the system during floods. The buzzer telegraph became a useful military device for a few years.

5. Wireless by Induction.—Meanwhile the induction system, another method not requiring wires, appeared. Preece demonstrated in 1855. over a distance of a quarter-mile, that messages could be sent by induction, *i.e.*, using low-frequency transformer action and convection currents, instead of high-frequency displacement currents in space. In 1892 Preece signaled between two points $4\frac{1}{2}$ mi. apart. These experiments predisposed a sympathetic attitude on Preece's part toward Marconi, who came to London in 1896 to put forward his first proposals for establishing wireless telegraphy in Great Britain.

6. Early Experiments and Proposals.—The periods of these probings for wireless telegraphy bracketed the years (1886–88) of Hertz's work. The same was true for another series of experiments and ideas more directly concerned with radiation. Mahlon Loomis conceived a wireless system wherein "disturbances in the static sea" would cause electric waves to travel through the atmosphere and ground; a U.S. patent was issued on it in 1872. Thomas A. Edison reported (1875) transfers of "etheric forces" in his laboratory that caused sparks of an oscillatory nature to appear in a micrometer gap between two carbon blocks mounted in a black box with a window, but with no external connections. In 1883 George FitzGerald suggested a method of producing electromagnetic waves in space by discharge of a conductor. In 1882 and 1886 A. E. Dolbear was granted U.S. patents on "a mode of electric communication for sending signals through the ether of space," but there is no record of the apparatus having worked.

Sir William Crookes made a remarkable prophecy of wireless telegraphy in the Fortnightly *Review* (1892). He foresaw the need of better wave generators than the induction coil, of a complement of wave lengths measured in miles down to feet, of more delicate receivers, of sharper tuning and the means of concentrating power in a single ,direction. The article came to the attention of Marconi and profoundly stimulated him. The radio industry that Marconi founded was to be preoccupied with Crookes' telegraphy specifications for a half-century. But during the latter half of that time it would be sharing attention with radiotelephony, which Crookes did not foresee and in which Marconi evinced only casual interest. .

7. Guglielmo Marconi.—A native of Italy, but from 1896 identified quite as much with England, Marconi early came under the influence of Lodge's demonstrations and Crookes' prophecy of wireless telegraphy. He was the pupil of Augusto Righi, professor of physics at the University of Bologna, who was working with waves 2.5 to 20 cm. in length and had invented an early quenched-spark emitter. Unlike his predecessors, Marconi was not a laboratory scientist but an entrepreneur with a driving purpose—to find the way to unguided electrical communication through space. He dedicated his life to translating radio from the laboratory to the market place, always looking for the slightest advance in reliability of wireless equipment and in the distances over which it would work. Marconi saw the commercial usefulness of a method of electrical transmission that, because it was not restricted by wires or cables, could reach an unlimited number of receivers anywhere at the same time.

Marconi was first to transmit and receive signals by Hertzian waves purposefully directed but without wires (1895). He used an induction coil with a telegraph key in the primary circuit. Across the secondary circuit was an untuned spark gap. Marconi did not terminate the gap in a dipole. as had Hertz and Lodge, but in a ground plate for one pole and in an elevated metal cylinder for the other. For a receiver he used a simple coherer with improvements in sensitivity. By the end of the year he had increased the transmitting range to more than a mile.

In 1896 Marconi went to London, secured patents on his system and interested government officials in it. Ranges of 2 to 9 mi. obtained that year were gradually increased to 200 mi. by 1901.

III. MARITIME WIRELESS AND THE VACUUM TUBE

Marconi set the pace for widening the transmission range of wireless. In 1897 he established the station at Needles, on the Isle of Wight, that took part in several records in wireless: 1897—first maritime use of wireless in England, to a tugboat 18 mi. away; 1898—first paid-for wireless telegram; 1899—first newspaper published aboard ship using press matter sent by wireless, 56 mi.; 1901—first 200-mi. communication. Marconi also was the first to bridge the English channel by wireless, in 1899.

1. Maritime Wireless.—The fact that radiated waves carried well over water led to the entrance of commercial wireless into the maritime field. where it filled a need not served at all by wire telegraphs. Apart from its obvious usefulness to ship owners in communicating with ship captains and pursers during the course of a voyage. it was quickly put to use by the press, by the military and in sea rescues.

By 1904 the role of wireless in summoning help to ships was so important that adoption of a universal code call of distress was in order. Addition of the letter D (for danger) to the "all stations" collective call CQ gave the CQD signal, eventually replaced by the Morse mnemonic SOS. When radiotelephones became common. especially on aircraft, the voice of distress, "May Day" (from the French *m'aidez,* "help me") was added.

2. Spread of Commercial Wireless **Telegraphy.**—Marconi's influence rapidly spread to other countries. A. K. H. Slaby saw Marconi's apparatus in England and introduced it into Germany in 1897, and the first German commercial wireless station was established on Borkum Island in 1900. Pioneer wireless work in Germany was also done by K. F. Braun, G. W. A. von Arco. Alexander Meissner and the firm of Siemens and Halske. Out of an amalgamation of these interests the Telefunken company was created in 1903.

Two outstanding names appear in the early wireless annals of the U.S.—those of R. A. Fessenden. physicist, and Lee De Forest. Fessenden lectured on Hertzian waves and experimented with them prior to 1900. when he was engaged by the U.S. weather bureau to develop wireless as a weather forecasting aid. He became a prolific producer of wireless inventions. De Forest, while a student in 1898. was attracted by demonstrations of the Hertz experiments. As Marconi had been, De Forest was influenced by the predictions of Crookes regarding the future of wireless. He set out to produce a better detector of waves than the coherer, and he produced several inventions of great importance.

3. Transoceanic Operation.—In 1900 Marconi built a station at Poldhu. Cornwall. Eng.. that established a number of records, and in 1907 he built another station in Clifden, County Connemara. Ire. The Federal Telegraph company opened a radiotelegraph service between San Francisco, Calif., and Honolulu. Hawaii, in 1912. The American Marconi company opened a similar circuit in 1914 and extended service across the Pacific to Japan by manual relaying in Hawaii during the next year.

4. Improvements in Transmitters.—The improvements in transmitter equipment and antennas in the first quarter of the century greatly extended the range and reliability of long-ware and medium-wave radiotelegraphy. Until the introduction of the vacuum tube, spark gaps, arcs and alternators took many forms during the 20-year period beginning around 1903.

Rotary Spark Gap.—Invented by Fessenden, the rotary spark gap consisted of a toothed or spiked wheel turning between two electrodes. A whistlelike note could be produced to any desired audible pitch by proper selection of wheel speed and number of teeth. Self-cooling. the gap could be decreased to any minimum length desired. The rotary spark gap was widely used in the 1906–20 period.

Quenched Sparks.—As the power supplied to ordinary open spark gaps and their associated oscillatory circuits was increased over the years, it was found that the sparking rate could be increased if ionization of the gas between the electrodes could be prevented. A technique was discovered by the German physicist, Max Wien. in 1906. wherein sparks—which in that day mere thin and often several inches in length—were increased in volume but reduced to a fraction of a millimetre in length. This resulted in an abrupt decay (or quenching) of the oscillation produced by the spark. The frequency emitted was therefore that of the circuit coupled with the antenna, excited by rapid, successive impacts from the quenched gap. Arc-over was prevented by using large electrode areas cooled by circulating air or water. For very rapid sparking rates a high-voltage direct current could be used, with an oscillating circuit in series with the quenched gap. As installed by the German Telefunken organization for telegraph use in 1909–15. the quenched gap was fed from alternators producing 500 to 1.000 c.p.s.

Rotary gaps and quenched gaps made the emitted telegraph signals more distinctive and more easily identifiable by the receiving operator. who often had to read them through the interference of static and other transmitter signals.' Rotary and quenched gaps produced tones more or less unique to each station. Despite such advances, it was clear that the intervals of no power, between bursts of rapidly decaying ether disturbances caused by discrete sparks. could not be reduced so long as sparks were employed; some source of continuous-wave production had to be found.

Marconi Timed Spark.—Marconi's timed-spark system made it possible to approach continuous-wave generation. It used staggertoothed wheels rotating on a common axis. These wheels drew off sparks at a faster rate than the single spider used by Fessenden and others. By careful design the wheels could be timed so that the decaying oscillations produced by one set of teeth and its associated spark gap were overlapped in phase by oscillations developed by a second set, and so on. The system was adapted only to very long waves (very low radio frequencies). it required bulky equipment to maintain the necessary stability. it had to be designed so that the frequencies produced matched the natural frequency of the antenna and its operation involved many other critical factors.

Arc *Oscillators.*—W. B. Duddell, an English engineer. discovered in 1900 that an arc lamp could be made to "sing" a musical note if it was placed in a direct-current circuit containing an inductance and a capacitance. V. Poulsen of Denmark, by cooling the lamp electrodes and enclosing the arc in an atmosphere of hydrogen, raised Duddell's limit of 10 kc. per second to 100 kc. per second: and. when coupled to an antenna, the arc generated and emitted the first pure continuous waves in the low-frequency wireless field. However. Poulsen's arc was not tested successfully until 1908. when it worked over a distance of 150 mi. Meanwhile, in 1906, the German Telefunken arc appeared; by 1913 Telefunken's Nauen station used it over a range of 1.550 mi. In 1910 the Federal Telegraph company brought the Poulsen arc to the United States. It was installed as standard equipment by the U.S. navy in 1912 and continued in use through World War I.

High-Frequency *Alternator.*—Fessenden applied in 1901 for a U.S. patent on a high-frequency alternator for the generation of continuous waves that would make possible the transmission of the human voice by wireless telephony. To Fessenden's specifications, E. F. W. Alexanderson, a pupil of Slaby working in the U.S., built in 1903 a 10,000-c.p.s. alternator. Later he built one of 80.000 cycles, with which, at Brant Rock: Mass., Fessenden was the first to broadcast music and speech (1906). Alexanderson's

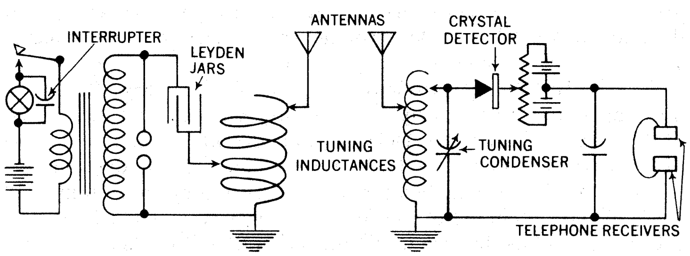


FIG. 3.— TUNED CIRCUITS AND CRYSTAL DETECTOR. ABOUT 1903

problem was the design of multipolar machines (*e.g.,* 300 poles mounted on the stator) with rotor speeds of about 20.000 r.p.m. and air-gap clearances of about 0.015 in. Such a machine, developing 100,000 c.p.s., was built by Alexanderson in 1909 for radiotelegraph use.

Resonance and Tuning.—Lodge patented in England in 1898; the use of adjustable inductance in the transmitter. antenna and receiving circuits of wireless systems. Lodge called this syntonic tuning (see fig. 3). While the patent was in conflict with some of Marconi's claims. Lodge had an influence on early tuning theory and the adaptation of antenna sizes and configurations to the frequencies being emitted and detected. John S. Stone applied for four-circuit tuning patents in 1900 and was the first in the U.S. to assert that antenna circuits and spark and detector circuits could be independently tuned and loosely coupled together, thus increasing selectivity (*see* fig. 4). Stone also studied the tuning of telephone wires and their adaptation to the guidance of electromagnetic waves.

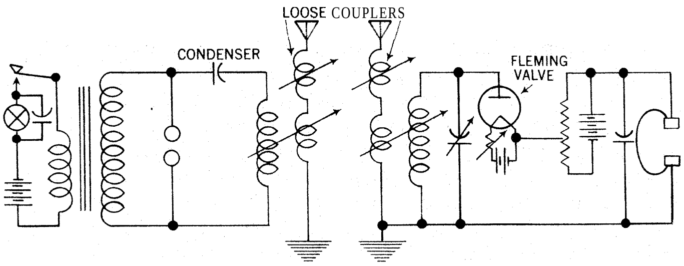


FIG. 4.—LOOSE COUPLING AND FLEMING VALVE. ABOUT 1907

In wireless, as in wire telephony. a parallel attack on the problems of .resonance had been made.

Antennas.—Antennas were found to have a natural resonance period important to the tuning of a circuit consisting of antenna. ground and coupling inductance. Marconi and his organization, Lodge. Fessenden and many others developed formulas for antennas of various virtual heights, for optimum ratios of antenna lengths to wave lengths and for various configurations—notably the vertical antenna and the flat-top antenna supported between towers and between ships' masts. Alexanderson invented the multiple-tuned panel transmitting antenna. It divided a directionally pointed, horizontal, tower-supported antenna into sections connected through down leads and tuning inductances to ground at various points throughout its length of approximately 900 ft. Alexanderson and his assistant. Harold Henry Beverage, developed a "barrage receiver" that incorporated directional discrimination and required long horizontal antennas (1916). In 1921 Beverage patented the "wave antenna" that became standard for long-wave reception throughout the world. It consisted of a wire supported on a straight-pole line of the length of one wave (approximately nine miles in practice) and oriented to the direction of arrival of the wave. It had the useful property of rejecting static that came from any other direction.

5. Improvements in Receivers.—The counterpart of increased power in transmitters was increased sensitivity in receivers. The single step of most significance was the substitution of a pair of head telephone receivers or headphones for the early pen inker as the receiving device used by the operator. Headphones were sensitive enough to work directly in a rectifying receiving circuit when a series potentiometer and a shunt-blocking condenser were added (see fig. 3). Between about 1903 and 1916 the standard method of telegraphing by wireless was headphone reception of hand-keyed Morse code (ship-to-shore) or slow-speed automatic Wheatstone (transoceanic) transmission.

As in the case of spark gaps in transmitters. many improvements were made in the rectifier element (detector) of receivers. These improvements served a vital purpose in the interval 1902–20, before the De Forest three-eleinent vacuum-tube circuit became available for general use after World War I. In Marconi service the coherer was replaced by the magnetic detector. As developed by Marconi in 1902, it was capable of moving a relay so that the relay could produce recordings of signals on paper tape. By 1907 the coherer had been generally outmoded by magnetic, electrolytic and crystal detectors in circuits of the kind shown in fig. 3.

Before 1900, Hughes in England had found that a steel needle resting lightly on a carbon block would rectify radio-frequency waves in a manner similar to a coherer but without requiring a decoherer. With headphones. the steel needle became the earliest form of crude wireless rectifier. but its use was short-lived. Contemporary with the magnetic detector was the electrolytic detector. an invention of Fessenden in 1902. consisting of platinum wire dipped in nitric acid. Beginning in 1903 G. W. Pickard. an American engineer, began experimenting with the rectifying properties of magnetite and other crystals that had surface spots sensitive to radio signals upon contact with wire probes called "cat whiskers." In 1906 Pickard discovered a superior crystal in silicon, and in that same year Gen. H. C. Dunwoody of the U.S. army discovered that carborundum and carbon in contact were less sensitive to vibration than other combinations and therefore were adaptable to shipboard use. Pickard used a combination of zinc oxide and chalcopyrite in contact; also tried were galena. molybdenum and other crystals. The independently conducted, trial-and-error search for these materials was in marked contrast to the organized scientific research in 1948. involving point contacts on germanium, that resulted in development of the transistor. Crystal rectifiers were the mainstay of wireless until they were gradually replaced by electron tubes.

6. The Electron Tube.—Sir John Fleming's vacuum diode valve of 1904, based upon his discovery that the "Edison effect" could be applied in a wireless receiver circuit for the detection of incoming waves. was a rectifier. It fulfilled the function of a crystal as a detector of high frequencies (see fig. 4). It was the first of a long series of electron tubes that had a heated source of a stream of electrons (cathode) and a collector plate, both in a partially exhausted glass housing with external electrical connections. The development of the electron tube is traced in the article ELECTRON TUBE: History. The De Forest triode audion of 1907 was the most important of the electron tube series. It contained two features absent in Fleming's valve: an external local battery. connected between plate and cathode, from which the tube derived its power to amplify weak input signals; and a third electrode, the grid. interposed in the electron stream and capable of controlling the plate current in accordance with incoming radio-frequency signals. Under optimum conditions. De Forest's triode displayed high amplification characteristics as a detector, although Fleming's valve had not. However, it was not until 1912 that the triode's amplification was stabilized and its versatility became clear. In that year H. D. Arnold and Irving Langmuir independently found that the triode amplifier could be stabilized if pumped to high vacuum, and De Forest increased amplification by operating his tubes in cascade—the plate output of one tube fed into the grid input of a second tube, etc. De Forest discovered that the audion could be made to oscillate, in suitable circuits, so as to generate radio frequencies. This meant that the vacuum tube could be used for transmission as well as reception. E. H. Armstrong in 1913 and De Forest in 1914 filed conflicting patent applications on the feedback circuit (*see* RADIO RECEIVER: *History*). The feedback circuit led a portion of the amplified plate current back into the grid of the same tube, greatly increasing its sensitivity by regenerating weak signals.

7. Developments During World War I.—Maritime wireless telegraphy was generally in use on ships and between ships and shore stations by the outbreak of the war. Arc transmitters up to 500 kw. in capacity had been installed at naval stations in the United States. and the Marconi timed-spark system linked units of the British commonwealth. New German Telefunken stations erected in the U.S. were among those that warned German ships, upon the declaration of war, to make for neutral ports. The British fleet was recalled by radio. During this period very long-wave transoceanic radiotelegraphy became well established for military purposes. using arcs and alternators for transmitting and triode tubes for receiving. In 1918 the U.S. army erected its Lafayette station at Crois d'Hins near Bordeaux. France, for transatlantic communication. It achieved world ranges on a wave length of 20.000 m. The original plant comprised two Poulsen-Federal arcs rated at 1.000 kw.

The Heterodyne Principle.—Radio frequencies generated by arc and alternator were above the range of audibility in a telephone receiver. so that they had to be modulated at a steady audible tone before being turned on and off with a telegraph key. This modulation was accomplished at either the transmitter or receiver. The German inventors modulated their alternators by means of a tone wheel. Poulsen tone-modulated his arc with an interrupter. Fessenden invented a method of tone-modulating a circuit at the receiver instead of at the transmitter by generating at the receiving station another high frequency.that differed from the transmitter frequency by a value within the audible range. The device that produced this steady interference pattern was called a heterodyne apparatus (1902). Fessenden used the heterodyne principle at his Brant Rock station in 1904, and it was necessary to generate the beat frequency by a ponderous local arc. Kevertheless, U.S. navy experiments in 1913 demonstrated the superiority of this method for radiotelegraphy. With the introduction of the vacuum tube as an oscillator in 1912, a simple receiving circuit component became available to generate a heterodyne beat-note audible in headphones. To solve a military problem with the U.S. army signal corps in Europe in 1918, Maj. E. H. Armstrong converted a received radio-frequency signal into an intermediate, supra-audio frequency by beating it with the output of a local oscillator, detecting signals twice before giving them audio amplification. He called this the superheterodyne method and patented it in 1919–20. It possessed advantages of stability over other methods of amplifying signals above the audio range. With the advent of the screen-grid tetrode in 1927, the superheterodyne became the most widely used receiver circuit.

Radio Direction-finding.–Direction-finding. or radiolocation, began in wireless telegraphy as a specialty of wave-direction measurement. In modern aviation and in some marine work direction-finding is an auxiliary function of radiotelephony. The original work on direction-finding was performed by Stone in 1904 and by E. Bellini and A. Tosi in 1906. The patents of the Bellini-Tosi system were acquired by Marconi in 1912, and in that year the first English merchant vessel was equipped with a direction-finder. Credit for major improvements thereafter is shared by an American, F. A. Kolster (1913) ; Marconi's assistant: Capt. H. J. Round, whose devices tracked down the German fleet in the battle of Jutland (1916) ; and R. L. Smith-Rose, a British physicist. Because of its usefulness in World War I, direction-finding equipment did not find full commercial use until the period 1921–25, by which time it employed vacuum-tube circuits. By 1925 the radio compass had come into widespread shipboard use.

8. Radiotelephony. — The technique of radiotelephony represents the coinbination of two developments: high-powered radiotelegraphy and weak-current wire telephony. From the time of Alexander Graham Bell and Hertz until 1906. the two modes of communication had been separated in orders of magnitude of power and frequency, even though they derived from a common theoretical source in Maxwell's equations. As early as 1896. Stone and M. I. Pupin were involved in a patent controversy in applying telephony to Hertzian waves.

The Microphone.—The first type of transmitter for voice pickup was the telephone instrument patented in 1876 by Bell. He originally used the same type of coil-diaphragm instrument for talking and listening, Bell, and also Elisha Gray, used transmitters in which the voice sound varied the electrical resistance and thus caused variations in the currents in telephone circuits. In 1877 Émile Berliner and Edison discovered that sound pressures on a diaphragm could be made to produce variable electrical currents. Edison invented the carbon-granule telephone transmitter in 1386. The term microphone. coined by Sir Charles Wheatstone in 1827 to describe an acoustical amplifier! was first used in connection with telephony by Hughes in 1878. In that year Hughes devised a sensitive microphone transmitter in which the variable circuit resistance consisted of a carbon rod resting in grooves in two carbon blocks. Improvements in detail upon the Edison and Hughes transmitters led to the development of modern microphones. Subsequent refinements that resulted in the high-quality microphones used in radio. television and recording studios are traced in the article MICROPHONE.

Modulation by Microphone.—The direct-current singing arc was made to "speak" audibly and its light to vary when a microphone was coupled ro its circuit by a transformer. Such a "photophone" was built by H. Hays and Bell in 1897. It was not devised to generate radio frequencies but to transmit audio frequencies over a light beam. A number of attempts were made to introduce a microphone at various points in spark-energized wireless circuits without success: although Fessenden is generally credited with having been first to transmit speech over a distance of a mile, using a high-speed. interrupted-spark transmitter (1900). A. F. Collins used a microphone in the primary of an induction coil, with antenna and ground but without spark balls. to transmit over a distance of three miles in 1902. Spark telegraph signals, especially on low radio frequencies, were too powerful and too widely spaced in time to be modulated, even by water-cooled microphones.

Use of *Arcs* and Alternators. — Poulsen used his hydrogen-arc generator of continuous wireless telegraph waves in 1904 to transmit voice over short distances. In Germany H. T. Simon and M. Reich (1903) and O. Nussbaumer (1904) suggested the application of high-frequency alternating currents to the purposes of wireless telephony. In 1906 the Telefunken arc of Von hrco was voice-modulated, making it possible to talk by wireless over a span of 25 mi., and in the same year Fessenden staged the first demonstration of the broadcasting of music and voice by radio, using a water-cooled microphone and an Alexanderson 80.000-cycle alternator at Brant Rock. Reception was reported by radio operators aboard many ships at sea. De Forest demonstrated an arc radiotelephone in 1907 in tests between a ferryboat on the Hudson river and its terminals in New York and New Jersey. Using a liquid microphone to modulate an arc. F. Majorana in 1908 telephoned from Rome, Italy. to Sicily. a distance of 300 mi.. and in 1910 H. P. Dwyer used a Poulsen arc to telephone from San Francisco to Los Angeles. Calif. (490 mi.). In 1911 Xlexanderson built a high-frequency alternator with a laminated-iron field. designed to act as a self-contained magnetic amplifier. Its input was a microphone and its output a varying field flux that amplitude-modulated the generated continuous waves. In 1914 Marconi long-wave radiotelephone signals originating at Clifden. Ire., were received aboard two Italian war vessels off the coast of Sicily, 1,750 mi. away.

IV. THE RISE OF BROADCASTING

Medium-frequency telephone broadcasting and short-wave telecommunication dominated the decade 1920–30. The radiotelephone, useful for private conversations, became most valuable in public mass communication and entertainment. Public demand for broadcasting service and equipment caused manufacturers to demand new electronic devices. circuits and equipment. Broadcasting studios. feeder networks and overseas remote pickups became commonplace. Early radio by-products, including public-address systems and telephotography, presaged the decade of electronics that was to follow. Short-wave transmission also came into its own during the 1920s.

1. Improvements in Transmitters. — Better performance in transmitters stemmed in part from transmitting tubes of larger size and greater efficiency. Two important improvements were the copper-to-glass seal and the water-cooled tube (1922). Broadcasting transmitters. which in 1922 operated at outputs of less than 500 w.. were increased in power; 50-kw. stations were common in 1928. and by the early 1960s outputs had reached 500 kw. Efficient use of power by the transmitter was found to be economically important, and efficiencies were increased by such advances as the constant-current system of modulation of R. A. Heising (1921).the class C amplifier (1932) and W. H. Doherty's linear radio-frequency power amplifier (1936).

Jacques and Pierre Curie discovered the piezoelectric effect in 1880, and they later found that if a high-frequency field is applied to a crystal held under pressure, and if the applied frequency exactly coincides with the natural period of vibration of the crystal. the crystal will oscillate and produce useful alternating voltages between its surfaces. This property proved invaluable in preventing radio transmitters from wandering off assigned frequencies. G. W. Pierce found that the resonance of a crystal is very sharp. He was issued several patents on applications (1924 to 1931) for vacuum-tube circuits containing quartz crystals as oscillating-circuit stabilizers. The first use of crystal-controlled master oscillators took place in 1923.

There are other less precise but effective ways of accomplishing frequency control. Pierce investigated magnetostriction effects in nickel, while W. H. Eccles, of the Marconi staff, used tuning forks as early as 1901 to keep stations on frequency. Identically ground crystals were employed on a wide scale during World War II in transmitters and receivers, and the practical subdivision of the radio-frequency spectrum among thousands of users in the middle of the 20th century was made possible only by crystal frequency controls.

2. Amateur Radio.—Young men had turned to wireless telegraphy as a hobby in the period 1903–12 in the same spirit that their fathers had strung rooftop wire telegraphs between houses. Thousands of the long-wave transmitters shown in fig. 3 and 4 (but without receiving tubes) were installed. Unfortunately amateurs increasingly interfered with commercial and government wireless, and in 1911–12 they became subject to licence restrictions. During World War I amateur sets were sealed; however, the operators' talents proved so valuable in military service that they were encouraged to resume amateur operations after the war. Amateurs adopted vacuum tubes when these became available around 1919, and they became an important source of listening material for the many thousands of people who bought broadcast receivers in the years following 1920.

In resuming operations in 1919, the amateurs had been crowded into a medium-frequency band that was not broad enough to accommodate them. They had also been assigned a medium-high-frequency portion of the spectrum believed unsuitable for long-distance operation. The good use to which they put these bands in 1920–21 was their most valuable contribution to the development of radio. In 1921 a U.S. amateur, P. F. Godley, with the co-operation of British amateurs and the post office, set up a receiver in Ardrossan, Scot., through which he received from a group of six American amateurs at Greenwich, Conn., a 12-word message in radiotelegraphic signals. The distance was 3,200 mi.. the power 1 kw. and the wave length 230 m. (1,300 kc.). Soon American. British, French and other European amateurs by the hundreds were in frequent communication at low power in this band as well as on 180 m. In 1923 amateurs used low-power, 100-m. waves to talk between New York and California.

3. Commercial Short-Wave Radio.—Commercial interests were caught off guard by the amateurs' successful exploitation of the upper medium-frequency (MF) and the lower high-frequency (HF) bands. Marconi had never lost faith in the possibilities of short waves, but he had dropped the investigation of them in the 1890s in favour of long waves that were yielding him quicker results. He had taken out a patent on "beamed transmission" in 1905, and in 1916 assigned C. S. Franklin to investigate short waves. Franklin's results, published in 1922, indicated that short waves, 15 to 100 m. in length, were suitable only for distances less than 200 mi. This conclusion was controverted by the experience of the amateurs, whose records spurred more experimentation by Marconi. the Radio Corporation of America and the American Telephone and Telegraph company. The first commercial long-distance radiotelegram dispatch by short waves was sent from Belfast. Me., to Buenos Aires, Arg., in 1923. In the same year Marconi dispatched his yacht "Elletra" to test 100-m. short waves at sea as received from Poldhu, using reflectors designed by Franklin to concentrate the transmitted energy in a beam. The signals from Poldhu were heard 1,200 nautical miles in the daytime and double that distance at night. In 1926 beam transmission was considered practical for commercial use, and by 1928 Marconi stations had been erected in England, Canada, Australia, South Africa and elsewhere throughout the British empire. The Radio Corporation of America had abandoned its ambitious plans for a long-wave radio central station and was installing short-wave equipment. By 1930 the American Telephone and Telegraph company had made an almost complete transition to short wave.

Opening up of the extensive short-wave portion of the radio spectrum made room for thousands of long-distance and other services that could not have been accommodated on longer waves. Antennas became snialler and less expensive to build. had increased radiation efficiency and had substantial portions of their energy directed toward desired reception points. Directivity of antennas reduced the interference between stations and permitted world-wide sharing of channels. Interference by static caused by distant thunderstorms was less. Because of these advances, transmitter power could be reduced or the existing power could be used to make transmissions more reliable. Short-wave radio was adapted to long-distance telephony and to high-speed. multichannel telegraph operations. After 1927 virtually no new long-wave radio circuits were established, and most of those in use at that time were gradually abandoned. The long-wave spectrum is still useful! to a limited extent, for specialized military radiotelegraph services and for navigation.

The Kennelly-Heaviside Layers.—In 1902, long before short waves were being used, A. E. Kennelly of Harvard university and the British mathematician Sir Oliver Heaviside independently reasoned that a stratified layer must exist in the upper atmosphere; between that layer and the surface of the earth the long waves of wireless must be contained, and this fact accounts for the waves not leaving the earth tangentially at the horizon as light waves do. With the beginning of short-wave investigations, this theory was rapidly expanded. A. H. Taylor accounted for the ground- and sky-wave components of short waves; L. W. Austin reasoned that sky waves underwent refraction rather than reflection; and Ernest Rutherford attributed refraction to the presence of free electrons in the layer. Frank Conrad developed the "multihop" theory of repeated refractions in the layer and reflections from the earth's surface. The height of the layer was measured by Sir Edward Victor Appleton in England. by triangulation, and by George Breit and Merle A. Tuve in America. who measured the echo of a transmitted pulse. The latter method eventually revealed the existence of several concentric layers rather than one. (*See* IONOSPHERE.)

Diversity Reception.—H. H. Beverage and H. O. Peterson, observing transoceanic short-wave signals in 1925. found that fading does not occur simultaneously in two receivers working on antennas spaced a short distance apart. 'This led to the development of space-diversity reception. in which the combined (or overriding) signals from two or more receivers. working off carefully placed. separate antennas, govern the operation of a receiving relay, which automatically selects the strongest available signal.

V. SPECTRUM EXPANSION AND ELECTRONICS

Continued progress in broadcasting: and a new probing of the ionosphere by short waves, tied the decade 1930–40 to its predecessor. In the period between 1933 and 1937, improved designs for broadcast antennas made possible higher efficiencies and better control of directional effects, thus further reducing interference between stations. Continuing research in the high-frequency portion of the spectrum led inevitably to exploitation of the short-wave band for international broadcasting. By 1932 broadcast transmitters were operating with sidebands 8.000 c.p.s. in width, making it possible to transmit undistorted voice and music tones as high in pitch as 8,000 c.p.s.; this meant better fidelity in reproduction (FM broadcasting almost doubled this tonal range two decades later). but unfortunately the quality of the receivers then in use was not equal to that of the transmitters.

1. Electronics.— A widespread movement to apply radio theory and apparatus to other fields began in the middle 1930s. The radio industry contributed the electron tube. the photoelectric cell, the oscilloscope. electronic amplifiers: the principle of feedback for automatic control and techniques for utilizing both audio and radio frequencies in many ways. The term electronics came into use in the mid-1920s to designate all of the theoretical and applied work involving the movement of electrons in a vacuum. About 1928 electronics began to be used as a collective term for all the applications of the electron tube and its associated circuitry to purposes not directly associated with radio emissions.

2. Marine Radiotelephony.— The earliest demonstration of two-way marine telephony was aboard the U.S.S. "New Hampshire" in 1915. In World War I the long-wave radiotelephone was used to communicate with submarine chasers and other small vessels and aircraft. Ship-to-shore radiotelephony was tested in 1920 on low-power long waves, and commercial radiotelephone service between land and steamships began in 1929 with the installation of radiotelephone equipment on the "Leviathan" By 1933 long-distance, short-wave, ship-to-shore radiotelephony was commonplace on the North Atlantic. Extensive use was made after 1934 of short-wave radio in commercial telephone service to small craft in coastal waters, as well as to private aircraft.

3. Commercial Radiotelephony. — Thefirst commercial long-wave radiotelephone circuit was established in 1920 between Long Beach. Calif.. and Catalina Island. a distance of 30 mi. One-way transatlantic tests on long waves occurred in 1923. and commercial transoceanic radiotelephone communication began in 1926. using long waves; short-wave transoceanic radiotelephony came in 1929. The multiple-unit, steerable receiving antenna was first used in 1934. Independent double-sideband transmission on a common carrier frequency originated on the Ketherlands-Java short-wave circuit in 1937, and by that year the principal countries of the world mere interconnected by 92 groups of radiotelephone circuits, making it possible to talk between any of about 93% of the world's telephones.

4. Aviation Radio. — Radio serves aircraft not only as a means of communication but as a navigational aid. The problems of designing aviation radio equipment are similar to those encountered in marine equipment, but they are aggravated by restricted space for equipment and antennas. as well as by interference from other electrical equipment, by unusual types of static and by a varying power supply. Also, in order to maintain continuous communication and navigation facilities, it is necessary to work several channels independently and simultaneously, and two or more transmitters and receivers therefore are required.

In the United States) the first navigational aids to aviation appeared in 1920, when the post office department established ground stations for the airmail service. By 1930 a radio-range beacon system had been developed for universal application to airways, and in 1931 a radio beacon system had been devised for the "blind" landing of aircraft, although it was not officially adopted until later. In Europe and the United States very short waves (above 30 mc.) were being used in instrument-landing systems in 1935. A rotating radio compass, making possible automatic direction-finding for airplanes, was developed in 1936. It worked as a homing device in connection with radio beacons. Radio altimeters, working on the principles of the marine depth-finder, became available in 1938. The first U.S. blind-landing system. in which a definite radio slope of descent could be followed by a pilot. was installed at Indianapolis, Ind., in 1940. (See Aircraft Instruments.)

5. Mobile Radio. — The Detroit, Mich., police department in 1928 became the first to dispatch police squads by radio, and by 1935 about 400 cities in the U.S. had police radio service, some in the 30- to 40-mc. bands. Widespread two-way operation from police cars and private vehicles came with the opening of the ultra-high-frequency (UHF) spectrum after World War II.

Broadcast receivers for automobiles were introduced in 1932, and within a year they were in wide use.

6. Advances in Techniques. — The principles of negative feed-back. set forth by Stuart Ballantine in 1923. were spectacularly applied by H. S. Black in 1934 to produce wide-band, noise-free amplifiers having marked stability of operation. These amplifiers also were capable of a high degree of linearity (the ability to produce an amplified output signal with a wave form as similar as possible to that of the input signal over a wide range of frequencies); thus they could reproduce a much wider range of modulations without distortion.

In 1930 a widely published graph of the radio spectrum showed all waves shorter than 10 m. (30 mc.) as "not now useful." Yet there was general agreement that radio would have to expand into the higher frequency bands. Marconi's 1896 patent had contemplated using waves having a minimum length of about 25 cm. (10 in): *i.e.*, a maximum frequency of about 1.200 mc. When tubes capable of generating such ultra-high frequencies did become available. no time was lost. Report was made of experiments with 3-m. VHF waves in 1930. and in the period 1930–35 there were many more reports, covering UHF as well as VHF The first important microwave telephone circuit was established across the English channel (Dover-Calais) in 1931. using an 18-cm. wave (UHF) The first multichannel telephone microwave circuit joined Belfast, Ire, with Stranraer. Scot. in 1937, on 3 to 6 m. (VHF) Transmission of super-high-frequency (SHF) electromagnetic waves in hollow wave guides was reported by W. L. Barrow in 1936 and by G. C. Southaorth in 1937.

VI. PULSE TECHNIQUES AND TELEVISION

During World War II radio development was cloaked in military secrecy. but the easing of restrictions in 1946 disclosed as many accomplishments as in any previous decade. The most important advance had been radar, not alone because of its military successes but because radar theory and the electronic apparatus and techniques that arose from it were basic to the further utilization of the highest-frequency reaches of the radio spectrum. Out of military research, too. came such new concepts as printed circuits. modular construction and miniaturization. The end of the war also permitted resumption of work on television. which rapidly began to overtake radio as the most important entertainment medium in many countries.

1. Modulation. — The continuous wave of power (the carrier) delivered into an antenna by an oscillating electron tube may be varied or modulated, in its strength or amplitude, by voice signals from a microphone. The process is called amplitude modulation (AM). As an extreme example, amplitude may be varied suddenly between zero and full strength by working a telegraph key. thus either interrupting a steady musical tone that modulates the carrier or interrupting the carrier itself; wireless began by using such coded interruptions of a train of sparks. The process of amplitude modulation, as used in standard radio broadcasting. consists in varying the amplitude of the carrier wave at a rate identical to the frequency of the sound to be transmitted; *e.g.,* if a tone with a frequency of 1.000 c.p.s. is to be broadcast, the strength of the transmitter carrier is varied 1,000 times per second. Frequency modulation, as its name suggests, consists in varying the frequency of the transmitter carrier wave (while its strength remains constant) at a rate identical to the frequency of the sound to be transmitted. The outstanding advantage of FM is its freedom from interference by atmospheric and man-made electrical noises. These unwanted noises are of an amplitude-modulated nature and hence are not detected by circuits in FM receivers.

It also is possible to transmit signals by other types of modulation, some of which are important to radiotelephony. radiotelegraphy, picture transmission, television and radar. In FM telegraphy, for example. two tones. differing in pitch, convey the dots and dashes of the code signals; this was done with Poulsen arcs in the period 1912–22. Alternatively. the carrier itself may be varied in frequency by changing certain circuit constants; this is called frequency-shift keying and was developed during World War II. FM was applied generally to telegraph carrier transmission over wires in the U.S. during and after 1937 In 1945 it was applied to microwave radio for public telegraph service. Frequency modulation also is used to transmit the sound for television.

Pulse *Modulation.*—An electron tube can be overloaded drastically but safely if the overloads are of extremely short duration and are interspersed with relatively long periods of inactivity. One electron tube especially designed for this type of service is the magnetron, a two-plate version of which was described by A. W. Hull in 1921. A water-cooled magnetron was available in 1930 having an output of 5 kw. at 20 mc. and 1 kw. at 85 mc. (in the HF and VHF frequency ranges). However, successful ultra-high-frequency radar had to await development of the British 10-kw multicavity magnetron tube (1940), public announcement of which was withheld. for security reasons, until 1946.

The signals sent by radar and other pulse methods may be likened to a line of poles along a roadway. So long as the poles are equally spaced and of equal height they convey no information. It is possible, however. to convey information in any of three ways: (1) by varying the height of the poles (pulse-amplitude modulation — PAM); (2) by moving individual poles a short distance one way or the other from their normal, equally spaced

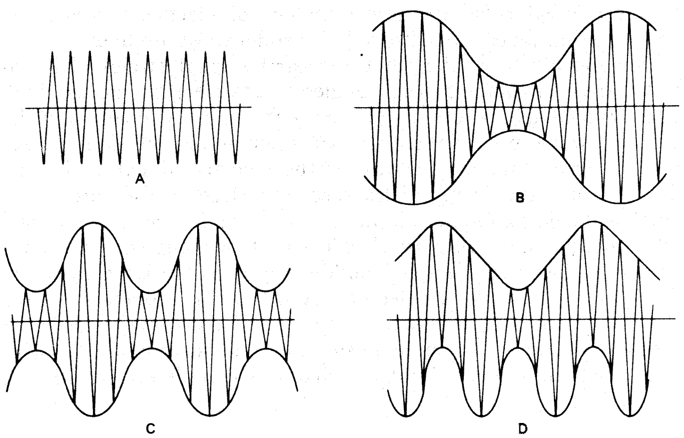


FIG. 5 — PRINCIPLES OF SINGLE-SIDEBAND OPERATION (A) WAVE FORM OF UNMODULATED CARRIER. (B) CARRIER MODULATED NORMALLY WITH UPPER AND LOWER SIDEBANDS. ONE REDUNDANT. (C) DIFFERENT SIGNAL DOUBLE SIDEBANDS AS IN (B); (D) SIGNALS OF (B) AND (C) IN SINGLE SIDEBANDS. REDUNDANCIES SUPPRESSED. WITH NO INCREASE IN NORMAL TOTAL BANDWIDTH.

positions (called both pulse-position and pulse-time modulation — PPM or PTM—developed in 1944); or (3) having grouped the poles into sets of five, for example, by omitting certain poles in accordance with a prearranged code (pulse-code modulation — PCM—developed in 1947). Pulse-modulation methods were adapted to multichannel telegraphy and eight-channel telephony. and pulsing was found particularly adaptable to microwave relay transmission in the super-high frequencies. Because of steepness of the wave fronts of the pulses and because the signals could be completely regenerated (*i.e.,* rejuvenated) at each repeater point. they were singularly free of noise, approaching the reliability and continuity of a wire line.

Single-Sideband Techniques.—Single-sideband (SSB) operation had been applied to long waves in 1927–37, but its potentialities for full utilization of the radio spectrum did not begin to be realized until the late 1940s. Before the advent of SSB, it was necessary to transmit both the upper and lower sidebands of speech. each of which is the mirror image of the other (fig. 5[B]); one sideband is the sum of, the other is the difference between. the carrier radio-frequency and the voice-modulation band of frequencies. In single-sideband operation. one sideband (*e.g.,* the lower) is suppressed, leaving only the upper, with its carrier. A second voice modulation (fig. 5 [C]), consisting of a lower sideband whose upper sideband image has been suppressed, can "ride" the same carrier (fig. 5[D]), and the carrier is thus doing double duty. However, the two voice sidebands are not limited to a single conversation; each can carry a number of them. closely packed into the spectrum like teeth in a comb. In addition. any of the voice channels may be further broken down into radiotelegraph channels. like teeth in a finer comb.

2. Television. — Television is an outgrowth of the techniques developed in (1) the transmission by wire of graphic material; (2) the utilization of the cathode-ray tube; (3) the perfection of the motion picture with its synchronized sound track; and (4) radio broadcasting. The period of early television development from 1924 to 1939 was interrupted by World War II, and when work in the U.S. was resumed in 1946. transmission was in the VHF band that had been opened during the. war. Coaxial cables were first used for intercity network television in 1946. and microwave radio transmission. using relay towers. began in 1947. The first coast-to-coast television broadcast over a nationwide system of microwave radio relay took place in 1951. Attempts were made. with better technical than commercial success; to introduce television into the UHF band in 1950. *See* TELEVISION: History of *Television.*

VII. MICROWAVES AND REMOTE CONTROL

The introduction of microwave radio relay systems after 1950, to replace wires and cable for general intercity communications throughout the world. ranked with any of the previous important developments in radio technology. Dissimilarities in the troposphere and ionosphere, and even meteor trails. came to be used in the propagation of high-power radio waves. Discoveries in solid-state physics brought a number of important developments in ceramics, phosphors and crystals, one of which — the transistor— replaced the electron tube in many of its applications and supplemented it in others. Radio communication took new forms, especially in aviation. Nonlanguage data transmission became important in the control of machines, missiles and space vehicles.

1. Microwaves. — By 1928, short-wave radiotelephony circuits among the principal nations had been completed, and microwave transmissions began in Europe in the 1930s. During World War II, microwave installations in the UHF band were used by military signal units in Europe, and in the United States the first practical SHF microwave radio system for transmitting commercial telegrams was placed in operation in 1945. In 1946 'the first radio relay system for long-distance telephone service was reported. Microwave radio techniques were applied in 1950 in France and Germany to public telephone service and in the U.S. to pipeline and railway communication and dispatching. Wave-guide techniques already had been used for antenna feeders and other SHF purposes. Coaxial cables had been tested comparatively with microwave radio relay systems in the U.S. for intercity telephone and television transmission; the microwave systems proved more economical and reliable. and by 1951 the Bell Telephone systems had begun a general adoption of microwave radio. By the end of the next decade. about one-third of the intercity telephone circuits and most television network programs were carried by radio relay links. The transmitter and relay towers were usually located on mountain tops or on tall city buildings and spaced about 30 to 40 mi. apart for line-of-sight transmission.

Antennas und dl-rays. — Antennas for microwave service include parabolic reflectors, electron lenses and horns. The size of an efficient antenna depends upon the wave length it is designed to transmit or receive; thus. as higher frequencies came into use, the size of antennas decreased. A familiar contrast is the 500-ft. broadcasting tower and the SHF "whip" antenna for police patrol cars.

Arrays of antennas may be so arranged and fed by transmission lines that they produce strongly directional signal patterns. In the 1960s there was increased use of pedestal-mounted, servo-operated. steerable paraboloid (dish) antennas. Another type was a stationary array of phased elements disposed in the form of crossed combs. The length, spacing and configuration of the "teeth" determined the pattern of the transmitted beam.

Ionospheric and Tropospheric Scatter Propagation. — Thomas L. Eckersiey reported in 1932 that cloudlike ionization concentrations in the Kennelly-Heaviside layers might be used to propagate VHF signals beyond horizon distances. D. K. Bailey. of the U.S. national bureau of standards, and several associates reported in 1952 that such propagation was observable over long distances. By 1955 Bailey and his associates reported transmissions of VHF signals through the ionosphere, using radar super-power pulsing techniques.

Henry G. Booker and others developed the hypothesis in 1950 that heterogeneity of turbulent volumes of the troposphere also propagates VHF radio waves beyond the horizon. Thus. it became possible to employ scatter techniques in inaccessible terrain, on sea routes and in the arctic where other radio systems meet unstable refraction conditions. By 1958 a dependable range of 650 mi. had been achieved by tropospheric scatter. using a power of 50 kw. in the CHF spectrum arid single sidebands carrying a 24-channel telephone-teleprinter traffic load. Commercial scatter systems ior combined telephony and television were inaugurated in 1957.

Meteor-Burst Communication.—Unseen meteors and meteoric dust particles bombard the earth's atmosphere day and night, often in quantities sufficient to support a type of sporadic radio communication that takes advantage of the propagation scattering effect of a trail of free electrons left in the upper atmosphere by each meteor. Since meteor bursts last only a matter of seconds. messages must be prepared in advance and high-speed data handling systems must be provided. The reflection paths of contact are automatically established by the occurrence of a meteor burst. resulting first in an instantaneous exchange of "trigger" signals between the two stations involved, followed by transmission of the message. When the signal strength falls below a predetermined level. communication is positively terminated so that no message material is lost, and transmission is resumed automatically upon the occurrence of a subsequent burst. Measurements of radar-type signals reflected by meteoric ionization were reported as early as 1948. The technique of applying such reflections to point-to-point radio was considered in Canada, Australia and the United States in 1952 in connection with other types of forward-scatter transmission, and two-way communication of this kind was first achieved in Canada in 1953.

2. Extremely High Frequencies **(EHF).**—Millimetre and submillimetre waves (4 mm. and less) were undergoing experimentation in the late 1950s. with prospects of great advantages for long-distance communication through multimode wave guides. Dielectric wave guides. containing no metal, were investigated in Germany before 1920. and in Great Britain, the Cnited States and Italy between 1936 and 1948.

At extremely high frequencies the thermal noise inherent in a vacuum tube severely limits the amplification of a very weak signal. The search for a solution to this problem led to a solid-state device called the parametric microwave amplifier in 1957. It consisted of a germanium diode detector, "pumped" at a lower frequency by a miniature pencil-type electron tube. to amplify the signal. Another type of EHF amplification was accomplished in 1957 by the maser (*q.v.*)—an ammonia- or helium-filled oscillator operating at temperatures close to absolute zero. The maser uses a cavity resonator tuned to the molecular resonance frequency of the gas.

John Bardeen and W. H. Brattain introduced another kind of semiconductor in 1948 that became kno n as the transistor (*q.v.*). They discovered that a metal point resting on a germanium crystal, when emitting a forward current into the crystal. would influence the reverse current in a nearby metal collector point. W. B. Shockley. an associate of Bardeen and Brattain, developed the theory and distinguished the different types of transistor junctions. The 1956 Nobel prize in physics was awarded to Bardeen, Brattain and Shockley for their work in this field.

3. Radiotelemetry for Missiles and Satellites.— The age of rockets and missiles brought with it the need for providing great amounts of information from test flights, so that performance could be evaluated. The process of encoding instrument readings. transmitting them on multichannel radio circuits and recording the data at ground stations developed into a special engineering field called telemetry. Later, with the advent of artificial satellites, and especially in the case of manned space flights, radio played an indispensable role in controlling orbital paths and relaying back to ground stations data that were obtained outside the Earth's atmosphere.

The transparency of the atmosphere to the passage of UHF and SHF radio waves was verified by reception of radar echoes from the Moon, first accomplished in 1946. By 1958 UHF voice transmission by lunar reflection had been proved feasible. opening the way to communication between any two points on Earth that were simultaneously within sight of the Moon. Extending this idea, successful experiments were conducted in communication by means of signals reflected from artificial satellites as well as signals received and retransmitted by satellites. Plans were under way in the U.S. in the early 1960s for a system of international communication utilizing a number of relay satellites in orbit about the Earth.

See also SPACE EXPLORATION.

VIII. FACTORS AFFECTING RADIO PERFORMANCE

1. Mechanism of Propagation.— When a charge of electrons is guided along a wire in response to the application of an electromotive force to one of its ends, a concentric electromagnetic field (which takes a form roughly analogous to parallels of latitude about the earth's axis) is formed about it. in a direction determined by the familiar righthand screw analogy of electric current. At the same time an electrostatic field is produced whose lines of force (again roughly by analogy like the earth's great circles of longitude) are everywhere at right angles to the electromagnetic field. This twofold field is formed outwardly to great distances from the wire, the wave front of the disturbance, involving collision of electrons in space, moving forward at the velocity of light. In this field is stored the energy of the electric charge on the wire. The combined field should not be thought of as having been established in a static manner. Because the electron flow along the wire takes the form of a wave, there is a building up of potential, a transformation of energy and a reflection from the wire's open end after the manner of a sound wave in an open organ pipe; possibly a second reflection from the opposite end, and so on until the wire is charged and the energy of the charge is completely stored in a steady field.

At this stage. removal of the electromotive force from the end of the wire causes collapse of the field and return of the energy to the wire. In an electromagnet the wire is wound in a coil about an iron core for the purpose of confining the field to a small area. The collapse of the field when the circuit is broken and the oscillating nature of the return of energy to it are made evident by the spark which occurs at the open contacts. In this case the inductive component of the collapsing field is high, the radiation component low. In the antithetical case of a straight antenna wire, the induction field is low and the radiation field is purposely made high. Radiation is promoted — indeed it is made possible — by applying to the antenna continuously reversing polarities of electromotive force, created by an alternator or more often by vacuum tubes or valves oscillating in tuned inductance-capacitance circuits in the transmitter. at radio frequencies (10,000 c.p.s. or more). The rapidity of reversals results in the forming of successive oppositely poled fields before the initial ones have had time to restore. to the antenna to which they were bound, the energy due to the initial fields! collapse. Thus the initial fields are detached and set free to continue onward and outward at the velocity of light in air. At frequencies lower than those used in radio, such detachments of energy are entirely insignificant. Even at radio frequencies there is little radiation from a transmission line electrically balanced with respect to the earth, consisting of a pair of parallel wires. closely spaced, fed simultaneously with opposite polarities; such low-loss transmission lines are often used to conduct power from transmitters to certain types of antenna proper. Radiation does occur when the parallel wires are moved apart or to an angle with each other; maximum radiation occurs under conditions of maximum unbalance, which is the general condition of an aerial or antenna wire in vertical relationship to the horizontal plane of the earth's surface. Another condition of unbalance is represented by the doublet, or dipole, consisting of a straight wire or rod fed from a discontinuity at its middle. In both these cases. controlled unbalance may be said to have produced effective coupling of guided power in the transmitter and antenna to the medium of propagation — that is, the transformation to radiated power is efficient. Receiving antennas and receivers are also effectively coupled to the medium of propagation by the same considerations of design. In fact, except for complications of economics, site limitations, the direction of arrival and polarization of the wave front and the necessity to discriminate between the wanted signal and interfering signals, sending and receiving antennas are alike in form and purpose and by the theorem of reciprocity are interchangeable.

The respective functions of transmitters and receivers is to emit and extract power to and from the medium of propagation. At the point of reception. the transverse wave associated with each ray of propagation may be represented by electrostatic and electromagnetic vectors lying at right angles in a plane normal to the ray. the electrostatic field being measurable in terms of potential gradient (microvolts) per unit of wave-front length (the metre), as applied against the effective height of the receiving antenna. In free space. away from complications resulting from proximity to the earth and from the constitution of the earth's atmosphere. the receiving field intensity can be calculated in terms of the current in the transmitting antenna. the frequency or wave length of the electromagnetic disturbance and the distance between transmitter and receiver. In the case of low frequencies at all distances, mathematical calculations can give useful figures of field intensity as foundation for further consideration of the variables of the transmitting medium.

Sky *Waves.*—Much effort has been expended by researchers in theoretically establishing, examining and measuring the now well-understood complexities of the propagating medium. The original Kennelly-Heaviside concept of stratified ionization of the upper atmosphere has been expanded to account for the observed and measured behaviour of radio sky waves. When solar radiation impinges upon the atmosphere from above, it is absorbed unequally at various levels. giving rise to the formation of layers with differing refractive (hence reflecting) properties. In the process of absorbing solar radiation, electrons are detached from gas molecules. The density of the electrons during the daytime and the rate of their recornbination with the ionized particles at night determine the changing usefulness of the layers to return radio waves to the earth. Several successive layers are postulated, each characterized by partial inversion of the vertical gradient of ionization density. with the highest value in the mid-position of each layer. The layers have been given designations and their approximate virtual daytime elevations above the earth's surface have been determined as follows: D. 50–90 km. (30–55 mi.); E. 110 km. (70 mi.); F_1, 175–200 km. (110–125 mi.); F_2, 250–400 km. (155–250 mi.). Ionization density is greatest in the outer F_2 and least in the inner D layer. At night the D layer disappears and F_1 loses its identity by combining with F_2 at 300 km. (185 mi.). Sunset and sunrise produce diurnally unstable conditions, as the layers rise and fall. Ionization and height vary also with the seasons and with latitude, in accordance with the altitude of the sun and duration of the hours of daylight. While all layers absorb some energy of the wave front by electron collision in the process of refraction. the air density in the D layer produces absorption with little refraction. In the other layers, propagation is best at night, and attenuation of high-frequency signals by absorption in the daytime increases sharply as the frequency used is lowered.

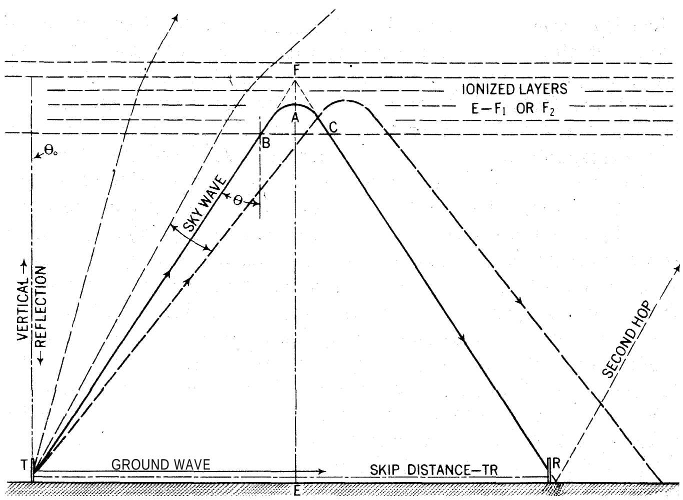


FIG. 6.— RADIO WAVES, SKY PROPAGATION (*see* TEXT)

Double Refraction.—Because of magnetoionic interaction between the earth's magnetic field and the free electrons whose progressively increasing drnsity refracts radio waves, the latter undergo double refraction and are split into two elliptically polarized components. The refraction indices and the absorption of the medium are both different for the two, so that a somewhat unstable, emergent resultant wave exhibits elliptical polarization. This has negligible effect upon the handling of message traffic, but does adversely affect the degree to which direction finders yield correct bearings for navigational purposes.

Critical *Frequencies.*—Important to the course which radio waves take through the refractive layers is the discrimination offered to their transit by virtue of their frequency. As frequencies are increased. experimental waves directed straight up toward the zenith have been found to require ever higher electron densities if they are to be reflected downward. There is a critical frequency, f_c, higher than which the waves will pass on through the layer and not be returned. This property of frequency discriminatiop is still effective when the angle of incidence, θ_0, is changed from the experimental 0° at vertical incidence to its practical value. θ, shown in fig. 6. Here the wave passes from point of transmission T to point of reception R through refraction along the arc BAC within a layer having an effective height of FE. The highest frequency which will travel the course TBACR has been called M.U.F., the maximum usable frequency for distance TR. height FE and the electron density in the layer. The M.C.F. bears to f_c the relationship: M.C.F. $= f_c$ *secant* θ. Government laboratories make available to radio station technicians graphs and nomograms predicting what M.U.F. will be under given circumstances, taking into account f_c, the time of day at longitude of FE. the latitude of FE, the season of pear! conditions related to the 11-year cycle of sun-spot maximum, the electron density and distances approximating TR and height FE. Transmitting station T will use if available an optimum working frequency of about 85% only of the M.U.F. to afford leeway for approximations used in the predictions and for propagation abnormalities. It is evident that if the frequency used exceeds M.U.F., the signal will follow the straight line TBF and be lost to R, instead of taking the trajectory TBACR. On the other hand, if the working frequency is reduced too much, the layer will absorb too much of its energy: signal strength at R will be too low, or an uneconomical power level will be required at T. The lowest useful high frequency, called L.U.H.F., is roughly half the M.U.F.; its calculation is complicated by variables connected with receiving conditions.

Modes of Transmission.—Fig. 6 depicts what is known as "one-hop" transmission from T to R. If R were twice as far removed from T. the same frequency could be used in two-hop propagation. As a matter of practice, two-hop and three-hop propagations are common and offer no difficulties compared with single hops so long as conditions in the reflecting layer are uniform. Along great circles of the earth, like meridians, which do not cut through the ionospheric transitional effects of sunrise and sunset, multihop transmissions girdle the globe, not only once but several times. and have required that special precautions be taken to prevent unwanted "echo" signals.

Skip Distance.—Assume that in fig. 6 the transmitter is emitting the M.U.F. but that the wave, as is ordinarily the case, is not the single ray TB but a rather wide solid cone of rays with apex at T, fanning out a few degrees with TB as an axis. Confining attention to the plane of the paper, all the rays in the cone to the right of TB will be reflected and fall at points to the right of R. All the raps to the left of TB (by definition of M.C.F.) will pass through the layer unreflected. No signals will reach the ground between T and R from the sky. TR is the skip distance. If the antenna at T is omnidirectional. TR defines the radius of a ground circle about T lying within the skip distance associated with the M.U.F. used.

2. Propagation Variables.—In relation to its medium of propagation. telecommunication has to concern itself not only with the fairly stable complexities which have been described but also with instabilities. For at times the refracting ceilings which the layers present to radio waves from below are almost mirrorlike and still, at other times they undulate. giving rise to shifting transmission paths that change phase interference relationships and polarization of wave fronts at points of reception. Again, especially in the auroral regions, extending 23° in radius about the earth's geomagnetic poles, and particularly around times of the equinox, ionization. also giving rise to aurora polaris, causes severe turbulences and abnormal absorption in the ionosphere. The earth's magnetic field converges on the arctic regions, leading charged particles from the sun to bombard them. The F_2 layer. especially, is adversely influenced during periods of abnormal earth currents. A statistical correlation has been observed between high sunspot numbers. the location of spots on the sun's limbs) the period of rotation of the sun on its axis and poor sky-wave propagation due to effects of extraordinary ultraviolet radiation into the upper atmosphere. A more recent theory identifies sunspots, earth currents, aurora and ionospheric turbulence as concurrent effects that find a common cause in critical juxtapositions of planets in the solar system. Sudden solar flares or eruptions, accompanied by direct ultraviolet radiation which reaches down into the low D layer on the light side of the earth. results in abnormally high absorption in that layer, whose normal characteristic is to absorb. rather than to refract, wave-front energy. The result is radio blackout. lasting minutes to hours. to which the names Dellinger effect and SID (sudden ionospheric disturbance) have been applied. Radio communication using sky-wave propagation is stopped for the duration of SID because of the inability of radio waves to reach the E and F layers.

Sunspots rotate with the surface of the sun and thus exhibit a periodicity of 27 days in repeating their influence upon radio transmission. The number of sunspots varies over an uneven 11-year period.

Sporadic Transmission.—Not all the variables of the atmosphere are adverse to the propagation of radio waves. Some of them make possible transmissions which otherwise would not occur. One has been given the name Sporadic E. to designate what behaves like a cloud stratum of ionization. E_s, with a "blobby" subsurface from which propagation is neither by refraction or reflection but is the summation of contributions of scattering. by secondary emission. from a multiplicity of sources closely spaced. Because integrated. such sources may give reliable transmission of very high frequencies below 150 mc. if the beam is aimed nearly tangential to the earth's surface. These transmissions are at frequencies exceeding the M.U.F. of the E layer. They are at a maximum in summer and in zones of visible aurora. Unlike refraction. the mechanism of scattering transmits in all directions from the ionized layer. This may cause direction-finder inaccuracies if, unknown to the manipulator taking a bearing, he happens to be standing within the skip zone of the transmitter. In that event he will be receiving the transmitter's signal not upon the observed bearing of a primary source but upon that of a secondary. scattering source located at some point in the E_s zone having no valid geographical relationship to the point of primary signal emission. The error may amount to 180°.

In the heterogeneous troposphere there exist, as a result of air turbulence, eddies demonstrating deviations from mean dielectric constants (and hence refractive indices) with which they are surrounded. These discontinuities produce scattering effects that at times cause abnormally strong signals. at others abnormally strong interference. In the troposphere. also, where the very high frequencies are transmitted. the air may stratify as to its quasi-optical refractive index, under meteorological influences; in such a way that radio waves are either led along a plane of maximum index between layers of lower index, or are confined between a layer and the earth. In either event, being trapped as though in a duct or wave guide leading over the horizon to distances beyond line of sight. attainable distances of communication are increased. Some observed instances have proved amenable to wave-guide analysis.

Diffraction.—Somewhat akin to scattering is diffraction. the bending of super-high-frequency waves around an obstacle. building or the protuberance of the horizon, thus increasing the service range of a transmitter. The intersection of the beam with the horizon defines a point above which the atmosphere may be thought of as a radiator of secondary emissions. In microwave beam practice. passive reflectors are sometimes employed to make definitive the jumping of an obstruction in lieu of diffraction.

3. Interference.— Proper reception of radio signals depends upon ability to receive wanted signals that are stronger than unwanted signals and accompanying noise. Another station using the same frequency in a different part of the world is an example of an unwanted signal. Another instance is a station whose frequency has been assigned so closely to that of the wanted signal that the harmonic content of the unwanted signal overrides or beats with the wanted wave. If the interference is caused by the interfering station's exceeding its authorized tolerance for frequency drift, the remedy lies in having the offending station put back on its assignment. Assuming the interfering station to be on its proper frequency, unless the situation can be cured by use of directive receiving antennas, relief must be sought from the authorities who made the assignments. Regulatory authorities have adopted and enforce standards of frequency departure tolerances! maximum harmonic content of emitted waves and authorized maximum power to be employed. in order to keep interfering signals within practical control. Based upon these factors, with additional allowances for filter inefficiencies and frequency drift inherent in receivers. the width of bands for all types of emission and modulation rates have been specified on a world-wide pattern.

Among the types of interference sometimes encountered for which there is no ready remedy at the receiver is cross modulation. When a powerful transmitter's wave strikes the ionosphere, the free electrons. which determine the dielectric constant and therefore the effect of refraction, are agitated to collide with ionized molecules at rates varying from high to low in accord with the wave's modulation. The wave front from another transmitter, striking the agitated layer at that point and at that time with a modulation pattern of its own. will be subjected to cross modulation from the more powerful wave.

4. Signal-to-Noise Relationships.— If a received signal is clear of interference from unwanted signals, its field strength can be amplified to any degree permitted by the thermal noise and vacuum tube shot effects in the initial stage of the receiver. These place a final limitation upon amplification, but serve to limit it only in the very high-frequency and super-high-frequency bands where other forms of interference are absent. All efforts at the receiver are therefore bent upon improving signal-to-noise-level ratio. S/N. The three avenues of approach are to improve S, to mitigate N or to introduce some distinguishing characteristic into S at the transmitter (frequency or phase modulation. for example) so that the receiver will be more responsive to S than to N.

Improvement of the signal may be achieved by increasing power at the transmitter. by choosing a type of modulation such as pulse-position modulation in which bursts of high power are obtainable without overloading vacuum tubes, by adopting directive antenna arrays or by frequency-diversity transmission. At the receiver many manipulations are possible, including choice of suitable space-diversity antennas. crystal-driven stabilizers and filters designed to accept all possible power of the carrier and its necessary side-bands and harmonics and to reject all other signals.

Antenna *Gain.*—Modern antennas for nonmobile use are designed to favour concentration in azimuth. or direction toward the correspondent station. of as much as possible of the transmitter's power. They are of two general classes: antenna arrays and wave antennas. Arrays take advantage of interference between two, three or more like antenna structures so placed with respect to wave length and the line of desired propagation that their power adds in the forward direction and cancels toward hack and sides. In a receiving array this results in desirable discrimination between a wanted signal and an interfering disturbance or signal arriving from a different direction. The power advantage which an array or other form of directive antenna achieves is called the antenna's gain. It is greatest for multielement VHF arrays and SHF reflectors and lenses. A wave antenna is generally less effective in concentrating its beam than an array, but in the larger forms associated with the lower frequencies it has economic advantages and will effectively handle a 2:1 ratio of frequencies. Some large wave antennas are steerable in range. Such a steerable antenna is in the shape of a rhombus or diamond floating on pulleys attached to four poles and so arranged that if the short diagonal is purposely altered in length by force applied through the pulleys, a counterweight pill correspondingly adjust the length of the long diagonal. keeping the antenna taut. The antenna wires at one end of the long diagonal are connected to the station feeder; wires at the opposite end terminate in resistors. When the long diagonal is altered. the angle which the sky wave, emitted from it, makes with the earth plane is modified. By manipulation of antenna configuration, therefore, the vertical angle of the wave's departure can be aimed at the point of reflection in the ionosphere. If the long diagonal was put in proper azimuth when the supporting poles were set. the beam will fall directly upon the point of reception. There an array of similar rhombic antennas a mile long may be lined up along the path of propagation for phasing and integration of their outputs. some having been steered low on the horizon to receive the one-hop mode of propagation and others steered higher to respond to other modes.

Fading.—Of the variables in propagation encountered in maintaining received signal strength at a high level, fading is the most widespread and serious. The term fading is broad enough to comprehend temporary loss of field strength at a receiver for any cause associated with the medium of transmission. Already discussed have been the common causes of fading experienced by waves taking any one path between transmitter and receiver. There remain to be considered the complications arising when a wave front takes more than one path at a time. By the same principles of wave interference met with in the study of optics and sound, if the wave front be reflected at two or more points and the reflected rays arrive at the receiving antenna in phase, their effects will add and the signal will be strengthened; if the rays arrive 180° out of phase, their effects will cancel and the signal will disappear; if the out-of-phase condition takes an intermediate value. there will be a corresponding change of signal strength. This phenomenon is evident whenever the ground wave interferes with a sky wave; when two sky waves take modes of propagation involving a different number of hops; or when one of the modes is along a layer. or between two layers; when, in communication between two airplanes in flight or between two beam radio towers. a direct wave beats w th another reflected from the ground or from air-layer interfaces caused by temperature-density inversion; or when the arrival waves have taken different routes in the horizontal plane; or one in the horizontal. the other in the vertical; or when polarization rotation occurs in a different manner or to different degree over two routes, or is caused by double refraction. Fading of all these types is called multipath interference. It is rare at very low frequencies. At other parts of the spectrum the fading occurs in cycles whose rapidity increases from around 60 times an hour at 1.000 kc, up to millions of times a second in the SHF and EHF bands. This rapid increase in the fading rate as transmitted frequencies are raised explains the occurrence of selective fading within sidebands so wide that the effects at the top of the sideband do not coincide with those at the bottom. The discovery that fading of a received signal does not occur simultaneously at two points that are three to ten wave lengths apart led to the invention of space-diversity systems of reception. The outputs of separated antenna-receiver systems, equipped with independent automatic volume controls and tuned to the incoming wave, are fed into a common mixing and limiting system that delivers a substantially constant signal to the terminal apparatus, even during periods when the fading is severe.

5. Radio Noise.—Industrial *Noise.*—Upon the assumption that in achieving the best possible signal-to-noise (S/N) ratio everything has been done to favour S, the qualities of N remain to be examined. Noise may be divided into two categories, man-made and natural. Man-made or industrial noise is greatest in the cities, least in rural or isolated localities. The latter are therefore preferred for receiving sites. The chief cause of man-made noise is electrical circuit transients which cause radiation from portions of circuits where sparks occur. Switches, motors, ignition systems are offenders; so are X-ray apparatus, diathermy machines and industrial precipitators, high-frequency heating and other equipment employing radio frequencies. Mitigation at the receiver is difficult. The use of directive antennas, wave traps and narrow-band receiver filters is sometimes effective. Usually the correction of industrial noise conditions is sought at their sources, by shielding or isolating radio-frequency circuits.

Atmospherics.—Noise from natural sources, entering the receiver by way of the antenna and affecting the receiver output in the same way as amplitude-modulated signals, takes two forms: atmospheric and extraterrestrial. The super-high-frequency band (centimetre waves) is the only one free from both forms of extraneous noise; so that in that band, receiver thermal (or resistance) noise alone limits the amplification level. Atmospheric noise, or static, is the characteristic natural interference which has to be dealt with in radio. At point of reception it represents the integration of the field strengths there apparent from nearby and distant thunderstorms going on within signaling distances, transmitted by means of ground wave and sky waves of all modes in accordance with the same laws which govern signal propagation. Atmospherics are at a maximum at night on account of sky-wave transmission from great distances. They are stronger in summer than in winter. weaker in high latitudes than in the tropics. Their sources are concentrated somewhat in geographical areas like the eastern Caribbean sea, where median values of field strength are shown by measurement to be high. Directive antennas are frequently oriented to discriminate between direction of arrival of atmospherics and the wanted signal. Since natural atmospherics, like man-made disturbances, contain random frequencies over a wide band, filters are introduced into receivers to reject sharply all noise except the components necessarily admitted with the signal sidebands. Amplitude limiters are also used.

Extraterrestrial *Noise.*—Extraterrestrial noise interferes with radio telecommunication in the very high-frequency band (metric wave lengths) and down to 20 mc. There its strength is. roughly, 20 times the thermal noise in the receiver. It is attributable to influences classified as galactic (stellar or cosmic), solar and meteoric. Galactic noise is at a maximum from the direction of the region of Scorpio and Sagittarius, in the galactic centre of the Milky Way.

Solar noise is of lower field strength than galactic noise at frequencies below 30 mc. but is appreciable at 100 mc. and more. Like cosmic noise it is of random nature, fairly constant in amplitude except at times of abnormal solar disturbances. At such times its strength. at 100 mc.. may exceed galactic noise. Solar noise increases are often concurrent with other effects of solar eruptions already mentioned—the influence of ultraviolet light in increasing D-layer absorption of radio-wave energy, and turbulences in the E and F layers which make them temporarily incapable of refraction and reflection. See RADIO ASTRONOMY.

IX. USE OF THE RADIO-FREQUENCY SPECTRUM

The value of the radio spectrum depends upon the skilful management of this natural resource. Radio waves recognize no political boundaries and therefore hold the threat, unless controlled, of interfering with radio operations in neighbouring and even far distant countries. Governments enforce within their own territories agreements upon such matters as call signs for identification;' allotment of frequencies to specified services; limitations upon the type of emissions (modulations), bandwidths and power which may be employed; and specifications leading to full occupancy of each band.

1. Frequency Sharing.—Congestion makes it necessary to adopt expedients for making maximal use of the various available frequency channels by assigning a single frequency to simultaneous use in different parts of the world, and by requiring stations to share their frequencies with others, to take advantage of differences in time zones or paucity of traffic to be handled. The urge to conserve spectrum space is made evident, in large transoceanic radiotelegraph operations, by the practice of assigning a single transmitter to cover the requirements of more than one circuit, Such forked use of a transmitter will cover from 1.5 to 2.0 channels of communication. On the most important circuits two transmitters are often allotted for dual operation, so that if transmission on one fails, service will not thereby be interrupted. Pairs of frequencies in a station's complement are also involved in dual emission on most circuits during twice-daily periods of transition between optimum uses of either wave.

2. Modulations, Bandwidths and Tolerances.—The bandwidth occupied in the spectrum by any emission depends upon the type of modulation, being narrow for hand-keyed Morse telegraphy, considerably wider for voice broadcasting and very wide for television. Bandwidths are therefore specified in accordance with emission types. A bandwidth may be considered the minimum safe separation between adjacent carriers so modulated. It includes the "guard-band" protection necessary to prevent overlap of its fundamental and harmonics with those of adjacent channels, if frequency deviations are held within specified tolerances. Except for single-sideband (SSB) operation, the band is considered as bisected by the assigned frequency of its carrier.

The types of emissions permitted and bandwidths specified in the international regulations annexed to the Buenos Aires convention of 1952 are shown in Table I.

TABLE I.—Radio Emissions and Their Bandwidths

Low Frequencies.—Groups 1 and 2 in Table III, the VLF and LF or ground-wave ranges; alone are capable of following the curvature of the earth. These ranges! called collectively terrestrial radio, are therefore used for long-distance communications as well as for navigational radio.

In the absence of any available alternative. VLF and LF radiotelegraphy was the favoured method for transoceanic use prior to 1927. After that year it rapidly gave ground to transmission on higher frequencies, but served as stand-by to protect short-wave circuits, especially where routes cut the auroral zones that exist around the earth's geomagnetic poles. Even this utility largely disappeared when: around 1946, electrical relay points located in or near the tropics were found capable of dividing east-west circuits between terminals into two coupled links, the one availing itself of relatively dependable north-south transmission, the other conducting the east-west circuit components through the tropical belt where auroral zones could be by-passed.

The longer VLF and LF waves interested Marconi and other early workers in transoceanic wireless telegraphy because of the results, measured in working mileages, that they yielded. Transmission is dominated by a ground wave propagated to distances up to about 1,000 mi.. plus a relatively stable mode of multiple mirrorlike reflections between the two concentric spheres consisting of the earth's or sea's surface and the troposphere and low ionosphere. These act as an effective and efficient wave guide. The rate of decay of the ground wave depends upon the conductivity and dielectric constant of the ground; except for the very lowest frequencies and extreme distances the decay rate is less over water than over land. The wave-guide effect tends to conserve signal strength over global distances. Except for sunrise and sunset effects, fading of signals is not a factor with long waves. The three chief drawbacks to long-wave operation are: the prevalence of noise and static (lightning disturbances are also propagated to global distances by the wave-guide mode of transmission) ; the requirements of large amounts of power to radiate from an antenna at the very low frequencies and to override the static; and the necessity for building large, high and consequently expensive antenna structures. VLF waves are generally not suitable for telephony because of the low ratio of the modulation to the carrier frequency.

Medium and High Frequencies.—MF transmission, Group 3 of Table III, occupies a mid-position between ground-wave and sky-wave propagation and is best understood by reference to conditions in adjacent bands. The lower part of the band found early use in ship-to-shore wireless telegraphy. Antenna sizes and power requirements are adapted for marine work; distances workable, however, are shorter than for high frequencies. The middle part of Group 3 is reserved for broadcasting. Its characteristics are well known to the public, a ground-wave service area of greater or less extent depending upon power assigned and a night area served by sky-waves subject to fading. Static conditions are moderate. Beaming of antennas and sharing of hours of operation among stations are practices that prevent mutual interference and increase public service.

Group 4, the high frequencies or short waves, are transmitted over global distances by multiple-hop refractions through the ionosphere. The HF band is one of the most crowded portions of the spectrum. It is generally true that ionospheric transmission ceases to be practical beyond 30 mc.

Higher Frequencies.—Groups 5 and 6 of Table III, VHF and UHF, the metre and decimetre waves, were extensively investigated during World War II. VHF transmission is primarily limited to line of sight, but it is stable and suitable for such uses as television broadcasting. With the advent of UHF transmitters of very high power, a new type of UHF transmission called UHF scatter propagation, was discovered. This effect was largely attributed to wave refractions in the troposphere (altitudes below 10 mi.). UHF scatter permitted the reception of weak but stable signals far below the horizon. Television transmission over several hundred miles by means of scatter propagation was accomplished in 1953.

Super-High Frequencies.—Group 7 (centimetre) frequencies are often referred to as microwaves. While Groups 6 to 8 are all quasi-optical, Group 7, SHF, is particularly adaptable to quasi-optical devices such as focusing antennas using parabolic reflectors, dielectric lenses and horns for concentrating and directing narrow beams of communication power. Expansion of use of this band was a spectacular development of the 1950s. Because of their extremely high carrier frequencies, microwaves furnish an ideal medium for such high-speed communication as multiplex telegraphy and telephony and television relays.

Microwave beams at 4,000 mc. ($7\frac{1}{2}$ cm.) have been used in the U.S. transcontinental television network, relaying video signals and hundreds of telephone channels from coast to coast. At an average span of 25–30 mi. between stations, more than 130 repeaters were used in each direction. Most of these relay stations were fully automatic and were installed in unmanned shelters, some accessible only from the air. A telegraph microwave is similar. Working on a frequency of about 4,000 mc., its paraboloid reflectors behind dipole antennas are located at the tops of towers and within line of sight over the horizon. Changes in the atmosphere seldom attenuate the signals beyond the ability of terminal equipment automatically to compensate, and diversity reception makes the outage record all but perfect. The frequency is not high enough (as at 10,000 mc., for example) to be interfered with by effects of scattering from hail. raindrops or snow; nor in the region of 0.5- to 2-cm. wave length where resonance of particles in water vapour. clouds and oxygen gas interferes. Again, 4.000 mc. is not low enough to be affected by atmospheric or industrial noise. The limiting transmission factors are the thermal agitation and vacuum tube shot effects in the first stages of the receiver, made troublesome because they are amplified along with the received signals. Transmitting power tube output is the order of one-tenth watt to ten watts. Double-frequency modulation is employed, the subcarrier being one megacycle. Signaling intelligence occupies the broad band from 30 cycles to 150 kc., accommodating 32 voice-frequency bands each capable of transmitting 16 teleprinter (or 32 multiplex printer) telegrams per minute.

The EHF or millimetre waves were at the forefront of radio research in the 1960s, and EHF held great promise for long-distance communications. Millimetre waves can propagate with low loss per mile through straight, hollow pipelines, if the so-called circular-electric mode is set up in the lines. In this mode, the lines of the electric field close upon themselves without touching the wall of the guide. In this way, wall currents in the guide are avoided and losses actually decrease with increasing frequency.

4. Radio **Spectrum** Management. — International agreements on radio take the form of conventions and annexed regulations. Like other treaties under international law they are, in general, binding only upon the ratifying states. Nations are not bound to attend the conferences. Delegations are not bound to sign. In signing they may take reservations that release them from particular provisions. Sovereign states may refuse to ratify, or in ratifying may also take reservations. Nevertheless, so greatly does national advantage lie in international co-operation in the radio field, and so unlikely is it that any other method will prevent chaotic conditions in the radio spectrum. that refusals to sign or ratify are rare. By ratifying, a state agrees to pass laws to enforce the provisions of the treaty, subject to its reservations.

International Telecommunication Treaties. — The first radiotelegraph conference of an international nature was called by invitation of the German government in Berlin in 1903, seven years after Marconi's successful demonstration of wireless. This preliminary conference produced the initial draft of an international convention, which was considered, revised and signed by delegates of 27 nations, together with its annexed Radio regulations, at the Berlin Radiotelegraph conference of 1906. At that time the Radiotelegraph union was formed, a governing body modeled after the International Telegraph union, which since its formation at Paris in 1865 had been responsible for the Telegraph convention and the International Telegraph regulations. The London conference of 1912 revised the convention and the regulations. The Washington Radio conference of 1927 inaugurated the subsidiary International Radio Consultative committee (C.C.I.R.), to take its place beside the already functioning consultative and exploratory technical committees on telegraph (C.C.I.T.) and telephone (C.C.I.F.); it also initiated an action, supplementing that of the International Telegraph union (Paris, 1925), to amalgamate the Radiotelegraph and Telegraph conventions. This objective was accomplished through creation of the International Telecommunication union at Madrid, Spain, in 1932, which codified and combined the 1875 Telegraph and the 1927 Radiotelegraph conventions. The regulations annexed to the Telecommunication convention were drawn up separately by a telegraph-telephone conference and by a radio conference at Madrid, as they were again at Cairo, Egy., in 1938.

The Madrid convention and the Cairo Radio regulations were revised at Atlantic City in 1947, at Buenos Aires in 1952 and at Paris in 1959; the Cairo Telegraph regulations were revised at Paris in 1949, with the United States a signatory to telegraph regulations for the first time, and again at Paris in 1558.

Agreements on Frequency Spectrum. — The history of the radio and telecommunication conferences after 1927 traces the shifting emphasis from marine radiotelegraphy to the later wide diversity of telecommunication. The complexity of making frequency allocations to users increased exponentially over the years despite the expansion of the usable spectrum into the upper frequencies.

The Washington conference was the first to produce a comprehensive frequency allocation table covering services other than marine. Its work was carried on at the Madrid, Cairo and Atlantic City conventions. As a result of work at Madrid. an official list of frequencies was produced, showing, among other things, the date of notification to the bureau of the ITU at Berne. Switz., of each use of each frequency and the date each service commenced, as a basis of establishing priority rights to such use. At Atlantic City in 1947 the delegates were faced with the de facto aftermath of World War II. during which the use of radio had expanded at an unprecedented rate under circumstances of enforced inactivity of the Berne bureau.

International Organization. — By the early 1960s there were about 100 member states in the International Telecommunication union. Headquarters had been with the Cnited Nations at Geneva, Switz., from 1948, when the former headquarters arrangement at Berne with the government of Switzerland was terminated. The ITU became a specialized agency of the Cnited Nations by resolution of the UN general assembly, Nov. 15, 1947.

The International Scientific Radio union, with headquarters in Brussels, Belg., is a member of the International Council of Scientific Unions (ICSU), a nonpolitical world organization of scientists maintaining relationships with Cnited Nations and its specialized agencies, particularly UNESCO. ICSU embraces several fields of science, including radio.

Donzestic Regulation. — In accordance with the international conventions, every important country enacted domestic legislation to enable the international provisions to be enforced. In Great Britain and Northern Ireland, control was in the hands of the postmaster general. by virtue of the Wireless Telegraphy act of 1904, subsequently renewed each year. The application of the act to shipping is regulated under the Merchant Shipping (Wireless Telegraphy) act. 1919, and the rules made by the board of trade under this act. In Jan. 1947 the British government. in harmony with other nationalization programs. purchased the assets of the British company which from 1929 had represented the merged international telegraph interests of cable and wireless; in the self-governing dominions similar action was taken. The government-owned operating company continued in control of operating the world-wide network until April 1950, when operations and assets in the United Kingdom were transferred to the British post office. In 1952 the post office put its international telecommunications under an external telecommunications executive.

In the United States, commercial radiotelegraph services are operated by private enterprise, regulated by the Federal Communications act of 1934, as amended in 1943. The law is administered by an appointive group of seven members constituting the Federal Communications commission. Among the features regulated by licences or rules of the commission are: assigned frequencies of transmission, tolerances of departure from assigned frequency, types of emission, transmitter power, specifications of performance relating to distortion and interference, hours of operation and qualification of operators and technicians.

See also references under "Radio" in the Index volume.

BIBLIOGRAPHY.—*General:* G. L. Archer, *History of Radio* (1938); W. R. Maclaurin, *Invention and Innovation in the Radio Industry* (1949); H. Pratt, "The First 50 Years of International Radio Communication," *Communication and Electronics*, no. 3, p. 371 (1952); O. E. Dunlap, *Radio's 100 Men of Science* (1944); J. M. Herring and G. C. Gross, *Telecommunications* (1936); G. A. Codding, Jr., *The International Telecommunication Union* (1952); P. Richard, "The Problems of Frequency Assignment in the Fixed Service Bands," *Telecommunication Jour.*, vol. 17, pp. 158–370 (1950); President's Communications Policy Board, *Telecommunications—a Program for Progress* (1951); Joint Technical Advisory Committee, *Radio Spectrum Conservation* (1952); J. Laffay, "The State of International Telegraphy," *Telecommunication Jour.*, vol. 20, p. 72 (1953); J. A. Smale, "Some Developments in Commercial Point-to-Point Radiotelegraphy," *Jour. Inst. El. Eng.*, vol. 94, part iii-A, p. 345 (1947), "Commonwealth Telecommunications," *Proc. Inst. El. Eng.*, vol. 100 (1953); S. Sparks, "International Radiotelegraph Communications," *Am. Inst. El. Eng. Paper 48–131* (1948); J. A. Krcek, "Aspects of Naval Communication Systems," *Trans. Inst. Radio Eng.*, vol. CS–1, p. 54 (1953); J. C. Walter, "A Million-Watt Naval Communication Transmitter," *Communication and Electronics*, no. 8, p. 369 (1953).

Handbooks: A. T. Starr, *Radio and Radar Technique* (1953); K. Henney (ed.), *The Radio Engineering Handbook*, 5th ed. (1959); H. Pender and K. McIlwain (eds.), *Electrical Engineers' Handbook*, 4th ed., vol. 2, *Electric Communication and Electronics* (1950); F. E. Terman, *Radio Engineers' Handbook* (1943); Federal Telephone and Radio Corporation, *Reference Data for Radio Engineers* (1956).

Periodicals: Institute of Radio Engineers, *Proceedings, Transactions, Convention Record;* American Institute of Electrical Engineers, *Transactions, Electrical Engineering, Communications and Electronics;* Institution of Electrical Engineers, *Proceedings; Proceedings of the National Electronics Conference;* International Telecommunication Union, *Telecommunication Journal;* Armed Forces Communications Association, *Signal;* American Radio Relay League, *Q. S. T.; Electronic Engineering; Wireless World; Electronic and Radio Engineer; Electronics; Bell System Technical Journal; Bell Laboratories Record; Electrical Communication; RCA Review; Western Union Technical Review; Post Office Electrical Engineers Journal.* (I. S. C.)

RADIOACTIVITY, ARTIFICIAL. Artificial radioactivity was discovered by Irene and Frédéric Joliot-Curie early in 1934. They made the exciting and important observation that the positrons which were emitted when aluminum was bombarded with alpha-particles (HE'') from polonium continued to be emitted after the source of alpha-particles was removed. The intensity of positrons decayed exponentially with a half-life of about three minutes. Immediately following the discovery oi Curie and Joliot. many more artificial radioactivities were produced by several groups of workers. mainly as the result of bombardment with high-speed charged particles from artificial sources. Many substances were rendered radioactive by bombardment with protons and deuterons which were accelerated in various types of high voltage apparatus; H. R. Crane and C. C. Lauritsen used a "cascade transformer" potential source, J. D. Cockcroft. C. W. Gilbert and E. T. S. Walton employed a voltage-multiplier circuit. R. J. Van de Graaff and M. A. Tuve and L. R. Hafstad used the "electrostatic generator." while E. O. Lawrence and co-workers accelerated the charged projectiles in the magnetic resonance accelerator or cyclotron (see ACCELERATORS. PARTICLE). A large addition to the list of radioactivities was made during 1934 and 1935 as a result of the work of E. Fermi and his associates, who produced the activities by the neutron bombardment of the elements. Since the Coulomb field of the nucleus does not oppose the entry of a neutron, as it does that of a charged particle, a large number of elements throughout the entire range of the pefiodic table were rendered radioactive in this manner.

By the end of 1935 about 100 artificial radioelements were known, and a review of the subject of artificial radioactivity, which included a discussion of the methods of production, was published by L. N. Ridenour and D. M. Yost in Chemical Reviews. Further work with deuterons. neutrons and protons, and in addition, high-energy alpha-particles and gamma-rays, from artificial sources: made a large increase in the number of induced radioactivities. A number of tables of radioactivities have appeared in various physical journals listing the radioactive isotopes, their properties and methods of production. For example, J. J. Livingood and G. T. Seaborg published, in the Reviews of Modern Physics (Jan. 1940), a table which described the properties of about 330 artificial radioactivities and Seaborg compiled a table which appeared in the same journal in Jan. 1944, which described the properties of about 420 artificial radioactivities.

The large currents and high energies available, especially with the cyclotron, have resulted in the discovery of a large number of radioactive isotopes (see ISOTOPE). The accomplishment of the self-sustaining nuclear chain-reaction in uranium marked another milestone in the field of artificial radioactivity. As a result, by 1961 there were known more than 1,000 induced radioactivities, there being at least one radioactive isotope for each of the elements of atomic number 1 to 103 inclusive. Because of the prodigious number of neutrons generated by the chain-reactor, it is possible to produce easily weighable amounts of artificial isotopes, and hence tremendous intensities of radioactivities, where the transmutation can be induced by neutrons.

GENERAL CONSIDERATIONS

The decay of the artificial radioelements follows, of course, the well-known exponential law, just as for the natural radioactive bodies, and the decay rate for each element is described in terms of a half-life. (The half-life is the time required for one-half of the initial number of atoms to decay.) Likewise the growth of a radioactivity when an element is under constant bombardment follows the familiar growth law, that is, the fraction of the saturation number of atoms formed in a time t is equal to $1 - e^{-\frac{0.69t}{T\frac{1}{2}}}$, where $T\frac{1}{2}$ is the half-life. After a time of activation long compared with the half-life of the substance, the activity reaches a saturation value which can not be increased by further activation (see RADIOACTIVITY, NATURAL).

Although the nomenclature for the artificial radioelements had not reached a standardized form by 1947, most of the investigators in the field had adopted the practice of using the contracted form "radioelement" rather than the more cumbersome term "radioactive element." For example, the well-known radioactivity of 14.8 hours half-life induced in sodium, as the result of bombardment with either neutrons or deuterons. is often referred to as being caused by "radiosodium" rather than the "radioactive isotope of sodium." The former, simpler nomenclature will be used here.

The radiations from the artificial radioelements are very similar in properties to those from the natural radioelements of the well-known uranium, actinium and thorium families (see RADIOACTIVITY, NATURAL and NUCLEUS). Single decay predominates, although numerous examples of chain decays, *i.e.,* cases where the product of the first decay is also radioactive, are known in artificial radioactivity. The beta-particles emitted during the decay of artificial radioactivities have the same continuous type of distribution in energy, with a definite upper energy limit, which has long been known to exist for the natural radioelements. (It is this continuous distribution of beta-particle energy which has led to the introduction of the neutrino, a particle of small or zero mass, one-half unit of spin ($\frac{1}{2}\cdot h/2\pi$) and no charge, in order to preserve the laws of conservation of energy and momentum in beta-decay.)

The upper energy limit for beta-particles decreases as the half-life increases; this Sargent relation (log half-life proportional to log energy) holds only roughly over a range of mass values and must be modified when the nuclear spin change accompanying the disintegration is greater than zero.

Decay by alpha-particle (He^{4+}) emission is fairly common among the artificial isotopes of elements above bismuth just as it is among natural radioactive isotopes in this region of the periodic table. While only the negative beta-particles (electrons) are emitted by natural radioelements, some of the artificial radioelements emit negative beta-particles and some of them emit positive beta-particles (positrons). Examples of radioelements which decay by the emission of both negative and positive beta-particles are known. Some of the decays are accompanied by gamma-rays (high-energy electromagnetic radiation) and some are not, just as in natural radioactivity, and these gamma-rays may be slightly or largely internally converted. (When a gamma-ray is "internally converted" or undergoes "internal conversion," it means that instead of the emission of a gamma-ray there is the ejection of an electron from the extranuclear structure of the same atom that contains the nucleus which is radiating, the kinetic energy of the ejected electron being equal to the difference between the energy of the gamma-ray and the binding energy of the electron.) Radioelements which give off gamma-rays can be detected through interposed material since gamma-rays cause much less ionization than charged particles, and hence are much more penetrating, than beta-particles of similar energy.

Positron emitters may decay by the alternative process of orbital electron capture, a method of decay which, up to 1947, had been observed only with the artificial radioelements. It was suggested by H. Yukawa and others, from considerations based upon the Fermi theory of beta-ray emission, that an unstable nucleus might reach stability by the capture of an extranuclear electron. The first experimental observation of decay by "K-electron capture" (often so called because by far the largest proportion of the orbital electrons captured by the nucleus come from the K-electron shell) was made by L. W. Alvarez, who found that an unstable gallium isotope of 83 hours half-life decayed by this mechanism. Many examples of this type of decay are now known. Decay by orbital electron capture may be unaccompanied by any detectable ionizing radiation except for the X-rays which must be emitted (since the vacant place in the inner shell must be filled with the emission of an X-ray or an Auger electron). However, many examples of orbital electron capture are known where the resultant nucleus is left in an excited state which drops to the ground state with the emission of a gamma-ray or a line of internal-conversion electrons or both. (The name "line of electrons" is often used to describe the monoenergetic electrons which are emitted from, *e.g.*, the K-electron shell, when gamma-rays undergo internal conversion. Some of the gamma-rays are converted in the L-, M-, etc., electron shells. The term "line" arises from the fact that with an electron magnetic spectrograph these groups of monoenergetic conversion electrons appear as lines on a photographic plate in contrast to the beta-particles from a beta-ray emitter, whose continuous distribution in energy darkens the plate continuously over a very broad energy range.) Some radioelements decay by both positron emission and orbital electron capture, some by orbital electron capture alone, and some entirely by positron emission.

Another class of radioactive substances, not peculiar to artificial radioactivity but most thoroughly studied here, are "nuclear isomers." Each member of a pair of nuclear isomers has the same atomic number and the same atomic weight (isotopic isobars) ; they represent two different energy states, the upper and the ground state, of the same nuclear species, differing in energy content and degree of stability. A theory which C. F. v. Weizsacker proposed in order to account for the existence of nuclear isomers ascribes the long lifetime of the upper, metastable state to a difference of several units of angular momentum between the metastable and ground state. This large spin difference forbids the transition from the upper to the lower state in a manner analogous to the forbidden transitions in optical spectra. Each isomer of a pair may be radioactive and decay independently of the other by beta-emission with its own characteristic half-life, or the isomer corresponding to only one energy state may be beta-active, and that corresponding to the ground state may be stable. Some isomers are genetically related to each other; the upper state, rather than decaying by beta-particle emission to a neighbouring isobar, decays by an isomeric transition to the ground state with the emission of a gamma-ray. (The present theoretical explanation for the phenomenon of nuclear isomerism leads to the prediction that the gamma-rays corresponding to an isomeric transition will undergo high internal conversion when the energy is small—of the order of tens or hundreds of kilovolts.) The first evidence for nuclear isomerism in artificial radioactivity was presented in 1935 by B. Kourtchatow and co-workers, and in 1937 A. H. Snell and also W. Bothe and W. Gentner simultaneously showed that an 18-minute period and a 4.4-hour period must both be ascribed to a bromine isotope of atomic weight 80.

METHODS OF CHEMICAL IDENTIFICATION AND CONCENTRATION

The chemical identification of artificial radioelements is based on the fact that isotopes are not appreciably separated by ordinary chemical reactions and the radioactive isotopes of a given element behave in the same manner as the stable isotopes of the element. The property of radioactivity does not influence the chemical behaviour (except in the case of extremely strong activities and then in the same way as an external source would do). Thus, after a transmutation has taken place leading to the formation of a new and unstable nucleus. the new atom has properties determined solely by its new atomic number and will behave chemically in all respects like its stable isotope or isotopes. Often only a few millions of atoms of the unstable transmutation product are formed. The behaviour of an element at such low concentration may be uncertain in many chemical procedures. For this reason, in order to establish the chemical identity of the transmutation product, it is usually expedient and often absolutely necessary-to add a small quantity of that element which is isotopic with the expected or suspected transmutation product. This added material is usually designated by the term "carrier." The carrier element is separated out chemically along with its unstable isotope and in this manner one can establish a radioactivity, with a characteristic half-life, which is isotopic with the carrier element.

In many cases, when the radioelement is not isotopic with the element from which it is formed, the radioactivity can be concentrated in a small amount of material by adding and separating out only a small amount of carrier. Such a high ratio of activity to carrier material (high specific activity) is desirable in many of the investigations which employ radioelements, especially in biological chemistry and physiological and biological studies. The ***specific*** activity may be defined as the ratio of the number of radioactive atoms to the total number of isotopic atoms with which the radioactive atoms are mixed.

When the radioactivity is isotopic with the element which is bombarded, the active isotope is necessarily mixed with a larger quantity of its inactive isotopes. However, it is sometimes possible to effect a separation of the radioactive isotope from the inactive isotopes and hence a concentration of the radioactive isotope in a small amount of material. L. Szilard and T. A. Chalmers were the first to show that radioactive iodine could be separated from ordinary iodine after irradiating with neutrons a nonionizing organic compound such as ethyl iodide. After the irradiation, a small amount of free iodine was added to act as a carrier for the free radioactive iodine, and after this iodine was reduced and precipitated as silver iodide it was found to contain practically all of the radioactivity. This method of concentration, which has subsequently been used to concentrate a number of radioelements, is now known as the "Szilard-Chalmers method." Its success depends upon the removal of the newly-formed radioactive nucleus from its chemical bond in the irradiated compound. The breaking of this bond is a result of the large amount of energy furnished by the recoil from the gamma-rays emitted during the neutron-capture process. The method is not limited to radioelements formed by irradiation with neutrons, but in principle can be applied to other methods of activation. It is, of course, essential that the radioactive atoms set free during the bombardment do not interchange with their isotopic atoms in the irradiated chemical compound. As examples of the application of this method, radioactive iodine, bromine and chlorine can be concentrated, using either organic compounds or the inorganic halogenates. Similarly, manganese dioxide precipitated from an irradiated permanganate is found to carry most of the radiomanganese under certain conditions. Whenever it is desired to use this method in order to produce a radioactive isotope with a high specific activity, a search is made for a compound which contains the element in a form which will not interchange with the freed radioactive atoms and from which the radioactive atoms will be liberated during and separable after the irradiation process.

O. Erbacher and K. Philipp; C. S. Lu and S. Sugden; and S. Roginsky and N. Gopstein developed a number of excellent methods for the extraction with high yields of concentrated radioactive halogens from neutron-irradiated organic halides. One of the techniques employed by Erbacher and Philipp depended upon the adsorption of the radioactive atoms on active charcoal, and Roginsky and Gopstein used aluminum oxide and active charcoal as adsorbents. V. Majer used a trace of colloidal gold to supply condensation nuclei for the deposition of active gold atoms formed in a neutron-irradiated, alkaline gold chloride solution.

A method for the chemical separation of genetically related nuclear isomers, which is a modification of the Szilard-Chalmers method, was invented by E. Segrb, R. S. Halford and G. T. Seaborg. The element which contains the radioactivity corresponding to an upper isoméric energy state is made into a compound suitable for the application of the Szilard-Chalmers method of concentration; the daughter radioactivity, which corresponds to the ground state and which is liberated from this compound as a result of the isomeric transition, is then chemically separable from the parent radioactivity. Segrb, Halford and Seaborg used this method to extract the bromine radioactivity of 18 minutes half-life, in the form of hydrobromic acid, from its parent isomer of 4.4 hours half-life, which was present as tertiary butyl bromide. D. DeVault and W. F. Libby made the same separation by precipitating silver bromide from an ammoniacal solution which contained the 4.4-hour radioactivity in the form of the bromate, while L. J. Le Roux, Lu, and Sugden separated the 18-minute radioactivity as silver bromide from both ethylene dibromide and *n*-butyl bromide. A number of chemical separations of nuclear isomers have been made, employing this principle, and these have been of aid in isotopic assignments and establishing the genetic relationships between the isomeric pairs.

In some cases when the transmutation product is not isotopic with the target element, it is possible to separate it from the target element without the use of carrier. This often gives the pure radioactive element, or compound of the element, in much too small an amount to be seen, detectable only by its radioactivity. A few examples will serve to illustrate the type of physical and chemical properties which may serve to make such a separation feasible.

M. Haïssinsky separated pure radiocopper, produced by neutron bombardment of zinc, by means of electrochemical deposition on lead, while J. Steigman effected the same separation by electrolysis. Segrè found that the radiosodium present in a sample of magnesium hydroxide, after the deuteron bombardment of the magnesium, could be dissolved out of the hydroxide quantitatively by treating it with water.

Partition between solvents affords another method for separating the radioactive isotope in its pure form in the absence of carrier material. D. C. Grahame and Seaborg have used the partition between ether and 6 N hydrochloric acid to separate pure radiogallium from zinc as well as radiomanganese and radiocobalt from iron.

When there exists a large difference in the boiling points, this may be used to effect a separation. For example, a gaseous, radioactive transmutation product can easily be separated from a nongaseous target element or parent element. Alvarez, A. C. Helmholz and E. Nelson have separated practically pure radiocadmium by collecting the vapour after heating deuteron-activated silver to its melting point.

When the radioactive transmutation product forms an extremely insoluble compound, it should be possible to collect the invisible precipitate on the walls of the containing vessel after centrifugation, as has been done for many of the naturally radioactive elements.

Another method of separation depends on the fact that the newly formed radioactive atom may have lost one or more of its extranuclear electrons at the moment of formation as a result of the recoil given to it by the gamma-ray emitted during the capture process. The charged atoms formed in this manner may be collected, during the bombardment of either a gaseous or a liquid substance, with the aid of an electric field. This method of concentration, which is sometimes applicable even when the radioactive product is isotopic with the target element, has been employed by Fermi and his associates and by F. A. Paneth and J. W. J. Fay and J. Govaerts. The collection of recoil radioactive atoms produced during bombardment with charged particles can also be used as a method for obtaining concentrated radioactive samples. A special use is sometimes made of the recoil technique in identifying the daughter isotopes of an alpha-emitter. Because of the great momentum of the alpha-particles, they impart enough recoil energy to the residual nuclei to dislodge them from the surface and allow collection free of other activities.

The use of adsorption techniques, analogous to "chromatography," has proved very effective. By the use of adsorbents of the ion exchange type in columns, and some organic types have proven especially effective, it has been possible to make difficult separations quite efficiently. This method was introduced and the early pioneering work done by G. E. Boyd and F. H. Spedding and W. E. Cohn and their co-workers. Cohn and E. R. Tompkins were the first to show the extreme power of the method by using it to separate neighbouring rare-earth elements.

The chemical work in connection with the identification and extraction of radioactive isotopes can usually be done in laboratories with rather usual facilities. However, in the extraction of radioactive isotopes at high levels of radioactivity special facilities are needed. Thus laboratory facilities for radiochemical research and production work can be classified according to the level of radioactivity involved in the operations—microcurie, millicurie and multicurie. (The "curie," originally the name for the amount of radon in equilibrium with one gram of radium, is now usually taken as the name for the general unit of intensity in radioactivity; a curie of any radioactive material undergoes the same number of disintegrations per unit time as one gram of radium, namely, 3.7×10^{10} disintegrations per second.) Since problems often require manipulations at more than one of these levels it may be necessary to have separate facilities for work at more than one level in a single laboratory. Ordinary chemical facilities are satisfactory for work at the microcurie level. Shielding material is needed between the operator and the equipment, thus requiring specially designed hoods, for work at the millicurie level. Manipulations at the multicurie level must be completely remotely controlled and carried out behind heavy, permanent shielding material.

METHODS FOR DETECTION OF RADIATIONS

There are a number of different types of instruments that are used for the measurement of the intensity of the radiations from radioactive substances. All of the common instruments depend upon the ionization, direct or indirect, produced by radiation. No attempt will be made to describe all of them, but some of those which were being used in 1947 by workers in this field will be mentioned briefly. The best type of instrument for a given problem depends upon the type and energy of the radiation and upon the sensitivity and stability which is required. A knowledge of the absorption curve for the radiation to be measured is often very important, especially if the radiation is of very low energy (*i.e.*, very soft), since this will make it necessary to pay particular attention to the effect of self-absorption in the sample and to use a detection device of the proper design.

One of the simplest instruments, widely used, is the Lauritsen modification of the electroscope, known as the "quartz-fibre electroscope." The electroscope is usually used inside an ionization chamber, which may be filled with any gas, although air is usually used for convenience, and the rate of drift of the fibre across a scale is measured. This instrument, which is suitable for the detection of all types of radiations from radioactive substances, is one compact unit and requires for its operation only a D.C. (direct current) potential source of the order of 200 volts. Its sensitivity is not as large as that of some of the other detection devices. The quartz-fibre electroscope can be used to best advantage with a radioactivity whose intensity is of the order of microcuries (10^{-6} curies), although intensities which are 1%, or even 0.1%, as strong as this can be measured.

A more sensitive arrangement of the integrating type, also suitable for the detection of all types of radiation from radioactive substances, is obtained with an ionization chamber connected to some kind of an electrometer. These chambers which usually consist of an outer cylinder with a central, coaxial electrode, normally use 300 to 400 volts of D.C. potential for their operation and may be designed so as to contain any gas. The gas may be at atmospheric pressure, which is necessary when a thin window is used, or higher pressures may be used to increase the detection sensitivity for penetrating radiation such as gamma-rays. The measurement of extremely soft radiation can be accomplished by introducing the sample into the inside of the ionization chamber. Any sensitive electrometer can be used; both the Edelmann electrometer and the Perucca electrometer have been used in practice and found to be satisfactory. Various vacuum tube electrometer systems have been used and this is the type which is generally used. The ionization current is amplified by a D.C. amplifier and is read as a deflection on a sensitive galvanometer; a modification in which the "rate of drift" of the galvanometer current is read increases the sensitivity for the measurement of the radiations from weak samples. Recently the vibrating reed electrometer has-been developed. This device converts the D.C. voltage, obtained by passing the ionization current through a high resistance, into an A.C. (alternating current) voltage which can be greatly amplified with very high stability. The "rate of drift" method can also be used with this instrument to increase its sensitivity. In general, electrometers are characterized by being useful over a tremendous range of sensitivities from 10^{-4} microcuries (limited by the type of electrometer) to several curies (limited by the design of the ionization chamber).

An ionization chamber of a different design can be used to detect single, heavily ionizing particles, such as protons, alpha-particles, etc., when connected to a high-gain, multiple-stage, A.C. (pulse) amplifier. Complete electrical circuits for the operation of such ionization chambers were commercially available from several sources in 1947. Electrons and gamma-rays (which show themselves only by the electrons liberated from the material they pass through) are not recorded with this arrangement. In a special arrangement, known as the "alpha pulse analyzer," such a type of ionization chamber can be used in connection with a multichannel circuit in which alpha pulses are sorted electronically according to size, hence making it possible to detect and identify the individual components in mixtures of alpha-emitters.

The most sensitive detection device is the Geiger counter, also known as the "point" counter, an instrument which detects individual ionizing particles of all kinds. A modification of the original Geiger counter which was widely used in 1947 is the Geiger-Muller counter, which was also known as the "tube" counter and the "Zahlrohr." With this instrument it is possible to detect the ionizing particles from a source as weak as 10^{-5} microcuries. The Geiger-Muller counter consists of a conducting cylinder and coaxial wire which is insulated from the cylinder. It is filled with some gas such as air or argon at reduced pressure, together with a "quenching" component such as an oxygen-containing gas like alcohol. and is operated with a negative voltage of 500 to 5,000 volts on the outer cylinder. The passage of an ionizing particle through the counter causes a temporary electrical breakdown (*i.e.*, an avalanche of ionization initiated by the first ion pair which is produced and greatly augmented by secondary ionization from collision processes, etc.) between the outer cylinder and the central wire, and this pulse is usually amplified by an A.C. (pulse) amplifier to a stage where it is capable of operating a mechanical recorder in a recording circuit. Complete electrical circuits, together with recorder, as well as counter tubes of many different designs are commercially available from many sources. The circuit which operates the mechanical recorder, and this is generally true wherever such a recorder is used, is usually the "scaling" type, *i.e.*, is so designed that the recorder needs to record only a certain known fraction of all the pulses from the counter and amplifier.

When the particle radiation from the radioactive element is of very low energy; the radioactive material, in the form of a gas, can be introduced into the interior of an ordinary ionization chamber or Geiger-Muller counter. An arrangement which allows a radioactive sample of solid material to be introduced into the interior of a counter and which allows background counts to be made while such a sample is inside, is the "screen-wall" counter described by Libby. Of course, when the low-energy particle radiation is accompanied by gamma-radiation it may not be necessary to introduce the sample into the interior-of the counter or ionization chamber. However, the lower efficiency of gamma-ray detection makes it necessary to have strong samples for measurements which depend entirely upon gamma-radiation.

The "proportional" counter, first described by H. Geiger and O. Klemperer, is a modification of the Geiger and the Geiger-Muller counter which is operated at a lower voltage (and with a higher gain pulse amplifier), so that only heavily ionizing particles such as protons, alpha-particles, etc., are detected.

For most work involving the radioelements the choice of detection device will be made from the following group: (1) electroscope, (2) Geiger-Muller counter, (3) integrating ionization chamber or (4) nonintegrating ionization chamber with linear amplifier. These instruments can be used to obtain absorption curves in order to determine the energy of radiations from radioactive substances. The upper energy limits of beta-particles are usually determined with the help of the relationship of N. Feather, $R=0.543E-0.160$, where R is the range in grams per cm.^{2} of aluminum and E is the energy in Mev (good only for $E>0.6$ Mev), while for gamma-rays the correlation of energy with absorption coefficient as listed in the tables compiled by Gentner and others can be conveniently used.

Brief mention should also be made of other experimental arrangements which are used primarily for detailed studies of the properties and energy of radiations. The beta-ray spectrograph or spectrometer uses a magnetic or electric field to bend. to an extent dependent upon their energy, alpha-particles, beta-particles, internal-conversion electrons, or the secondary electrons from gamma-rays. The particles are detected either by a photographic method or by a counter or ionization chamber. Another arrangement involves two or more counters connected to an amplifier of a type which records the counts only when the counters discharge simultaneously. This "coincidence counter" arrangement is often used to determine the energy of gamma-rays by determining the absorption curve of the secondary electrons which are producing the coincidence counts. In addition, there is the expansion chamber or cloud chamber of C. T. R. Wilson (usually used with a magnetic field), in which can be seen and photographed the water drops which condense along the path of an ionizing particle.

Another instrument which should be mentioned is the secondary electron multiplier tube as adapted to counting purposes. This device, which detects single positive ions, electrons and photons by producing a large current of secondary electrons inside a single vacuum tube, is most useful for special problems in physics where work in a vacuum and an extremely low background (less than one count per minute) are paramount factors. A device proposed by P. J. Van Heerden is the "crystal counter" for detecting electrons. In this method the dielectric properties of a crystal of some material, *e.g.*, silver chloride, are used in such a manner that a pulse suitable for detection and recording can be generated upon the passage of an ionizing particle through the crystal.

An ingenious adaptation, introduced by A. J. Dempster and co-workers. of the mass spectrograph to the determination of the mass of radioactive isotopes has led to a powerful method for making the isotopic assignment of radioactivities. In this method a portion of the sample, containing a radioactivity whose mass number needs to be established, is placed on the filament source of a mass spectrograph. Operation of the instrument then separates the isotopes and deposits them on a detecting surface. The position of the radioactive isotope on this surface can be determined by the use of some radiation detection device, such as a counter or photographic plate, and the mass corresponding to this position can be learned from calibration experiments. An increasing number of isotopic identifications are being made by this method.

TYPES OF REACTIONS AND METHODS OF PRODUCTION

The artificial radioelements are prepared chiefly from the stable isotopes of the elements (see NUCLEUS) with the help of various kinds of bombarding particles, such as neutrons, deuterons, alpha-particles (helium ions), protons, high-energy gamma-rays and X-rays. Any charged particle which can be accelerated to a sufficiently high energy to enter the nucleus is a potential projectile for producing nuclear transmutations. The long-lived, heavy, radioactive elements, such as uranium, plutonium (the synthetic element with atomic number 94), 'thorium, etc. serve as the source of many radioactive (fission product) isotopes as a result of the fission reaction. In some cases artificial isotopes, even though relatively short-lived, serve as the source for the production of other such isotopes; such higher order reactions are more common in the case of neutron irradiations because of the extremely high neutron intensities available. The artificial radioisotopes with mass numbers smaller than those of the stable isotopes of the same element reach stability by the emission of positrons (or by orbital electron capture) ; those with larger mass numbers attain stability by the emission of negative beta-particles. A radioelement whose mass number lies between the mass numbers of two stable isotopes is usually a negative beta-particle emitter although many examples exist in which the isotope decays in both directions.

In order to identify completely a radioactivity it is necessary to establish the mass number of the active isotope as well as the atomic number. The latter assignment is usually made by chemical separations. The mass number of the radioactive isotope can be deduced sometimes from a study of the known mass numbers of the stable isotopes of the target element after the chemical separation has established the type of reaction; often the identification must be made by the method of "cross bombardment," *i.e.*, the preparation of the radioactive isotope by several independent nuclear reactions. A new radioactivity is sometimes found to decay to or grow from, in one or more steps, a previously known radioactivity. In this case the mass number of the parent or daughter may be established through the genetic relationship. The bombardment of separated isotopes offers a powerful method for the isotopic identification of induced radioactivities, in view of the excellent isotope separation methods which have been recently developed. When a radioactive isotope is formed as the result of a reaction which involves a rare isotope, the bombardment of the pure, separated isotope will, of course, result in a larger yield. Isotope separation experiments performed after bombardment (see above) also are useful for isotopic identification. For the use of a radioactive substance as a tracer (see below) in a chemical or biological problem a knowledge of the atomic number is sufficient, and radioactive isotopes whose mass numbers have not been established are nevertheless valuable.

The types of reactions leading to thé formation of the artificial radioelements. will now be described (these reactions also often lead to the production of stable isotopes). For brevity it will be convenient to use a simplified notation, rather than to write out the entire reaction each time. For example, the bombardment of iron with neutrons to produce radiomanganese will be described by $Fe^{56}(n,p)Mn^{56}$, rather than by the more cumbersome equation

$$_{26}Fe^{56}+{}_0n^1\rightarrow{}_{25}Mn^{56}+{}_1H^1$$

(where the superscripts denote mass numbers and the subscripts atomic numbers). The notation n$-$neutron, p=proton, α=alpha-particle, d=deuteron and γ=gamma-ray will be used.

The discussion which follows will also include a few statements regarding the yield of radioelements formed in the various reactions. It must be emphasized that only rough qualitative statements can be made, since the situation is too complex to allow a quantitative treatment in a few words. No summary of experimental data on the various reaction yields and the variation of the yields with energy and atomic number has been published; a summary of this type awaits more systematic data.

It may be helpful to point out that the considerations of Bohr have led to the view that the transmutation which occurs as the result of the impact of any particle with an atomic nucleus (with a few exceptions) proceeds by a mechanism which must be treated as two independent processes: namely, (1) the amalgamation of the particle with the nucleus to form an intermediate metastable compound nucleus, and (2) the eventual breaking up of the intermediate nucleus into the end products. All of the reactions in step (2) which are energetically possible will take place but the rates for the competing reactions may differ so greatly that some reactions can not be detected.

Neutron Reactions.— Neutrons are obtained from three types of sources: (1) chain-reacting piles; (2) indirectly from charged particle accelerators; and (3) those which utilize the radiations from the natural radioelements.

The neutrons from the latter type are usually produced by the reaction $Be^9(\alpha,n)C^{12}$ and the sources may be prepared by mixing powdered beryllium with alpha-particle emitters such as radium, radon or polonium. Neutrons produced in this manner have a more or less continuous distribution in energy extending up to about 13 Mev (million electron volts) for radon alpha-particles. (The electron volt, a unit of energy widely used in atomic and nuclear physics, is equal to 1.59×10^{-12} ergs, and is the amount of energy acquired by a particle of electronic charge when it falls through a potential difference of 1 volt.) The action of monoenergetic gamma-rays (of sufficient energy) on beryllium and on deuterium gives rise to monoenergetic neutrons, usually known as "photoneutrons," with energies of the order of hundreds of kilovolts when gamma-rays from the natural radioelements are used.

Artificial sources of indirectly produced neutrons are obtained by bombarding various elements with fast-moving charged particles, the energy of the neutrons depending upon the energy of the bombarding particles. However, the neutron energies have a strong dependence upon the reactions used for their production, so that, taking into account the experimental conditions used for their production, certain rough statements can be made with regard to the energies of neutrons from various artificial sources. Two common sources are (1) deuterons (say 5 to 10 Mev on beryllium (the Be+d source), giving neutrons with energies extending up to about 13 Mev and (2) deuterons on deuterium (the D-d source). The D-d source is used to most advantage when deuterons with energy of the order of a few hundred kilovolts are available and under these conditions gives rise to neutrons within the narrow energy range of 2.5 to 3 Mev. The bombardment of lithium or boron with deuterons (5–10 Mev) produces neutrons with energies extending up to about 25 Mev. Neutrons in this high energy range are produced also by the bombardment of beryllium with high energy (*e.g.*, 20 Mev) deuterons. With extremely high energy deuterons (200 Mev), neutrons with energy in the range of 100 Mev are produced, probably with all target materials.

The uranium chain-reacting "piles" give rise to sources of neutrons of intensities which are huge by comparison with these other sources. Such sources give rise to neutron fluxes which are larger than those mentioned above by orders of magnitude, and furthermore tlie area over which these fluxes are maintained is larger by many, many orders of magnitude. With such "neutron factories" it is possible to transmute elements on a weighable scale; in fact, it is possible to produce radioactive isotopes on a scale of not only micrograms or milligrams, but also grams, or even kilograms in some cases. Also it is possible to use second and higher order reactions in their production, *i.e.*, produce by transmutation an isotope which in turn can be used to produce another isotope by neutron absorption, and so on. Neutrons from this type of source extend in energy up to some 10 Mev, with all lower energies present, and often the pile is so designed as to give a high flux of predominantly "slow" neutrons (see next paragraph).

Previous to the advent of neutrons with energies in the 100

Mev area, common usage had evolved a rough classification of neutrons into groups on the basis of their energy; "very fast" neutrons, often called "fast" neutrons, were those, *e.g.,* from a lithium plus deuterons ($Li+d$) or boron plus deuterons ($B+d$) source, with energies extending from about 20 Mev to about 10 Mev, while neutrons with energies within the range starting at about 10 Mev and extending down to an indefinite energy region (of the order of thousands of electron volts) were known as "fast" neutrons or "medium fast" neutrons (especially those at the lower end of this energy range). "Slow" or "thermal" neutrons is the name given to those neutrons which have suffered a sufficient number of collisions usually with hydrogen or carbon nuclei as the result of passage through paraffin or water or graphite, to slow them to thermal velocities, *i.e.,* about 0.025 electron volt of energy. Slow neutrons were discovered by Fermi and co-workers, and these authors as well as many others give a discussion of their properties and of the slowing process. Neutrons in the energy range immediately above the thermal range are sometimes designated as "resonance" neutrons, a result of the fact that many nuclei absorb such neutrons only within extremely narrow energy ranges, that is, absorb them in a resonance fashion.

Reactions between medium fast neutrons and nuclei produce artificial radioelements by the following main types of transmutations: (1) the simple, radiative capture, known as the n,γ reaction; (2) neutron capture followed by proton emission, or the n,p reaction; (3) neutron capture with alpha-particle emission, the n,α reaction; and (4) neutron capture followed by the emission of two neutrons (net expulsion of one neutron), or the $n,2n$ reaction. With very fast or very high energy neutrons (10 to 100 Mev or higher) more than one proton, alpha-particle or neutron may be ejected, and in all combinations, the relative yields depending on the particular energy of the incident neutron and upon the atomic number of the target element. The n,γ and $n,2n$ and $n,3n$, etc. reactions give radioelements which are isotopic with the target element, and hence the Szilard-Chalmers method of concentration is used when it is desired to obtain a high ratio of active to inactive material, *i.e.,* a high specific activity. When the n,p or n,α or $n,p\alpha$, etc., reactions are used or the Szilard-Chalmers method employed, large amounts of material can be used effectively in order to obtain large specific activities. Radioelements formed by the $n,2n$ or $n,3n$, etc. reactions are largely positron emitters, while the n,y reactions usually lead to negative beta-particle emitters.

The n,γ type of activation occurs most efficiently with slow neutrons and to a smaller extent with fast neutrons. It is the most common and widely studied of all nuclear reaction types. Elements throughout the entire range of the periodic table can be activated in this manner; the cross sections for slow neutron absorption, which are extremely large for some elements, vary in an irregular manner from element to element and from isotope to isotope. The n,p and n,α, etc. transmutations require fast neutrons (except for two or three cases in the lightest elements). The energy required increases regularly as one proceeds up the periodic table, since the outgoing charged particles must escape the nuclear potential barrier, and for atomic numbers as high as 50 only the neutrons with energy greater than 10 Mev are effective. The $n,2n$ reaction requires neutrons with energy above about 10 Mev for good yields because the net result is the expulsion of a neutron whose binding energy amounts to about 8 Mev for most of the elements.

There is another type of activation by fast neutrons which involves those isomers in which the ground state is stable. The kinetic energy of the captured neutron excites the nucleus to its upper, radioactive, isomeric state, a neutron being re-emitted, with reduced energy, after the excitation process. In keeping with our method of writing nuclear reactions, this method of excitation is known as an n,n process and a typical example is written $In^{115}(n,n)In^{115*}$. (The asterisk, as used here, denotes a radioactive isomer of a stable nucleus.)

Deuteron Reactions.—Moderately intense radioactivities can, in general, be induced as the result of bombardments with high-energy deuterons which are produced in the cyclotron of Lawrence and M. S. Livingston. Most of the cyclotrons which were in operation in 1947 were producing deuterons of 5- to 15-Mev energy and currents of 10 to 200 microamperes; the 60-in. cyclotron at Berkeley, Calif., was furnishing 20-Mev deuterons and the 184-in. cyclotron at Berkeley was furnishing 200-Mev deuterons. Other types of artificial deuteron sources induce radioactivities of lower intensities, since they produce deuteron beams of much lower energy.

Artificial radioelements, both negative and positive beta-particle emitters, are produced by deuterons of moderate energy (say up to about 10 Mev) in the following ways: (1) deuteron capture and proton emission, known as the d,p reaction, which is, since the net result is the capture of a neutron, equivalent to the n,γ reaction; (2) deuteron capture followed by neutron emission, or d,n reaction; and (3) deuteron capture with alpha-particle emission, the d,α reaction. The yields from all of these reactions increase with increasing energy of the deuterons up to a point and, for a given deuteron energy, decrease with increasing atomic number of the target element. This decrease is most marked for the d, α reaction, since the outgoing, doubly-charged alpha-particles must penetrate the Coulomb barrier of the nucleus (*e.g.,* with 8-Mev deuterons this reaction is not observed for nuclei of atomic number as high as 50, while the d,p and d,n reactions are observed throughout the entire range of the periodic table). It should be pointed out that the d,p reaction occurs largely by a mechanism known as the Oppenheimer-Phillips process. wherein the deuteron, upon approaching the nucleus, is polarized in such a manner as to give rise to the capture of the neutron without the usual amalgamation of the bombarding particle (deuteron) to form a temporary intermediate nucleus. This obviates the necessity for the deuteron to penetrate the potential barrier of the nucleus.

With energies in the range 10 to 200 Mev and higher, more than one proton, alpha-particle or neutron may be ejected, and in all combinations, depending on the particular energy of the incident deuteron and upon the atomic number of the target element. The name "spallation" reaction has been suggested for this type of nuclear transformation in which many small particles are chipped from the nucleus as the result of a collision with an extremely high energy particle.

A few examples will serve to illustrate the intensity of radioactivities which are induced with deuterons. The bombardment of copper for 20 minutes with 20 microamperes of 8-Mev deuterons produces Cu^{64} (half-life 12.8 hours), by the reaction $Cu^{63}(d,p)Cu^{64}$, with an intensity of about 5 millicuries (*i.e.,* 5×10^{-3} curies). Such a sample would give a discharge rate corresponding to about 10^{7} times the natural background of an ordinary Lauritsen, quartz-fibre electroscope. In a typical experiment a 4-hour bombardment of phosphorus with 100 microamperes of 16-Mev deuterons produces about 50 millicuries of P^{32} (half-life 14.3 days or $1\;24\times10^{6}$ seconds) by the reaction $P^{31}(d,p)P^{32}$. With the aid of the relation $-dN/dt=\lambda N$, where $-dN/dt$ is the number of disintegrations per second and λ the disintegration constant, we find for N, the number of active atoms, $3.7\times10^{10}\times0.05\times1.24\times10^{6}/0.69=1/3\times10^{16}$. (The disintegration constant, λ, defined by the equation $-dN/dt=\lambda N$, is equal to 0.69 divided by the half-life.) *See* RADIOACTIVITY, NATURAL. This corresponds to approximately one-sixth of a microgram of radioactive P^{32}.

Alpha-Particle (Helium Ion) Reactions.—Helium ions which are accelerated by electrical means are entirely equivalent to alpha-particles from the natural radioelements and therefore are often called alpha-particles. However, artificially accelerated helium ions, because of the larger intensity of particles available and the higher energies attainable, have largely displaced the natural alpha-particles for the production of radioelements. For example, 100 mg of radium (with its decay products) emits about 10^{10} alpha-particles per second, spread out in all directions, while 1 microampere of alpha-particles corresponds to 3×10^{12} particles per second, directed upon the target. When the cyclotron is in adjustment for deuterons, it is also almost in adjustment for alpha-particles, since deuterons and helium ions have nearly the same value of e/m; and, because the alpha-particles have the same velocity and twice the mass, they attain twice the energy that deuterons do when they are accelerated with the same voltage. Most of the cyclotrons in operation in 1947 furnished alpha-particles of 10- to 90-Mev energy. The 60-in. Berkeley cyclotron was producing 40-Mev alpha-particles and the 184-in. cyclotron at Berkeley was furnishing alpha-particles with 400 Mev of energy.

Artificial radioelements, both negative and positive beta-particle emitters. are produced as the result of alpha-particle capture followed by neutron emission, the α,n reaction, and by alpha-particle capture and proton emission, the α,p reaction. The yields increase with increasing energy of the projectile and, for a given energy, decrease with increasing atomic number. In the heavier elements, say above lead, a helium ion of less energy than about 20 Mev can not enter the nucleus;, so no reactions are seen.

With higher energies more than one particle is ejected, and in all combinations, depending on the particular energy of the incident alpha-particle and upon the atomic number of the target element.

The excitation of nuclei by a process which might be designated as an α,α reaction is another method of activation which occurs with alpha-particles. Theoretical considerations suggest, however, that this activation often occurs as a result of an interaction between the electric fields of the alpha-particle and the nucleus and not as a capture and re-emission of the bombarding particle as in the case of the n,n reaction.

Proton Reactions. — Just as in the case of deuterons and alpha-particles, the cyclotron offers the best source of high-energy protons. Many investigators have prepared a large number of radioelements by means of proton bombardments.

A most common reaction is the capture of the proton followed by neutron emission, or the p,n reaction, producing mainly elements which decay by positron emission (or orbital electron capture). The yield increases with the energy of the proton and decreases with the atomic number of the target element. This type of transmutation is observed throughout the entire range of the periodic table when protons greater than about 10 Mev are used. If the radioactive substance formed in a p,n reaction emits positrons and thus returns to the target element, the energy threshold for the reaction is equal to the difference between the neutron and hydrogen mass (0.8 Mev), plus the mass of two electrons (1.0 Mev) plus the upper energy limit of the positron spectrum from the radioactive substance. (Similarly the energy threshold for the formation of a positron emitter from a $d,2n$ reaction is equal to 4.0 Mev plus the positron upper energy limit.) When the radioactive product decays by orbital electron capture, the energy threshold may be as much as 1 Mev lower than that which would be calculated for the formation of an emitter of zero-energy positrons.

The radiative capture of the proton, known as the p,γ reaction, is observed with the very lightest elements, and it has also been observed with a few elements of medium weight ($Z=30$). This reaction is important only at energies below or near the threshold for the p,n reaction. The yield from this reaction, especially for the very lightest elements, exhibits sharp maxima at certain sharply defined energies of the protons corresponding to definite "resonance levels."

As is the case for the other incident particles, at higher energies reactions occur in which numbers of particles are ejected, the number and type depending on the energy and atomic number. Also the utilization of the kinetic energy of protons to excite nuclei by the p,p reaction occurs, as in the case of the n,n and the α,α reactions.

Gamma-Ray Reactions. — Gamma-rays of sufficient energy are capable of ejecting neutrons from atomic nuclei to produce radioelements by the γ,n reaction, a type of transmutation also known as "photo-disintegration." Bothe and Gentner, who studied this reaction using the 17-Mev gamma-rays produced in the reaction of protons with lithium and the 12-Mev gamma-rays from boron plus protons, found that the yield varied irregularly from element to element. Mainly positron emitters are formed and the yield is comparatively low. The reactions giving rise to gamma-rays of high energy are of the resonance type, occurring at voltages below 1 Mev and hence the direct acceleration type of apparatus, operating at high beam currents, is the best source.

The betatron and synchrotron can be used to accelerate electrons to extremely high energy, in fact any energy up to hundreds of Mev and these electrons can in turn generate X-rays up to this energy. Such X-rays lead to the ejection of neutrons, protons, alpha-particles, and in all combinations, depending on the energy and atomic number.

Lower energy X-rays have been used to excite certain stable nuclei to their isomeric, radioactive states. This type of excitation has also been effected by bombardment with high-energy electrons.

The Fission Reaction. — In Jan. 1939, O. Hahn and F. Strassmann reported their important discovery that the bombardment of uranium with slow or fast neutrons resulted in the cleavage into pairs of radioactive products of medium atomic weight. The existence of this entirely new type of nuclear reaction was immediately confirmed in many laboratories throughout the world, and L. Meitner and O. R. Frisch, after confirming the reaction, suggested the name "fission" for the process. Subsequent work by a large number of investigators resulted in the chemical identification of many of the fission products. Hahn and Strassmann and others found that thorium also undergoes nuclear fission when bombarded with fast neutrons, and A. V. Grosse, E. T. Booth and J. R. Dunning found that the same is true for protactinium (slow neutrons are ineffective in these cases). The products of these cleavage processes, because of the high neutron to proton ratio of uranium, have an abnormally high neutron to proton ratio; hence all are negative beta-particle emitters and many chains of successive decay are found. Some of the radioactive isotopes formed in this manner can be formed in no other way and others can also be formed by some of the methods outlined in the sections above.

The events leading to the discovery of the fission process present an interesting history. In their original work Fermi and co-workers bombarded uranium with neutrons and obtained a series of radioactivities which, on the basis of chemical experiments, they were led to assign to "transuranium elements," *i.e.*, elements with atomic number greater than 92. The experiments of Hahn, Meitner, and Strassmann and others appeared to confirm this point of view, and for several years the transuranium elements were the subject of much experimental work and discussion. I. Curie and P. Savitch, in 1938, found a product of 3.5 hours half-life which had the chemical properties of a rare earth. but they failed to give a complete interpretation of this astonishing discovery. Early in 1939 Hahn and Strassmann described experiments which made it certain that they had observed the production of radioactive barium isotopes as the result of the bombardment of uranium with neutrons. Subsequent work has shown that practically all of the radioactivities formerly ascribed to transuranium elements are actually the result of fission products. N. Bohr suggested on theoretical grounds, and it was soon confirmed experimentally, that it is the rare isotope U^{235} which is the most susceptible to this fission process, *i.e.*, undergoes fission with the highest probability per incident neutron and does so even with neutrons of small energy (slow neutrons). (About 300 radioactive fission products were known by the late 1950s.) The fission of uranium and thorium by charged particles and by high-energy gamma-rays has also been observed.

It was soon shown by H. von Halban, Joliot and L. Kowarski as well as Szilard and W. H. Zinn, and confirmed by many others, that secondary neutrons are emitted during the fission of uranium. The secondary neutrons could themselves produce still more fissions and the possibility of the occurrence of a chain reaction, under the proper conditions, was immediately recognized. The large energy per fission (approximately 200 Mev) shows that the propagation of such a chain could involve the release of immense amounts of energy.

The attainment of the self-sustaining nuclear chain reaction with natural uranium, mixed with material such as graphite for producing thermal neutrons by the neutron-slowing process, has been successful and such "piles," as they are called, serve as neutron sources of tremendous intensity. Such uranium piles are used to manufacture the famous Pu^{239} isotope of the synthetic element plutonium (atomic number 94) and, in conjunction with thorium, can be used to manufacture the new isotope U^{233} of uranium. The isotope Pu^{239} and presumably also U^{233}, share with U^{235} the property of readily undergoing the fission reaction with neutrons and therefore these three isotopes are the fuel material for much smaller piles, giving higher neutron intensities, than those which operate on natural uranium. The chain-reacting pile serves as a source for the production of radioactive isotopes, both the fission product isotopes and those which can be produced by neutron irradiation, in large amounts. Among the valuable fission product isotopes for tracer research is eight-day I^{131} which has been much used in biological studies.

In 1947 I. Perlman, D. H. Templeton and J. J. Howland made the observation that a number of elements well below the thorium-uranium region undergo the nuclear fission reaction when subjected to bombardment with very high energy particles. This work was done at the University of California and the source of their high energy particles was the 184-in. cyclotron. They observed that the elements starting with bismuth (atomic number 83) and on down to tantalum (atomic number 73) undergo the nuclear fission reaction when irradiated with 400-Mev helium ions and that a number of these elements also undergo this reaction when irradiated with 200-Mev deuterons or 100-Mev neutrons. For these elements the fission process is characterized by a distribution of the radioactive fission product isotopes leading essentially to one broad peak in the distribution-yield curve rather than the characteristic two peaks with a pronounced minimum between them in the curve for the fission products produced in the slow neutron irradiation of uranium and plutonium. The fission product distribution extends to lighter elements as might be expected in view of the lighter mass of these elements as compared with uranium and plutonium. Thus, some of the fission product radioactive isotopes formed in these reactions are different from any which are formed in the fission of the heavy elements such as uranium and plutonium.

It should be emphasized that this observation of the fission reaction in relatively common elements such as lead opens no possibility for the production of self-sustaining nuclear chain reactions with these elements and there is no possibility for their employment as sources of atomic energy. One reason for this stems from the fact that any secondary emitted particles which might conceivably be eligible for perpetuating such a chain reaction have much too small an energy to be able to do so.

APPLICATION TO CHEMISTRY AND MEDICINE

The artificial radioactive isotopes have found, and will continue to find, a wide application as research tools in many scientific fields such as chemistry, biochemistry, medicine, physics, biology, physiology, zoology, botany, industrial operations, etc. This application arises chiefly as a result of their use for tracer or "atom tagging" experiments. It is beyond the scope of this article to give a complete discussion of the results, but because of the importance of such work, a brief discussion of the results and possibilities in the fields of chemistry and medicine, and their related fields, will be given.

In the tracer or atom tagging method of investigation, the element is usually present largely in the form of its natural mixture of inactive isotopes and is "tagged" by the addition of an adequate amount of one of its radioactive isotopes. The mixture which has been "labelled" in this manner is then put into the experiment and the course of the added element, often present in some complicated molecule, is followed by means of the measurement of the radioactivity. By use of this principle it is possible, even in the presence of more of the element throughout the system, to trace the course of that particular amount and form of the element which is under investigation.

One of the most important and interesting uses to which artificially induced radioactive isotopes have been put has been the investigation of the properties of those elements which do not exist in nature. In most cases so far, this type of chemical investigation has used a "tracer" technique in which the chemical properties of the radioactive elements are investigated by using amounts so small as to be unweighable and the course of the element in the reactions is followed by means of its radioactivity rather than by chemical means. Thus the orders of magnitude of solubilities of the compounds of the radioactive elements are inferred on the basis of "carrying" experiments, it being generally true that tracer amounts are carried well only if the anion of the precipitate forms an "insoluble" compound with the cation being carried. Other chemical properties such as oxidation potentials can be deduced, making use of this technique. A great deal about the chemical properties of an element can be learned by this method of investigation which is the only possible method when only submicrogram amounts are available.

The most spectacular examples of the application of the tracer technique lay in the discovery and in the study of the chemical properties of ***new*** elements nonexistent in nature, *i.e.,* with the transuranium elements of atomic numbers 93 and higher. In the case of element 94 (plutonium) a long and complex process for its separation from uranium and fission products was to a considerable extent worked out before anyone had ever seen any plutonium even under the microscope. These studies also led to the elucidation of the electron structure of the heaviest elements, the evidence indicating that these form a series of actinide elements with the added electrons for most of the 14 successive elements starting with thorium going into the *5f,* an inner electron shell, similar to the addition of successive electrons to the inner 4f shell in the case of the 14 previously known lanthanide earths.

The first transuranium element was discovered by E. M. McMillan and P. H. Abelson at the University of California in May 1940. Using the neutrons from the cyclotron, they were able to show, on the basis of their chemical and physical experiments, that a beta-particle emitting radioactivity of 2.3 days half-life formed during the irradiation of uranium with neutrons is caused by the isotope 93^{239} (neptunium), which is the decay product of the 23-minute U^{239} formed by radiative neutron capture in U^{238}. Their experiments on the tracer scale showed that element 93 (neptunium) has at least two oxidation states, an upper state (or states) and a lower state (or states), with chemical properties quite analogous to the VI and IV (or III) forms of uranium. For example, they showed that the Np^{239} under reducing conditions is carried and under oxidizing conditions is not carried from aqueous solution by lanthanum fluoride, indicating that the fluoride of the lower oxidation state of neptunium is insoluble and the fluoride of the higher state is soluble. They found that a greater oxidizing power is required to oxidize neptunium to its upper state than is the case for the corresponding oxidation of uranium.

After the discovery of neptunium, the next transuranium element to be investigated was the element with atomic number 94. This element was produced by Seaborg, McMillan, A. C. Wahl and J. W. Kennedy at the University of California late in 1940. The isotope involved was the one of mass 238 formed by the deuteron bombardment of uranium. These investigators were able to show that the deuteron bombardment of uranium in the cyclotron leads to a new isotope of neptunium, the 2.0-day beta-particle emitter, Np^{238}, formed from a *d,2n* reaction on U^{238}. They found that this isotope of neptunium decays to an alpha-emitting isotope of element 94 (plutonium), namely, Pu^{238}, and that this alpha-emitter has a half-life of about 50 years. Early tracer experiments with this isotope showed that plutonium has at least two oxidation states, an upper state (or states) and a lower state (or states), and that it requires even stronger oxidizing agents to oxidize plutonium to the upper state than is the case for neptunium.

The experiments of Seaborg, R. A. James, L. O. Morgan and A. Ghiorso in the Metallurgical laboratory at the University of Chicago have led to the identification of isotopes of elements 95 (americium) and 96 (curium), making it possible to study the chemical properties of these elements by the tracer technique. Deductions from work on the tracer scale with these isotopes led to the conclusion that the III oxidation state is the most stable and by far the most important state for these elements in aqueous solution. In fact in the case of curium the evidence indicates that the III state is the only one that exists in aqueous solution, and its chemical properties are similar to those of the tripositive rare earths. By the early 1960s. isotopes of elements through 103 (lawrencium) had been produced artificially.

Of course in the meantime it has been possible to produce neptunium and plutonium in weighable amounts in the chain-reacting piles. The isotopes which have been produced in this manner are the neptunium isotope of mass 237 and the plutonium isotope of mass 239, the latter being the isotope which is so important in the atomic energy field. With these isotopes it has been possible. using the methods of ordinary chemistry, to greatly extend the knowledge of the chemical properties of these elements.

There are also a number of lighter elements which are now known to be extremely rare or nonexistent in nature. but whose chemical properties have nevertheless been rather well defined as the result of their production by artificial means and the investigation of their properties by the tracer technique. These are the elements with atomic numbers 43, 61, 85 and 87. Many experiments with these elements have been performed with unweighable amounts.

C. Perrier and E. Segrè were able to show in 1937 that the deuteron bombardment of molybdenum produces radioactive isotopes of element 43, and they used these to study the hitherto unknown chemical properties of this element. This is particularly interesting from an historical point of view because this is the first of the artificial elements to be discovered. Their experiments showed that the chemical properties resembled those of the heavier homolog, rhenium, to a much greater extent than they resembled those of manganese, the lighter homolog. They used rhenium as carrier for the radioactivity in order to show that element 43 is precipitated by hydrogen sulphide from alkaline or acid (less than 10 N) solution. They investigated other properties, including the volatility of the oxide and chloride and the conditions for the electrolytic de'position of the metal. R. P. Schuman and also D. C. Lincoln and W. H Sullivan. working on the Plutonium project of the Manhattan District, independently observed the radioactivity (with long half-life) resulting from the lower isomeric state of 43^{99}, formed in the fission of uranium. This is interesting because it is possible now to isolate this isotope in weighable amounts. This particular isotope of element 43 was discovered by Segrb and Seaborg. who produced it from the deuteron and neutron bombardment of molybdenum and found that the upper isomeric state has a half-life of 6.6 hours and the lower isomeric state has a half-life of greater than 40 years. The discoverers, Perrier and Segrb, suggested the name "technetium," symbol Tc, for element 43.

A radioactive form of element 61 was positively identified in the experiments of J. A. Marinsky, L. E. Glendenin and others, on the Plutonium project of the Manhattan District, who found the isotopes, 61^{147} and 61^{149} with half-lives of about 3.7 years and 47 hours respectively, formed in the fission of uranium. This element is a rare earth and the chemical experiments on the tracer scale show that its behaviour is. similar to that of the preceding element neodymium. Experiments involving selective adsorption and elution (removal by dissolution! on ion-exchange resins led to the unambiguous separation of the element from its neighbours. The availability of the isotope 61^{147} in large amounts from fission makes it now possible to isolate the missing element 61 in weighable amounts. Marinsky and Glendenin have suggested the name promethium, symbol Pm. for element 61.

The discovery of radioactive element 8j (isotope 85^{211}), from bismuth plus 32-Mev alpha-particles, by D. R. Corson. K. R. Mackenzie and Segrè, made it possible for these workers to investigate its properties. The general behaviour is that of a metal. with little resemblance to the other halogens. It is precipitated by hydrogen sulphide in 6 *N* hydrochloric acid solution with various carriers, and the sulphide is insoluble in ammonium sulphide. Volatility at comparatively low temperatures is observed; a piece of bombarded bismuth loses most of the activity before melting (275° C.). There is no precipitation upon the addition of silver nitrate to a dilute nitric acid solution using iodide as carrier. These investigators gave the name "astatine," symbol At, to this element.

A radioactive form of element 87 resulting from the alpha branching decay of actinium was discovered by M. Perey in France. This isotope, given the name AcK, has the mass 223 and decays by negative beta-particle emission with a half-life of about 21 minutes. The experiments of Perey showed that this element behaves as expected, like a heavy alkali metal; *e.g.*, it is carried by the compound caesium perchlorate. Perey gave the name "francium," symbol Fr, to this element.

Perhaps the most extensive application of the artificial radioelements in chemical work has been to the study of "exchange reactions." In exchange experiments the atoms of an element in one of its valence forms or types of chemical combination, are labelled by admixture with some radioactive isotope of the element which is the same form or chemical combination. To this system is added the element in another state of valence or form of combination, containing none of the radioactive isotope: the presence of radioactivity in this second chemical form, after it has been separated from the first, shows that an effective exchange of atoms between the two different states of the element has taken place. Experiments of this type give information on chemical bond types, the strength and reactivity of chemical bonds and the effect of solvents on these properties, the structure of ions and compounds, the mechanism of reactions and the mechanism of catalysis. In addition, exchange reactions often offer an excellent and convenient method for the introduction of radioactive atoms into compounds.

Although the subject of exchange reactions is too complicated to make accurate, complete generalizations possible, it seems profitable to make a few rough statements about homogeneous exchange reactions. If we consider exchanges of a given element between two sorts of molecules or ions in which it is held by electron-pair bonds to different numbers or kinds of other atoms, we may say in general that such exchange reactions do not proceed with appreciable rates except in those cases where there are reversible reactions which enable the exchanging atoms to reach equivalent states of chemical combination. For example, there is no exchange of atoms between phosphate and phosphite ions, sulphate and sulphite ions, sulphur and carbon disulphide, iodide ion and iodoform, etc. On the other hand, exchanges have been found between chloride and chlorate ion (caused by the oxidation-reduction equilibrium), between lead nitrate and lead chloride (an extreme example of the ionization exchange mechanism), and between iodide ion and iodine (through the formation of a symmetrical intermediate, I_3^-). When the two exchanging molecules differ only in their net charge, another exchange mechanism—the transfer of an electron from one to the other—may become possible. For example, exchanges have been observed between Fe^{++} and Fe^{+++} and between MnO_4^{--} and MnO_4^-. It is no doubt true that some exchanges occur through a simple transfer of atoms between molecules during a collision; such a mechanism is a special case of exchange through the formation of an intermediate. In many cases, the observation of exchanges of this sort suggests the existence of unstable intermediates which might not be known from other reaction studies.

Probably the most important isotope from the standpoint of future possibilities is the radioactive C^{14}. This isotope, discovered by S. Ruben and M D. Ramen at the University of California, has a half-life of some thousdnds of years and therefore before the advent of the chain-reacting pile was practically unavailable becduse of the difficulty of its production in the large amounts needed to produce substantial radioactivities However, the intense neutron source in the piles makes it possible now to produce this isotope in such quantity and high specific activity as' to place it in a class along with the most available and suitable isotopes. It can be produced in either of two ways, the neutron irradiation of carbon, preferably enriched C^{13}, by the reaction $C^{13}(n,\gamma)C^{14}$, or the neutron irradiation of nitrogen by the reaction $N^{14}(n,p)C^{14}$. Both of these reactions take place with slow neutrons. The reaction with nitrogen is of course preferable from the standpoint of producing C^{14} of the highest specific activity, it being in fact possible to produce isotopically pure C^{14} in this manner. The radiation is of relatively low energy. making it necessary for its detection to employ instruments designed with this in mind, and, in the investigations, to pay close attention to the self-absorption problem.

There is a whole vista of opportunity opened, as a result of the availability of the C^{14} isotope. Organic chemists, biochemists, physiologists and men of medicine have dreamed for years of the day when a radioactive isotope of carbon suitable for tracer investigations should become available. A few of the possibilities which have opened through the availability of this isotope will be indicated below, but of course this field is so vast that it is certain that the best ideas are yet to come.

A great deal has been said in comparison of the potentialities of radioactive C^{14} and the separated stable C^{13} in these fields. Actually these isotopes complement each other and it is fortunate that both are available. There now exists the interesting possibility of tagging uniquely each of two different carbon atoms in a molecule or system and then *simultaneously* observing the course of each of these. Also the separated C^{13} makes possible the production of radioactive C^{14} of higher specific activity from the reaction $C^{13}(n,\gamma)C^{14}$.

Another isotope which has great potentialities is the radioactive H^3 which has a half-life of about 10 years. This isotope can be used in many of the ways indicated for the use of C^{14} if it is present in a molecule in a nonlabile position. The availability of the intense neutron sources makes it possible to produce this isotope in weighable amounts by means of the reaction $Li^6(n,\alpha)H^3$. The radiation consists of extremely low energy beta-particles and therefore its detection demands the use of special instruments, it being necessary to introduce the material in the form of a gas into the inside of the Geiger-Müller counter, ionization chamber or electroscope.

Besides radioactive C^{14} and H^3, such isotopes as the 14.3-day P^{32}, the 87.1-day S^{35}, the 180-day Ca^{45}, the 47-day Fe^{59}, the 250-day Zn^{65}, the 55-day Sr^{89}, the 8-day I^{131} and many others have offered and will offer many opportunities for important research.

The first and most obvious application in organic chemistry for C^{14} would be in an examination of the mechanisms of many isomerizations and rearrangements of organic molecules. There are a number of reactions in which carbon atoms or groups of carbon atoms move from one part of a molecule to another and the question of just how this migration is accomplished has been a subject for discussion among organic chemists for mnny years. By labelling the migrating groups in certain positions it should be possible to determine the precise sequence of events in such a reaction. In many types of rearrangements it is impossible to tell, by ordinary means, which carbon atoms are actually migrating. It is easy to see how a selective labelling of atoms would allow an unequivocal answer to these questions to be obtained.

This type of information is of interest not only for itself and the light it will throw upon the behaviour of organic substances, but it is a necessary preliminary to the synthesis of tagged compounds of biological interest and to the examination by degradation of metabolic products derived from administered labelled materials.

It is in this latter field of biochemistry that the carbon isotopes will have their greatest usefulness. The determination of the intermediary metabolism of the major structural and energy-transforming materials of living organisms such as fats, proteins and carbohydrates, as well as the catalytic or organizing substances such as vitamins, hormones and enzymes. will undoubtedly make great strides as a result of the availability of isotopic carbon and some of the other isotopes as well. Turning to biological systems there is a virtually unlimited field of important work for the organic chemist and workers in all branches of biology.

It is not out of the question that a complete understanding of the photosynthetic mechanism might give men the ability to synthesize food and fuel at will, using this principle. This could give rise to a literal harnessing of the sun's energy. With the aid of C^{14} this might be accomplished. A number of experiments have been performed with the 20.5-minute C^{11}, but this short half-life placed definite limits on the extent of progress which was possible. Nevertheless. Ruben, Kamen and W. Z. Hassid were able to use radioactive C^{11} in a study of photosynthesis in which considerable progress was made. Radioactive carbon dioxide was fed to the unicellular green alga *Chlorella* and also to higher plants under various controlled conditions in the light as well as in the dark. The results obtained by 1947 were quite interesting. The higher plants and the algae absorb carbon dioxide in the dark. This process takes place concurrently with the release of CO_2 by respiration, so that the net effect is an evolution of carbon dioxide. Only by the tracer technique was it possible to demonstrate a simultaneous uptake and evolution of carbon dioxide. The dark uptake of carbon dioxide is likely the first step in photosynthesis and can be represented by the equation $RH + CO_2 \rightleftharpoons RCOOH$. Decarboxylation experiments have shown that the bulk of the radioactive carbon is in the carboxyl group. Attempts to identify the radioactive substances formed in the dark and in the light had been unsuccessful up to 1947. It is of considerable interest to note that formaldehyde, which has played a prominent role in many proposed mechanisms, was not identified from the radioactive carbon dioxide introduced. Experiments with the ultracentrifuge and diffusion methods indicate the average molecular weight of the radioactive molecules to be about 1,000, which explains the failure to identify chemically these molecules with any small molecules.

The radioactive elements, in particular radioactive carbon, will of course receive widespread use in studying animal metabolism. Some examples may be used to illustrate in a general way the manner in which these elements may be used as an aid in the solution of such problems. Thus, in the highly intricate process of carbohydrate metabolism in man, present knowledge has been gained, for the most part, only as a result of painstaking analytical work by classical methods. In general these methods are not capable of high precision, and are not adapted for the determination of highly labile compounds. Thus it is quite likely that many important details of the process under investigation have not been revealed. Almost certainly, the use of radioactive tracers will bring these details to light. Aside from circumventing many analytical difficulties, the use of labelled elements can yield important information not possible by other methods. It is often the case in biological systems that reactions proceed under steady-state conditions. With radioactive tracers it is possible to follow the formation of a compound in the presence of a considerable amount of the previously synthesized compound or to measure synthesis while the net reaction constitutes breakdown. Such measurements will be of great value in determining the mechanisms of biological reactions. For example, B. Hastings and his collaborators at Harvard have used C^{11} in the study of glycogen formation in the liver, and have found that the incorporation of carbon dioxide into organic molecules takes place there. Many carbon dioxide incorporating reactions have been studied with C^{13} by H. G. Wood and C. H. Werkman. The present availability of C^{14} will make possible the elucidation of many mechanisms in the metabolism of carbohydrate and fat. Many biologists believe that artificial radioactivity has given biology and medicine what is probably the most useful tool for research after the discovery of the microscope because almost all of the elements and compounds in biological systems can be tagged and their course through living systems studied.

The most simple and direct use of an element as a tracer is accomplished by its administration as a simple inorganic compound, in which case the distribution of the tagged element in the various structures of the plant or animal is determinerl by measuring the radioactivity of the samples of tissues and body fluids. A large number of experiments of this type have been performed, principally to aid in the understanding of mineral metabolism. For example, the absorption of iron as related to anaemia has been studied by G. H. Whipple and P. F. Hann at the University of Rochester.

Radiophosphorus because of its availability has been the most widely used of all the artificially prepared radioelements as a tracer for metabolic studies in biological systems. The distribution of administered phosphorus in human and animal tissues has been extensively studied. For example, it has been observed that the retention of a single dose of disodium phosphate varied in different tissues in the following decreasing order: bone, muscle, liver, stomach plus small intestines, blood, kidney, heart, lungs and brain. In other experiments there was found to occur a selective accumulation of radiophosphorus in leucaemic tissues. This was important in that it indicated that the leucaemic tissues could be subjected to a greater degree of beta-particle irradiation than would the normal tissues, which in turn indicated the application of radiophosphorus as a potentially valuable therapeutic agent.

The synthesis of the biologically important organic phospholipids has been studied by G. Hevesy and co-workers in Copenhagen, Denmark, and I. L. Chaikoff and co-workers in California. It is compounds like these that are now considered to be vital links in the complex low temperature oxidation mechanisms characteristic of living systems. Chaikoff and associates have shown the importance of the liver in such synthesis and transport; how the turnover of these substances through the liver can be altered by the administration of choline and certain amino acids and how newly synthesized molecules are absent altogether from the blood when the liver is removed. Using surviving tissue slices they have demonstrated the dependence of the synthesis upon the proper functioning of certain respiratory enzyme systems.

The first real insight into the mechanism of the action of insulin on carbohydrate metabolism has come from the studies of J. Sacks at Michigan with P^{32} on the effect of this hormone on the turnover of phosphorus compounds in muscle. All of these studies, of which only a few were mentioned, would have been impossible without the use of a labelling agent.

Extensive metabolic studies have been made with the use of radioactive iodine as an indicator. The pioneering work in this field was done by S. Hertz and his co-workers in Boston, Mass., and J. G. Hamilton and co-workers at California. The thyroid gland, through its synthesis of the iodine-containing hormone, thyroxine, controls the metabolic rate of the entire organism. Nevertheless, the quantities of iodine compounds produced and distributed are so small that even the finest micromethods are hardly adequate fur the task of studying these processes. With the use of radioactive iodine the analytical difficulties can be largely overcome, and in addition, types of measurements can be made which are not possible from chemical analysis.

Among the measurements that have been made with radioactive iodine are the uptake of orally administrred radiviodine by the intact thyroid glands of normal human subjects and by the thyroid glands of patients suffering from various types of thyroid disorder. The course of the uptake may be simply followed by placing a Geiger counter in the vicinity of the throat. The thyroids of patients with hypothyroidism were shown to accumulate iodine at a slow rate, while there was a relatively large uptake of administered iodine in the thyroid glands of patients with nontoxic goitres. In contrast to these behaviour patterns the thyroids of patients with hyperthyroidism were shown to take up administered radioiodine at a remarkably rapid rate, and also to discharge the iodine from the gland in a rapid iashion. It is seen from these studies of the behaviour pattern of the thyroid gland toward an administered dose of radioactive iodine that an aid toward diagnosing the condition of the thyroid gland is available.

A large amount of work on iodine metabolism has been done by Chaikoff, I. Perlman and M. E. Morton at the University of California. They were able to follow in some detail the distribution of organic iodine compounds from the thyroid gland through the blood to peripheral tissues in various states of thyroid activity. They were also able to demonstrate that, to a limited extent, tissues other than the thyroid gland are able to synthesize thyroxine; and by using isolated surviving tissues, they were again able to tie in the synthesis of an organic compound with the energy-producing enzyme systems.

B. C. Smith and E. H. Quimby at Columbia university have used the gamma radiations from intravenously injected $Na^{24}Cl$ to determine the rate of passage of sodium into the extracelluar phase of the tissues in cases of peripheral vascular disease, and thus determined the competency of the circulation, another example of use for diagnosis.

Many more possibilities for the use of radioactive isotopes in biochemical and physiological work might be suggested, but those given above suggest typical possibilities. Obviously, many of these problems arc of profound significance in terms of human weliare.

The study of the mechanism of action of antibiotic substances, many of which act by means not completely understood at present, will he possible. For example, the synthesis of radioactive penicillin or streptomycin mirht give rise to a method for investigating the mechanisms by which these great substances operate. The mechanism of action of antibodies might also be investigated by the use of tracers.

Another possible use of tracers is, of course, in the study of cancer. Here, in addition to the possibilities cited in connection with the use of radioactive indicators in the investigation of mechanisms, there is the therapeutic possibility of effecting the selective deposition of the radioactive material in the cancerous tissue, as has been mentioned in the case of leucaemia. It has occurred to many investigators that it should be possible in the future to synthesize some compound containing a radioactive substance, this compound having the property of being selectively absorbed by the cancerous tissue so that the radioactive rays can act directly at this spot without giving harmful effects on the body's healthy tissue.

Another possibility is that of tagging bacteria with radioactive C^{14}. This does appear to be feasible and to open great possibilities in the study of disease. In fact, Chaikoff and A. Kaplan have made a beginning by tagging the tuberculosis bacillus with radioactive phosphorus.

The therapeutic uses of radioactive substances have already been mentioned and the application of radioactive I^{131} in the work of Hertz and of Hamilton and M. H. Soley, to the treatment of patients suffering from hyperthyroidism has been outlined. Another place where therapeutic value has been established is in the work of J. H. Lawrence and co-workers who have had some success in the application of radioactive P^{32} to the temporary control of the blood diseases, polycythaemia vera and leucaemia. A large number of other therapeutic uses will surely be found. It will be possible to apply alpha-particles, beta-particles and gamma-rays to this purpose and it is worth pointing out that all of these radiations are represented in isotopes which can be produced in quantity so that it is quite likely that the use of radium and its descendents in this type of therapy will soon be superseded by the artificial radioactive elements.

The present availability of the large quantities of radio-activities has opened the possibility oi their use in industry and industrial processes. It will be possible to use radioactive indicators to follow the course of products and impurities in large industrial processes. Applications should be iound in the testing of the efficiency of distillation apparatus, in testing for leaks, and in many other ways. The intense sources of gamma-rays will find application in the field of radiography to look for imperfections in metal products, to study the path of fast moving parts and other applications.

With respect to chemical problems of direct interest to industries, many examples could be cited. Among these may be mentioned studies, with C^{14}, of the mechanism of catalytic cracking, isomerization and alkylation of hydrocarbons which are of profound interest to the oil industry. The future seems to hold unlimited possibilities for the application of radioactive tracers to scientific problems. It is certain that the applications of radioactive tracers which have been made so far arr just the beginning of what is going to become an extremely large and successful field of research.

BIBLIOGRAPHY.—G. von Hevesy and F. 4 . Paneth, *A manual of Radioactivity* (London, 1938) ; G. T. Seaborg. "Artificial Radioactivity." *Chemical Reviews,* vol. 27 (Aug. 1940) ; E. Pollard and W. L. Davidson, Jr., *Applied Nuclear Physics* (1942) ; F. Rasetti. *Elements of Nuclear Physics* (New York, 1936) ; G. T. Seaborg, "Table of Isotopes," *Reviews of Model-f~Physics,* vol. 16 (Jan. 1944) ; Summary of "Nuclei Formed in Fission" (Issued by the Plutonium Project), *Journal of the American Chemical Society,* vol. 68 (Nov. 1946) and *Reviews of Modern Physics,* vol. 18, No. 4 (Oct. 1946) ; J. Mattauch and S. Fluegge, *Nuclear Physics Tables* (New York, 1947) ; H. Semat, *Introduction to Atomic Physics* (New York. 1946) ; G. T. Seaborg. "The Transuranium Elements," *Science,* vol. 104 (Oct. 25, 1946) ; N. Feather, *Nuclear Physirs* (London, 1936); M. D. Kamen, *Radioactive Tracers in Biology* (New York, 1947). (G. T. Sc.)

RADIOACTIVITY, NATURAL. The subject of radioactivity deals with the spontaneous emission'of energy by matter. The phenomenon was first observed in 1896 as a natural occurrence. exhibited to a significant extent only by the elements of greatest atomic weight (uranium. thorium and certain other elements associated with them in nature in very small amount). As detailed below: its early study led to revolutionary changes in man's ideas concerning the structure of matter. Then, when these new ideas had become commonplace through familiarity, it was discovered in 1934 that radioactive varieties of elements not naturally radioactive could be produced by artificial transmutation (see RADIOACTIVITY, ARTIFICIAL). Furthermore, it was soon recognized that this induced radioactivity is of essentially the same character as the natural activity of the heavy radioelements. As a result of this new discovery the subject of radioactivity was enlarged. within a period of a few months, to cover all the elements from hydrogen to uranium, but it was also divided, for strong methodological reasons. according to the categories "natural" and "induced." in spite of its recognized unity. The situation was not changed when radioactive varieties of previously unknown elements, belonging to positions in the periodic table beyond that of uranium, were produced in profusion artificially-, nor when some of the naturally-occurring radioelements were similarly produced: the division remained valid for reasons of history. That division is accepted here: it is justified by the fact that the "classical" study of radioactivity provided the basis for a great proportion of the fundamental developments in physics over a period of more than 30 years, and by the consideration that at the end of that period it also provided the means of transmutation by which the first artificially-produced radioelements were formed. This article, then, attempts to give the history of classical radioactivity, as well as the facts available by the mid-1950s regarding the naturally-occurring radioelements.

History.——At the beginning of the period thus covered, ideas concerning the structure of atoms were entirely speculative. The study of radioactive processes and radiations led, in a few years, to the realization that atoms, in certain cases, are not permanently stable (E. Rutherford and F. Soddy, 1903). In a few more years it led to the conclusion that, so far as mass is concerned, the atom is mostly emptiness—almost the whole of the mass is concentrated in a nucleus, occupying roughly one-billionth (10^{-12}) of the total volume (Rutherford, 1911). It led to artificial transmutation, the modification of an atomic nucleus caused by an external agency, in a few years more (Rutherford. 1919),; and two years before the discovery that such modifications might lead to newly formed nuclei which are artificially radioactive (Irène and Frédéric Joliot-Curie, 1934) the neutron was discovered as a product of transmutation (J. Chadwick, 1932). This last discovery proved basic for any success which theories of nuclear structure later achieved; also, practically. it may be held that its exploitation has already wrought greater changes in world affairs than the manifold exploitation of the discovery of the electron has wrought over, more than twice as many years.

The beginning of the study of radioactivity dates from Feb. 1896, and was an indirect consequence of the discovery of the X-rays made a few months earlier by W. C. Rontgen. It was known that the production of X-rays in a vacuum tube was accompanied by a strong phosphorescence of the glass. and it occurred to several investigators that ordinary substances made phosphorescent by visible light might emit a penetrating radiation similar to X-rays. Following out this idea. A. H. Becquerel exposed among other substances a phosphorescent compound of uranium (uranium potassium sulphate) placed in position on a photographic plate enveloped in black paper. A weak photographic effect was obtained. This was shown to be caused by a penetrating radiation capable of passing through sheets of matter opaque to ordinary light. Further investigation showed that this photographic action was exhibited by all compounds of uranium and by the metal itself, and had nothing to do with phosphorescence. It was shown that if the uranium were kept in darkness its action did not vary appreciably with time.

Becquerel showed that the rays from uranium, like the X-rays, were capable of discharging a body whether positively or negatively electrified. A uranium compound brought close to the charged plate of a gold leaf electroscope causes a rapid collapse of the gold leaves. A modified form of gold leaf electroscope was frequently employed by earlier workers for the purpose of comparing the radioactivity of substances. Rutherford (1899) made a systematic study of the discharging effect produced by the rays from uranium and showed that it was caused by the production of charged carriers or ions in the volume of the gas through which the radiations pass. In an electric field, the positive ions travel to the negative electrode (cathode) and vice versa. thus causing the discharge of the electrified body. If the gas is contained in an ionization chamber and a sufficiently strong field is applied, the ions are all swept to the electrodes before appreciable loss of their number can occur by recombination. The ionization current then reaches a steady maximum value which is not altered by a large increase in voltage. The maximum current through the gas is called the saturation current: its value is proportional to the intensity of the incident radiation. The ions produced in a gas by the rays from uranium and other radioactive substances are identical with those produced by X-rays, and the mechanism of conductivity of the gas is the same in the two cases (see ELECTRICITY, CONDUCTION OF: Conduction *in Gases*).

Radioactive Substances Separable from Uranium and Thorium Minerals.—Some time after Becquerel's discovery, Marie Curie made a systematic examination by the electric method of a large number of chemical elements and their compounds to test whether any possessed the radioactive property of uranium. Only one other element, thorium, was found (1898) to show this effect to a degree comparable with that of uranium—a result independently observed by G. C. Schmidt. Mme. Curie also examined the activity of the various compounds of uranium and found that their radioactivity was an atomic property, *i.e.,* the activity was proportional to the amount of the element uranium present and was independent of its combination with other substances. In testing the activity of the minerals containing uranium, however, she found that the activity was always four or five times as great as that to be expected from their uranium content. If the radioactivity were an atomic phenomenon. this could only be explained by the presence in these minerals of another substance more active than uranium itself. Relying on this hypothesis. Mme. Curie made a chemical examination of uranium minerals in order to try to separate this new radioactive substance. For these experiments. the Austrian government generously provided her with a ton of the residues from the state manufactory of uranium at Joachimsthal (Jachymov). Bohemia. From these residues. which were three to five times as radioactive. weight for weight. as uranium, Mme. Curie separated a substance far more radioactive, which she called polonium in honour of the country of her birth. This substance is usually removed nith the bismuth in the mineral, but by special methods can be separated from it. A further examination (P. and M Curie and G. Bémont, 1898) revealed the presence of a second radioactive substance which is normally separated with the barium; to this second substance the name radium was given. By means of successive fractionations of the chloride, the radium was gradually concentrated, until finally it was obtained nith a specific activity more than a million times greater than that of uranium. The atomic neight was determined as about 225, and a characteristic spark spectrum of bright lines, analogous in many respects to the spectra of the alkaline earths, was observed. From the chemical point of view radium possessed all the characteristic properties of a new element. It had a definite atomic weight, a well-marked and characteristic spectrum and distinct chemical properties. Its comparative ease of separation and great' activity attracted much attention, although similar radioactive properties are possessed by a large number of other substances, equally distinct chemically. F. O. Giesel in the early days took an active part in the preparation of pure radium compounds and was the first to place preparations of pure radium bromide on the market. He found that the separation of radium from the barium mixed with it proceeded much more rapidly if the crystallizations nere carried out using the bromide instead of the chloride. He stated that six or eight crystallizations are sufficient for an almost complete separation.

In addition to polonium and radium, many other radioactive substances have been separated from uranium and thorium minerals with a specific activity comparable with that of radium, although only one of them has been isolated in a pure state. This last is protactinium, discovered independently by O. Hahn and L. Meitner and Soddy and J. A. Cranston in 1918 The others are actinium. discovered by A. Debierne (1899), ionium. discovered by B. B. Boltnood (1907) and radiothorium (1905) and mesothorium (1907), discovered by Hahn.

Besides these substances, in which the duration of the activity is measured by years, many more radioactive bodies have been found which have a transient activity lasting only seconds. minutes or hours. From the scientific point of view. these short-lived radioactive substances are just as important as those which have a much longer life.

Emanations or Radioactive Gases.—In addition to their power of emitting penetrating radiations, the substances thorium, actinium and radium possess another striking and important property. Rutherford first showed (1900) that thorium compounds (especially the oxide) continuously give rise to a radioactive emanation or gas. This emanation can be carried away by a current of air and its properties tested apart from the substance which produces it. The emanations from all three substances possess the property of ionizing gases with which they are mixed. This activity of the emanations is not permanent but disappears according to a definite law with the time, *i.e.*, the activity falls off in a geometrical progression as time increases arithmetically. The three emanations are distinguished by the different rates at which they lose their activity. The emanation of actinium is very short lived, the time for the activity to fall to half value (half-value period) being 3.92 sec. The corresponding time for the thorium emanation is 54.j sec. and for the radium emanation 3.825 days. The property of giving off an emanation is shown in a striking manner by actinium. A compound of actinium is wrapped in a sheet of thin paper and laid on a screen of phosphorescent zinc sulphide. In a dark room the phosphorescence. marked by the characteristic scintillations, is seen to extend on all sides from the active body. A puff of air removes the emanation and with it the greater part of the phosphorescence. Fresh emanation immediately diffuses out and the experiment may be repeated indefinitely. The emanations have all the properties of ordinary gases. although they are intensely radioactive. They can be transferred from point to point by currents of air. They can be separated from the air. or other gas with which they are mixed. by the action of extreme cold. Rutherford and Soddy showed that under ordinary conditions the temperature of condensation of the radium emanation mixed with air is — 150° C.

Rutherford and Soddy also made a systematic examination of the emanating power of thorium compounds under different conditions. The hydroxide emanates most freely, while from thorium nitrate practically none of the emanation escapes into the air. Most preparations of actinium emanate freely. Radium compounds, except in very thin films, retain most of the emanation. The occluded emanation can in all cases be released by solution or by heating. On account of its relatively long period of decay, the emanation of radium can be collected like a gas and stored, when it retains its characteristic properties, in some degree, for a month or more. A more detailed account of the properties of the radium emanation will be given later.

Active Deposits.—The radioactive emanations possess another interesting and important property. The surface of any body exposed in the presence of an emanation acquires a temporary activity. Like the emanations, this induced activity, as it was first termed (M. Curie?1899), decays with time, though at a rate quite different from that of the emanation which causes it. The bodies made active behave as if they were covered by a very thin film of intensely active matter (Rutherford, 1900). This active coating can be partly removed by rubbing the surface, and can be dissolved by strong acids. On evaporating the acid, the active matter remains behind unchanged in amount. The active deposit obtained on a platinum mire or plate can be volatilized at a white heat, and redeposited on the cooler bodies in the neighbourhood. The activity can be concentrated to some extent on the negative electrode in a strong electric field, indicating that the radioactive matter carries a positive charge. This activity produced on inactive bodies is caused by a deposit of nongaseous matter derived from the transformation of the emanations. Each emanation gives a distinctive active deposit which decays at a characteristic rate. The active deposits of radium, thorium and actinium are complex substances, and consist of many distinct products. Several hours after removal from the emanation the active deposit of radium decays to half value in 27 min., that from actinium to half value in 36 min., that from thorium to half value in 10.6 hr.

Radiations from Radioactive **Substances.**—All radioactive substances possess in common the property of emitting radiations that darken a photographic plate and produce electrical conductivity in gases through which they pass. Very active preparations also possess the property of causing marked phosphorescence in some substances. Bodies that phosphoresce under X-rays usually do so under rays from radioactive matter. Barium platinocyanide, the mineral willemite (zinc silicate) and zinc sulphide are the best-known examples.

There are in general three types of radiation emitted by radioactive bodies; these have been named alpha (a), beta (β) and gamma (γ) radiations. Rutheriord in 1899 showed that the radiation from uraniurn is complex, consisting of (a) an easily absorbed radiation, stopped by a sheet of paper or a few centimetres of air, these he called a rays, and (b) a far more penetrating radiation, capable of passing through several millimetres of aluminum, and these he called β rays. Later, P. Villard found (1900) that radium emits an extremely penetrating kind of radiation capable of detection through 20 cm. of iron or several centimetres of lead. To this last the name γ-radiation was subsequently applied.

Alpha Rays.—These rays consist of a stream of material particles which are projected at high speed from radioactive matter. The α particles from all types of radioactive matter are identical in mass and consist of charged atoms of helium projected with velocities of about 10,000 mi. per second. The a particles are expelled from each radioactive substance with a characteristic speed and have a definite distance of travel or range in matter before being stopped. The ranges of the α particles from the different radioactive substances vary between about 2.5 cm. and 8.j cm. in air at standard pressure and temperature. Most of the energy emitted from radioactive bodies is associated with the a rays.

Beta Rays.—Beta rays consist of a stream of electrons which are projected with high velocities, approaching in 'some cases that of light. Contrary to what happens in a emission! a radioactive body emits β particles over a considerable range of velocity.

Gamma Rays.—These rays, which are generally of a very penetrating character, have been shown to be of the same nature as X-rays. The most penetrating of the γ rays accompany the emission of β rays. Differing from the α and β particles, the γ rays are undeflected by a magnetic or an electric field. In general the γ rays from a radioactive body consist of groups of electromagnetic radiations of widely different frequencies.

The three types of radiation from active bodies are analogous in many respects to the radiations produced by the passing of an electric discharge through a vacuum tube at low pressure, but the individual particle energy is on a much higher scale. In order to produce electrons of speed corresponding to those emitted by radium C, a voltage of 3,000,000 would have to be applied to the tube, and to excite X-rays of the frequency of the γ rays of this body 2,500,000 v. would be necessary. Similarly the energy of the α particle from radium C' corresponds to nearly 8,000,000 ev. (electron volts).

Theory of Radioactive Transformations.—Radioactive bodies spontaneously, and over considerable periods of time, emit a great number of α and β particles. In addition, new types of matter, such as emanations and active deposits, appear and these are quite distinct in chemical and physical properties from the parent matter. This radiating power is an atomic property. for it is unaffected by combination of the active element with inactive bodies, and is uninfluenced by the most powerful chemical and physical agencies at the physicist's command.

In order to explain these results, Rutherford and Soddy in 1903 put forward a simple but comprehensive theory. It assumed that the atoms of radioactive matter (unlike the atoms of ordinary elements) are unstable and that each second a definite fraction of the number of atoms present spontaneously breaks up with explosive violence, each atom expelling either an α particle or a β particle with great velocity. Taking as a simple illustration the case in which an α particle is expelled during the explosion. the resulting atom has decreased in mass and possesses chemical and physical properties entirely distinct from those of the parent. Considering the individual process multiplied many billionfold, a new type of matter has thus appeared as a result of the transformation. The atoms of this new matter are again unstable and break up in turn, the process of successive disintegrations of the atom continuing through a number of distinct stages. On this view, for example, the radium emanation is a new substance derived from the transformation of radium. The atoms of the emanation are far more unstable than the atoms of radium and break up at a much quicker rate.

The law of radioactive transformation according to this theory will be considered at this point. It is experimentally observed that, with all simple radioactive substances, the intensity of the radiation decreases in a geometrical progression as time increases arithmetically, *i.e.*, $I/I_0=e^{-\lambda t}$, where I is the intensity of the radiation at any time, t, I_0 the initial intensity, and λ is a constant. Now according to this theory, the intensity of the radiation is proportional to the number of atoms breaking up per second. From this it follows that the atoms of active matter present decrease in a geometrical progression with increasing time, *i.e.*, $N/N_0=e^{-\lambda t}$, where N is the number of atoms present at a time, t, N_0 the initial number, and λ the same constant as before. Differentiating: $dN/dt=-\lambda N$, thus λ represents the fraction of the total number of atoms present which break up per second. The radioactive disintegration constant λ has a definite and characteristic value for each type of matter. For many purposes it is convenient to distinguish the products by stating the time required for one-half the initial number of atoms to decay. This is termed the half-value period of the product and is numerically equal to $\log_e 2/\lambda$. The average life of the atoms of a product before transformation is given by $1/\lambda$. As far as observation has gone, the law of radioactive change is applicable to all radioactive species (radioisotopes) without exception. It appears to be an expression of the law of probability, for the average number breaking up per second is proportional to the number present. From this point of view the number of atoms breaking up per second should have a definite average value, but this number should vary from second to second within certain limits predictable according to the theory of probability. The theory of this effect was first put forward by E. Schweidler (1905) and was later verified by a number of experimenters, including K. W. F. Kohlrausch, S. Meyer, and E. Regener and H. Geiger. This variation in the number of atoms breaking up from moment to moment becomes marked with weak radioactive preparations when, on the average, only a few atoms break up per second. The variations observed are in good agreement with those to be expected from the theory. This effect does not in any way invalidate the law of radioactive change: on an average the number of atoms of any simple kind of matter breaking up per second is proportional to the number present.

Next it is required to calculate how the amount of a radioactive product, which is supplied at a constant rate from a source. varies with the time. As example, the case of the production of emanation by radium will be considered. The rate of transformation of radium is so slow, compared with that of the emanation. that it may be assumed without sensible error that the number of atoms of radium breaking up per second (*i.e.*, the supply of fresh emanation) is on the average constant over the interval required. Suppose that initially radium is completely freed from emanation. In consequence of the steady supply the amount of emanation present increases. but not at a constant rate, for the emanation is in turn breaking up. Let q be the number of atoms of emanation produced by the radium per second and N the number present after an interval t, then $dN/dt=q-\lambda N$, where λ is the disintegration constant of the emanation. It is obvious that a steadv state will ultimately be reached when the number of atoms of emanation supplied is on the average equal to the number of atoms which break up per second. If N_0 be the final steady value, $q=\lambda N_0$. Integrating the previous equation it follows that $N/N_0=1-e^{-\lambda t}$. If a curve is plotted (fig. 1) with N as ordinate and the time as abscissa, it is seen that the recovery curve is complementary to the decay curve of the emanation alone. The abscissae of fig. 1 represent multiples of the time T for half the product to be transformed. The activity of the emanation falls to ½ in the time T. to ¼ in the time 2 T, and so on.

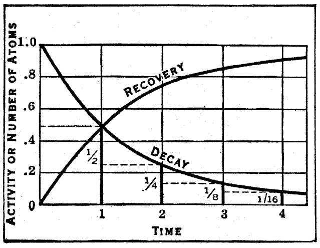


FIG 1—CURVES ILLUSTRATING THE EXPONENTIAL LAW OF DECAY AND RECOVERY OF RADIOACTIVITY

This process of production and disappearance of active matter holds for all the radioactive bodies belonging to a disintegration series. Some special cases of the variation of the amount of active matter with time which have proved of great importance in the analysis of radioactive changes follow.

(a) Suppose that initially the matter A is present and that this changes into B, and B into C; it is required to find the numbers of atoms, P, Q and R, of A, B and C present at any subsequent time t.

Let $\lambda_1, \lambda_2, \lambda_3$ be the decay constants of A, B and C respectively. Suppose n is the number of atoms of A initially present. From the law of radioactive change it follows:

$$P=n\,e^{-\lambda_1 t},$$
$$dQ/dt=\lambda_1 P-\lambda_2 Q, \qquad (1)$$
$$dR/dt=\lambda_2 Q-\lambda_3 R. \qquad (2)$$

Substituting the value of P in terms of n in (1),

$$dQ/dt=\lambda_1 n\,e^{-\lambda_1 t}-\lambda_2 Q;$$

the solution of which is of the form

$$Q=n(ae^{-\lambda_1 t}+be^{-\lambda_2 t}),$$

where a and b are constants. By substitution it is seen that $a=\lambda_1/(\lambda_2-\lambda_1)$. Since $Q=0$ when $t=0$, $b=-\lambda_1/(\lambda_2-\lambda_1)$.

Thus $$Q=\frac{n\lambda_1}{\lambda_2-\lambda_1}(e^{-\lambda_1 t}-e^{-\lambda_2 t}). \qquad (3)$$

Similarly it can be shown that

$$R=n(a\,e^{-\lambda_1 t}+b\,e^{-\lambda_2 t}+c\,e^{-\lambda_3 t}) \qquad (4)$$

where

$$a=\frac{\lambda_1\lambda_2}{(\lambda_1-\lambda_2)(\lambda_1-\lambda_3)},\quad b=\frac{\lambda_1\lambda_2}{(\lambda_2-\lambda_3)(\lambda_2-\lambda_1)},\quad c=\frac{\lambda_1\lambda_2}{(\lambda_3-\lambda_1)(\lambda_3-\lambda_2)}$$

It will be seen from (3) that the value of Q, initially zero, increases to a maximum and then decays according to an exponential law with the period of the more slowly transformed product, whether A or B.

(*b*) A primary source supplies the matter A at a constant rate, and the process has continued so long that the amounts of the products A, B, C have reached steady limiting values. The primary source is then suddenly removed. It is required to find the amounts of A, B and C remaining at any subsequent time t.

In this case of initial equilibrium, the number n_0 of atoms of A supplied per second from the source is equal to the number of atoms which change into B per second, and also from B into C. This requires the relation $n_0=\lambda_1 P_0=\lambda_2 Q_0=\lambda_3 R_0$ where P_0, Q_0, R_0 are the initial numbers of atoms of A, B, C, present and $\lambda_1, \lambda_2, \lambda_3$ are their constants of transformation.

Using the same notation as in case (a), but remembering the new initial conditions, it can easily be shown that the numbers of atoms, P, Q and R, of A, B and C existing at the time t after removal of the source are given by

$$P=\frac{n_0}{\lambda_1}e^{-\lambda_1 t},$$
$$Q=\frac{n_0}{\lambda_2-\lambda_1}\left(e^{-\lambda_1 t}-\frac{\lambda_1}{\lambda_2}e^{-\lambda_2 t}\right),$$
$$R=n_0(ae^{-\lambda_1 t}+be^{-\lambda_2 t}+ce^{-\lambda_3 t}),$$

where

$$a=\frac{\lambda_2}{(\lambda_1-\lambda_2)(\lambda_1-\lambda_3)},\quad b=\frac{\lambda_1}{(\lambda_2-\lambda_3)(\lambda_2-\lambda_1)},\quad c=\frac{\lambda_1\lambda_2}{\lambda_3(\lambda_3-\lambda_1)(\lambda_3-\lambda_2)}.$$

The curves expressing the variation of P, Q, R with time are in this case quite different from those obtained in case (*a*).

(*c*) The matter A is supplied at a constant rate from a primary source. Required to find the numbers of atoms of A, B and C present at any time t later, when initially A, B and C were absent.

This case is closelv related to case (*b*) and the solution can be obtained from general considerations. Initially suppose A, B and C are in equilibrium with the primary source which supplies A at a constant rate. The source is then removed and the amounts of A, B and C remaining vary according to the equations given under (*b*). But the source after removal continues to produce A at the same rate as before. Since initially the product A was in equilibrium with the source and the radioactive processes are in no way changed by the removal of the source, it is clear

that the total amount of A present is unchanged. It is merely divided between two portions. If P_1 is the amount of A present with the source at the time t and P the amount remaining in the part from which the source was removed at $t=0$, then $P_1+P=P_0$, where P_0 is the equilibrium value.
Thus

$$\frac{P_1}{P_0}=1-\frac{P}{P_0}.$$

The ratio P/P_0 can be written down from the solution given in case *(h)*. Similarly, the corresponding values of Q_1/Q_0, R_1/R_0 may be at once derived. It is obvious in these cases that the curve plotted with P_1/P_0 as ordinate and time as abscissa is complementary to the corresponding curve with P/P_0 as ordinate. This simple relation holds for all recovery and decay curves of radioactive products in general.

The variation in the numbers of atoms of successive products with time when the periods of the products are known, have so far been considered. In practice, the variation of the numbers of atoms is deduced from measurements of activity. Using the same notation as before, the activity of any product, such as A, is proportional to its rate of breaking up, *i.e.*, to $\lambda_1 P$, where P is the number of atoms present. If two products are present, the activity is the sum of two corresponding terms, $\lambda_1 P$ and $\lambda_2 Q$—at least if activity is'dctermined by the counting of particles. If it is measured by the ionization method, and the particle from the second product produces K times the ionization produced by the particle from the first product, the activity observed is proportional to $\lambda_1 P+K\lambda_2 Q$. In this way it is possible to compare the theoretical activity curves of a mixture of products with those obtained experimentally.

Analysis of Radioactive Changes.—The analysis of the successive changes occurring in uranium, thorium. radium and actinium proved a difficultmatter. In order to establish the existence of a new product and to fix its position in the scheme of changes, it is necessary to show (a) that the new product has a distinctive period of decay and shows some distinctive physical or chemical properties; (b) that the product under consideration arises directly from the product supposed to precede it in the scheme of changes and is transformed into the product which is regarded as its successor.

In general, it was found that each product showed some distinctive chemical or physical behaviour which allowed its partial or complete separation from a mixture of other products. It must be remembered that in most cases the amount of radioactive matter under examination was too small to be detected by weight, but its presence was inferred from its characteristic radiations and rate of change. In some cases, a separation could be effected by ordinary chemical methods; *e.g.*, thorium X is separated from thorium by precipitation of thorium with ammonia. Thorium X remains in the filtrate and is practically free from thorium. In other cases, a separation was effected by deposition on a metal from the solution of active matter; for example, polonium (radium F) always is deposited on bismuth and may be separated by placing a bismuth plate in a solution containing it. Radium C is separated from radium B by adding nickel filings to a solution of the two in dilute hydrochloric acid; radium C is deposited on the nickel. In other cases a partial separation was effected by electrolysis. or by making use of differences in volatility; *e.g.*, when radium A, B and C are deposited on a platinum plate, on heating the plate, radium B is volatilized first and may be deposited on any cold surface in the neighbourhood. A striking method of separating certain products depends upon the recoil of an atom which breaks up with the expulsion of an α particle. Some of the residual atoms acquire sufficient velocity in consequence to escape from the parent source and be deposited on bodies in the neighbourhood. This is specially marked when the parent source is in the form of a very thin layer on a clean surface. This property was first investigated by S. Russ and W. Makower and by Hahn. Hahn showed that by means of recoil actinium C″ may be obtained pure from the active deposit containing actinium B and C, for actinium C emits α rays and actinium C″ is driven from the plate by the recoil. In a similar way a new product, thorium C″, was isolated, and radium B was separated from radium A and C.

As the analysis of the successive changes proceeded, products were identified which at first were thought not to emit any characteristic radiation, and these were called rayless products. Closer investigation has shown that in these cases. also, a radiation is emitted, a β radiation so easily absorbed that its presence is difficult to detect. The products actinium, mesothorium 1 and radium D belong to this class. It may be worth noting that the presence and properties of an intermediate product emitting a very feeble radiation can be readily inferred if in turn it is transformed into a product emitting a marked radiation. Thus. if in a preparation consisting initially of a pure product emitting an easily-detectable radiation—as in case (a) above—the radiations of a daughter product begin to appear, it can generally be decided whether the rate of growth of the daughter product is correctly described by equation (3) or equation (4) of the previous analysis. If (4) is applicable, even though no other radiation can be detected, it must be assumed that an intermediate product is involved. The disintegration constant of this rayless product can then be determined by accurate comparison of the observed growth curve of its daughter with the predictions of the theory.

In Table I a list is given of the remarkable series of daughter products formed from uranium, thorium and actinium. The system of nomenclature is not ideal; in general, products of average life greater than one year have been given distinctive names

TABLE I.—*Naturally Occurring Radioactive Species*

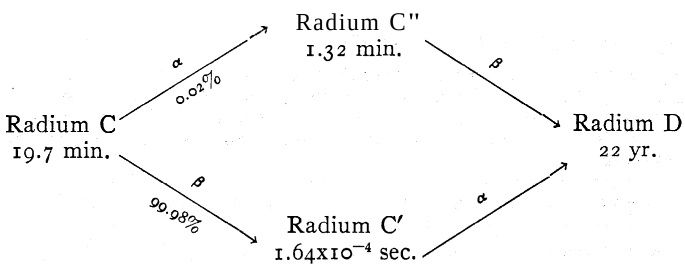
Radioactive species (parent bodies and daughter products)	Mass no.	Atomic no.	T (half-value period)	Type of change	Mean range of α rays in air (15°C. and 760 mm.)
Uranium-Radium series					
Uranium I	238	92	4.51×10^9 yr.	α	2.69
Uranium Xi	234	90	24.1 days	β	—
Uranium X2	234	91	1.17 min.	β	—
Uranium Z	234	91	6.7 hr.	β	—
Uranium II	234	92	2.50×10^5 yr.	α	3.26
Ionium	230	90	8.0×10^4 yr.	α	3.16
Radium	226	88	1,620 yr.	α	3.29
Radon (emanation)	222	86	3.825 days	α	4.05
Radium .4.	218	84	3.05 min.	α, β	4.66
Radium B	214	82	26.8 min.	β	—
Radium C	214	83	19.7 min.	β, α	4.08
Radium C′	214	84	1.64×10^{-4} sec.	α	6.91
Radium C″	210	81	1.32 min.	β	—
Radium D	210	82	22 yr.	β	—
Radium E	210	83	5.02 days	β, α	—
Radium F !Polonium)	210	84	138.3 days	α	3.84
Radium E″	206	81	4.2 min.	β	—
Radium G (end product, uranium-lead)	206	82	—	—	—
Thorium series					
Thorium	232	90	1.39×10^{10} yr.	α	2.49
Mesothorium 1	228	88	6.7 yr.	β	—
Mesothorium 2	228	89	6.13 hr.	β	—
Radiothorium	228	90	1.90 yr.	α	3.96
Thorium X	224	88	3.64 days	α	4.28
Thoron (emanation)	220	86	54.5 sec.	α	5.00
Thorium A	216	84	0.158 sec.	α	5.64
Thorium B	212	82	10.6 hr.	β	—
Thorium C	212	83	60.j min.	β, α	4.73
Thorium C'	212	84	3.0×10^{-7} sec.	α	8.56
Thorium C″	208	81	3.1 min.	β	—
Thorium D (end product, thorium-lead)	208	82		—	—
Actinium series					
Actinouranium	235	92	7.13×10^8 yr.	α	2.90
Uranium Y	231	90	25.6 hr.	β	—
Protactinium	231	91	3.53×10^4 yr.	α	3.52
Actinium	227	89	22 yr.	β, α	3.4
Actinium K	223	87	21 min.	β, α	(*c.* 4.0)
Radioactinium	227	90	18.6 days	α	4.71
Actinium X	223	88	11.2 days	α	4.32
Actinon (emanation)	219	86	3.92 sec.	α	5.69
Actinium A	215	84	$1\ 83\times10^{-3}$ sec.	α, β	6.46
Actinium B	211	82	36.1 min.	β	—
Actinium C	211	83	2.16 min.	α, β	5.43
Actinium C'	211	84	0.52 sec.	α	6.56
Actinium C″	207	81	4.79 min.	β	—
Actinium D (end product, actinium-lend)	207	82	—	—	—

(printed in italics). The successive products following the emanations are in all cases denoted by the letters A. B. C, etc. In some cases intermediate products nere discovered after a system of nomenclature had been accepted, and mere named to indicate as far as possible their positions in the series. As the radioactive emanations are now known to be isotopic, the names radon. thoron and actinon have been suggested as distinctive and indicative of the similarity of these products.

In the table, T is the half-value period of the product. It will be seen that the value of T, which is a measure of the relative stability of atoms, varies between 1.39×10^{10} yr. (thorium) and 3×10^{-7} sec. (thorium C'). The atomic weights of uranium, radium, uranium-lead. thorium, thorium-lead and protactinium have been directly determined by chemical methods, and the atomic numbers of uranium, thorium, and lead by standard X-ray methods. The mass numbers and atomic numbers of the other products are deduced on the assumption that the expulsion of an α particle (helium nucleus) reduces the charge (atomic number) of the radioactive nucleus by two units and the mass number by four units, whereas the expulsion of a β particle raises the atomic number by one unit, but does not change the mass number (see below).

Branch Products.—In the great majority of cases each radioactive product breaks up in one definite way, each atom giving rise to one α particle, or to one β particle and to one atom of the new product. Clear evidence, however, has been obtained that in a few cases the atoms of a single product break up in either of two alternative ways: they may emit either an α particle or a β particle. The two daughter substances thus produced then transform, in general, so as to give a common granddaughter.

The most striking cases of branching occur with the C products of radium, thorium and actinium, each of which breaks up in two distinct ways. In the radium series the scheme of transformation is



where the main branch is by way of a β disintegration to radium C', which emits an α particle and changes into radium D. Only 0.02% of the radium C atoms emit an α particle, forming radium C'', which emits a β particle. Radium C' has an exceedingly short period of transformation which was first measured approximately by J. C. Jacobsen (1926).

In the case of thorium C, two sets of α particles were early observed (Hahn, 1906), one-third of the total number having a range of 4.7 cm. and the more abundant group a range of 8.6 cm. Here (as with radium C) the main branch proceeds by a β ray change to the C' product, which gives rise to the particles of 8.6 cm. range and has an even shorter period than radium C'. The approximate half-value period of thorium C' was first determined by J. V. Dunworth (1939).

In the actinium series, the predominant (99.7%) process is α disintegration leading to the C'' product, only 0.3% proceeding by β disintegration to actinium C'.

The C products in all three series are isotopes of bismuth (see below) and in the radium series there is a second active isotope of this element, radium E. It is interesting to note that branching occurs with this product also. In 1947 E. Broda and N. Feather showed, by the method of recoil, that a β emitting thallium isotope, radium E'', is formed by α emission roughly once in every 3×10^6 disintegrations of radium E. Within a few years rare modes of α disintegration were also established with actinium and actinium K, and rare modes of β disintegration with radium A and actinium A.

One case of branching is of special interest as it differs from all others, and the description already given does not strictly apply to it This occurs in the sequence between uranium X_1 and uranium II. It was shown by Hahn (1921) that two alternative intermediate products, uranium X_2 and uranium Z, occur in this sequence Both these products are β emitters and the branching ratio is such that uranium Z is produced in a small fraction of the transformations only (variously determined as 0.2% to 0.6%). It is probable that uranium X_2 is produced directly from uranium X_1 in all disintegrations and that the formation of uranium Z is by a process of internal nuclear rearrangement which takes place as an alternative to β emission in a small fraction of transformations of uranium X_2. As uranium X_2 and uranium Z give rise to the same substance. uranium II by the same type of change, they must have not only the same atomic number but also the same mass number; their nuclei must therefore contain the same particles but in different configurations. Their discovery constituted the first recognized case of nuclear isomerism. This phenomenon is known to occur widely among the artificially produced radioelements (see RADIOACTIVITY, ARTIFICIAL); in fact long-lived isomers of radium E ($T=2.6\times10^6$ yr.) and actinium C' (T= a j sec.) were produced artificially in 1950–51, though they do not occur as members of the natural series.

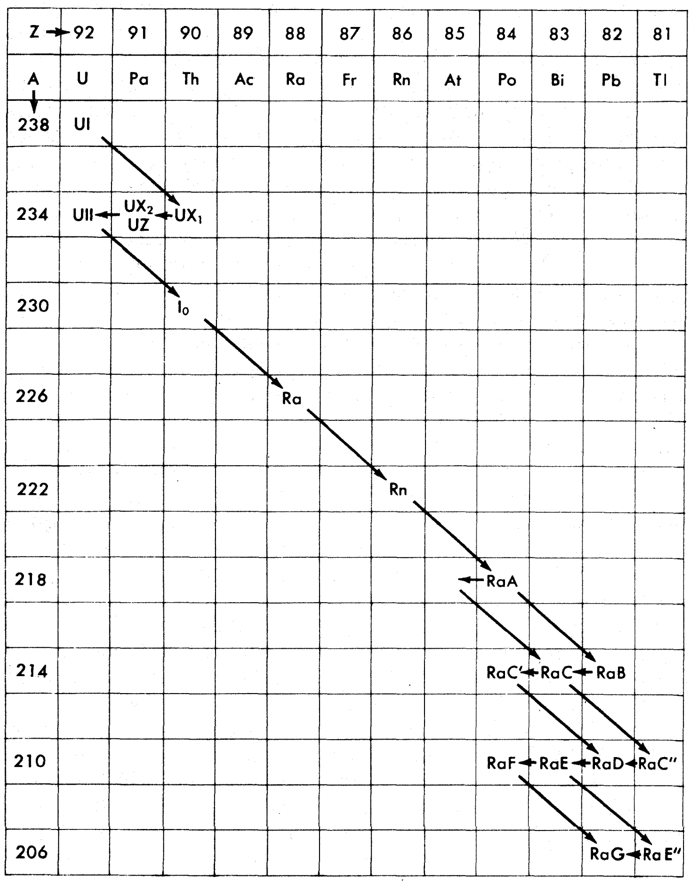
Chemistry of Radioelements (see RADIUM; URANIUM; etc.).—Throughout the classical period of research in natural radioactivity no one was able to obtain the radioactive products of short life in sufficient quantity to examine them by the ordinary chemical methods; but by the use of the radioactive method of analysis it was possible to form some idea of their chemical behaviour. Certain interesting points came to light. Soddy found that the two products radium and mesothorium, although quite dissimilar in radioactive properties, mere chemically so nearly identical that it was impossible by chemical methods to separate one from the other. Other pairings of the same kind had long been suspected. namely. thorium and radiothorium, thorium and ionium and radium D and lead. Soddy named such inseparable species isotopes, since they appeared to belong to the same place in the periodic classification of the elements. (See ISOTOPE.)

Following a detailed chemical study of the active species by Soddy. A. Fleck and G. von Hevesy, an important generalization relating the type of activity to the change in chemical behaviour was announced independently in 1913 by A. S. Russell, K. Fajans and Soddy. This displacement law states that the daughter product after α disintegration belongs to a place in the periodic table two lower than that of the α emitting parent, and the daughter product after β disintegration to a place one higher than that of its β emitting parent. For example, by loss of an α particle from ionium of Group IV, the resulting product, radium, belongs to Group II, and the loss of another α particle gives rise to the emanation which belongs to Group O, and so on. This displacement law soon received a simple explanation. From the work of H. G J. Moseley, the chemical properties of an element are defined by the atomic number, which represents the resultant positive charge of the nucleus. The loss of an α particle of mass 4, carrying two positive charges, lowers the atomic number by two, whereas the emission of a negatively charged β particle raises it by one. Thus, once the atomic number and the mass number of one member of a radioactive series have been determined, these quantities can be deduced for all other members of the series from a knowledge of the radiations emitted in the transformations. It is instructive to arrange the members of the different radioactive series as in figs. 2–4, where the atomic numbers are plotted as abscissae and the mass numbers as ordinates. It will then be seen that the three series exhibit a remarkable similarity after the three bodies of atomic number 90 (ionium, radiothorium and radioactinium).

The active species of the three series, taken together, have atomic numbers which cover the range from 81 to 92, inclusive. Of those elements with atomic numbers between 84 and 92, all isotopes are radioactive; for the common elements thallium (81), lead (82) and bismuth (83), some of the isotopes are radioactive, others are stable. Several active products are isotopic with one another, and this is often indicated by corresponding names; thus all the A products and all the C' products are isotopes of polonium, the C products are isotopes of bismuth. the B products of lead and the C'' products of thallium. The isotopes of lead are of special interest as they include the stable end products of the three series—a statement which will be discussed more fully later.

Transformation of Uranium.— In 1900 Sir William Crookes found that the β ray activity of ordinary uranium could be removed by a single chemical operation and concentrated in an active residue. This represents the separation of the product uranium X_1, of half-value period 24.1 days, which emits β rays and γ rays. A complete analysis of the transformations of uranium at first proved to be a matter of much difficulty. Boltwood showed that the a ray activity of uranium was about twice as great as the equilibrium activities of the other a ray products in the uranium-radium series. indicating that the uranium fraction contained two successive a emitters. This was confirmed by Geiger, who showed that the a rays from natural uranium consist of two groups, equal in number, but with ranges of roughly a.j cm. and 3 cm. The two α ray emitters were named uranium I and uranium II. Assuming these two a emitters to be isotopic, and uranium I to be the ultimate psrent. Fajans concluded. on the basis of the displacement law. that the α disintegration of uranium I must be followed by two β disintegrations to give uranium II. Identifying uranium X_1 as the first of the predicted β emitters. he predicted that the second should have chemical properties analogous to those of tantalum, and promptiy succeeded in isolating it experimentally (1913). This product, uranium X_2, has a half-value period of 1.17 min. and emits energetic β rays. Several years later Hahn found the branch product. uranium Z. also intermediate between uranium X_1 and uranium II. but for present purposes it is sufficient to state that by either branch an α disintegration followed by two β disintegrations leads from uranium I to uranium II. In conformity with this conclusion, the mass numbers of these uranium isotopes are now known to be 238 for uranium I and 234 for uranium II. The growth of uranium II from uranium X_1 through uranium X_2 was first observed by C. H. Collie (19311.

Another β ray substance arising in the transformations of natural uranium was discovered by G. N. Xntonoff (1911). This substance. uranium Y, of half-value period 25.6 hr.. has the same chemical properties as uranium X_1. Its equilibrium activity is only a few per cent of the equilibrium activity of uranium X_1, so that it cannot be in the main line of succession. For some time it was regarded as a branch product, probably of uranium II. and it



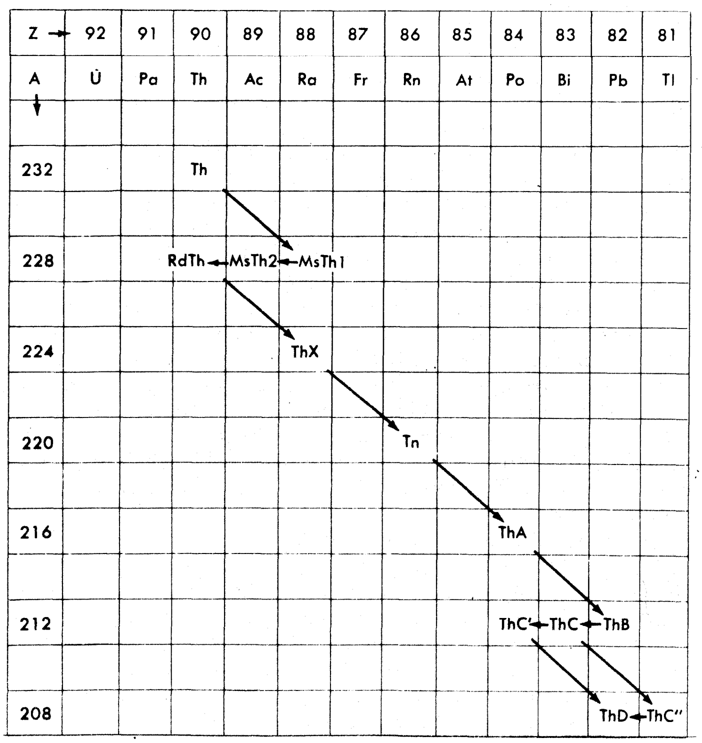
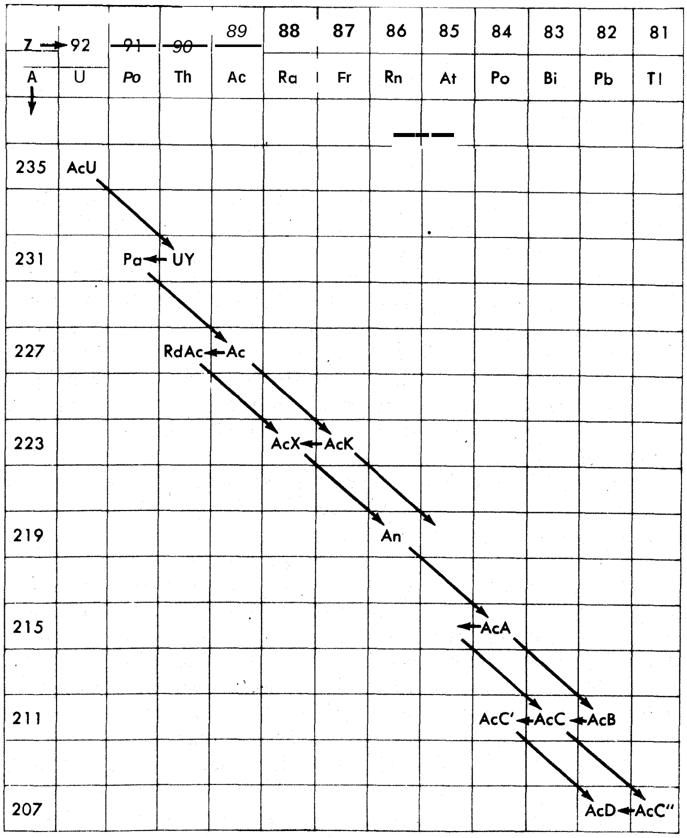


FIG 2–4 — ARRANGEMENT OF RADIOACTIVE SERIES WITH THE ATOMIC NUMBERS PLOTTED AS THE ABSCISSAE AND THE MASS NUMBERS AS ORDINATES THE THREE SERIES EXHIBIT A REMARKABLE SIMILARITY AFTER THE THREE BODIES OF ATOMIC NUMBER 90, VIZ IONIUM RADIOTHORIUM AND RADIO ACTINIUM



was also believed to be the parent of protactinium and the actinium series. It later became clear that the second assumption is correct, but the first incorrect. Cranium Y is the daughter product of the α emitting uranium isotope of mass number 23j, the so-called actinouranium. A mass-spectrogtaphic analysis of uranium demonstrating the existence of all three isotopes (mass numbers 238, 23j and 234) was first successfully performed by A. O. Nier. In natural uranium the U^{238}/U^{235} ratio is 139, and the U^{238}/U^{234} ratio about 17,000. From these results, and from a measurement of the number of α particles emitted by 1 g. of uranium per second, the periods of uranium I and uranium II were determined, allowance having been made for the weak activity resulting from the actinouranium.

Ionium.—The early work of Boltwood, R. J. Strutt (later Lord Rayleigh) and H. N. McCoy showed conclusively that the amount of radium in old minerals is directly proportional to the amount of uranium. This is what would be expected on the basis of the transformation theory (see above) if radium is a direct descendant of uranium in the disintegration series, and if the mineral had remained undisturbed for a time considerably longer than the half-value period of radium, or of any long-lived product intermediate between uranium and radium in the series. In that case the ratio of the numbers of atoms of radium and uranium present in the mineral would be the same as the ratio of the half-value periods of these two bodies.

In order to obtain direct proof of this genetic relation between uranium and radium, attempts were made, first by Soddy, to detect the growth of radium in samples of uranium from which all trace of previously associated radium had been carefully removed. The presence of radium in solution can most sensitively be detected by bubbling air through the solution into an ionization vessel and looking for ionization caused by the emanation produced. On the basis of a rough knowledge of the half-value periods concerned, Soddy had calculated that if radium were produced from uranium directly, without intermediate product, then the emanation method was sufficiently sensitive to detect the radium formed in one kilogram of uranium nitrate during the course of a week. The experiment showed that the initial rate of production of radium in purified uranium was certainly less than 10^{-4} of the amount calculated on this simple assumption. The next assumption to try out was that a single long-lived product was the direct parent of radium and the direct daughter of uranium. On the basis of this assumption the accumulation of radium in initially purified uranium would proceed at first according to the square of the time—equation (4) above. This result was ultimately obtained by Soddy (1915) in experiments extending over several years.

In the meantime Boltwood (1906) had separated the hypothetical intermediate product from the mineral, that is he had obtained a product in which the accumulation of radium was directly proportional to the time elapsed. In the following year he reached more precise conclusions regarding the chemical properties of the new product and suggested the name ionium, by which it became known. Ionium, which is present to the extent of rather less than two parts in 10^5 in uranium minerals, is now known to be a thorium isotope of mass number 230. This fact explains why it is impossible to separate ionium chemically from any natural thorium (mass number 232) which may be present in a uranium mineral and, since very few uranium minerals contain less than one part in 10^4 of thorium, why it is so difficult to obtain ionium isotopically pure. If such purity is required, the ionium-thorium fraction from a high-grade uranium ore must finally be submitted to physical separation in the mass spectrograph.

Radium. — The amount of radium in an unaltered uranium mineral is always proportional to the amount of uranium in the ratio of 3.43 parts of radium by weight to 10^7 parts of uranium. Its extraction is a tedious task, but it is not complicated by the presence of any long-lived isotope of radium, even though there may be some thorium and thorium products in the mineral. Since the chemical properties of radium are closely related to those of barium, the radium is normally separated with the barium from the other constituents of the mineral. It can then be completely purified from barium by fractional crystallization of the chloride or of the bromide. Mme. Curie and Debierne first isolated (1910) metallic radium by electrolysis of the fused salt, using a mercury cathode. The metal resembles metallic barium, being white in colour and tarnishing rapidly on exposure to the air. It melts at about 700° C. and boils at 1,140° C. The chemical properties of radium and its compounds have been studied by the usual methods. All the evidence, whether from its spectrum or from the solubility of its salts, shows it to be a higher homologue of barium.

In general, the salts of radium are available in quantities of only a few milligrams, possibly mixed with barium. It is therefore most convenient to measure the amount of radium by radioactive methods, rather than by weighing, for then the purity of the radium salt is not significant. The unknown preparation is compared with a sample of radium salt of known radium content which has been standardized directly or indirectly by means of the international radium standards. When the amount of radium present is not less than 1/100 mg. the intensity of the γ radiation (emitted by the active deposit, and mainly by radium C) is used as the basis of measurement. The tube containing the radium is placed at a suitable distance from an ionization chamber which is surrounded by a lead screen at least 3 mm. thick. The effect in the chamber is then caused only by the penetrating γ radiation. By comparison of the ionization current due to the unknown preparation with that produced by a known amount of radium at the same distance, the quantity of radium in the unknown preparation can at once be deduced, provided the radium is in equilibrium with its short-lived products. This last condition is adequately ensured if the radium preparation has been sealed off for at least one month. This method of estimation is simple and direct, and has the great advantage that the radium can be tested in a sealed off glass or metal tube, which is the usual mode of packing. For very weak preparations of radium, use is made of the emanation method, which has already been described. By this method quantities of radium as small as 10^{-12} g. can be measured to within a few per cent. The emanation method has been employed with great success for determining the quantities of radium in minerals and in rocks.

In 1912 a preparation consisting of 21.99 mg. of pure radium chloride, sealed in a thin glass tube, was adopted as the international radium standard and deposited in the Bureau International des Poids et Mesures at Sèvres, near Paris, Fr. At the same time a preparation made by O. Honigschmid, and containing 31.17 mg. of radium chloride, was adopted as a secondary standard and preserved in Vienna, Aus. Arrangements were made for the issue of duplicate standards to all governments who wished to purchase them. These duplicates were prepared in the Radium Institute of Vienna, and compared by the γ ray method with the official secondary standard in Vienna and with the international standard in Paris. In 1934 the original standards were replaced by new standards prepared by Honigschmid from the purest radium chloride, free from any detectable trace of barium. The Paris standard now (1957) contains 22.23 mg. and the Vienna standard 30.75 mg. of initially pure salt. The purchase and sale of radium is generally conducted on the basis of certificates given in terms of the international standard.

Physically, the ideal method of specifying the strength of a long-lived radioactive preparation is in terms of the mean number of disintegrations occurring per second in the sample. Corresponding to a half-value period of 1,620 yr., this number, for one gram of pure radium, is 3.62×10^{10}. This value is for one gram of radium free from its disintegration products; when the radium is in equilibrium with radon and the short-lived active deposit, the number of α disintegrations is four times as large. Originally, the unit one curie was introduced (1910) to specify the amount of radon in equilibrium with one gram of radium. It was later modified to become a unit of activity (disintegration rate) equal to the activity of one gram of pure radium. Because of the experimental uncertainty attaching to this natural unit (about 1%) the curie was later defined by international agreement (1950) as an activity of 3.700×10^{10} disintegrations per second, of whatever type.

From about 1909 to 1939, the wide use of radium for therapeutic purposes and its high cost led to a close search for uranium deposits as a source of this element. The most important uranium deposits in Europe were then those of Joachimsthal (Jáchymov) in the Erzgebirge, originally under control of the Austrian government. The production of this pitchblende mine amounted, at the peak, to about three or four grams of radium per year. When this rate of production failed to meet the demand, low-grade ores. containing on the average only about 2% of uranium oxide. began to be worked in Colorado. From about 1913 until 1922 the greater part of the world supply of uranium was produced in the United States from such ores. but in 1922 rich deposits of pitchblende were found at Katanga in the Belgian Congo. As these deposits were developed, the U.S. and Joachimsthal production practically ceased and Belgian producers obtained a virtual monopoly. This monopoly came to an end after the discovery in 1930 of an extensive occurrence of pitchblende on the shores of Great Bear lake. S.T., Can. From that date until 1939 the Belgian Congo and Canada shared the world market for radium. By the outbreak of World War II in 1939 the total quantity of purified radium in the world probably amounted to more than 1,000 g. After 1945 the growing availability of artificially produced radioelements considerably reduced the demand for radium for medical applications, but the demand for uranium increased for other purposes. To follow this development here would, however, be out of place: it has nothing to do with natural radioactivity.

During World Wars I and II large quantities of radium were used for gun sights, night compasses: instrument dials, etc. The radium was mixed with phosphorescent zinc sulphide to form a paint which is continuously luminous. although as a result of the destruction of the zinc sulphide by the rays, the luminosity gradually decays. Active preparations of mesothorium and radiothorium mere used for similar purposes.

Radon. — Radon (radium emanation) differs from the other products of the uranium series only in that it exists in a gaseous form at ordinary temperatures. It is produced from radium. and is transformed into radium A by α decay. Its half-value period is 3.825 days. If a radium salt is dissolved in an acid solution the radon may be pumped off with the large quantity of hydrogen and oxygen liberated by the action of the radiations on the water. It may then be purified by sparking the mixture and condensation with liquid air. The volume of radon at normal pressure and temperature in equilibrium with one gram of radium is 0.65 cu.mm. This small quantity of gas, together with the active deposit of short life in equilibrium with it, contains initially three-quarters of the total α activity of the radium before its separation. In a pure state, radon is 150,000 times as active weight for weight as pure radium. Notwithstanding the minute volume of radon available, its boiling point has been determined at various pressures. At atmospheric pressure radon boils at $-62°$ C. and freezes at $-71°$ C.; its critical temperature is $+105°$ C. Liquid radon appears colourless when first condensed; at the temperature of liquid air the solid glows with a bright rose colour. The specific gravity of the liquid is 4.4 at $-62°$ C.

Radon has no definite chemical properties and in this respect belongs to the group of inert monatomic gases of which helium and argon are the best-known examples. It is partially soluble in water and readily adsorbed on charcoal.

An intense source of β and γ radiation may be obtained by introducing purified radon into fine capillary tubes. Such radon "needles" have been widely used for therapeutic purposes, while the use of very thin-walled glass tubes provides a powerful line source of α rays. The β and γ activities of such, tubes rise to a maximum about four hours after introduction of the radon, and then decay with the period of radon (3.825 days). A method was developed in 1955 of producing "solid" sources of radon at ordinary temperatures. If a glow discharge is maintained between metallic electrodes in a gas containing radon, it is found that under certain conditions the radon is collected on the negative electrode, in the surface of which it remains occluded. Active sources, which can even be used in a vacuum without significant loss of emanation, can thus be prepared on thin foils of platinum or aluminum. Only when the metal is heated is the radon released. The strength of a radon preparation can be accurately determined by comparison of its γ ray activity with that of a radium standard. since the penetrating γ rays. both from the radium and the radon in equilibrium, arise mainly from the same product, radium C.

Radium Active Deposit of Short Life. — This name may be regarded as applying collectively to the short-lived products radium A, radium B, radium C and radium C' (together with the rare branch products radium C" and astatine 218) which grow into equilibrium with a source of radon in the course of a few hours; in practice, however, it is generally applied to sources of radium B in equilibrium with radium C. radium C' and radium C".

If a negatively charged wire or plate is exposed to radon for one minute and is then withdrawn. it is found to have collected a deposit of radium A. This deposit consists of atoms of radium A which have recoiled from the α disintegration of radon and which. being ionized in the process, have been collected in the electric field. The α activity of such a deposit falls rapidly at first, according to the period of radium A (3.05 min.). and then rises again to a much smaller maximum value as the atoms of radium A change successively into radium B, radium C and radium C'. At that stage the α activity is due predominantly to radium C'. Eventually, this α activity, as well as the β and γ activities due to radium B and radium C, decay together with the period of radium B (26.8 min.). Alternatively, if the negatively charged collector is exposed to radon for an hour or two. obviously the active deposit comes into approximate equilibrium with the radon during the exposure. On withdrawal, the only significant change of activity during the first few minutes then arises from the decay of the α activity due to radium A (about one-half of the total α activity); the β and γ activities decay only slightly in this time. When this α decay is effectively complete, say in 20 min.. the remaining α, β and γ ray activities of the source decay with the 26.8-min, period of radium B. It is to such a source, produced by "long" exposure to radon, that the name active deposit of short life is commonly applied. Most of the classical experiments on α particle scattering and artificial transmutation were made during the years 1909–29 using active-deposit sources of this type.

Radium Active Deposit of Long Life.—Mme. Curie first noticed (1903) that the activity of a body, left in a closed vessel in contact with the emanation from a radium preparation for several months, did not decay completely within the first day after removal. as it would if the dominant decay period were of the order of 27 min.. but that a residual activity (about 5×10^{-5} of the initial amount) remained which did not decrease appreciably over a much longer interval. The relation of this active deposit of long life to the active deposit of short life was worked out by Rutherford and by Meyer and Schweidler in the following two years. On metal plates exposed to radon for a few days only, Rutherford observed the growth of both an α and a β activity of long life. He showed that the β activity reached equilibrium considerably earlier than did the α activity. and he concluded that the dominant decay period of the long-lived active deposit was that of an effectively rayless product. This product and the two products which follow it in the active deposit of long life are still known by the names Rutherford assigned to them — radium D ($T = 22$ yr.), radium E ($T = 5.02$ days) and radium F ($T = 138.3$ days) — furthermore, his identification of radium F with polonium, the first active substance separated from pitchblende by Mme. Curie in 1898, has been fully justified by later research.

For all practical purposes the sequence of disintegrations in each of the two active deposits of radium is the same: two β disintegrations followed by an α disintegration. Thus radium B and radium D are isotopic, radium C and radium E are isotopic. so, also, are radium C' and radium F. There is a further regularity: in the first sequence each disintegration is more energetic than the corresponding disintegration in the second sequence. This fact might suggest that the second products are of less interest than the first, yet in spite of it, and the greater difficulty of obtaining strong sources of the longer lived products, much fundamental work has been done with radium E and radium F. The great advantage of these products is that neither emits γ rays in significant amount. For that reason radium E was for many years the natural choice for those workers who wished to study the problem of β disintegration in its simplest context and. when electrical methods of detecting single α particles superseded the more tiresome method of scintillation counting, the use of radium F avoided the troublesome effects of unwanted background ionization due to β and γ rays. Chadwick's discovery of the neutron was made by using the α particle? of polonium (rather than the more enerretic α particles of radium C′) to bombard beryllium.

The most convenient starting material for the preparation of sources of radium (D+E+F) is provided by the disused glass capillaries and "seeds" in which radon has been sealed for therapeutic use and in which it has finally decayed. The active deposit of long life is found deposited on the inner walls of such containers and may he removed by dissolution in strong acid.

Transformations of Thorium.— The close similarity of the three radioactive series has already been pointed out (*see* figs. 2–4). This similarity is particularly marked between the uranium and thorium series. In the thorium series the sequence of transformations thorium→mesothorium 1→mesothorium 2→radiothorium is closely analogous to the sequence uranium I→uranium X_1→uranium X_2→uranium II in the uranium series, so that thorium and radiothorium are isotopic. as are uranium I and uranium II. On the other hand. since the atomic number of thorium is go, whereas that of uranium is 92, there is one less α disintegration in the sequence from radiothorium to thorium B than there is in the sequence from uranium II to radium B. Thus, from radiothorium onward the thorium series should rather be compared with that part of the uranium series starting from ionium. If this comparison is made. it will be observed that the α disintegrations in the thorium (radiothorium) series are all somewhat more energetic than the corresponding α disintegrations in the uranium (ionium) series. This fact is linked with another: that the mass numbers of the members of the thorium series from radiothorium onward are all two units less than the mass numbers of the corresponding members of the uranium series. In the thorium series. however, there is no counterpart of the radium active deposit of long life; the last α active product is thorium C'.

In a more detailed comparison one difference may be noticed between the series which is of practical consequence. In the uranium series the decay period of uranium II is several million times greater than the decay period of uranium X_1; in the thorium series the period of radiothorium (1.90 yr.) is less than that of mesothorium 1 (6.7 yr.). This fact makes it relatively easy to obtain strong sources of pure radiothorium (by growth and subsequent separation from the mesothorium extracted from thorium minerals in bulk), whereas it is practically impossible to obtain more than insignificant samples of uranium II by the corresponding process (see *Transformation* of *Uranium* above). Since radiothorium is the last product in the thorium series with a period greater than four days, the availability of intense and reasonably long-lived thorium-series sources depends on this favourable circumstance. If a sample of radiothorium is sealed in a glass tube, the whole of the rest of the series will have grown into equilibrium with it in the course of one month: thereafter such a preparation provides a source of the most penetrating γ rays (from thorium C″) available with the natural radioelements. Furthermore, if a negatively charged plate is exposed above an emanating preparation of radiothorium for a period of a few hours, the active deposit collected on the plate provides a source of the most energetic α particles (from thorium C′) naturally available. Much fundamental work has been done with sources of these types. Csing the α particles of thorium C', work on artificial transmutation and nuclear scattering was extended to higher energies (Rutherford and Chadwick, 1925) and the first evidence of resonance scattering by light nuclei was found (S. Devons, 1939). Using the penetrating γ rays. the mode of γ ray absorption by electron-positron pair creation was established (C. D. Anderson and S. H. Neddermeyer, 1933; Chadwick, P. M. S. Blackett and G. P. S. Occhialini. 1934) and the phenomenon of nuclear photodisintegration was discovered (Chadwick and M. Goldhaber. 1934) and further explored (Chadwick. Feather and E. Bretscher, 1937).

Mesothorium 1, the grandparent of radiothorium, is isotopic with radium, and most thorium minerals are of low grade and contain uranium and subsequent products. Commercial mesothorium, therefore. generally has radium as "impurity." If the uranium-thorium ratio in the mineral is 1:10 by weight, nearly one-quarter of the initial activity of the mesothorium concentrate is due to radium (70% of the activity after 20 yr.), assuming equilibrium conditions. By weight, however, in the finally purified mesothorium salt. radium is initially in excess in the ratio 7j:1. Because of these considerations. the only direct method of obtaining mesothorium 1 free from radium is to await its growth in an originally purified sample of thorium. Radiothorium, on the other hand. when it is eventually separated from the commercial mesothorium-radium mixture, carries with it no trace of radium or its products.

Transformations of **Actinouranium.**—It was early recognized that actinium occurs in all unchanged uranium minerals in constant proportion with the uranium: however Boltwood showed that the equilibrium activity of actinium and its products is only a few per cent of the equilibrium activity of the main-sequence products of uranium. At first it was thought that this invariable association could be explained in terms of series branching; later it was found that the correct explanation lay in the fact that the parent members of the two series are isotopic. Actinouranium. the uranium isotope of mass number 23j (see *Transformation* of *Uranium* above), was not discovered until 1935 (A. J. Dempster), but already in 1929 there was strong reason for assuming the existence of this isotope on the basis of F. W. Aston's mass-analysis of the isotopes of uranium lead (see End *Products* of the *Transformations* below). Actinouranium. as its name implies, is the parent of the actinium series as it occurs in nature: it is transformed by a main sequence of four disintegrations (α, β, α, β) into radioactinium. a thorium isotope of mass number 227. The intermediate products in this sequence are uranium Y, protactinium and actinium. Protactinium is an α emitter of relatively long life ($T=3.43\times10^4$ yr.) which occurs in uranium minerals to the extent of about 15% by weight of the radium present. Because of this fact, and because no other long-lived product in any of the three series is isotopic with it, it has been possible to separate protactinium in weighable amounts in a pure form. A. von Grosse determined the atomic weight as 231 in 1935.

From radioactinium onward, and apart from minor branchings, the sequence of transformations in the actinium series is similar to the corresponding sequences in the thorium and uranium series, if the products of the radium active deposit of long life are again disregarded. Mass numbers are one less throughout than those of the corresponding products of the thorium series, and α disintegration energies are greater—except that of the last member of the series. actinium C′. In a broad survey there is nothing of note to be recorded concerning the individual, short-lived products. except that actinium K, the β emitter of half-value period 21 min., originally discovered by M. Perey in 1939 as the daughter product of actinium in a 1.2% mode of α disintegration, was the first isotope of francium (atomic number 87) to be identified. Many other isotopes of this element have since been produced artificially. Actinium K itself also produces a branch product in a rare (0.004%) α mode. This product is an isotope of astatine (atomic number 85), of mass number 219 and half-value period 0.9 min. (E. K. Hyde and A. Ghiorso, 1953). Neither astatine nor francium is represented by a main-sequence product in any of the three naturally occurring radioactive series.

None of the actinium-series products has been used in any of the classical researches involving the radiations from radioactive substances. but in the early years of the exploitation of the fission process the parent body of the series. actinouranium. assumed an importance out of all proportion to its natural abundance. Actinouranium is the only naturally occurring isotope of uranium or thorium which is fissionable using neutrons of thermal energies. It is curious to reflect that this fact assumed such unique importance that an isotope. which had eluded discovery by traditional methods of mass-spectroscopy until 1935. had by 1945 been isolated in kilogram amounts by electromagnetic separation.

End Products of the Transformations.— Once the true nature of the radioactive process was generally recognized and the notion of the transformation series accepted, it became almost necessary to postulate a stable end product (either a known or an unknown element) for each of the three series. From a study of the radium active deposit of slow decay. Rutherford concluded (1905) that radium F (polonium) is the last active constituent of the active deposit and the last member of the uranium series as a whole. He knew the atomic weight of radium (M. Curie, 1903) and had established the fact that polonium was the fifth α emitter in the main sequence from radium onward; he was convinced without formal proof (*see* below) that the α particle is a charged helium atom. On this basis he deduced the atomic weight of the end product to be closely that of lead (in terms of present-day mass numbers. $226-[5\times4]=206$). Pointing out that old uranium minerals invariably contain lead. he suggested that the lead is in fact present as the stable end product of the series. At the same time he gave strong reasons for concluding that the activity separated with lead from uranium minerals: as originally by K. A. Hofmann in 1901, is that due to radium D. These suggestions were made six years before the displacement law mas formulated, but they are seen to be consistent with its provisions. The sequence of transformations from radium D to the assumed end product is β, β, α; thus the two products are isotopic. Moreover, chemically, it soon became clear that radium D is indistinguishable from ordinary lead.

The suggestion that lead is an end product of radioactive transformation was made independently by Boltwood in 1905, and in the following two years he supported this suggestion by chemical analyses showing that the amount of lead present in unaltered uranium minerals of high grade is greater the greater the geological age of the mineral.

During 1914 several determinations were made of the atomic weight of the lead separated from primary uranium minerals (Hönigschmid, T. W. Richards. Maurice Curie). In all cases a value considerably lower than that of ordinary lead (207.21) was found. Based on a wider survey of material. later determinations gave values little different from 206 in some cases (G. P. Baxter and C. M. Alter, 1935; J. P. Marble. 1936). All these results helped to establish the correctness of the previous conclusion that radium G, the daughter product of polonium, is the stable lead isotope of mass number 206.

The analogous decision for the thorium series was not reached so easily. Most thorium minerals contain some uranium, and the end product of this series accumulates three times as rapidly as the end product of thorium. But in 1914 Soddy had already obtained a preliminary value of 208.4 for the atomic weight of the lead in a thorite from Ceylon, and in 1919 Honigschmid obtained a more accurate value of 207.9 with a Norwegian thorite. By that time, however, the displacement law was well established and the sequence of transformations in the main series was fully worked out. and little doubt remained that the end product thorium D was the lead isotope of mass number 208.

Definite proof of the earlier conclusions was finally achieved when the mass spectrograph was applied to the analysis of radiogenic leads of varied origin! and the first direct evidence concerning the identity of the end product of the actinium series was obtained in the same investigation. Thus. for a thorium-lead from Brevig in Norway, Aston found an isotopic constitution 4.6% Pb^{206}, 1.3% Pb^{207} and 94.1% Pb^{208}, and. for a uranium-lead from Morogoro, Tanganyika. 93.1% Pb^{206} and 6.9% Pb^{207}. Since the isotopic constitution of ordinary lead is 1.5% Pb^{204}, 23.6% Pb^{206}, 22.6% Pb^{207} and 52.3% Pb^{208} it was clear that no admixture of ordinary lead could explain the presence of Pb^{207} in uranium-lead, when Pb^{208} was absent. It was thus concluded that, as Pb^{206} is the end product of the yranium series, so Pb^{207} is the end product of the associated actinouranium series, *i.e.*, that actinium D is the lead isotope of mass number 207. This was the first definite assignment of a mass number to any member of that series.

Production of Helium.— In 1902 Rutherford and Soddy suggested that the helium which is invariably found in radioactive minerals is somehow produced in the process of disintegration of radioactive matter. In 1903 Sir William Ramsay and Soddy observed the production of helium by radium and also by radium emanation. Rutherford then adopted the simplifying hypothesis that the production of helium and the emission of α particles are one and the same process, and eventually established the correctness of this view in a masterly series of experiments. In 1906 he showed that the value of e/m (charge/mass) is the same for the α particles from all products, being closely one-half the value of the corresponding constant for the singly charged hydrogen ion.' If the α particle were in fact a positively charged atom of helium it should in consequence be doubly charged. Rutherford and Geiger, therefore, determined the charge carried by the α particle and in 1908 obtained the value 9.3×10^{-10} E.S.U. (electrostatic units). Though Rutherford was convinced that this result implied that the magnitude of the elementary ionic charge was 4.65×10^{-10} E.S.U. (and that the α particle is a doubly charged helium atom), it cannot be pretended that the direct determinations of this quantity at that date gave much support to his view: they ranged from 3.1 to 4.06×10^{-10} E.S.U. In order to convince others, obviously a further proof of the α particle—helium identity was required. This was supplied in the following year when Rutherford and J. T. Royds introduced an intense source of radon into a very thin-walled glass capillary tube, and observed the accumulation of helium in an evacuated vessel surrounding the tube. In a control experiment they showed that the thin glass was quite impervious to ordinary helium under considerable pressure.

As a footnote to this account. it may be remarked that by 1910 R. A. Millikan had already published a preliminary value for the elementary ionic charge of 4.9×10^{-10} E.S.U.—and that the currently accepted value (1957) is 4.80×10^{-10} E.S.U.

The rate of production of helium by radium in equilibrium with its short-lived products was first measured accurately by Sir J. Dewar (1908) and Boltwood and Rutherford (1911). In terms of the international radium standard, one gram of radium in equilibrium with its three subsequent α ray products produces at standard temperature and pressure (S.T.P.) 172 mm.^{3} of helium per year.

Following a suggestion made by Rutherford earlier in the same year. Strutt began a long series of experiments in 1905 with the object of determining the ages of radioactive minerals, from a measurement of the helium contained in them and a knowledge of the amounts of uranium and thorium present. Obviously this method can give merely a lower limit to the age, since there must be some tendency for the helium to escape, except from especially compact and well-crystallized specimens. When the whole of the helium is retained in a high-grade uranium mineral, the effective internal pressure rises, under equilibrium conditions, at the rate of roughly one atmosphere per 1,000,000 yr. Strutt's early work led to estimates of a few hundred million years for the ages of certain Ceylon thorianites containing approximately 70% thorium. but. when the question of the end products of the series had been satisfactorily resolved, it became general to rely rather on determinations of lead/uranium and lead/thorium ratios for estimates of ages of such high-grade minerals. In respect of minerals containing only minute traces of uranium and thorium, however. the helium method was later revived with considerable success. The suggestion originated with A. Holmes (1929) and depended for its success on the development of improved methods of measurement of small quantities of helium (down to 10^{-10} cm.^{3}) by F. A. Paneth and his collaborators. It is possible to estimate ages of a wide variety of igneous rocks over the range 10,000,000 yr. and upward by this method (Holmes and Paneth, 1936; A. C. Lane and W. D. Urry. 1935. 1936).

Heat Emission of Radioactive Matter.— In 1903 it was shown by P. Curie and A. Laborde that a radium compound is always hotter than the surrounding medium, and radiates heat at a constant rate of about 100 g.cal. per hour per gram of radium. The rate of evolution of heat by radium has been measured subsequently by a number of observers. The source of this heat is the energy of the emitted radiations, and is not to be sought in any additional interatomic process. Since the α particles have a large kinetic energy and are easily absorbed by matter, all these particles are stopped by the radium itself or by the envelope surrounding it, and their energy of motion is ultimately transformed into heat. To this contribution must be added the energy supplied by the recoil of the radioactive atom after the expulsion of the α particle, together with that portion of the energy of the β and γ rays absorbed in the envelope.

This view of the heating effect was fully confirmed by measurements of Rutherford and H. R. Robinson (1913) and others. who found that each of the α ray products of radium gave an effect equal to that calculated from the energy of the α particles and the absorbed β and γ rays. Radon and its products, when removed from radium. were responsible for three-quarters of the heating effect of radium in equilibrium. The heating effects of radon, radium A and radium C decayed at the same rates as their activities. Accurate measurements give, for the total heating effect of radium in equilibrium with its short-lived products, and surrounded by sufficient material to absorb all the radiations, a value of 140.1 cal, per hour per gram. Of this 124.4 cal. are due to a particles and recoiling atoms. 6.3 cal. to β particles and 9.4 cal. to γ rays. On account of the great penetrating power of much of the γ radiation, it is difficult to measure its heating effect accurately, but the results show clearly that it is greater than that of the β rays, and that the two together contribute rather more than 11% of the total heating effect of radium in equilibrium with radon and the active deposit of short life.

Experiments on the evolution of heat from radium were early recognized as demonstrating the astonishing amount of energy accompanying the transformation of active matter, especially where α particle. are emitted. For example, one curie of radon in equilibrium with its products emits heat initially at a rate of about 114 cal. per hour. The total amount of heat emitted during its transformation into radium D is about 15,000 cal. The volume of one curie is 0.65 mm.^{3} and its mass 6.5×10^{-6} g. Thus 1 g. of radon emits during its life about 2.3×10^9 cal. of heat. By contrast the combustion of 1 g. of carbon yields 8×10^3 cal., and very few chemical reactions give larger yields.

The distinction between radioactive disintegration and a chemical reaction is that the first involves the nucleus of the atom. whereas the second involves only the outermost electrons. In each case. the energy which is released comes from the rearrangement of the constituent particles. and results in a slight decrease in the mass of the system. The constituent particles in the nucleus are so closely packed, compared with the atomic electrons, that their rearrangement energies are enormously greater and the decrease of mass becomes measurable in favourahle cases. The mass decrease. m, is related to the energy release. E, by the equation $E=mc^2$, where c is the velocity of light. This equation was deduced by Albert Einstein who demonstrated (1905) that, according to the theory of relativity, there is no essential difference between mass and energy. but that energy has mass and mass represents energy. It was first directly confirmed by experiments on artificial transmutation. It appears that in disintegration processes. both natural and artificial, matter is partially converted into energy, a very small change of mass corresponding to a very large release of energy. The most striking example of the enormous amount of energy which can be obtained in this way is provided by the "ideal" fusion process in which helium nuclei are built up from their constitcents with the transformation of roughly 0.75% of the total mass into energy (*see* NUCLEUS).

Nature and Properties of a Rays.—Early experiments showed that the α particle. from whatever radioactive atom it is emitted, is an atom of helium carrying two positive charges. Since helium is the second element of the periodic classification, a doubly charged helium atom is a bare helium nucleus, thus the process of α disintegration consists in the emission of a helium nucleus from the nucleus of a radioactive atom. Only when such an a particle has lost its original energy of emission by passage through matter is it finally neutralized, capturing two electrons and thereafter remaining individually unrecognizable as an ordinary atom of helium gas.

The laws of absorption of a particles in matter were first worked out by W. H. Bragg and R. D. Kleeman (1905). Selecting a narrow pencil of α rays from a thin film of radium of high specific activity, and using a shallow ionization chamber, these investigators found that the curve of ionization per centimetre of path against distance from the source could be analyzed into components of the same shape and of eaual maximum value. representing the contributions due to the radiations from the four α ray products present in equilibrium in the source. For a single α ray product the component curve showed that the ionization per unit path increases with distance from the source to reach a maximum and then falls away rapidly to zero. Empirically. therefore. Bragg and Kleeman were able to define a characteristic range for the a rays from the various products in the series. In order to explain their empirical results they adopted the following assumptions: each product emits α particles of a definite velocity: each α particle travels in an approximately rectilinear path through matter losing energy by ionization at a rate which increases as the velocity decreases: because the number of ions produced by a single α particle is very large the distance traversed in a given medium for complete loss of energy depends only on the initial energy of the particle. Subsequent investigations by more powerful methods entirely confirmed the essential correctness of these assumptions.

The absorption of α particles in matter results essentially from collisions with electrons. As the mass of the α particle is more than 7,000 times the mass of the electron, the energy lost in a single collision is an extremely small fraction of the total energy. This is the reason why a large number of collisions is necessary to stop the a particle completely, and why the stopping distances of all a particles of the same initial velocity are the same. except for small fluctuations. Moreover. since an impact with an electron cannot deflect the a particle appreciably, the a particle will follow a straight path. Collisions with atomic nuclei. which may cause large losses of energy and abrupt changes of direction. are too infrequent to affect the general picture. The fluctuations attending the stopping process were considered theoretically by Niels Bohr in 1915, with results with which later experiments generally agreed. The effect is known as the straggling of the range. In air the mean fluctuation of the ranges around the average value is between 1% and 2% for the various groups of a particles naturally observed. The average value of the range, known as the mean range, is generally used to characterize these groups of a particles. Values of the mean range in air at 15° C. and 760 mm. are given in Table I. Roughly, the mean range is related to the initial velocity of the α particles by Geiger's equation $R=KV^3$, the constant K being determined by the fact that the initial velocity of the a particles of radium C', of mean range 6.91 cm.. is 1.92×10^9 cm.sec.$^{-1}$.

On account of its great energy of motion, the effect caused by a single α particle can be detected in various ways. Crookes first noted (1903) that the α rays produce scintillations when they fall on a screen of phosphorescent zinc sulphide. It was later shown (1908) that each of these scintillations results from the impact of a single a particle. The number of scintillations can be counted with the aid of a suitable microscope, and over a period of about 20 years this method proved of great utility in many investigations. Depending on the human observer, the method was tedious and slow, and it fell into disuse with the introduction of the Geiger-Müller (G-M) counter and the pulse ionization chamber (see below), but the development of the highly sensitive photomultiplier tube later made possible the replacement of visual by electrical recording (S. C. Curran and W. R. Baker, 1944), and scintillation detectors again figured largely in the equipment of laboratories devoted to radioactive research. In place of the thin layers of microcrystals of zinc sulphide or diamond previously employed, a single large crystal of sodium iodide activated with thallium, or a crystal of anthracene, or even a liquid scintillator such as a solution of terphenyl in xylene, may be used as occasion demands. Moreover, with these developments, use of the scintillation method is no longer confined to experiments involving α particles; the modern scintillators are sensitive to β particles and γ rays as well.

In 1910 S. Kinoshita showed that a single α particle produces a detectable effect on a photographic plate. When the a rays fall on a plate at nearly grazing incidence the tracks of the a particles in the developed emulsion are clearly visible under a high-power microscope (M. Reinganum. 1911). With the introduction of special fine-grained emulsions this method became a powerful means of investigation under appropriate conditions.

By the expansion method developed by C. T. R. Wilson (1912), the track of an a particle or a β particle through a moist gas is made visible by condensation on each of the ions produced. The photographs of these tracks bring out in a striking way not only the individual existence of α and β particles, but the main effects produced in their passage through matter.

Rutherford and Geiger first devised an electrical method of detecting single a particles in 1908. The α particles entered. through a small window. a metal tube containing a gas at reduced pressure, and an electric field was applied between the wall of the tube and a central wire electrode. When the applied field was suitably increased the charge communicated to the central wire was large enough to be detected by a sensitive electrometer. A simple counter was later devised by Geiger which responded to single β particles as well as to single a particles. This consisted of a fine needle point (or a small sphere at the end of a wire) placed axially in a metal cylinder. A strong electric field was again required. The modern tube counter of Geiger and W. Müller (1928) has essentially the same arrangement of electrodes as the first counter of Rutherford and Geiger. the thin axial wire being made the anode. This counter is more usually employed, coupled to a simple valve amplifier and electronic scaling unit. for the detection of β particles or of γ radiation. For this application, the conditions are chosen so that the ion-multiplication is very high; then the magnitude of the impulses produced becomes independent of the original ionization. It can also be arranged that the magnitude of the impulse is proportional to the original ionization; then it is possible to distinguish between the impulses produced by α particles and those produced by β particles.

In the counters just described the primary ionization due to the particle is magnified by use of a strong electric field to produce further ionization by collision. An alternative method of detecting a particles is to use a simple ionization chamber and obtain all the magnification electronically. This method was first successfully applied by H. Greinacher (1926) and was further developed by C. E. Wynn-Williams (1927, 1931). From four to six amplification stages may be required and the voltage amplification may be of the order of 10^6 or more. By this method of linear amplification a particles can be counted in the presence of β and γ radiation of much greater intensity.

When α rays fall on a sheet of matter, slow electrons are emitted. These were first studied by J. J. Thomson (1904), and were called by him δ rays (delta rays). Most of the δ rays have an energy corresponding to only a few volts, but a few particles are precent which have much higher energies, some reaching to one two-thousandth of the energy of the a particle (corresponding to tnice its velocity). The δ rays can best be studied by photographing the tracks of α particles in a Wilson cloud chamber containing a gas at low pressure. The swifter δ particles are themselves able to ionize the gas and their tracks are easily visible. Chadwick and K. G. Emeleus and also P. Auger. have shown that the number and velocity of the swifter δ rays agree excellently with the view that they are produced by the collision of a particles with the atomic electrons. The primary process of ionization is the removal of an electron (δ particle,. Secondary ionization is then produced by δ particles which have sufficient energy. In general the primary ionization is about one-half the total ionization observed. For the α particles of radium C', the total ionization in air is about 2.2×10^5 ion pairs per a particle.

The α particle at the moment of expulsion from a radioactive nucleus is doubly charged, and at first it was supposed that it retained this charge until very near the end of its range where the charge was neutralized by the capture of two electrons. Later work, however, by G. H. Henderson and Rutherford showed that the α particle changes its charge several thousand times in its passage through matter. When a rays pass through a sheet of matter in a good vacuum, the issuing rays consist of doubly charged, singly charged and neutral helium atoms. At high speeds the doubly charged particles predominate; at low speeds most of the particles are singly charged or neutral. It seems clear that the a particle in its passage through matter occasionally captures an electron and that this may be removed in a subsequent collision. This process of capture and loss of electrons is repeated many thousand times before the a particle is brought to rest.

Although most a particles travel in an almost rectilinear path through absorbing material, there is in general a small scattering or deflection of the a particles in passing through matter, amounting on the average to a few degrees. This scattering occurs mainly toward the end of the path. In addition, occasionally there is a large-angle scattering. This large-angle scattering is caused by a close collision of an α particle with a single atom of matter. A detailed study of the laws of single scattering of a particles was first made by Geiger and E. Marsden (1913). This investigation confirmed in precise detail predictions based on the nuclear atom model put forward by Rutherford in 1911 (*see* NUCLEUS). Later, Blackett obtained expansion photographs showing close collisions of α particles with the nuclei of light atoms. such as hydrogen. helium, nitrogen and oxygen. In general a forked track is observed, one branch caused by the scattered α particle and the other by the recoiling nucleus.

Relation Between Range of α Rays and Period of Transformation.— It was early observed that there appeared to be a connection between the period of transformation of a product and the velocity of the a particles which it emits. The shorter the period of transformation. the greater is the velocity of expulsion of the a particle. This connection was originally expressed in terms of R, the range of a particles in air, and λ, the constant of transformation. by the relation $\log \lambda = A + B \log R$ (Geiger and J. M. Nuttall, 1911). Herr A and B are constants for the a emitters of any one transformation series. and B is in fact nearly constant for all three series. If the initial velocity, or the initial energy, of the α particles is used instead of the range. a relation of the same general form is obtained.

The Geiger-Nuttall relation. although only approximately fulfilled. was rightly regarded as of fundamental importance. One of the most striking successes of the theory of a disintegration, advanced by G. Gamow and by R. W. Gurney and E. U. Condon in 1928, was that it provided an explanation of this empirical rule.

Theory of α Disintegration.— The difficulty encountered in forming a theory of a disintegration can be illustrated by the case of uranium. Scattering experiments using the a particles of thorium C' (energy nearly 9 Mev) show that there is no appreciable departure from the coulomb potential down to a distance of 3×10^{-12} cm. from the uranium nucleus. At smaller distances, to which these α particles cannot penetrate. there must be large deviations from this potential. to account for the nearly stable binding of α particles in the nucleus. The general shape of the potential field between the nucleus and an a particle is therefore as shown in fig. 5, where the dotted line represents the coulomb potential energy

$$V(r) = \frac{2Ze^2}{r}$$

On the other hand. the α particles emitted spontaneously by

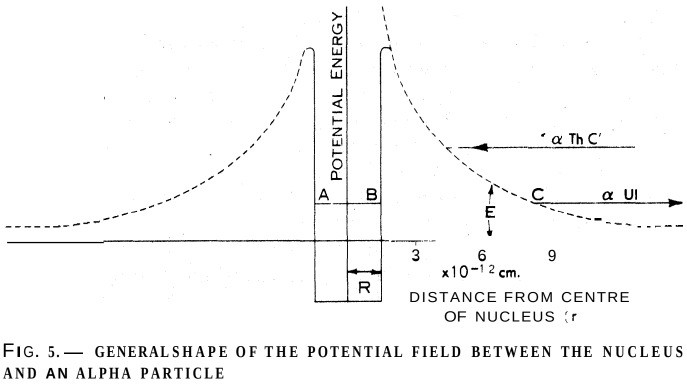


FIG. 5.— GENERALSHAPE OF THE POTENTIAL FIELD BETWEEN THE NUCLEUS AND AN ALPHA PARTICLE

uranium have an energy of only about 4 Mev. As these α particles must come from inside the nucleus, it is impossible to explain, on the basis of classical mechanics, how they can surmount a "potential barrier" requiring at least twice their energy. In quantum mechanics (*q.v.*), however, there is the possibility of "leakage" through the barrier. An adequate description of the theory can only be given in terms of E. Schroedinger's equation for the time variation of the wave function of the α particle, which enables a calculation to be made of the probability of the α particle being found outside the nucleus after a certain time. A semi-classical description can be given by supposing that the α particle inside the nucleus has available energy indicated by the height of the line AB (fig. 5), along which it oscillates making collision with the walls of the barrier. At each collision, the particle has a small but finite chance of penetrating the barrier and escaping, The greater the chance of penetration, the fewer oscillations mill be necessary, on the average. for escape to occur and thus the shorter the period of transformation. This chance depends markedly on the height and thickness of the barrier, or (as the figure indicates), on the available energy of the particle, that is on the energy of disintegration. Thus it can be seen that in a general way a body which emits fast α particles will have a short period, and one which emits slow α particles will have a long period. Detailed calculation leads, in fact, to a relation between the transformation constant and the energy of the α particle which is similar to the Geiger-Nuttall relation. Further, the calculation leads to values of the nuclear radii R (fig. 5) of the radioactive atoms which are. for members of the same series. close to one another and in general agreement with values of the nuclear radius as deduced in other ways.

Long-Range α Particles and Fine-Structure Groups. — For many years it was believed that all α particles emitted by a given product were emitted with exactly the same velocity. The first departures from this rule were found in the cases of thorium C' and radium C'. In thorium C', two weak groups of α particles were found (1916) which have ranges of 9.8 cm. and 11.6 cm., considerably longer than the normal group of 8.6 cm. range. The long-range emission of radium C' is more complicated. consisting of several groups with ranges between 7.7 cm. and 11.5 cm. In each case. the intensities of the long-range groups are very small, being about 10^{-4} to 10^{-6}, or less, of that of the main group. These long-range groups are believed to arise in the following way. The β transformation of the C nucleus sometimes leaves the C' nucleus in an excited state. There are then two possibilities: the nucleus may go to the ground state by emitting a γ radiation. when the normal α disintegration follows. or an α particle only may be emitted. taking away the excess energy of the excited nucleus. The relative probabilities of these two processes are the probabilities of γ emission and of emission of an α particle of high energy. Except when the energy available for α disintegration is very great, the probability of γ emission is generally much the larger of the two. This explains' why long-range particles have been found only with radium C′ and thorium C. On this explanation. the measurement of the energies of long-range groups gives part of the energy level system of the α emitting nucleus, and the energy differences should correspond to the energies of γ rays emitted from that nucleus in alternative modes of de-excitation. This has been borne out by examination of the γ ray spectra relative to the transitions in question.

The more common complexity in α emission involves the so-called fine-structure groups. It was originally observed by S. Rosenblum (1929), who was the first to investigate α particle spectra using a focusing spectrograph. A complexity of this type, of greater or less prominence. was later shown to be an almost universal feature of α disintegration. Among the α emitters of the main sequences. direct or indirect evidence of fine-structure emission was found (by the mid-1950s) for all except the polonium isotopes radium A, thorium A. actinium A, radium C′ and thorium C'. As the name implies, normal α emission in general consists not in the emission of a single group of α particles all of the same energy, hut in the emission of α particles having a sharp-line spectrum of energies in a narrow range. Only because of the narrowness of this energy range (generally less than 5% of the maximum energy in any case) did the effect escape notice for so long. The explanation of the phenomenon is basically simple: here α disintegration always occurs from the normal state, but the product nucleus may be left in its normal state or in some excited state. In the latter event less energy is available for the emitted α particle, and the energy retained is almost immediately released as γ radiation from the product. More difficult considerations are involved in explaining relative intensities in detail. but the rapid decrease in α disintegration probability with decrease in available energy is the main factor limiting the excitation of the product nucleus to its lower energy states. If the lowest excited state of the product nucleus has too high an energy, fine-structure groups will not be observed. This is almost certainly the explanation of the nonobservance of such groups with the five polonium isotopes listed. The products of α disintegration in these cases are isotopes of lead and it is known from other evidence that, particularly for even mass numbers, first excited states of lead isotopes are of unusually high energy.

The predicted correspondence between energy differences among fine-structure groups and energies of γ rays has been confirmed in all cases investigated in detail, only in this connection, and in relation to long-range α particle emission, it should be stated that α particle energies must he "corrected" for the energy of nuclear recoil before an accurate balance is achieved.

Properties of β Rays. — The early experiments showed that β particles which are emitted in radioactive disintegration consist of negative electrons spontaneously liberated in the transformation process. The maximum energy of emission varies widely for different products, from several thousand electron volts up to a few million electron volts. The penetrating power of the rays varies correspondingly: *e.g.*, β rays of radium D are so easily absorbed by matter that they are difficult to detect, while those of radium C can pass through a few millimetres of aluminum before they are finally stopped. At first sight, the laws of absorption of β particles by matter appear different from those relating to α particle absorption, although the process of energy loss is essentially the same. The difference is mainly due to the fact that the electron mass is less than one seven-thousandth of the mass of the α particle, as a result of which β particles are much more easily scattered. Whereas an α particle can be deflected from its straight path only by collision with a nucleus, a β particle can also transfer a large fraction of its energy and momentum to any of the extranuclear electrons which it encounters. Consequently. β particles are frequently deflected from their course and in general pursue tortuous paths in their passage through matter. If they may still be regarded as having a "range" in matter, this range is far from being so well-defined as that of the α particle. Thus the study of the passage of β particles through matter is much more complicated. both in theory and in experiment. than is the same problem for a particles. Although the energy of β particles is in general considerably less than the energy oi the α particles from radioactive bodies, their velocity is generally much higher. For that reason alone, β particles produce fewer ions per unit path than α particles do. and the disparity is increased roughly fourfold due to the difference in charge. An a particle of 3 Mev has a velocity of about 0.04 c (c being the velocity of light) and produces about 4.000 ion pairs per millimetre of its path in air; a β particle of the same energy has a velocity of about 0.99 c and produces only about 4 ion pairs per millimetre of path. Because of this small rate of energy loss a β particle has a much greater range than an a particle of the same energy. Thus, in the example, the aparticle has a range in air of about 1.7 cm., the β particle approximately 13 m. The difference in behaviour between α and β particles is strikingly shown in experiments with the expansion chamber. In contrast to the short, straight and densely ionized tracks of the α particles, those of the β particles are long, show many gradual deflections and occasional forks resulting from close collisions with electrons, and are sparsely populated with ions. In addition to the loss of energy by ionization, there is a loss of energy by radiation, caused by the sudden deceleration of the β particle in nuclear encounters, an effect which is responsible for the emission of X-rays of the continuous spectrum when cathode rays are stopped by a target. The production of γ rays hy β rays in passing through matter was first observed by J. A. Gray (1911).

A great difficulty in the study of the detailed properties of β particles is that the particles emitted by a single radioactive product are not homogeneous, but differ widely in velocity. In the early days, it was found that the absorption of the β rays irom a single product appeared to follow an exponential law, and different groups of β rays were characterized by different absorption coefficients. The exponential law is now known to be the almost fortuitous result of the initial wide-spread energy distribution and the complexity oi the absorption process; a group of homogeneous β rays is not absorbed according to an exponential law. Insofar as absorption methods are still used to analyze the β radiations irom radioactive products. determination of effective foil ranges (Feather, 1938) replaced determinations of exponential absorption coefficients. For energies greater than about 0.7 Mev the foil range increases linearly with the β particle energy.

β Ray Spectrum and the Disintegration Process.—The β particles arising irom the disintegration of a single product are expelled with velocities covering a wide range. This fact was first adequately recognized when the β rays from a product such as radium B or radium C were analyzed in a uniform magnetic field.

Originally, the magnetic spectra so obtained were recorded photographically and many sharp lines were observed, each line representing a group oi particles having a well-defined velocity of emission. Then the more tedious electrical methods of recording were tried (more tedious because a spectrum has to be mapped from point to point, rather than recorded as a whole) and it was found that the lines were superimposed on a continuum. representing particles of all velocities from zero up to a limiting value characteristic of the β ray product concerned. With some products, as later investigations showed, the line spectrum is very complex; with some products it is relatively simple; with radium E, in particular, it is entirely absent. This last fact alone is sufficient to suggest that the line spectrum represents electrons of secondary origin, but it was not definitely known when the question was first decided. In 1914 Rutheriord. Robinson and W. F. Rawlinson showed that a line spectrum could be obtained with a source consisting of a radon-filled capillary tube having a metal sheath sufficiently thick to obliterate all trace oi homogeneity in the electrons emitted from the active deposit in the tube. The line spectrum which was then obtained was quite similar in structure to the natural spectrum, and could have been due only to the effect of y rays from the source in ejecting electrons from the atoms in the surface layers of the metal sheath. It was most likely, therefore, that the natural line spectra observed with unshielded sources were to be similarly explained. as being due to internal conversion of y rays in the radioactive atoms themselves (*see* below). In 1914 also, Chadwick showed by the electrical method, that even when the line spectrum is prominent as with radium (B+C) it represents only a small fraction of the total electron emission of the source. By far the greater iraction belongs to the continuous distribution. Chadmick therefore proposed that the continuous distribution represents the primary β particles. and the line spectrum a secondary effect due to γ radiation, as Rutheriord and his collaborators independently concluded. Later experiments showed that in all cases the disintegration electrons are ejected from the radioactive nucleus mith a continuous distribution of velocities, and that the number of particles in this continuous spectrum corresponds, within the accuracy of experiment, to one particle for each disintegration. The iorm of the distribution was determined for most oi the natural β emitters. The general result is that in the simplest cases the distribution curves are similar, showing a definite maximum and then decreasing to zero at a well-defined upper limit of energy. The form of the distribution in the region of very low energies is difficult to determine accurately; on the other hand, it is the upper limit oi the energy mhich is characteristic of the radioactive product. Radium E and uranium X_2 provide essentially simple spectra, the upper limit of energy in the first case being 1.17 Mev and in the second 2.32 Mev. The value of this end-point energy is an important constant, for in theory it fixes the total energy released in the β disintegration. There is a relation between the maximum energy of β rays emitted by a product and its rate of disintegration. first pointed out by B. W. Sargent (1933), but the relation is not so simple as the Geiger-Nuttall relation in the case of a disintegration.

The distribution curve of the β ray spectrum should be simplest when the product nucleus is formed only in its ground state, as is the case in the absence of γ radiation. In most cases, however, β transformation is more complex and the new nucleus can be formed in any one of a number of excited states; the transitions from these excited states to the ground state account for the y radiation which accompanies such β transformations. In these cases, thereiore, the energy distribution curve of the β ray spectrum will be complex, consisting oi a superposition of a number of continuous spectra, each one of which has a definite upper energy limit and corresponds to a β transformation to a certain quantum level of the resulting nucleus. The successful analysis of a complex β ray distribution into simple or partial spectra provides information on the quantum states of the new nucleus, as in the case of the fine structure of a emission. Because of the nature of the spectra, this analysis is difficult to carry out in practice, but developments of older coincidence methods (W. Bothe and others, 1935, 1937; Feather, 1940) have greatly increased the possible range of experiment.

The process of β decay, in which the transformation of one nucleus into another appears to take place with a release of energy varying between wide limits, is in such strong contrast to the process of a decay, and indeed of all other nuclear phenomena, that for some time the facts were not generally accepted. It was suggested, *e.g.*, that β particles are all liberated initially with identical energies and that the continuous spectrum results irom varied losses of energy suffered by the different particles in escaping irom the atom. This supposition was disproved by direct experiment, in mhich the average energy released per disintegration of radium E was measured calorimetrically. The experiments (C. D. Ellis and W. A. Wooster, 1927; Meitner and W. Orthmann, 1930) gave an average energy of 0.34 Mev, in close agreement with the average value deduced from the observed distribution curve. and far from the upper limit of 1.17 Mev. There can thereiore be no doubt that β particles are emitted from the nucleus with different energies. On the other hand, all phenomena connected with α and γ ray emission show that the radioactive nuclei have well-defined quantum states and that the energies of the initial nucleus and oi the product nucleus have well-defined values. In order to retain the conservation of energy for the process of β decay it is necessary to assume that part of the energy of disintegration is emitted in the iorm of a new arid undetected type of radiation. W. Pauli (1931) suggested that this radiation may consist of particles bearing no electric charge and of small. possibly zero, mass. Such particles. called neutrinos, would have practically no interaction mith matter and thus could not be detected directly. On this assumption the β decay process consists of the simultaneous emission of an electron and a neutrino, mhich share the constant total energy of disintegration between them in arbitrary proportions. The β particle then has its maximum energy when the neutrino is emitted with zero velocity, and the total energy of the disintegration process is equal to the maximum energy of the β rays plus the self-energy of the electron, mc^2, assuming that the neutrino mass is zero. In all cases where a test has been made, this assumption has led to consistent results.

In addition to preserving the conservation oi energy in the β decay process, the assumption of a neutrino resolves other difficulties, for experimental evidencr shows that nuclear angular momentum cannot be conserved unless an additional particle is emitted along with the electron in β decay. The correct relations regarding spin may he restored if a spin of one-half quantum unit is ascribed to the neutrino. At the mid-1950s all attempts to observe effects resulting irom the interaction oi neutrinos with matter had failed. but such a result can be expected from the properties which the neutrino must be assumed to possess. Some experiments, with artificially produced β emitters, in which the energ) anti linear momentum oi the emitted β particle and the associated recoiling nucleus were measured, indicate, however, that linear momentum is not conserved if only these two particles are involver1 in the disintegration. These experiments gave further support to the hypothesis of the neutrino.

A successful theory of the β disintegration process mas first put forward by E. Fermi (1934), on the basis oi the neutrino hypothesis. Fermi supposed that β disintegration consists essentially of the transformation, inside the nucleus, of a neutron into a proton. with the simultaneous emission of an electron and a neutrino. In this way he was able to explain the general shape of the continuous spectrum of primary β rays, and also to deduce a relation between the transformation constant and the maximum energy of β particlrs, analogous to that found empirically by Sargent. Although many details remained to be decided. this theory stood the test of more than 20 years comparison mith experiment, and in the mid-1950s it appeared to provide the only possible description and explanation of β disintegration on the basis of quantum mechanics.

Properties of γ Rays.—The γ rays from radioactivr substances are electromagnetic radiations. A γ radiation may be characterized by its wave length, usually expressed in X units (1 X unit = 10^{-11} cm.), by its irequency ν, or more often by the energy of the quantum $h\nu$, generally stated in electron volts. The spectrum of the γ radiation irom any one product consists of one or more discrete lines which may differ widely in wave length and in intensity. The spectral region occupied by these lines extends upward from the soft X-ray region of a few thousand electron volts quantum energy to the region of a few million electron volts.

The absorption of γ rays by matter is analogous to the absorption of X-rays. but at the higher frequencies the relative importance of the various absorption effects changes. The absorption follows an exponential law with thickness of matter traversed, but, in order that experimentally determined absorption coefficients will be significant, it is essential that the geometrical conditions of the experiment should be such that scattered radiation is prevented from reaching the detector.

The absorption of γ rays in matter is mainly caused by interaction mith the electrons. There are three distinct processes—scattering, photoelectric absorption and the creation of positive and negative electron pairs. The relative importance of these three processes depends upon the irequency oi the radiation and the atomic number of the absorber. The experimental investigation of the three types of interaction is thus complicated by the difficulty of separating their effects.

In the classical theory of scattering, a free electron is assumed to he set in vibration by the electric field of the incident radiation. emitting spherical waves of the same frequency as the incident waves. Thus on the classical theory the scattered radiation has the same wave length as the incident radiation. This theory proved adequate to describe the scattering oi soft X-rays by light elements. However, it was noted by J. A. Gray (1913) that scattered y radiation is more easily absorbed than the incident γ radiation, indicating a change of wave length, but these experiments did not attract much attention. The explanation of the change of wave length on scattering and the calculation of its magnitude, was given by A. H. Compton (1923), together with more direct experimental proof. Compton's argument was that the process of scattering must be regarded, on the quantum theory, as a collision between a photon (quantum of radiation) of energy $h\nu$ and an electron. In such a collision, the electron will, in general, be ejected from the atom and the photon will be deflected from its original direction. In this case, since the photon transfers momentum and energy to the electron, the scattered quantum will have less energy than the incident quantum. Scattering will therefore be accompanied by a change of frequency or wave length. However, if the electron is very tightly bound in the atom, the collision will be effectively with the whole atom and there will be scattered radiation of unmodified frequency. That such scattering occurs is clear from the diffraction and interference effects obtained with crystals; these effects could not occur if the scattered radiation were not coherent. This unmodified scattering becomes less important with increasing energy of the photon; with high-energy y rays it can only be detected with difficulty.

The Compton effect (*q.v.*) is of great importance in the case of high-frequency radiations, such as in general compose the y rays emitted by radioactive substances, ior it means that the radiation becomes degraded to longer nave lengths as it passes through matter. In detail, the effect has been established experimentally by observation both oi the change of irequency as a function of angle of scattering, and also of the simultaneous production of the scattered quantum and the recoil electron. A detailed quantum theory oi the eifect has been given by O. Klein and Y. Nishina (1929) on the basis of P. A. M. Dirac's relativistic theory of the electron.

Absorption of γ rays by the photoelectric effect occurs when the whole energy $h\nu$ of the quantum is transferred to an electron in one or other of the K, L, *M*, etc., levels of the atom. The photoelectron is ejected with kinetic energy $E = h\nu - W_i$, where W_i is the energy required to ionize the atom in the corresponding quantum level. In this case, the quantum oi radiation disappears completely and the residual atom takes up the momentum available according to the conservation law.

For light elements and for γ rays of energy of the order of 1 Mev, absorption occurs almost entirely by Compton scattering. For heavy elements anti radiation of low energy, absorption is due mainly to the photoelectric eifect. In the intermediate range, the two processes are comparable in their effects.

The third mode of absorption—electron-positron pair creation—does not become effective until the energy of ? rays exceeds 1 Mev. Its occurrence mas not recognized until 1934; in what follows its discovery and its general character will be briefly described.

In 1932 experiments by L. H. Gray and G. T. P. Tarrant, C. Y. Chao and others showed that for γ rays of high energy the absorption in heavy elements is not entirely accounted for by Compton scattering, coherent scattering by bound electrons or the photoelectric effect. Some additional effect had to be postulated and it was found that it involved the production in the absorber of secondary radiation of which the main component had a quantum energy of about 0.5 Mev, independent of the energy of the primary radiation. This secondary radiation was nt first attributed to nuclear fluorescence, but a more satisfactory explanation came with the discovery of the positron. The additional absorption process was then shown to he due to creation of positron-electron pairs, and the secondary radiation was explained as the annihilation radiation of the positrons so created.

The explanation of this process is derived from Dirac's relativistic theory of the electron and its requirement of negative energy states as well as positive energy states for the free particle. In order that this theory shall coniorm with reality, the negative energy states must be regarded as in general completely filled (and in that condition unobservable) but an electron in such a state may be raised to a state of positive energy by absorption of a suitable quantum. A quantum of energy greater than 2 mc^2, where mc^2 is the rest energy of the electron, is required. This absorption process will manifest itself in the creation of a pair of particles, a negative electron in a state of positive energy and a positive electron corresponding to the "hole" left in the negative energy states. This process is analogous to the photoelectric effect. It cannot occur in empty space ior, as the quantum is wholly absorbed, energy and momentum cannot both be conserved; it occurs ,in the electric field near a nucleus and the nucleus takes up the extra momentum. The probability of pair production increases with increasing quantum energy of the radiation and is proportional to the square of the nuclear charge number. Z, of the absorbing element. As the probability of Compton scattering is proportional to Z, the number of extranuclear electrons, and decreases with increasing energy, the total absorption coefficient should first decrease and then increase again, as the quantum energy increases. The energy at which the absorption is least should increase with decreasing *Z*. For lead, the minimum absorption coefficient occurs lor γ rays of about 3 Mev, for aluminum, for γ rays of about 20 Mev energy.

γ **Ray Spectra.**—The spectral distribution of y rays has been examined in a few cases by means of diffraction in crystals. The first work oi this kind was done in 1914 by Rutherford and E. N. da C. Andrade who studied the spectrum obtained by transmission through a thin crystal of rock salt using the γ radiations emitted by a fine glass tube filled with radon. A complicated spectrum of sharp lines was observed and the wave lengths of some of the γ rays of radium B and radium C were deduced from the measurements. Later, similar experiments were conducted by M. Frilley and J. Thibaud, using the method of surface reflection at nearly grazing incidence.

These early experiments were carried out with flat unstressed crystals. In 1930 J. W. M. DuMond and H. A. Kirkpatrick gave the theory a focusing spectrograph employing a bent crystal, either in transmission or reflection. The method was first applied to the study of y rays by H. Huluhei and Y. Cauchois in 1934, using a transmission instrument to record the spectrum photographically with an extended source. This method was later developed into one of great precision by DuMond and collaborators (1947). Using an effectively line source of radon and a scintillation counter as detector these workers achieved an accuracy oi 1 part in 4,000 in the wave length of the γ ray of energy 609.4 kev (1 kev = 1000 electron volts) of radium C (1952). The real limitation of the method is one of intensity—it requires sources at least 100 times as intense as any other method for successful application—otherwise it has the great advantage of simplicity of interpretation. With this proviso, it is certainly applicable up to y ray energies of 1.5 Mev.

Nearly all the information on γ ray spectra of the natural products was obtained before the above developments took place, and was in fact derived from a study of the line spectra of electrons to which reference has already been made. In 1921 Ellis continued the work of Rutheriord, Robinson and Rawlinson, comparing the natural line spectra with the excited line spectra representing the electrons ejected from thin foils of heavy elements by γ rays. Ellis obtained conclusive evidence that the more intense lines in the natural spectra occurred in groups, corresponding to similar groups of lines in the excited spectra. For a given product, or for a given foil, the energy differences among the lines in the various groups were constant, being characteristic oi the product or (alternatively) of the material of the foil. Ellis identified these energy differences as the differences between the energies of binding of the extranuclear electrons in the *K*, L, *M*, etc., levels of the atoms concerned, and so attributed each group of lines to a single γ ray, whose quantum energy $h\nu$ was given consistently by the quantities $E_1 + W_K$, $E_2 + W_L$, $E_3 + W_M$, etc.; E_1, E_2, E_3 being the energies corresponding to the electron lines of a given group and W_K, W_L, W_M the electron-binding energies as specified. The excited line spectrum, on this interpretation, represents the ordinary process of photoelectric absorption in the material of the foil, the natural line spectrum a process of internal conversion of the γ ray in the atom of origin. By a detailed comparison of the intensities of corresponding lines in the natural and excited spectra, Ellis and G. H. Aston (1930) first showed that the internal conversion process is more complicated than the external process of photoelectric absorption. It mas later recognized that the original description was inadequate: the process of internal conversion is more correctly described as a direct transfer of energy from the nucleus to the extranuclear system. The excited nucleus may get rid of its energy of excitation either by emission oi a quantum of γ radiation, or hy ejection of an electron from the outer atom. In the latter event, part of the energy of excitation is retained for a short time as energy oi ionization of the atomic level from which the electron was ejected. Subsequently, this energy, also, is emitted as a quantum of fluorescent X radiation, or again alternatively, and in part only, as kinetic energy of an electron ejected from a less tightly bound atomic level, according to another type of internal conversion process first described by Auger in 1926.

In the study of γ ray energies by the method of the natural line spectrum it was originally a matter of practical as well as theoretical importance to know whether the binding energies W_K, etc., effective in the conversion process are those of the initial or the product atom, *i.e.*, whether γ rays are emitted before or after the expulsion of the disintegration particle from the nucleus. This was investigated by Ellis and Wooster (1925), Meitner and others, by various methods. The general conclusion was that, in all cases investigated, whether of α or β disintegration, the y ray follows the emission of the disintegration particle. For example, the γ rays which are ascribed to the disintegration of radium B, of nuclear charge number 82, are actually emitted, following the β disintegration of that body, irom nuclei of charge number 83, and are converted in the electronic levels of atoms of atomic number 83. The associated fluorescent X radiation is that of bismuth ($Z = 83$), not that of lead ($Z = 82$). This general conclusion accords with the modern view concerning the origin of γ radiation introduced in the discussion of α and β ray spectra; *i.e.*, that γ radiation is emitted from the nucleus rather than the outer atom (a question undecided until 1922) and that the necessary excitation of the nucleus is provided at the expense of the energy carried away by an α particle or a β particle in a disintegration process.

For a complete description of any radioactive transformation, in which a parent product X gives rise to a daughter product *Y*, it is necessary to know not only the energies hut also the intensities of all the radiations, both primary and secondary, emitted by *X*. As regards the primary radiations, α or β particles, the detrrmination of relative intensities is comparatively simple ior the α particles, though still difficult for the β particles. Even the determination of energies is not always unambiguous in a complicated case of β-disintegration (see β

Ray Spectrum and the Disintegration Process above). Supposing energies and intensities oi the primary radiations of X to be known, however, there may be 'deduced the relative energies and the intensities of population oi the various energy states in which the nuclei of *Y* are formed. Here it is not necessary that the ground state of Y should be among the states so populated. Formally, the next step is to check that the energies and intensities of the secondary radiations, internal conversion electrons and γ ray quanta, are such as to account precisely for the complete de-excitation of the originally excited Y nuclei. In order to carry out this check, each y ray energy has to be identified as the difference between the energies oi excitation of two nuclear states (and for this purpose states other than those populated in the primary disintegration map have to be postulated), and to the intensity of the y ray has to be added the intensities of the corresponding internal conversion electrons in order to derive the total intensity of the de-exciting transition from the upper to the lower state in question. In most cases the intensities of internal conversion electrons can be determined with good accuracy, but the determination of γ ray quantum intensities is still a matter of considerable experimental difficulty when the spectrum is other than very simple. For this last determination the most reliable method makes use of the Compton effect. The number oi Compton electrons produced in a foil, or in a scintillator, under standard conditions, gives the intensity of the γ ray, when the scattering coefficient is known. When it is realized that ior a y radiation of definite energy the Compton electrons have all energies from zero to a maximum, it will be obvious that this method cannot be one of high resolution without great sacrifice of sensitivity.

Thus a formal account oi the process of achieving a complete description oi a radioactive transformation has been given. In practice the sequence of events is generally quite different: the description is built up and refined as, and when. information on one or another aspect of the transformation becomes available. For some natural products, mainly a emitters, the description is now reasonably complete; ior others, in particular the complex β emitters such as radium C and mesothorium 2, in spite of many detailed investigations, much remained in doubt in the mid-1950s. Only the general basis of the interpretation appears secure in all cases.

Radioactivity of Ordinary Matter.— All matter shows a very weak radioactivity, which in most cases is caused by the presence of extremely small amounts of the well-known radioelements. Thus, in general, one gram oi a common metal will contain an impurity of the natural radioelements of the main series equivalent in activity to about 10^{-14} or 10^{-15} g. of radium. However by the mid-1950s six cases had been definitely established in which the activity is not caused by a contamination of the known radioactive elements but is characteristic of the element itself. The six elements are potassium, rubidium, indium, lanthanum, samarium and lutetium. The activities of potassium and rubidium were discovered by N. R. Campbell and A. Wood in 1907; the others were iound many years later.

Potassium emits a β radiation of maximum energy 1.33 Mev and a small amount oi penetrating y radiation. These two radiations are in no way related. The product of β disintegration is calcium; the γ radiation is emitted following an alternative mode of transformation, by capture of an orbital electron, which decreases the nuclear charge by one unit and so produces argon. This type of transiormation is not represented among the naturally occurring heavy radioelements, but, since its discovery by L. W. Alvarez in 1937, is well known among the artificially produced active species. By separation of the isotopes of potassium it has been shown that both activities are due to the isotope of mass number 40 present in ordinary potassium to the extent of about 1 part in 8,000. The half-value period is 1.2×10^{9} yr.

Rubidium emits an easily absorbed β radiation, but its amount is, weight for weight, greater than that of potassium. The active isotope is that of mass number 87, which has an abundance of 27% in ordinary rubidium. The period of transiormation is 6×10^{10} yr.. and the product is strontium. Strontium has been extracted irom a sample of lithium mica which contained irom 2% to 3% of rubidium. A mass-spectroscopic examination oi this strontium showed that it consisted almost wholly (99.7%) of strontium 87, whereas ordinary strontium contains only 7% of this isotope.

The discovery of the β activity of indium was made by E. A. Martell and W. F. Libby in 1950. In this case the active isotope is indium 115, which constitutes 96% of the natural element. The half-value period is 6×10^{14} yr.

The activity of lanthanum was first detected in 1950. In 1947 a second isotope, lanthanum 138, was found to occur to the extent of 0.09% in ordinary lanthanum, and the activity later observed by R. W. Pringle and collaborators has been ascribed to this isotope. It is transiormed chiefly by electron capture, followed by y emission, giving barium 138 as product, and to a lesser extent by β emission producing cerium 138 The period of transiormation is 7×10^{10} years.

Samarium was shown to be a natural α emitter by von Hevesy, M. Pahl and R. Hosemann in 1933. The α particles have a mean range of 1.13 cm. in standard air and an energy of 2.16 Mev. It was established, by separation of isotopes, that the active isotope is samarium 147 (B. Weaver, 1950); half-value period 1.3×10^{11} yr. Samarium is unique among the stable elements of even atomic number in that there is a gap in the mass spectrum of its isotopes of even mass number: samarium 146 is missing, When this species was produced artificially (D. C. Dunlavey and G. T. Seaborg, 1953) it was shown to be an α emitter of period $j \times 10^{7}$ yr. These two isotopes of samarium, thereiore, of mass numbers 146 and 147, are natural α emitters, but only samarium 147 is of sufficiently long life to be found in significant amount (15%) in terrestrial sources.

The rare (2.5%) isotope oi lutetium of mass number r76 mas discovered in 1936. In 1938 M. Heyden and W. Weielmeier iound natural lutetium to be radioactive and ascribed the activity to this isotope. This ascription was later confirmed. Lutetium 176 emits β particles followed by low-energy y rays. It is probable that the alternative mode of capture disintegration also occurs with intensity of the order of 3%. The half-value period is 4.6×10^{10} yr.

In surveying the results which have been obtained in these difficult investigations of weak natural radioactivities, two generalizations may be noted. The first is that for elements of odd atomic number greater than 7, any isotope of even mass numher is radioactive. Potassium 40, lanthanum 138 and lutetium 1j6 exemplify this rule. The only case in which the rule had not been verified was that of vanadium. Vanadium 50 was discovered in 1949, present to the extent of 0.25% in natural vanadium, but all attempts to detect its radioactivity as oi the mid-1950s had failed. The second generalization is that, if two elements of neighbouring atomic number have isotopes of the same mass number, then at least one oi these isotopes is radioactive. Potassium 40, rubidium 87, indium 115, lanthanum 138 and lutetium 176 represent the unstable members of isobaric pairs of this character. If vanadium 50 is stable, this rule is broken twice: titanium 50 and chromium 50 are certainly stable species. Three other examples of the apparent infringement of the rule remained; they were provided by the neighbouring isobaric pairs cadmium 113 and indium 113, antimony 123 and tellurium 123, rhenium 187 and osmium 187. In spite of various reports. first that osmium and then that rhenium is radioactive, the most thorough investigation (D. Dixon and A. McNair, 1954) can be taken as showing that neither is demonstrably so. It is unlikely, ior example, that the transiormation period of rhenium 187 can be less than 10^{15} yr. Somewhat similar statements can be made in respect of the other two pairs. The theoretical basis for this rule concerning neighbouring isobars lies in the assumption that the mass of the neutrino is zero. By the mid-1950s it seemed so unlikely that this assumption was seriously in error that it was reasonable to suppose that at least four species, then classified as stable on the direct evidence of experiment, are in fact feebly radioactive. Vanadium 50 could be one of these, and probably cadmium 113 another (Feather, 1952).

BIBLIOGRAPHY.—Marie Curie, *Radionctivitk* (Paris, 1935); E. Rutherford. J. Chadwick and C. D. Ellis, *Radiations fronz Radioactive Substances* (London, 1930, New York, 1931); S. Meyer and E. Schweidler, *Radinactivitat* (Leipzig, 1927); G. von Hevesy and F. A. Paneth, *A Manual of Radioactivity* (London, 1938); Irène Joliot-Curie, *Les Radioéléments naturels* (Paris, 1946); O. Hahn, *Applied Radiochemistry* (New York, 1936); A. S. Russell, *An Introduction to the Chemistry of Radioactive Substances* (London, New York, 1922); F. Rasetti. *Elements of Nuclear Physics* (New York, 1936, Glasgow, 1937); S. Devons, *Excited States oj Nuclei* (London, Toronto, 1949); N. Feather, *Nuclear Stability Rulrs* (London, 1952); M. Siegbahn (ed.), *Beta- and Gamma-Ray Spectroscopy* (New York, Amsterdam, 1955).

(E. RU.; T. CK.; N. FR.)

RADIO ASTRONOMY is a branch of astronomical science. In its first quarter-century it contributed fundamental information to a variety of classical astronomical problems: the statistics of meteors. the structure of the sun's outer envelopes, our galaxy's spiral structure, the temperature of the interstellar gas and the nature of the red shift.

History.— In the United States in 1931, Karl G. Jansky. a Bell Telephone laboratories communications engineer. was exploring atmospheric radio-frequency disturbances which might interfere with transoceanic telephone service. He noticed that while some disturbances were caused by local thunderstorms and some by distant thunderstorms, there was a third noise-component that appeared to be of extraterrestrial origin. With the aid of a rotatable directional antenna he was able to identify this source with a direction closely corresponding to that of the galactic centre. Jansky noticed that this extraterrestrial radiation had the characteristics of noise similar to that generated in metallic conductors. He attributed this cosmic static to the interaction between electrons and ions in interstellar space. Grote Reber, using very modest equipment, demonstrated that the origin of the cosmic radio-frequency radiation was not confined to the region of the galactic centre but was spread along the galactic plane, with a strong secondary maximum in Cpgnus. The radio detection of the sun and the study of its transient phenomena came in the early 1940s After 194j the development in radio astronomy mas impressive. Among the groups in many countries that contributed were the Radiophysics laboratory in Sydney, Aust.; the Jodrell Bank experimental station associated with the University of Manchester, Eng.; the Cavendish laboratory at Cambridge. Eng.; the Leyden (Neth.) university group; the École Kormale Superieure in Paris. Fr.; the National research council at Ottawa. Can.; and in the United States. the department of terrestrial magnetism of the Carnegie institution in Washington; the Naval Research laboratory, Washington; Harvard College observatory: Cornell university, Ithaca, N.Y.; Ohio State university. Columbus; and the National Radio observatory in West Virginia. New installations were being constructed in the mid-1950s by California Institute of Technology, Pasadena. and the University of Michigan, Ann Arbor.

Antennas.—A great variety of receiving antennas has been used in radio-frequency observations. Most modern work is done with antennas of one of the three following types.

(a) Fixed Type.—A parabolic antenna, such as the one employed in Manchester or the "transit" array type built by John D. Kraus at Ohio State university, which consists of helices mounted on a plane rectangle of hard\\-are cloth, often has a high resolution in at least one co-ordinate. but it cannot be aimed and observations must be made when the object crosses the meridian.

(b) Steerable Paraboloid.—This instrument resembles an optical reflector in that the electromagnetic radiation is reflected by a parabolic surface to a focus where a receiving element is placed. A servomechanism moves the reflector (dish) in two co-ordinates to track the diurnal motion of any celestial object. Examples are the jo-ft. dish at the Naval Research laboratory, the 60-ft. antenna at Harvard College observatory, the 2j-m. Leyden instrument and the huge 250-ft. dish planned at Manchester.

(c) *Interferometers.*—These produce fringe systems similar to those produced by optical interferometers. They are particularly useful for observing sources of small angular diameter. For example. if the sun is observed with an ordinary antenna when superposed on the galactic background, it may be barely perceptible at metre wave lengths. The interferometer (which treats the sun as virtually a point source in comparison with the galactic background) corrects automatically for this extended source because the galactic background fills in both maxima and minima of the interference pattern and only the solar pattern is observed.

Multielement forms of the interferometer such as the Mills cross permit accurate measurement of the positions of the discrete radio sources and disturbed areas on the sun.

Features of Cosmic Radio-Frequency Radiation.—Any heated body emits radio-frequency waves in accordance with the usual laws for the emission of radiation. The radiation from an antenna which emits waves at a certain selected frequency has an intensity many times that of a thermal source, however. In the heated body the particles are moving in random directions at random phases. whereas in the antenna the electrons are moving to and fro in unison.

The radio-frequency radiation received from extraterrestrial sources has the character of a random noise superposed on the background of thermal radiation from the surroundings. It is as though an ordinary telescope. its dome and all the terrestrial surroundings were brightly glowing, and the astronomer had to measure sun and stars which appeared as objects only slightly brighter than their background.

Hence. the radio-frequency detection equipment must be able to discriminate between objects with surface brightnesses only slightly greater than those of the surroundings. The intensity of the source can be expressed in terms of the temperature of a black body that would give the same intensity of thermal radio noise, and a standard black body source can be used to calibrate the receiver. The limit of detection corresponds to a difference of about 1" C. between the temperature of the object and that of its surroundings.

Although the radio-frequency radiation emitted by many sources, such as the quiet sun, the moon and certain diffuse nebulae, is of thermal origin, much cosmic static has a definite nonthermal origin, especially the radiation from the neighbourhood of flares and other active regions on the solar surface and the radiation from discrete sources which are regions of small angular size that emit intensely in the radio-frequency region. The nonthermal component often has many times the intensity of the thermal component.

Radio-frequency cosmic radiation differs from optical radiation in one important way. Whereas the wave length of visible light is very small compared with the aperture of the telescope, the wave length of the radio-frequency radiation is often comparable with or even larger than the aperture of the radio telescope. The resolving power. *i.e.*, the ability to distinguish two objects separated by a small angular distance d, depends on the ratio of the wave length λ to the aperture D ($d = 1.2 \lambda/D$). For a 60-in. telescope and a wave length of 5×10^{-5} cm. (an average for visible light), $d = 4 \times 10^{-7}$ radians or 0.08 sec.

With a 60-ft. dish and 21-cm. radiation, the angular resolution is $1\ 38 \times 10^{-2}$ radians or about 0.8°, *i.e.*, somewhat larger than the angular diameter of the moon or sun. With the wave lengths ordinarily employed, most radio telescopes have resolving powers considerably less than that of the human eye. Accordingly, interferometric techniques are applied much oftener than in optical astronomy.

Very high resolution in frequency can be obtained. The profile of the 21-cm. line of neutral hydrogen gas can be studied to yield important information on the motion of the gas and its temperature.

The range of wave length over which observations can be secured also must be considered. The long wave length limit is between 1j and 30 m. It is fixed by the degree of ionization of the ionosphere. The upper limit of the wave length is fixed by the condition that a radio wave can travel through an ionized gas only as long as its frequency is greater than a critical frequency ν_c, in megacycles (mc.) per second, given by

$$\nu_c^2 = 8.06 \times 10^{-5}\ N_E$$

where N_E is the number of electrons per cubic centimetre. Radio waves of frequencies less than ν_c are reflected by the ionosphere. Since the degree of ionospheric ionization, *i.e.*, the number of electrons per cubic centimetre depends on the solar radiation in the far ultra-violet, ν_c will vary from time to time. The atmosphere is opaque for wave lengths shorter than 1.5 mm. There are strong absorptions at 2.5 mm., j mm. and 1.34 cm. The transparency at 8.j mm. is better than the sky in the optical regions. At the high-frequency end of the spectrum the radio astronomer begins to be hampered by nuisances, such as rain, that also plague optical astronomers.

Techniques.—Radio astronomy differs from conventional optical astronomy in that for nearby objects—meteors, the moon and eventually the terrestrial planets—it is possible to direct signals to them and obtain the reflection. The well-publicized radar reflections from the moon are the best-kno n example. On the other hand. if a radar reflection could be obtained from Venus, it would constitute a powerful method for establishing the scale of distances in the solar system. Orbit theory gives the relative positions and distances of all the bodies in the solar system, but the scale can be fixed only when one particular distance (*e.g.*, the distance from the earth to Venus) is found at one particular epoch. The difficulty is that the strength of radar echoes decreases with the fourth poaer of the distance instead of with the square of the distance. as does the light picked up by optical telescopes.

The most striking application of radar techniques has been to the study of meteors. As a meteor passes through the rarefied upper atmosphere of the earth it ionizes a column of gas. A radio wave may be reflected from this column; from the intensity of the reflected beam, and because the intensity depends on the angle between the initial beam and the path of the meteor, it is possible to get the direction of the meteor and eventually its velocity. In this way, extensive data have been obtained on the orbits of meteors and meteor streams. The radar technique possesses one important advantage. Since the radar reflection depends only on the ionization of the air by the meteor, it can be applied during the day as well as during the night. Thus it has been possible to identify several daytime meteor streams that had not been previously observed. The radio observations also substantiated the more reliable optical observations in showing that the orbits of meteors are elliptical, rather than hyperbolic, *i.e.,* meteors belong to the solar system.

Radio observations have yielded important information concerning the lunar surface. Optical observations had shown that the visible surface of the moon underwent a temperature fluctuation with an amplitude of 134° C. during the course of a month as the sun rose and set. Radio waves are emitted not from the visible surface but over a range in depth of several inches. The temperature of these layers as measured from the radio wave intensities fluctuated with an amplitude of only 45°. This evidence showed that the surface layers must have good insulating properties; presumably they consist of finely powdered rocks in a vacuum. Thermal emission also has been observed from Venus.

Jupiter was found to emit in short radio-frequency pulses. The peak energies measured near 22 mc. per second amount to about 10^{-23} watts per cycle per second per square metre. When Jupiter emits in its characteristic frequency, it is the brightest object radio-wise in the sky.

It has been suggested that this radiation is produced by lightning or by volcanic action. Lightning might produce shock waves that could cause oscillations of charged particles in the Jovian atmosphere. Presumably, similar efiects could be produced by volcanoes. but volcanoes would be fixed in place on the planetary surface, whereas the lightning discharges would not. Studies of the durations of the outburst phenomena in conjunction with the visual observations provide, on the one hand, valuable data on the ionosphere of Jupiter and, on the other. the means to correlate recognizable optical features with the radio emission. The sources appear to occur in the same latitudes in the tropical band. Jupiter's great red spot is the strongest producer of radio noise, but not the only one.

It is perhaps significant that radio-frequency radiation is observed from Jupiter and not from Saturn, because in Jupiter, ammonia is beginning to form droplets. whereas in Saturn it is nearly all frozen out. Hence, ammonia may play the same role in Jovian meteorology as water does in terrestrial meteorology.

Solar Radio Observations.— The sun is a most interesting object for radio studies. since simultaneous optical and radio-frequency studies of active regions may be made. First. it is essential to distinguish between the thermal radiation of the undisturbed (quiet) sun and the nonthermal radiation emitted from disturbed regions near sunspots.

The equation for critical frequency (above) shows that at the lower frequencies (longer wave lengths) radiation is obtained only from the outermost solar envelope. the corona. where the kinetic temperature is 1,000,000° C. or more. At higher and higher frequencies it is possible to penetrate deeper and deeper into the corona and finally into the chromosphere. Ultimately, at the shortest wave lengths (highest frequencies) it is possible to reach almost to the optical surface of the sun.

The radio emission from the quiet sun is of thermal origin; its intensity depends on the temperature of the radiating gas and on the total amount of material in the line of sight. By a judicious combination of optical and radio data, a model can be constructed of the solar chromosphere and corona that is more accurate than one obtained by using optical data alone. Furthermore, observations of the occultation of the strong radio source, the Crab nebula, have shown that the outer corona is not spherically symmetrical but has a nonuniform structure.

The nonthermal radio-frequency solar radiation (*i.e.,* the radiation that is caused by charged particles moving in preferential directions somewhat as do the electrons in an antenna) is even more interesting. Several distinct nonthermal radiations exist; some have been correlated with optical activity, notably flares. Generally, nonthermal radiation can be classified as a slowly varying component, noise storm. or as an outburst. The slowly varying component is detected as an excess emission extending from 1 cm. to 1 m.; it may last over a period of weeks and is often circularly polarized. Storms are observed over a range from about 1 to 20 m. One type lasts between an hour and a week, consisting of sudden bursts or pulses of energy lasting from 0.1 to 10 sec. The radiation is virtually all polarized. In another type of storm. each burst or disturbance lasts about 10 sec. The total storm lasts from 30 min. to j hr. and the radiation is often unpolarized. Outbursts correspond to a great intensification of radio-frequency energy. They are often associated with flares, are usually of short duration (1 to 10 min.) and are observed over the entire frequency range from 1 cm. to 30 m. Paul Wild developed a frequency sweeping device that enables the observer to follow these transient events over a wide range of frequencies as a function of the time. Interferometric techniques show that solar radio-frequency noise originates in regions of great solar activity; *i.e.,* near spots. At times of high activity, charged particles in these regions are accelerated to very high energies.

Galactic and Extragalactic Sources.— The radio-frequency radiation from sources outside the solar system can be classified as follows: (1) thermal radiation irom heated gases; (2) nonthermal radiation from the galactic background; (3) nonthermal radiation from discrete sources; (4) 21-cm. radiation irom neutral hydrogen.

Thermal noise has been observed in the great diffuse nebulae, such as Orion, Lagoon and Trifid. An electron moving in one free (hyperbolic) orbit in the neighbourhood of a proton may jump to another with the emission of radio-frequency radiation. The dependence of the intensity of the radiation on the frequency is just what would be expected ior the electron densities and temperatures inferred irom the optical observations. By a judicious combination of optical and radio data, it is possible to correct for the absorption of light in space.

The general galactic background has a much higher intensity than could be attributed to stars radiating as does the disturbed sun. This radiation has been attributed to the emission by accelerated electrons in interstellar space.

Of the discrete sources, the most intense have been identified with optical objects, although some (*e.g.,* the Cassiopeia source) are near the limit of detectability. It is necessary to have not only accurate positions but also accurate sizes. Four groups of discrete sources have been listed, excluding diffuse nebulae: (1) remnants oi supernovae; *e.g.,* the Crab nebula; (2) galactic nebulosities of a new type: (3) peculiar extragalactic nehulac; and (4) normal estragalactic nebulae.

Thr radio angular size and position of the Crab nebula, a supernova of 1054, agrees with the optical position. It was shown to be not a thermal source; the detection of polarized continuous optical radiation suggested that the emitted energy comes from accelerated particles in a magnetic field, rssentially synchrotron radiation.

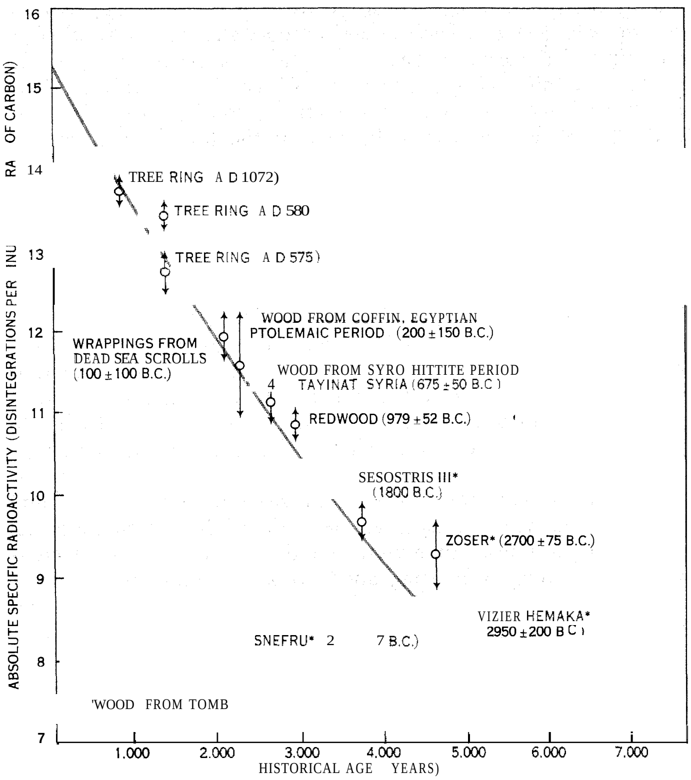
The Cassiopeia B source in Tycho Brahe's nova of 1572, Cassiopeia A, the Puppis source, and IC 443 are all examples of filamentary nebulae, moving with high velocities, that are strong radio sources; the higher the velocity, the stronger is the radio-frequency radiation. The strong Cygnus source has been identified with colliding galaxies which radiate more energy in the radio region than in the optical region. Among normal appearing galaxies that have unusual radio-frequency radiation is the elliptical galaxy M87 in Virgo. The Andromeda nebula and the Magellanic Clouds more nearly resemble our own galaxy.

The 21-cm. radiation emitted by neutral hydrogen was predicted in 1944 and discovered in 1951. From the shape, intensity and displacement of this line it is possible to obtain data on the motions of the interstellar gas and its temperature. Observations show the gas to be concentrated in the spiral arms and to have a temperature near 100° K.

BIBLIOGRAPHY.—B. Lovell and J. Clegg, *Radio Astronomy* 11952) : J. Pfeiffer, *The Changing Universe* (1956) ; J. L. Pawsey and R. N. Bracewell, *Radio Astronomy* (1955); G. P. Kuiper (ed.), *The Sun,* pp. 676–92, 466–531 (1953) ; L. H. Aller, *Atmospheres of the Sun and Stars,* ch. 9 (1953) ; A. Unsöld, *Physik der Sternatnosphären* (1955). L. H. Aller, *Gaseous Nebulae,* ch. 8 (1956) ; *Astrophysical Journal,* 119:206 (1954). (L. H. A.)

RADIOCARBON DATING. Radiocarbon age dating. developed in the late 1940s at The University of Chicago, is an example of the application of one of the newest sciences (atomic energy) to one of the oldest (archaeology). The technique involves measuring the relative activities of radioactive carbon (C^{14}) in (1) present-day living organic matter and (2) the sample under investigation, and multiplying the logarithm of this ratio by the rate at which the activity of C^{14} decays with time. Careful measurements have shown that the activity of any given preparation of carbon-14 is reduced by exactly one-half during each interval of 5,568 ± 30 years. This value is called the half life of C^{14}.

Radiocarbon is produced in nature by an indirect process involving the interaction of cosmic rays from outer space with the nitrogen in the earth's atmosphere. The competing processes of formation and of decay of C^{14} have been going on for so long that the equilibrium has been established. and the world inventory of C^{14} is estimated at about 70 metric tons. Radiocarbon therefore has been introduced into the biosphere, and all living matter contains a small quantity of radiocarbon which averages 15.3 ± 0.1 disintegrations per minute per gram of contained carbon. This



SAMPLES OF OBJECTS OF KNOWN AGE DATED BY RADIOCARBON METHOD

The curve is calculated from the assay for modern wood and the laboratory measurement of the half life of radiocarbon (5,568 ± 30 years). The individual points show the specific radioactivities of the various samples of known age (the latter given in parentheses). The age of the sample as estimated by the radiocarbon method is shown by the point on the curve corresponding to the indicated specific radioactivity. The range in specific radioactivity for a given sample is the standard deviation based solely on the number of counts taken; it does not include other errors, such as those arising from contamination

activity remains constant throughout the life of the organic matter because of the above-mentioned equilibrium processes.

However, at death the introduction of radiocarbon into the specimen ceases, while the normal decay of the contained radiocarbon continues according to the half life mentioned above. Therefore an archaeological specimen (for example. a mummy,or a tree) which yields 7.65 disintegrations per minute per gram of carbon instead of 15.3 is judged to be 5.568 ± 30 years old. If the material shows only one-fourth the radiocarbon content of living matter, the age of the specimen is 11.136 ± 60 years, etc.

Age dating has revealed that there lived in North America over 9,000 years ago people who were capable of performing the finest basketry work; that the continents of North America and Europe were both glaciated in their northern latitudes 11,000 years ago; and that the calendars of the ancient Babylonians and the Mayas can be correlated with that of the Christians. The accompanying graph indicates the correlation obtained between the ages of various samples as determined by radiocarbon dating and by conventional methods.

Refinements in the technique of measurement have been made by reducing, as far as possible, the effects of spurious radiation, including background activity due to cosmic radiation. and radioactive impurities in the shielding of counters and in the materials of construction of the counter itself. These refinements permit the extension of radiocarbon dating to samples which could be as much as 50,000 years old. Lahoratories at research institutions scattered throughout the world are co-operating in dating archaeological specimens hy this method.

See Willard F. Libby, *Radiocarbon* Dating, 2nd ed. (1955); G. J. Fergusson, "Radiocarbon Dating System," *Nucleonics,* vol. xiii, no. 1 (Jan. 19.55). (W. F. Li.)

RADIOCHEMISTRY: *see* Radioactivity, Artificial: *Application to Chemistry and Medicine.*

RADIO COMPASS, a radio receiving set which permits determination of the line of travel of waves as received from transmitting stations. *See* Navigation; Radio.

RADIOLOGY is the branch of medicine that deals with the employment of X-rays as an aid in the diagnosis of disease and the use of X-rays, gamma rays and other forms of ionizing radiation in the treatment of disease. For details of the physical nature. method of production and technical and industrial applications of the various components of the electromagnetic spectrum. *see* Radioactivity, Artificial; Radioactivity. Natural; and X-Rays.

This article is organized as follows:

I. DIAGNOSTIC RADIOLOGY

A. Apparatus

1. Quality and Intensity of Radiation **Employed.**—Concern with the carious implications of thermonuclear weapons has stirred up a largely unwarranted fear of possible risk from even such small tissue doses as those delivered in X-ray diagnosis. Of course, it is unwise to employ diagnostic radiology (or, for that matter, drugs or surgery) unless there is real need for it. When there is such need, X-ray examinations conducted by qualified radiologists involve risks smaller than those encountered every day at home. at work and on the street, and smaller than the risk of getting along without needed examinations, especially when these may reveal a serious disorder.

In some of the work for which X-rays are used, the quality or penetrating ability of the radiation is expressed in wave length, in frequency or in terms of its absorbability in filters of standard composition and thickness; and its intensity is designated in ionization units, such as the roentgen. In X-ray diagnosis, however, it is the practice to indicate radiation quality and intensity by stating the voltage and current applied to the tube, the current being expressed in milliamperes. abbreviated ma. (1 ma. = 0.001 amp.), and the voltage in peak kilovolts. abbreviated kv. Current is measured by means of a milliammeter inserted between the two halves of the secondary winding of the X-ray transformer at a point where the potential is close to zero; and tube voltage is measured by means of a kilovoltmeter wired across the primary of the X-ray transformer.

Certain aspects of alternating currents and of pulsating unidirectional currents will be reviewed at this point When plotted on a time scale the instantaneous voltage of the current produced by a single-phase, 60-cycle, alternating-current generator, a sine curve is observed. Rising from zero, voltage reaches full potential during the first $\frac{1}{240}$ sec., returns to zero by $\frac{1}{120}$ sec., falls to full negative value by $\frac{1}{80}$ sec. and returns to zero by $\frac{1}{60}$ sec., repeating the pattern indefinitely. That portion of the curve lying between the first and third zero points is called one cycle, and it is the repetition of this cycle 60 times in each second that gives 60-cycle current its name. Obviously the designation of the voltage of such a current requires reference to the factor of time and for such applications as heating, lighting and power the "root mean square" value is employed. This is abbreviated R M.S. and means the square root of the mean of the instantaneous voltages throughout the entire cycle.

A time-voltage plot of the potential applied to the tube of a self-rectified X-ray machine consists of a distorted sine curve in which the peak of the half cycle that is used is lower than that of the half cycle that is suppressed; and in the case of full-wave rectification the plot becomes a series of more or less distorted half cycles, all having the same electrical sign.

In pure sine wave alternating current, R M S. voltage may be computed from maximum instantaneous voltage (MIV) or vice versa by substitution in the equation

$$\text{R.M.S.V} = \frac{\text{MIV}}{\sqrt{2}},$$

but in pulsating unidirectional currents this simple relationship breaks down. The R.M.S. values for such nonsinusoidal currents could be determined by suitably designed meters or by complete analysis of the instantaneous voltages throughout the curve. but this is not commonly done because in the production of X-rays it is the maximum instantaneous voltage of the current passing through the tube that is of particular importance. This voltage is termed the peak voltage. and since in practice it amounts to several thousands of volts it is commonly expressed in kilovolts (1.000 v. = 1 kv.). In most X-ray generators the so-called kilovoltmeter is merely an ordinary A.C. voltmeter wired across the primary winding of the high-tension transformer but calibrated in peak kilovolts by means of direct sphere gap measurements of tube voltage made by the manufacturer during the factory calibration of the machine.

For fluoroscopy and the making of X-ray films, tube current may be as low as 3 ma. or as high as 500 ma. or even higher. and voltage usually ranges from 45 kv. to 90 kv. or even up to 130 kv. The magnitude of the voltage applied to an X-ray tube has tn-o important effects on the radiation that is produced. It determines the wave-length composition of the beam and therefore its penetrating ability, and in addition affects the intensity of all beam components exponentially. For example, a tube voltage of 45 kv. will produce a certain amount of rather soft radiation having a maximum shortness of approximately 0.274 angstroms (Å) (0.274 $\times 10^{-8}$ cm.), a type of radiation so feebly penetrating that it is unsuitable for the fluoroscopy or filming of heavy body parts. Doubling the voltage (to 90 kv.) brings the maximum shortness of the beam down to 0.137 Å, thus providing penetration adequate for the thickest anatomical parts, and in addition this voltage change quadruples the intensity of all the components of the beam.

Contrary to a widely held misconception, there is no specific relationship between the part to be examined and the voltage. current and exposure time that should be employed. Over a considerable range. these factors—voltage, current and exposure time—may be juggled almost at will. provided only that the time intensity product of the radiation reaching the film approaches a constant that has been determined empirically as adequate for recording the tissue densities of the body part that is being examined. The experienced radiologist or X-ray technician uses voltages of approximately 60 kv. and currents of about 25 ma. for thin body parts that can be well immobilized. thus keeping the exposure time within the range where minor time switch errors are of negligible importance and allowing the use of fine-focus tubes: but when the work to be done requires that the exposure time be as short as possible: he sets the time switch for $\frac{1}{60}$ sec. or sometimes even & sec., sets the current at the maximum allowable for the tube (for example, 500 ma.) and then adapts to variation in the thickness and density of body parts by varying voltage.

2. X-Ray Generators.—In their simplest form the X-ray generators used in diagnosis consist of a hot-cathode X-ray tube, a controllable means of heating the cathode. a source of alternating current and a means of regulating the voltage of that current. Circuits of this sort are known as self-rectified because in them the X-ray tube itself acts as a rectifier, passing one half cycle and suppressing the other half cycle of the raw alternating current that is supplied by the transformer. Thousands of sets of this design are in daily use throughout the world, functioning as dental X-ray machines. portable and bedside X-ray machines and in small fluoroscopes. They are adequate where the service is intermittent and the loads range from 3 ma. to 10 ma. at potentials from 40 kv. to 75 kv., but for heavy work full-wave rectification is preferable.

In theory, full-wave-rectified generators differ from the self-rectified sets described above merely by the insertion of four electronic or solid-state rectifiers between the high-voltage terminal of the transformer and the terminals of the X-ray tube. In practice. honever, they are much more complex, including voltage stabilizers for the filament of the X-ray tube, voltage regulators for the primary windings of the high-voltage transformer and the X-ray filament transformer. devices for the automatic selection and limitation of tube voltage and current, circuits for energizing the rotors of rotating anode tubes, meters, fuses, circuit breakers and some means for the precise timing of both short and long exposures. In addition, they allow employment of higher voltages and larger tube currents. All modern generators are completely insulated or "shockproof." regardless of whether they are of the self-rectified or the valve-tube-rectified type.

3. X-Ray Tubes.—The tubes used in X-ray diagnosis consist of a well-exhausted glass-enveloped diode surrounded by a metallic housing that is lined with lead except at a small port through which the useful beam of X-rays emerges. The space between glass insert and housing is filled with insulating oil. In the simplest and smallest sets the tube housing is integral with the transformer housing, but in larger machines the two usually are separate, tube and transformer being connected by means of flexible, shielded, insulating cables. In these modern descendants of William David Coolidge's hot-cathode tube, the cathode stream is focused as a ribbon on a steeply inclined target so that the heat of impact will be distributed as widely as possible and yet the optically effective source of the rays will approach a point. Frequently two filaments are provided—one focusing the electrons sharply for use when great detail is required and small currents are allowable, the other distributing the electrons over a larger target area for use when heavier currents must be employed. Targets are of two general types—those that are stationary and those that rotate or spin during operation. In the stationary anode tube, the target is of swaged tungsten embedded in a massive copper anode which extends out through the glass envelope to conduct the heat of electron bombardment into the insulating oil that surrounds the tube. Sometimes there is a pump or impeller to circulate the oil, and usually there is a blower to expedite removal of heat from the housing.

Rotating anodes turn on precision bearings that are mounted nithin the exhausted glass envelope and therefore must be devoid of ordinary lubricants which would ruin the vacuum. The stator lies outside the envelope, its lines of force passing through the glass to operate the rotor which is attached to the anode stem. Sometimes the anode disk is of massive copper with an embedded belt of tungsten to receive the electron bombardment. but more commonly it is of solid tungsten capable of withstanding a cherry-red heat during heavy loading. For many applications rotating anode tubes are extremely satisfactory. but they have the serious limitations of dissipating target heat almost exclusively by radiation through the glass envelope and lacking the direct conduction through copper that is so efiective in the case of stationary anode tubes.

4. Films, Screens and Cassettes.—X-ray films consist of an acetate cellulose base coated on both sides with an emulsion of

silver halide and gelatin. It is possible to prepare emulsions that are particularly sensitive to X-rays, but since most X-ray films are used in conjunction with calcium tungstate intensifying screens, the emulsions are given maximum sensitivity to the fluorescence of calcium tungstate rather than to X-rays themselves.

For the examination of certain parts—such as the teeth, fingers and toes—plain film without screens is ordinarily used. and in such applications it suffices to wrap the film or otherwise enclose it in a covering such as black paper or cardboard which is opaque to visible light but not to X-rays. For the filming of heavier parts, however, the exposure time can be reduced and the contrast in the image enhanced if films pressed between two intensifying screens are used instead of plain films. These screens must be in intimate contact with the emulsions if sharp detail is to be recorded. Such contact is provided by rigid lightproof containers known as cassettes. The fronts of cassettes are made of bakelite or magnesium to exclude light but admit X-rays, and when phototiming is employed the backs also must be reasonably radiotranslucent. The screen attached to the inside of the cassette front frequently is thin because it must transmit most of the radiation, but the rear screen is thick, absorbs more radiation and fluoresces more actively. In the making of a film—for example, of the chest—the patient stands facing a 14-in. × 17-in. duplitized X-ray film (double emulsion) contained in a double-screen cassette of the sort described above, the X-ray tube being arranged so that its beam of radiation passes through the patient's back in a direction perpendicular to the surface of the film. The X-rays induce a moderately brilliant fluorescent image of the lungs, ribs, heart, etc., on the front screen, produce a slight photographic effect directly on the front and rear layers of film emulsion. and finally induce a brilliant fluorescent image on the rear screen. The light from the two fluorescent images photographs itself onto the emulsion along with the two direct X-ray images. and in the completed film all four images, being superimposed, appear as one.

5. Grids.—X-rays arise on the target of an X-ray tube at the point where it is bombarded by electrons emitted by the cathode. In fine-focus tubes the effective X-ray source may have a diameter as small as 0.3 mm. and in coarse-focus tubes as large as 4 5 mm. All else being equal, X-ray images are sharpest in detail when the radiation source approaches a point and become blurred when the source is large. In the discussion that follows, a point source of radiation will be assumed. for convenience.

From their point of origin X-rays are propagated in straight lines in all directions over a solid angle of 4π. but most of them are absorbed in the lead lining of the housing and the cone of useful radiation that emerges through the port has an apex angle of only approximately 15°. Within the ordinary meaning of the terms, X-rays cannot be reflected or refracted by the substances they encounter on their straight-line course to the X-ray film, but some of them do become scattered. For small. thin parts, scattering is practically negligible, but for heavy parts, such as the skull and trunk of an adult, the radiation that is scattered in the patient's body fogs the image formed by the straight-line or primary radiation to such a degree that finer details become indistinguishable.

Prior to 1917 good X-ray plates of the skull, spine, hip, etc., required that the primary beam be narrowed to a very small diameter to reduce scattering, and 14-in. × 17-in. plates of the entire pelvis of a heavy subject were so badly fogged by scattered radiation as to be of little clinical usefulness (glass plates were used in those days rather than films). However, as early as 1912 Gustav Bucky in Germany laid the groundwork for overcoming this difficulty, and by the early 1920s there became commercially available. first in the U.S. and later in Europe, moving grids designed by the U.S radiologist Hollis Potter. These instruments, knonn as Potter-Bucky grids or, less properly. as Potter-Bucky diaphragms, became an indispensable part of the equipment of all diagnostic radiologists. Such grids. consisting of an assembly of lead strips interspaced with strips of wood. plastic or other radiotranslucent material, are interposed betneen patient and film and are kept in motion while the exposure is being made. The lead strips are aligned as radii of a segment of a theoretical cylinder that has a diameter equal to twice the target-film distance. A small portion of the primary or unscattered radiation that emerges from the patient's body impinges squarely on the edges of the lead strips, where it is absorbed, but most of it passes through the interstices between the strips and thus to the film. The scattered radiation, on the other hand, being no longer aligned with the translucent interstices, impinges for the most part on the sides of the lead strips, where it is absorbed.

In Bucky's original stationary grids, the metallic members were thick and widely spaced, thereby causing disturbing patterns on the film, and Potter's contribution was to conceive and build grids that could be moved during exposure, thus obliterating the pattern of their grid members but not interfering with their ability to absorb scattered radiation. Modern moving girds are fat rather than curved; they are built to extremely precise dimensional tolerances, have great ability to absorb scattered radiation, and reciprocate throughout the exposure instead of starting before the exposure begins and continuing to move in the same direction until the exposure has been completed. Stationary grids were improved even more. In their original form they were virtually useless except as precursors to a great idea, but the work of the Swedish radiologist Eric Lysholm revived interest in them. Excellent European and U.S. units became available, some composed of parallel strips, others having two systems of parallel strips aligned at right angles to one another to form crisscross or honeycomb grids. Grids of this latter type came to be used widely for bedside raying, raying in the operating room, for angiography and for spot filming of the stomach and intestines. In a type of moving grid developed later, transverse members are aligned at less than 90° to the longitudinal members; this retains most of the advantages of honeycomb grids and yet makes it possible to move the grid assembly during exposure and thus leave no pattern of it on the film.

Unlike the moving grids, the stationary ones inevitably leave their own images on films along with the images of the body parts that are being examined. In modern stationary grids, however, these superimposed patterns are regular and faint, detracting little from appearance and nothing from clinical usefulness.

6. Fluoroscope.—A fluoroscope is an apparatus for the direct observation of body tissues by means of X-rays. It consists of a fluoroscopic screen supported in front of the port of an X-ray tube so that a patient may be interposed between the screen and the source of the radiation. A shutter usually is provided to control the area of the beam of radiation emitted by the tube. and a sheet of plywood or other strong but radiolucent material is interposed between tube and patient to provide a surface on which the patient lies when the instrument is tilted from the vertical into the horizontal position. Many crystalline substances will glow when exposed to X-rays. Among the best for clinical fluoroscopy is zinc cadmium sulfide mixed with traces of other materials. A fluoroscopic screen consists of a piece of cardboard coated with a layer of such fluorescent salts and faced nith a sheet of thick lead-bearing plate glass that is highly opaque to X-rays but alrnost perfectly transparent to the greenish light given off by the fluorescing crystals.

B. Techniques

1. Timing the Exposure.—When the intensity of the X-ray beam is low and the exposure time of the order of ten seconds, errors of plus or minus a few tenths of a second are negligible and the simplest of spring-driven time snitches are adequate to time the exposure; but for tube currents of from 100 ma. to 500 ma. and exposure times of the order of $\frac{1}{60}$ sec.. precise timing becomes important and difficult, much of the difficulty being inherent in the pulsating nature of the current applied to the X-ray tube When 60-cycle current is employed, X-rays are emitted by the target not continuously but in brief bursts starting from zero, rising to full intensity and then returning to zero every $\frac{1}{120}$ sec. (each half cycle). Brief exposures therefore must be measured out in half cycles, and it is important that the exposures be initiated and terminated approximately at zero points on the voltage wave. In other words, the timing device and the contactor

must be phased with the generator. Such phasing formerly mas accomplished reasonably well even with heavy conventional magnetic contactors, but it was rendered easier and more precise by the substitution of the electron discharge in heavy-duty thyratrons for mechanically operated metal-to-metal contacts.

In the early 1940s it became possible to time X-ray exposures automatically by means of multiplier phototubes. Phototiming, as it is called, gradually was made available in commercial X-ray machines. In general radiography the phototube and a fluorescent screen are mounted in a box that is impervious to light but has a top that is transparent to X-rays. This box, known as a detector, is located beneath the Potter-Bucky grid where it receives radiation that has passed through the patient's body, the film and the cassette. The detector is calibrated empirically so that when the film has received an amount of exposure that will assure an optimum image, the phototube will have received sufficient fluorescent light to cause it to trigger an electronic switch and thus terminate the X-ray exposure. In photoflubrography (described below) the phototube is mounted in the camera head and, like the lens. "observes" the fluorescent screen. In the case of the filming fluoroscope, which is so important in the examination of the gastrointestinal tract, the phototube scans an image produced on the fluoroscopic screen by radiation that has passed through the patient's body and through the back of the film cassette.

2. Processing X-Ray Films. — When the technician who exposes an X-ray film also develops it, the composition and temperature of the developer and the length of development need not be regulated precisely because modern films have wide latitude and the experienced worker learns to shorten or prolong development until inspection before a safelight indicates that an acceptable image has been obtained. Where the volume of work requires division of labour, however, the situation is different. One set of workers exposes the films to carefully measured amounts of radiation, and another group working in darkrooms develops them in solutions of standard strength and temperature for standard periods of time. Automatic film processing machines found wide acceptance in the years after World War II. Even in small laboratories the simpler hand-operated processing tanks usually included constant-temperature baths. The common practice is to standardize exposures so that development for five minutes at 68° F. in standard-strength developer will yield films of optimum density. For special examinations, such as those conducted in the operating room in conjunction with surgery, the solutions may be warmed in order that developing time may be shortened, the saving in time being considered more important than the inevitable reduction in the quality of the image.

Polaroid film, with its self-processing features, and the process known as xerography, which employs charged selenium plates, hold intriguing possibilities, particularly under emergency conditions where X-ray films and processing solutions might be unobtainable. Unfortunately, however, in their state of development in the early 1960s, both these systems were so much less sensitive than the standard system using films and intensifying screens that they required excessive doses of X-rays to the tissues of the patient.

3. Stereoscopic X-Ray Filming. — Three-dimensional vision is helpful in the radiography of any part of the body and is almost essential in X-ray examinations of the skull and trunk. The two films that are required for stereoscopic filming are made with the film and body part in identical spatial relationship for each but with the X-ray tube shifted slightly between the two exposures. The amount of the shift is determined by the relationship between the distance from the film to the target of the X-ray tube at the time the exposure is made and the optical distance from the film to the eyes of the observer at the time the two films are examined. If these two distances are identical the tube shift should be 66 mm., which is the average interpupillary distance, but if the commoner situation obtains and target-film distance is greater than film-eye distance, then the tube shift must be increased proportionally.

Even without. the aid of instruments some workers become able to view one of the films with one eye, the other with the other eye, and then fuse these two slightly dissimilar, real, flat irnages into a single, virtual, three-dimensional image. It is more convenient, however, and for some persons actually essential to employ a special viewing apparatus.

4. Contrast Media. — The lungs show in X-ray films and in fluoroscopic images by virtue of the sharp difference between the X-ray absorbing power of the air that distends them and that of the pulmonary tissue itself. This difference in absorbing power is called "contrast." The heart, being composed largely of muscle and blood, contrasts strongly with the air-filled lungs adjacent to it but scarcely at all nith the liver beneath; bones are distinguished from surrounding muscle and the various parts of bone from one another by virtue of the calcium phosphate they contain. To a great extent, however, the clinical usefulness of the X-ray examination depends on the employment of artificial contrast media. The most extensively used opaque medium is barium sulfate Stirred into aater and flavoured nith a little chocolate sirup, this insoluble heavy metal salt is employed for examination of the esophagus and stomach; mixed aith powdered resins and water it becomes a barium enema for the examination of the rectum, colon and terminal ileum. An iodized organic compound is used for examination of the gall bladder. urinary tract. blood vessels, spleen and liver. X-ray visualization of the bronchi better than that obtained merely by the contrast of contained air is made possible by the introduction into the bronchial tree of unsaturated vegetable oil partially saturated with iodine. An emulsion of ethyl iodophenylundecylate also is used in bronchography and in the examination of the spinal canal (myelography).

5. Fluoroscopy. — Fluoroscopy has a great advantage over filming in that with it motion can be seen, but there are many offsetting disadvantages, the most important of uhich is the inevitable radiation hazard to operator and patient. In addition, fluoroscopy lacks objectivity because it leaves no permanent record, and the image on the screen is so faint that to see it the room must be well darkened and the eyes of the fluoroscopist fully dark-adapted. The dark-adapted eye employs largely the rod type of vision, nhich is suitable only for rather coarse "seeing." Thus. many of the finer anatomical details that would be seen well by the cone vision used in examining brightly transilluminated X-ray films cannot be seen at all on the fluoroscope. Formerly fluoroscopy was widely employed to detect fractures of the extremities and to aid in their reduction, but it was recognized that this practice is dangerous to patient and physician, as well as being diagnostically inferior to filming. The most important remaining clinical use of fluoroscopy is in the examination of the gastrointestinal tract and the spinal cord, where it is used in conjunction with filming.

Photofluorography.—From the earliest days of radiology, attempts were made to make permanent records of fluoroscopic images by photographing them. but until the late 1930s the maneuver saw little practical application. The advantage of photofluorography lay in its ability to employ small, inexpensive and easily processed photographic roll film instead of large. costly, individual sheets of X-ray film, its disadvantage in the fact that fluoroscopic images were faint and the camera lenses available for recording them slow. As far as the chest is concerned, the disadvantages finally were overcome by developing faster film emulsions, faster screens and refractor lenses large enough to cover a 64-mm. by 70-mm. area on roll film and yet having a speed of f/1.5. Millions of members of military and civilian populations were subjected to small-film chest surveys, but though such photofluorography of the chest is of genuine importance as a public health measure it is not a rival of the older methods as a means for the detailed study of pulmonary diseases.

The substitution of large-aperture reflector lens systems for the f/1.5 refractors improved the quality of chest microfilms and reduced the X-ray dose to the patient.

Electronic *Amplification.*—After 1947 electronic amplification of the fluoroscopic image received increasing attention from numerous U.S. and European workers, but not until the late 1950s was there much clinical application. Methods are of three general types:

1. Employment of X-rays to produce an electron image of the part; acceleration of the electron image by high-voltage fields

aided by electron lenses or mirrors; and conversion of the enhanced electron image into a visible image.

2. Employment of television techniques by the method of Morgan, Moon or Jacobs.

3. Adaptation of developments in solid state physics (*q.v.*).

Developmental problems are numerous and difficult, with the constant necessity of choosing between a desirable increase of image brilliance without too much sacrifice of image resolution.

X-Ray *Motion Pictures*.—Within a year following Wilhelm Conrad Röntgen's announcement of the discovery of X-rays, attempts were made to produce X-ray motion pictures. Scores of publications on the subject appeared thereafter in the public and scientific press. In the so-called direct method a motion-picture positive is made from a sequence of individual X-ray negatives; in the indirect method the positive is printed from a motion-picture negative of the fluoroscopic screen. Both methods required such large doses to the tissues of the subject that they were limited to experimental work with animals; in the case of the indirect method, however, modern image amplifiers have removed this difficulty. For maximum resolution a 16-mm. motion-picture camera records the image directly from the screen of an image amplifier, but where resolution is not too important it may be preferable to televise the image of the amplifier and then photograph the image on the television screen.

C. Applications

1. Teeth.—Intraoral films were early employed for detecting abscesses in the bone about the apexes of the teeth, for locating unerupted or impacted teeth and for discovering retained broken tooth roots. Their field of usefulness was enlarged until they came to play an important part even in the periodic examination and cleaning of the teeth. Small cavities at abutting surfaces, poorly fitting fillings and inlays, recession of the bone from the necks of the teeth and, most important of all, subgingival deposits of salivary calculus—such lesions as these are easily detectable in X-ray films though they may escape all but the most skillful and searching direct inspection.

2. Bones.—For the first few years following Röntgen's discovery, it seemed that X-rays might be used in medicine chiefly as an aid in the diagnosis and reduction of fractures. X-ray films are used not only for the detection of injuries but also for demonstrating the presence of tumours, infections and almost every other form of skeletal disease. In normal bone the cortex shows in X-ray films as a dense amorphous shell and the spongy portion as a honeycombed structure made up of the shadows of the coarse primary trabeculae, on which are superimposed the shadows of the fine secondary trabeculae. Disuse of living bone causes a generalized loss of density known as osteoporosis, but when portions of bone are killed by disease or injury before osteoporosis has occurred, they retain their original density for long periods of time. Some tumours and infections cause localized destruction of bone and others cause the hone to become denser than normal (sclerosis). Certain parts of normal living bone, such as marrow, periosteum and articular cartilage, though not themselves discernible by X-rays, may when diseased produce subtle changes in visible bone adjacent to them, thus leading to their own detection. Rickets, scurvy, syphilis, tuberculosis, Paget's disease (osteitis deformans), benign and malignant tumours and many other skeletal diseases produce changes in the X-ray appearance of bones that are almost always easy to see and frequently so characteristic as to warrant a specific diagnosis.

3. Chest and Heart.—Internists and surgeons must lean heavily on the findings of the radiologist for the detection and management of such pulmonary diseases as tuberculosis, pneumonia and cancer, though of course it is necessary to weigh all the evidence in making the final diagnosis and not depend on X-rays alone. Active fibrocaseous tuberculosis usually produces rather characteristic dense splotches in one or both of the lung apexes, but at certain stages in their course some of the pneumonias and histoplasmosis show X-ray patterns almost identical with those of tuberculosis. Malignant tumours arising in the bronchi usually reveal themselves promptly by causing bronchial obstruction with resulting rather typical areas of lung collapse. Foreign bodies accidentally introduced into the trachea or bronchi frequently are dense enough to show directly in X-ray films; when radiotranslucent they may be detectable with the aid of opaque media or by virtue of changes they produce in the air patterns of the lung. When the diagnosis of pulmonary tuberculosis has been established, repetition of the X-ray examination is one important method for observing the results of treatment.

Radiology may be employed to determine the size and shape of the heart and great vessels, and, with the aid of opaque media, it provides detailed information about the chambers and valves of the heart and the pulmonary vessels, particularly in children suffering from congenital defects.

4. Skull, Brain and Spinal Cord.—The X-ray criteria employed for diagnosing injuries and diseases of bone are most dependable in regions where cortex is thick and well differentiated from spongiosa, as in the long bones of the extremities. Cortex is well developed in the vault of the skull: and fractures, tumours, infection, etc., in the skull are usually reasonably evident. In the face bones, however, where the cortex may be as thin as paper, such lesions may be almost invisible.

Because of the air that they contain, the normal mastoids and the sinuses (frontal, ethmoid, maxillary, sphenoid) show as black shadows sharply silhouetted against bone, and if fluid or benign or malignant tumours are present they too will stand out in contrast with the air. Certain tumours of the pituitary gland cause the sella turcica to enlarge in a characteristic fashion, and in young children a long-continued increase in intracranial pressure may be inferred from a resulting separation of the bones of the skull.

The brain itself is radiotranslucent except for several normal and occasional pathological patches of calcification, and so it is necessary to employ contrast media when the brain is to be examined, the medium of choice being oxygen or air. When such gases are introduced into the subarachnoid space, the procedure is termed encephalography; when they are injected directly into the hollow chambers or ventricles at the centre of the brain it is called ventriculography. In either case, the X-ray examination is done with stereoscopic films, and the object is to study the internal and 'external contours of the brain by virtue of the gas that is in contact with them. Development of cerebral angiography (see Blood *Vessels*, below) greatly expanded the radiologist's ability to diagnose tumours of the brain and small aneurysms of the cerebral vessels.

Opaque media are much more effective than gas for examining the spinal cord and the canal in which it lies, a procedure known as myelography. Under fluoroscopic control, the contrast material in the subarachnoid space is maneuvered into all parts of the spinal canal from the tip of the caudal sac in the lumbosacral region up to (but not into) the cisterna at the base of the brain. The films that are made at all levels and in several positions show the cord itself as a translucent or negative shadow and the surrounding subdural space as a dense shadow by virtue of the opaque medium it contains. Protruding knobs of intervertebral cartilage, spikes or ridges of arthritic osteophytes, tumours of bone, cord or meninges are among the abnormalities that may be detected by myelography; but normal variation is great and differentiation difficult even when the examination is conducted by teams of specially trained neurosurgeons and radiologists.

5. Gall Bladder and Bile Ducts.—In 1923 E. A. Graham introduced a method for the X-ray examination of the gall bladder, known as cholecystography, which came into universal use. An iodized organic compound contrast medium, after being given, by mouth in tablet form, is absorbed from the gastrointestinal tract into the blood and then removed from the blood stream by the liver and combined with the bile. A normal gall bladder, receiving through its cystic duct watery, weakly iodized bile, concentrates it until eventually it becomes thick and its iodine content high. In X-ray films made 10 to 15 hours following administration of the opaque medium, the normal gall bladder casts a dense shadow and any cholesterol stones present stand out as negative shadows against the iodized bile. If the gall bladder is seriously diseased or its cystic duct is occluded, bile will fail to reach the gall bladder or, reaching there, will fail of concentration, either of these events resulting in nonvisualization.

Cholangiography, or examination of the bile ducts, usually is conducted in conjunction with surgery to assure that stones or a tumour obstructing the ducts have not been overlooked. A contrast medium is injected either through a T tube tied into one of the bile ducts or by means of a hypodermic needle introduced through the wall of a duct or of the gall bladder itself. Intravenous cholangiography (*i e.*, with contrast medium injected into a vein) introduced in the late 1950s, met with little success.

6. Urinary Tract.—Pyelograms are X-ray films of the urinary tract made following the introduction of an opaque medium. In the retrograde method, the opaque medium is injected through ureteral catheters introduced with the aid of a cystoscope In the excretion or intravenous method, it is injected intravenously followed by filming at intervals of 5 to 15 minutes.

Most tumours lying in the fleshy part of the kidney outside its collecting system compress, stretch and otherwise distort the calyces and pelves. Tuberculous abscesses are prone to break through into the calyces, allowing the opaque medium to extravasate into diseased tissue. and the infrequent kidney stones that are radiotranslucent may be rendered visible by the opaque medium in the same way that opaque medium reveals cholesterol gallstones Cystograms are films of the urinary bladder made after the direct or excretory filling of that organ with opaque medium. Bladder tumours, diverticula and urethral obstruction by chronic prostatic enlargement produce rather characteristic alterations in the appearance of the cystogram.

7. Female Reproductive Tract.—Sterility of the human female may result from various causes, one of which is occlusion of the fallopian tubes. The best means of demonstrating such occlusion is to make X-ray films following the injection of iodized oil into the uterus. In the normal subject. the oil passes out through both fallopian tubes to spill into the peritoneal cavities, where, 24 hours later, it becomes smeared over the serous surfaces of loops of bowel and appears by X-ray as a slightly opaque, crumpled veil. When no connection exists between the uterine cavity and the peritoneal cavity, the peritoneal spread of the oil does not occur, and when occlusion is due to saclike adhesions about the outer ends of the fallopian tubes, the oil breaks up into droplets and is retained in the watery fluid that fills the sacs, While the purpose of the injection is diagnostic, it is believed that it may sometimes be therapeutic as well, breaking up adhesions if they are not too tough and developing communication where none existed before.

When a pregnant woman is known to have an obstetrically adequate pelvis and a presumably normal fetus. pelvic X-ray examination seldom is called for, but if circumstances require quantitative knowledge as to the dimensions of the birth passages, X-ray examination provides by far the best means of measuring them.

Since X-rays diverge from their point of origin, the X-ray images of anatomical parts that are parallel with the plane of the film are always somewhat larger than the parts themselves; and if the parts are oblique to the film, that too causes distortion of the image. With the aid of a little special equipment and the application of a little simple geometry it is possible to compensate for distortion and translate measurements of film images into the actual dimensions of the maternal or fetal parts they portray, the procedure being known as pelvimetry or fetometry.

8. Blood Vessels.—For many decades injections of opaque heavy metal salts were used for making X-ray films of the blood vessels of anatomical specimens, and later angiography of the living subject became of clinical importance. When vessels of the brain are to be injected, most radiologists prefer to use the contract material in 30% concentration, but for the chambers of the heart and the great vessels leading from them concentrations as high as 70% are necessary. Several films must be made in rapid succession, each exposure being brief. the first in the series phased carefully with the beginning of the injection. Some radiologists use long strips of roll film driven past a window that is transparent to X-rays but opaque to light, while others prefer cut film carried in motor-driven conveyers.

Angiograms are used for the investigation of certain brain tumours; to identify obstructions and abnormal communications involving vessels of the extremities; and, above all else, for the study of the abnormal anatomy of the great vessels in patients with congenital heart disease for whom cardiac or vascular surgery is contemplated.

9. Stomach and Intestine.—X-ray examination is an important. almost indispensable, agent in the diagnosis of gastric and duodenal ulcer; benign and malignant tumours of the esophagus, stomach and bowel; diverticulosis and diverticulitis; ulcerative colitis; regional ileitis; and several other diseases. Barium sulfate is the contrast medium almost invariably employed. Formerly it was fluoroscopic examination that made the diagnosis, with films occupying a position of secondary importance, but many modern radiologists look upon fluoroscopy largely as a means of obtaining small, so-called spot films of various parts of the tract. In spot filming, the fluoroscopist manipulates a small segment of the gastrointestinal tract into position beneath the fluoroscopic screen and adjusts the amount of barium that it contains and the pressure applied to it until he has an optimum view. A film is now brought into position between the patient and the fluoroscopic screen. and, when the X-ray machine setting has been changed from the continuous small current adequate for fluoroscopy to the high voltage and large currents needed for rapid filming, the exposure is initiated with a foot snitch and terminated automatically with a phototube. Ulcers usually deform the outline of the stomach or duodenal bulb and, in addition, frequently excavate craters which, when filled with barium, are highly diagnostic. Cancers appear as soft tissue masses protruding into the lumen of the stomach or bowel and distorting the appearance of the gastric or intestinal mucosa.

II. THERAPEUTIC RADIOLOGY

One of the most remarkable attributes of the X-rays that Röntgen discovered in 1895 was the seemingly innocuous way in which they penetrated human tissue without causing pain: a feeling of heat or any other immediate sensation; but it did not take long for experimenters to learn that in spite of the absence of immediate effect, large doses led presently to redness of the skin, blistering and ulceration. Even small doses, it was found, if repeated often enough were followed by serious skin lesions that. showed up only after a considerable lapse of time. Of course, an agent so capable of damaging normal tissue mas bound to be considered for employment therapeutically if some means could be found to direct its damaging effects specifically against diseased parts.

Something eventually was learned about the fundamental nature of the biological action of radiation, and research on this subject continues, but usefulness did not wait on a complete understanding. Radiation therapy became one of medicine's few means of restraining and in some cases curing cancer.

The radiations employed in therapeutic radiology include X-rays ranging in voltage from about 5 kv. to more than 4,000 kv., radium, artificial radioisotopes, electrons. neutrons and other high-speed particles. Important differences in the physical distribution of the dose determine which of these should be used for a particular application. but biologically speaking it is the similarities rather than the differences that are most obvious throughout the entire range from the low-voltage X-rays used in contact therapy to the high-speed particles of the largest cyclotrons.

For historical and other reasons a discussion of radium and low- and medium-voltage X-ray therapy lends itself particularly well to an exposition of principles that apply throughout the entire radiation range. It is for this reason alone that radium. artificial radioisotopes and X-rays of low (5–100 kv.) and medium (100–400 kv) voltage are emphasized below. This distribution of emphasis should not be misinterpreted as indicating that multi-million-volt X-rays and high-speed particles are clinically unimportant.

The ideas of Heinrich Geissler, J. W. Hittorf, Sir William Crookes and P. E. A. Lenard were important immediate antecedents to those of Rontgen, and in the years after 1895 the stream of those ideas were swelled by innumerable tributaries. Italians such as Enrico Fermi supplied ideas in nuclear physics. Frenchmen such as the Curies, H. Coutard, A. Lacassagne and C. Regaud discovered radium and established the importance of the time factor as a modifier of the reaction of tissue to radiation. German physicists made important contributions, and German physicians such as H. Holthusen studied large masses of clinical material to establish much empirical knowledge. Scandinavians typified by G. Forssell and R. Sievert refined and advanced dosimetry and made large-scale clinical application of facts established in the laboratory.

British contributions were of two sorts. In the closing decades of the 19th century and the opening decades of the 20th such physicists as J. J. Thomson, C. T. R. Wilson, H. G.-J. Moseley and the two Braggs led in the development of X-ray physics. and later such physicians as Ralston Paterson and David Smithers and such radiation physicists as W. V. Mayneord. W. J Meredith and H. ill. Parker increased the precision with which radiation beams might be regulated and directed and advanced knowledge as to the response of normal and diseased tissues to such beams.

In the U.S., W. D. Coolidge conceived and produced X-ray tubes superior to anything available before, and Arthur Holly Compton and his students, employing X-rays to study the nature of matter, discovered in the process new and important facts about the X-rays themselves. Ernest Lawrence's pioneering cyclotron typified a whole group of instruments developed for accelerating particles of various sorts, and the biological experirpents on ionizing radiation that were carried on during World War II under John Lawrence in California and under Robert Stone in Chicago served as patterns for many later similar activities.

A. Dosage

1. Measurement. — The dose employed in X-ray therapy cannot be defined merely by stating the voltage and current at which the X-ray tube is operated. Numerous other factors are involved, including diameter and filtration of the X-ray beam. target-skin distance and the size and location of the lesion being irradiated. The need of dependable dosage guides was recognized more or less clearly from the outset, but their development proved difficult. Tried and found wanting were the measurement of the heat produced by the absorption of X-rays; the intensity of fluorescence; colour changes in several different combinations of chemicals; the blackening of silver bromide paper; the liberation of iodine from a solution of iodoform in chloroform; and an increase in the electrical conductivity of selenium under the action of X-rays.

Ionization Methods. — Rontgen's original papers described the ability of X-rays to ionize air. and in 1896 J. J. Thomson independently discovered the effect and suggested its use by physicists as a means of measuring X-ray intensity. P. Villard in 1908 advocated ionization for measuring the clinical dose, but his idea was not practical at that time because the large, delicate ionization chambers that were serving physicists so well were not suitable for clinical work and no others mere available. Gradually, however, small rugged chambers were developed, and in 1928 at the second International Congress of Radiology in Stockholm. Swed., there was adopted the "r" or roentgen unit, which became the standard throughout the world.

Roentgen Unit. — The roentgen unit was defined in Stockholm as follows:

> The unit of dose is that quantity of roentgen radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produces in 1 c.c of atmospheric air at 0° C and 760 mm mercury pressure such a degree of conductivity that one electrostatic unit of charge is measured under saturation conditions.

This definition sufficed as long as the X-rays to be measured were produced at voltages up to 200 kv., but as r.meters began to be employed in the 1.000-kv. range and for the gamma rays of radium. the following definition was substituted:

> The roentgen shall be the quantity of X or gamma radiation such that the associated corpuscular emission per 0.001293 g. of air produces, in air, ions carrying 1 esu of quantity of electricity of either sign. (The mass of 1 c.c. of dry atmospheric air at 0° C. and 760 mm. of mercury pressure is 0.001293 g.)

Rad.—When the absorbed dose is the chief matter of interest, the roentgen unit has the disadvantage that absorption in air is independent over a considerable wave-length rahge, whereas in water-containing tissues energy absorption per gram increases from approximately 84 ergs for long-wave-length (low-voltage) radiation to about 93 ergs per gram for short-wave-length (high-voltage) radiation. The unit of absorbed dose is the rad, representing the amount of radiation which delivers energy equivalent to 100 ergs to a gram of irradiated tissue.

Roentgen (r) Meters. — The condenser-type r meters in general use in the United States consist of two parts, a chamber-condenser unit and a charging-measuring unit. Three sizes of chamber usually are supplied: a large one that measures up to 25 r; an intermediate size measuring up to 100 r; and a small chamber for measurements up to 250 r. The electrometer that measures the charge has three corresponding scales calibrated from 0 on the left to 25 r, 100 r or 250 r, respectively. on the right.

Chamber-Condenser Unit. — In the 100-r unit the chamber itself is a small plastic thimble that contains one cubic centimetre of air at room temperature and pressure. The inside of the wall of the chamber, which has been rendered conducting by a thin coating of carbon. constitutes one electrode and is connected to the metal sheathing that forms one of the plates of a 60-micro-microfarad condenser. The second electrode is a carbon-coated plastic rod mounted in a block of high-impedance material with its tip protruding into the air in the chamber, its base in electrical contact with the insulated plate of the condenser. Care is taken to exclude air from all parts of the system except the space inside the chamber itself.

Charging and *Measuring* Unit. — The charging and measuring unit consists of a hand-driven plastic disk that generates a static charge by rubbing against a leather pad, plus a quartz fibre electroscope that is calibrated in roentgen units. In using the instrument. the condenser is plugged into the charging unit and the charging wheel is rotated until the fibre stands at 0. The charged condenser is then disconnected from the electrometer and placed for a measured period of time with its chamber in the beam of the X-ray that is to be measured. The X-rays ionize the air in the chamber, causing it to become an electrical conductor, and this in turn allows the charge on the central plate of the condenser to leak to the wall of the chamber and thence to the outer plate of the condenser. When the partially discharged condenser is reconnected to the electrometer, the fibre has moved from the fully charged 0 position on the left toward the discharged 100-r position on the right, the precise amount of loss of charge being read directly in roentgens without computations of any sort.

Roentgen meters of this sort are secondary standards requiring initial checking against large standard chambers and occasional subsequent rechecking. but when they are carefully built and properly calibrated their accuracy is well within the limits necessary for radiation therapy. The required dose varies uidely from as little as 1.200 r in some lymphomas to as much as 5,000 r in most laryngeal carcinomas.

2. Low-Voltage X-Rays. — Until the close of World War I most clinical X-ray apparatus could not be operated at voltages in excess of 100 kv.; while this was more than enough for diagnosis, it limited therapeutic applications to lesions lying at or close to the surface of the body. Regardless of the inciting voltage, the raw beam as it leaves the X-ray tube contains amounts of long-wave-length radiation that are enormously greater than the amounts of short-wave-length rays. Because the long-wave rays are easily absorbed, they are said to be soft, while the short penetrating rays are said to be hard.

If raw radiation from a tube operated at 100 kv. is allowed to fall on a patient's skin, the soft radiation will be strongly absorbed in the superficial layers, so that an exposure time long enough to result in serious skin damage delivers only small amounts of relatively hard radiation to tissues lying a few centimetres beneath the surface. Filtration through three millimetres of aluminum will harden such a beam so that it may be possible to deliver 20% of the surface dose to tissues five centimetres beneath the surface, but it is impractical to deliver doses of therapeutic magnitude to tissues ten centimetres below the surface unless the voltage at the X-ray tube is raised well above 100 kv.

Formerly the degree of reddening of the skin was used as an indication of the dose, but this so-called erythema dose had serious limitations and was abandoned in favour of actual tissue doses expressed in roentgens. Along with the conception of erythema dose went also an undiscriminating attitude toward the employment of radiation for almost any of the cutaneous diseases. Radiation has its place in dermatology, but it is dangerous as well as useful and its employment must be restricted to physicians who are specially trained in its use. Under competent supervision, low-voltage X-rays are indicated in the treatment of such conditions as small- to moderate-size skin carcinomas, large keratoses, obstinate circumscribed neurodermatitis, plantar warts, superficial hemangiomas, ringworm of the scalp, cutaneous lymphomas and Kaposi's sarcomas, but in skin lesions if drugs and other agents will suffice these should be used in preference to X-rays.

Contact Therapy.—Much of the very soft radiation produced at any operating voltage is absorbed in the glass wall of the X-ray tube, and when voltages are reduced below 30 kv. almost none of the rays are hard enough to pass through the glass. For some of the vascular birthmarks, keloids, skin cancers and certain other skin lesions, it is desirable to be able to irradiate superficial tissures heavily with only a minimum dose to deeper structures. This is made possible by special X-ray tubes in which the port for the emergence of the radiation is a thin sheet of beryllium rather than glass. Such tubes are operated at voltages of the order of five peak kilovolts and the circuits are arranged so that it is safe to press the port against the skin of the patient. These three factors—closeness of the target to the skin, low operating voltage and minimum beam filtration—operate to minimize the depth dose and maximize the dose at the surface.

3. Medium-Voltage X-Rays.—By 1915, German scientists had added three concepts and a group of associated techniques which became basic to the radiation therapy of deep-lying lesions. These concepts were: the role of voltage, filtration and the geometry of patient and X-ray beam in determining the dose delivered to deep-lying tissues. The techniques were Walter Friedrich's thimble chamber for measuring the dose in air, body cavities, wax, water, etc., and Friedrich Dessauer's 200-kv. X-ray generators, isodose charts, and employment of wax, water bags and similar material to reduce the patient's body to a straight-sided geometric form to which his isodose charts could be applied. In the next three decades knowledge and experience advanced enormously; but Dessauer's paper, presented in 1921 to the American Roentgen Ray society, lacked little that is really fundamental to an understanding of medium-voltage X-ray therapy as it is now practised.

Increasing the voltage to 200 kv. made it possible to treat deep-seated lesions, most of which had been inaccessible before; but raising it another 50 kv., though desirable, did not prove to be essential. Increasing the voltage still further to 400 kv. brings additional advantages, but most workers agree that they are more than offset by decreased flexibility and considerably greater cost.

There are certain practical advantages in raising the voltage of X-ray therapy machines to 1,000 or even 2,000 kv., but. as in the case of cobalt-60 (see *Artificial Radioisotopes,* below), there is no specific advantage in the shorter-wave-length radiation thus produced. The most important working tool of the radiation therapist continues to be the 250-kv. X-ray generator.

4. Radium.—Opinion as to the clinical importance of radium (*q.v.*) fluctuated widely after the discovery of this element mas announced by the Curies in 1898. Administered internally, it is a slow but lethal poison devoid of any therapeutic value; but confined in airtight needles or capsules, sheathed with a filtering layer of $\frac{1}{2}$ mm. or more of platinum, it constitutes a gamma-ray emitter of established clinical importance. Radium needles or capsules having only thin layers of brass or Monel metal as filters emit large quantities of electrons or beta rays and are of only limited clinical value.

The hardest gamma rays of radium have a hardness or penetrating power approximately equivalent to the hardest of the X-rays produced at 3,000 kv.; but paradoxically the important medical role of radium is to deliver large ionizing doses to superficial tissues while minimizing the effect at a depth. The explanation lies in the geometry of the situation. Gamma rays, like X-rays, diverge from their point source of origin in a solid angle of 4π, so their intensity falls off as the square of the distance from that point of origin. Radium usually is employed in rods of appreciable diameter and length which act as multitudes of point sources re-enforcing one another, but to simplify the explanation that follows, it will be assumed that the radium has been concentrated in a single minute sphere. Since it is possible to bring the source of the gamma rays into almost full contact with surface tissue, it follows that tissues one centimetre distant from that source will receive only about 1% of the dose that is delivered at the surface. and tissues five centimetres distant only about 4% of the dose delivered at one centimetre. (These values ignore losses by absorption and gains by scattering, though both must be taken into consideration in actual practice.)

In a few instances several grams of radium have been concentrated in heavily shielded containers that can be backed off five to ten centimetres from the surface of the patient's body. Such gamma-ray beams filtered through one millimetre of platinum deliver depth doses distinctly better than those obtained with radium at the surface or inserted into the body but are inferior in this respect to well-filtered 250-kv. X-rays from tubes stationed 80 cm., 60 cm. or even 50 cm. away from the surface of the body. These so-called telecurie radium applicators would lose all justification with the availability of megacurie radiocobalt applicators, but heavily filtered interstitial and intracavitary radium employed sometimes alone and sometimes in conjunction with X-rays meanwhile continued to be important.

5. Artificial Radioisotopes.—In addition to the series of naturally occurring radioisotopes of uranium known collectively as radium which emit gamma radiation and have an aggregate half life of 1,590 years. there are available as products of cyclotrons and nuclear reacting piles a great number of artificial radioisotopes of many different elements. In some of these the radiation intensity decays to half its initial value in fractions of microseconds, while others have half lives longer than that of radium. A few of these isotopes had been investigated clinically by the early 1960s, but most of such work remained to be done. Phosphorus-32 administered intravenously as a sodium phosphate in doses of one to two millicuries a week for four to eight weeks is employed for the treatment of chronic leukemia. Iodine-131 administered orally as a solution of sodium iodide in doses of six to eight millicuries, repeated if necessary at trimonthly intervals, is used to reduce excessive activity of the thyroid gland, and occasionally cancer of the thyroid responds favourably to much larger doses. By the second half of the 20th century there was great interest in the clinical possibilities of cobalt-60. Megacurie cobalt applicators possess many of the virtues that are lacking in, and avoid most of the faults that are inescapable in, telecurie radium applicators. The charge of radioactive Co^{60}, though weighing only 12 g. and comprising a rod only 0.7 cm. in diameter and 3 cm. in length. will produce gamma rays of 1.13 and 1.32 Mev with a source intensity more than 200 times that of the same weight of pure radium or 260 times that of radium chloride. The decay of intensity by one-half within 5.3 years requires occasional substitution of new cobalt and the consideration of decay time in computing the output of the applicator, but at most these are only minor inconveniences. Cobalt applicators have certain practical advantages. but, as was anticipated, the radiation they deliver has no specific advantages over that from other sources.

To shield against unwanted gamma radiation, the container is constructed of uranium 13 cm. thick or lead 26 cm. thick; the removal of all beta radiation from the beam requires merely a thin aluminum filter. With such a cobalt source stationed 80 cm. distant from the skin, the surface dose to a 5 cm. by 5 cm. area is approximately 35 r per minute and the dose 10 cm. beneath the surface is 18.2 r per minute.

B. Radiation Physics

The work of calibrating X-ray machines, mapping the doses of the radiation that is purposely delivered to the tissues of a patient's body and protecting patients and radiation workers from unwanted radiation is a subspecialty within the specialty of radiation therapy. Modern treatment centres require the full-time services of considerable numbers of graduate physicists specially trained in this branch of physics. Much oversimplified, dose mapping may be summarized as follows:

The intensity and hardness of the X-ray beam are adjusted by varying the operating voltage and current and the nature and amount of interposed filter. For example, one combination will be found which yields a beam that will have its intensity reduced to one-half by the addition of a testing filter of one millimetre of copper. Such a beam is designated as having a hardness of one millimetre of copper half value layer (mm. Cu. hvl.). Another combination will yield a hardness of 1.5 mm. Cu. hvl., and a third a hardness of. for example, 3 mm. Cu. hvl.

These calibrations depend on r meter measurements of the beam with and without the added test filters, and from time to time the physicist checks them with his meter, but for the day-to-day work beam hardness is adjusted merely by selecting the interposed filter, voltage and current indicated on the calibration charts.

Other tables are prepared showing the dose in roentgens per minute measured at points located, for example, 50 cm. and 80 cm. from the target of the tube.

From roentgen measurements made with the thimble chamber at the surface and inserted into phantoms of wax. water or similar absorbing and scattering material. tables and isodose charts are prepared to show the doses that will be delivered at various points beneath the surface for given beam hardness. tube-skin distance, beam diameter and minute surface intensity.

It is the responsibility of the clinical radiologist to judge as closely as possible the size and location of the lesion, the amount and delivery rate of radiation most likely to be effective. and the tolerance of neighbouring uninvolved tissues. When this has been done the physicist determines the hardness intensity, geometry and aiming of the single or multiple beams best suited to place the radiation in the amounts and at the points stipulated! following which the technician administers the treatment as directed.

The usefulness of the physician-radiologist is enlarged greatly by such assistance from physicists and technicians, but it is necessary that he be competent in their fields as well as his own; legally as well as morally he must be responsible for the whole.

C. Clinical Aspects

The tissues of the body are unaffected by radiation that merely passes through them; it is only absorbed radiation that produces an effect. When there is an effect it is invariably cell injury, and the direct agency in this injury appears to be the ionization invariably associated with absorption.

The relationship between the degree of ionization and the nature and magnitude of the biological response is constant throughout the low- and medium-voltage range. In the multimillion-volt range, direct comparison is difficult because measuring instruments regularly employed for lower-voltage radiation are no longer fully dependable and the type of ionization itself changes slightly. It seems probable, however, that with the change in type of ionization there is an advantageous alteration in the ratio between the intensity of ionization and the magnitude of cell response.

Opinions differ as to whether radiation should be used to treat nonmalignant conditions such as arthritis, bursitis and hypertrophic lymphoid tissue. The former viexi---that such therapy, though possibly ineffective, certainly was innocuous—no longer is tenable, and physicians increasingly believe that X-ray treatment should not be employed where other therapeutic methods are available. On the other hand, the value of radiation in the treatment of cancer is established beyond all argument (see Cancer; Cancer Research). In the radiation therapy of cancer both the effect on the host and the effect on the diseased tissue are important. The body is not totally without natural defenses against cancer, but those defenses usually are not quite adequate and new cancer cells develop more rapidly than old ones are destroyed.

The aim of the radiation therapist is to deliver major damage to cancer cells with minimum damage to the adjacent normal tissue, hoping to tip the scales to such an extent that the natural defenses of the body will regain the upper hand. When too large a dose is given, cancer growth may be increased rather than diminished because the restraining action of a healthy tissue bed has been lost.

Radiosensitivity of tumours is influenced by numerous factors including cell type; tumour size and location; and age and general health of the host. Small tumours located rather superficially in young and otherwise healthy patients respond better than do large deep-seated tumours in debilitated elderly patients. Grouped in order of decreasing sensitivity, the response by cell type is as follows: (1) lymphocytes; (2) granulocytes; (3) epithelial cells, (a) basal cells of secretory glands, (b) basal cells of testes and ovaries: (c) basal cells of skin and intestinal tract, (d) alveolar cells of lungs, bile ducts, and (e) tubules of kidneys; (4) endothelial cells; (5) connective tissue cells; (6) muscle cells; (7) bone cells; (8) nerve cells.

The probability of clinical cure is not proportional to the degree of cell sensitivity, however. For example, the cells of Hodgkin's disease are extremely sensitive to ionizing radiations, but, though patients skillfully treated respond strikingly at first, this favourable response seldom is permanent. On the other hand, cancer of the cervix of the uterus with cells much less sensitive than Hodgkin's tissue can be cured. Skin cancer is curable unless it has been neglected until it has extensively invaded bone or cartilage. Cancer of the larynx. nasopharynx and tongue are particularly suited to radiation therapy because the mutilation incident to surgical extirpation is so disabling. Cancer of the cervix of the uterus responds well to radiation and cancer of the body of the uterus to surgery combined with radiation. Cancers of the stomach and bowel are best treated surgically. In many cases where there can be no expectation of cure, radiation may provide relief from pain and frequently considerable prolongation of the period of usefulness and relative comfort.

See also references under "Radiology" in the Index volume.

(J. W. J. C.; P. C. H.)

Bibliography.—Ralston Paterson, *The Treatment of Malignant Disease by Radium and X-rays* (1948); U. V. Portmann (ed.), *Clinical Therapeutic Radiology* (1950); Otto Glasser (ed.), *The Science of Radiology* (1933); Otto Glasser *et al., Physical Foundations of Radiology* (1944); H. De W. Smyth, *Atomic Energy for Military Purposes* (1945); John K. Robertson, *Atomic Artillery and the Atomic Bomb* (1945); C. F. Behrens (ed.), *Atomic Medicine* (1949); Bernhard Krönig and Walter Friedrich, *Physikalische und biologische Grundlagen der Stvahlenthevapie* (1918); G. W. C. Kaye, *X-Rays,* 4th ed. (1923); Otto Glasser *et al.* (eds.), *Medical Physics* (1944).

RADIOMETER, an instrument for measuring the intensity of radiant energy. The term is applied most often to instruments of the vane type described below, but it can also be applied to the bolometer, pyrheliometer, thermopile and radio balance. For information on these instruments see Heat: Sensitive Radiometers and *Absolute* Radiometers.

It was noticed by A. J. Fresnel that a body delicately suspended in *vacuo* is apparently repelled by radiation. Using this principle. Sir William Crookes constructed an instrument, which he called a radiometer, by pivoting a vertical axle carrying vertical vanes inside an exhausted bulb; one side of each vane was blackened and the other side bright, the black sides all facing the same way round the axle. When rays from the sun or other light source or dark radiation from a warm body fall on the vane, the black sides are repelled more than the bright sides, and the vanes are set into rotation. The more intense the radiation the more rapidly do the vanes rotate. It was Crookes's idea that the instrument might be used to measure the intensity of radiation.

Instead of allowing free rotation of the vane system on a pivot, it may be suspended by a quartz fibre. Radiation falling on the black face of the vane will then cause the system to turn round until the restoring couple, because of the torsion of the suspension, balances the deflecting couple due to the radiometer action. A small mirror, attached to the vane system and reflecting a beam of light on to a scale, enables very small deflections to be observed. Ernst Pringsheim constructed such an instrument in 1883 and used it for spectrographic investigations in the infrared. In 1893 E. F. Nichols improved the radiometer by using mica vanes, one at each end of a horizontal arm suspended on a quartz fibre and each blackened on its front surface. Radiation falling on both vanes would tend to turn them in opposite directions, and if they were correctly adjusted the system would not move under the influence of general stray radiation. The radiation to be measured was allowed to fall on one only of the vanes, and the resulting deflection of a spot of light was observed. With such a radiometer Nichols was able to measure the radiation from individual stars. The radiometer has been applied to measurements of ultraviolet radiation and to that of short Hertzian waves (wave length one to two millimetres).

The explanation of the radiometric action has presented a problem of considerable interest. The question arises whether the rotation of the vanes may be caused by the direct impact of the radiation, somewhat as the rotation of a cup anemometer is caused by the wind. This explanation has been disproved in several ways. If, for example, the vanes are made of transparent material and blackened on the back face, they move toward the direction from which the light comes. The ordinary radiometer effect must be caused, therefore, by stresses set up in the gas. As the pressure of the gas is reduced, the rotation increases to a maximum and then decreases. Even in a very high vacuum, however, a small effect persists. directed away from the light. The magnitude of this residual effect agrees with the value as calculated from the electromagnetic theory of light, which predicts a small pressure because of incident radiation.

The ordinary radiometric action in the presence of gas has been rather definitely shown to be a consequence of the creep of the gas over the unequally heated surface of the vanes near their edges, as was suggested by J. C. Maxwell in 1879. The gas creeps toward the more heated part of the vane's surface and produces there a slight condensation of the gas and an increase in its pressure; the inequalities of pressure thus created give rise to a reverse flow in the surrounding gas, but this flow is hindered by viscosity, so that some inequality of pressure persists and forces the vane back. This phenomenon of gas behaviour, known in other occurrences as thermal transpiration (with "transpiration" used in the pure sense of leaking), is discussed in E. H. Kennard, *Kinetic Theory* of Gases, 1st ed., pp. 333–37 (1938).

BIBLIOGRAPHY.—J. Strong and others, *Procedures* in *Experimental Physics* (1938); M. Czerny and G. Hettner, *Zeits. f. Physik*, 30:258 (1924); P. S. Epstein, *Zeits. f. Physik*, 54:537 (1929); W. Gerlach and W. Schütz, *Zeits. f. Physik*, 78:43 and 418 (1932). (E. H. KD.)

RADIO RECEIVER. The two principal parts of a radio system are the transmitter and receiver. The waves radiated from transmitting antennas set up voltages in a receiving antenna, so that the first function of a receiving set is to select the signal desired. This must then be amplified and further modified so that a faithful reproduction of a program can be produced by the loud-speaker. Although a modern broadcast transmitter may have an output of 50 kw., often only a few microwatts from distant stations are available at the receiving antenna, principally because of the spreading out of the radio waves as they are propagated through space. A large amount of amplification is thus required in order to obtain a sound output of one watt, for example.

History. — The first demonstration of the production and reception of radio waves was made by Heinrich Hertz in Germany in 1887. His receiver consisted of an open wire loop with spheres attached to the ends to form a gap. The presence of the waves was "detected" by observing a spark set up in the sphere gap. Hertz was interested only in studying the properties of the waves and expressed no thought of practical application. It remained for Oliver Lodge to develop a system of wireless communication in England in 1894. The receiver included an antenna, tuned circuit, a detector consisting of a glass tube filled with metal filings called a "coherer" and a relay-controlled inker for recording Morse code. Lodge subsequently received several patents on radio apparatus — two of the better-known covering tuned circuits and loop antennas.

There was much activity in wireless telegraphy following Lodge's initial disclosures. Many new and improved types of detectors or "cymoscopes" were invented. These included magnetic types by Guglielmo Marconi, Ernest Rutherford and others; electrolytic by F. K. Vreeland, R. A. Fessenden and Lee De Forest; and a wide variety of crystal detectors using carborundum, galena and iron pyrites.

The first electronic device to appear in radio receivers was the Zehnder trigger tube cymoscope in Germany in 1892. This was a glow tube in which the potential difference between anode and cathode was set to a value of several hundred volts. A discharge could then be initiated by impressing a radio signal between the pair of trigger electrodes with which the tube was provided.

The first thermionic electron tube for radio use was patented by J. A. Fleming in England in 1904. This was a vacuum diode detector tube, known as the Fleming oscillation valve. Its apparent advantage over other types of detectors was the ability to undergo mechanical shocks and static surges without "jarring out." Its inherent insensitivity to weak signals, together with the primitive status of manufacturing, limited its application.

The three-element vacuum tube was invented by De Forest in 1906. A receiver using an audion, as it was called, could deliver more power to an output device than was received from the antenna, so that it was operating in the dual capacity of detector and amplifier. Subsequent work showed that it could be used simply as a radio-frequency (R.F.) or audio-frequency (A.F.) amplifier, or even as a modulator. De Forest manufactured radio sets equipped with audions for several years. The audion was greatly improved by others during World War I and was manufactured in large quantities.

One of the most remarkable applications of the audion was to the feedback, or regenerative, circuit. In this, coupling was introduced between the plate and grid circuits such as to produce an appreciable increase in both the selectivity and sensitivity of the circuit. By providing adequate coupling, such a circuit could be made to oscillate continuously without benefit of external grid signal.

It is difficult to place proper priority for the invention of the feedback circuit. In 1913 Alexander Meissner was granted a patent on an oscillator in Germany and E. H. Armstrong presented a paper describing regenerative circuits. Other names associated with contemporary work were those of C. S. Franklin and H. J. Round in England and De Forest and Irving Langmuir in the United States. A four-way litigation initiated by Meissner, Armstrong, De Forest and Langmuir was decided finally in favour of De Forest by the supreme court of the United States in 1928, and it reaffirmed its action in 1934.

Considerable progress was made in the theory, construction and applications of vacuum tubes and their circuits between 1910 and 1920, much of it in connection with the World War I efforts and long-line carrier-current telephony. The greatest single impetus to be noted in radio history, however, was the introduction of radio broadcasting in 1921. This created a tremendous demand for receivers as transmitters were established throughout the world. The vacuum-tube receiving circuits were battery operated for the first few years, but rectifier-type power packs soon appeared for plate and grid supplies. These were followed almost immediately by the self-contained alternating-current sets, which were made possible by the development of tubes whose cathodes could be operated on alternating current without introducing excessive hum in the output.

The first broadcast signals were amplitude modulated (AM) exclusively, and many types of receiving sets were in use. Some of the commonest were: regenerative, superregenerative, reflex, tuned radio frequency, neutrodyne and superheterodyne. The superheterodyne came to be used almost exclusively for broadcast reception. although a few portable models employ tuned-radio-frequency circuits.

The difficulties of static elimination inherent in AM operation led Armstrong to develop frequency modulation (FM). Although he began work on the problem in 1914. his system was not perfected until 1933 and several more years elapsed before much use was made of it.

Modulated Waves.—It is impractical to transmit audible signals by wireless because the radiated output of an antenna depends upon its size expressed in terms of the wave length of the signal to be transmitted. Since the wave-length range is 3,720 to 37.2 mi. for the ordinary broadcast audio-frequency range of 50 to 5,000 cycles per second, it is only too obvious that not only would the necessary audio-frequency antennas be prohibitively large but there would also be the possibility of a 10.000 to 1, or 40 db., variation in the output over this 100-to-1 frequency range. Furthermore, only one station could be on the air at once in any given locality. since it would be impossible to tune out the unwanted signals. Thus, it is practical to transmit wireless signals only at the high frequencies known as radio frequencies.

The problem was easily solved in radiotelegraphy by the comparatively simple process of keying, or turning on and off, a high-frequency signal. However. it was necessary to devise a different method to transmit a "message" in the form of articulate speech or music. Such a method was found in the utilization of a high-frequency wave as a vehicle, or carrier, for the comparatively low-frequency message. The exact mechanism consists of modifying, or modulating, the carrier signal in some manner by the audio signal, the resultant radiated signal being known as a modulated wave.

Any high-frequency electromotive force, of a form denoted by the formula e = E cos (wt + 0), is completely specified if the amplitude E, angular frequency ω and phase angle θ are given. An audio-frequency signal to be transmitted can be introduced into the given radio signal by causing it to modify any one of these functions. the three methods being known as amplitude. frequency and phase modulation, respectively. A fourth possible method involves breaking up the signal into pulses. However. this discussion will be limited to amplitude and frequency modulation since they are the most commonly used.

Amplitude *Modulation.*—If, in the general equation above, E is set equal to E, + $E_m \cos \omega_m t$, the result is

$$e = (E_c + E_m \cos \omega_m t) \cos \omega_c t = E_c (1 + m_a \cos \omega_m t) \cos \omega_c t$$

in which E_c is the amplitude of the unmodulated carrier voltage; E_m is the amplitude of the modulating signal voltage; ω_m is the angular frequency of the modulating signal voltage; ω_c is the angular frequency of the carrier voltage; and m_a is the amplitude modulation index (E_m/E_c). Applying a trigonometric identity now gives

$$e = E_c \cos \omega_c t + E_s \cos (\omega_c + \omega_m)t + E_s \cos (\omega_c - \omega_m)$$

in which E_s is the amplitude of the side bands $(m_a E_c/2)$, where (w, + ω_m) is the angular frequency of the upper side band and (w, − ω_m) is the angular frequency of the lower side band.

This is the equation commonly used for an amplitude-modulated signal, which consists of a carrier term together with upper and lower side bands for each component of the modulating signal. In order to transmit, at a carrier frequency of 1.000 kc.. music of regular broadcast quality covering a frequency range up to 5 kc., a band width of 10 kc., or 993 to 1.003 kc.. is required. Since this involves a maximum frequency variation of only 0.5% on either side of the carrier frequency, no special difficulty is involved in the design of the equipment.

The process of removing the original signal from the modulated one at the receiver is known as demodulation. As an illustration of this. assume the response curve of some nonlinear device. such as a crystal or vacuum tube operating over the curved portion of its characteristic, to be given by

$$i = a_1 e + a_2 e^2$$

Substitution in the equation for an amplitude-modulated signal and application of trigonometric identities yields, in addition to radio-frequency terms, an audio-frequency response given by

$$2a_2 E_c E_s \cos \omega_m t = a_2 m_a E_c^2 \cos \omega_m t$$

and

$$a_2 E_s^2 \cos 2\omega_m t = \frac{a_2 m_a^2 E_c^2}{4} \cos 2\omega_m t$$

The former corresponds to the original signal to be transmitted; the latter to second harmonic distortion.

Frequency Modulation.—This is accomplished by introducing into the frequency of the signal to be radiated a variation about the carrier frequency that is proportional to the modulating signal. This gives, after some manipulation, for the general equation for a frequency modulated voltage,

$$e = E_c \sin \left(\omega_c t + k_f \frac{E_m}{\omega_m} \sin \omega_m t\right)$$

in which k_f is the ratio of the maximum variation in frequency to the maximum strength of the modulating signal.

This can be expanded to yield a carrier and an infinite number of pairs of side bands whose amplitudes are expressed in terms of Bessel functions (*see* FUNCTIONS, SPECIAL). Although from a practical standpoint it is only necessary to pass a limited number of side bands, the required band width is much greater than that for the AM signal, which requires only one pair of side bands for each component of the modulating signal.

In particular, it has been found possible to transmit a maximum audio frequency of 7.j kc. within a band width of 200 kc., which shows that FM transmission is not practical in the regular band of j50 to 1.500 kc. allocated for AM broadcast A special band of 88 to 108 mc. is used for the stations being spaced 200 kc. apart.

TYPES OF RADIO RECEIVERS

Regenerative Receivers.—One of the first circuits in common usage is shown in fig. 1. In this the single tube acted as both radio-frequency amplifier and detector. The input circuit was tuned by means of the variable air condenser and taps on the vario-

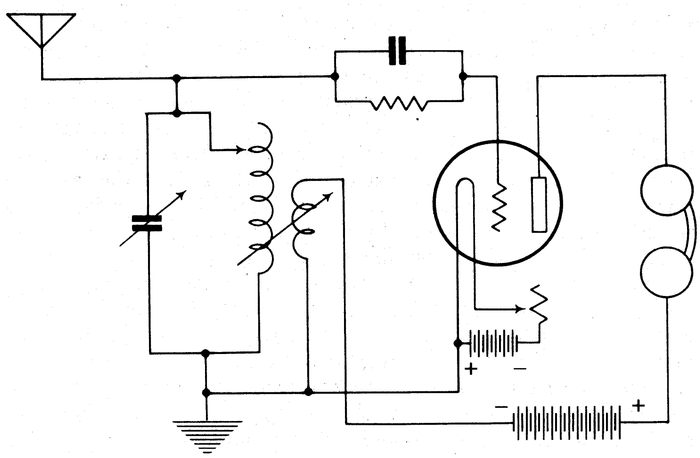


FIG. I.— SINGLE-CIRCUITREGENERATIVE RECEIVER

coupler tuning coil, and the amount of feedback was controlled by rotating the tickler coil. This circuit was especially common in home-built sets, principally because of its simplicity. Other types of regenerative receivers were the two- and three-circuit, tuned plate, Cockaday, etc. Most of them had a tendency to oscillate and to act as a radio transmitter while being tuned. The radiated output would combine with other signals present to produce obnoxious squeals and whistles in neighbouring sets. This, together with a demand for more selective receivers as the number of broadcast transmitters with closer frequency allocations increased, eventually limited the regenerative receiver to long-wave and marine use.

Superregenerative Receiver.—The selectivity and sensitivity of a regenerative receiver increases rapidly with the coupling and resulting approach to the condition for sustained oscillation. Arm-

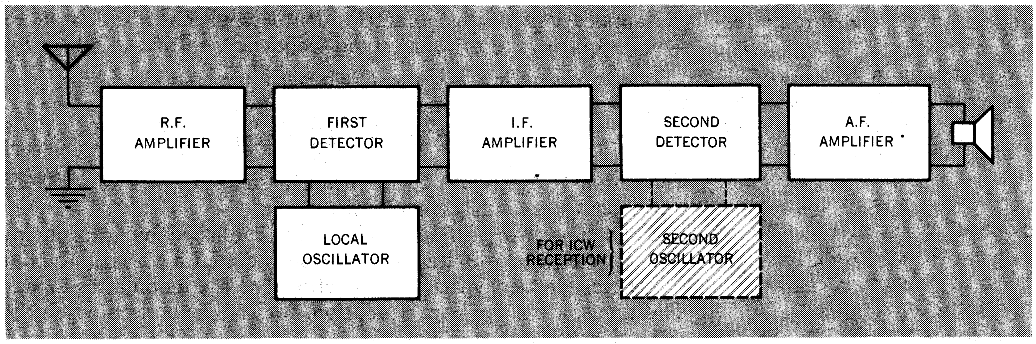


FIG. 2.—BLOCK DIAGRAM FOR SUPERHETERODYNE RECEIVER

strong in 1922 first described a circuit for taking advantage of this by superimposing a supersonic signal upon the received signal in a manner such as to prevent the circuit from oscillating at a high frequency. This principle is used in the superregenerative receiver, which is characterized by extremely high sensitivity. Because of poor quality of output, its use is limited principally to short-wave reception in police and radio amateur sets.

Reflex Receiver.—Reflex action consists of feedback action between the plate circuit of one tube and the grid circuit of the preceding tube. In the reflex receiver, the antenna signal was first amplified by one stage of tuned radio frequency (T.R.F.) and then applied to the grid of the detector tube. The audio-frequency output of the latter was then fed back to the grid of the first tube by means of an audio-frequency transformer, the headset or loud-speaker being connected in the plate circuit of that tube. Thus, the first tube acted simultaneously as a radio-frequency and audio-frequency amplifier, to give sufficient output to operate a small loud-speaker upon occasion. This was an important consideration in the days of high-priced tubes, parts and batteries. Poor selectivity was the principle factor which brought about an early obsolescence.

Tuned-Radio-Frequency (**T.R.F.**) Receiver.—It was found that an increase in both sensitivity and selectivity could be obtained by introducing one or more stages of the tuned-radio-frequency amplification preceding detection. However, the plate-grid capacitances in triodes created a tendency for the circuit to oscillate. Although a limited amount of feedback action was desirable, it was necessary to control it carefully in order to prevent oscillations. Bridge circuits for accomplishing this were developed by C. W. Rice and L. A. Hazeltine. A set utilizing the last was known as the neutrodyne receiver, considered to be the last word in receivers until superseded by the superheterodyne.

Some of the weaknesses inherent in early types of tuned-radio-frequency receivers were separate tuning for each stage and non-uni'form neutralization, sensitivity and selectivity over the broadcast band. The first was removed by gang tuning and the need for neutralization by use of screen-grid tubes, but the problem of varying sensitivity and selectivity remained in tuned-radio-frequency receivers. As a result! this type is used in only a few portable broadcast receivers and certain isolated applications where the selectivity requirements are not too stringent.

Superheterodyne Receiver.—A circuit which gave uniform performance over a wide range of station frequencies was developed by Armstrong while working in France during World War I. This made use of the heterodyne principle, which consists of combining two frequencies to give a different frequency. It had been introduced by Fessenden of the University of Pittsburgh in 1913, to convert radiotelegraph signals into interrupted audio-frequency code signals.

In the Armstrong superheterodyne receiver. or supersonic heterodyne receiver as it was called first in England, the incoming signal is combined with the output of an oscillator to produce a given supersonic frequency, called the intermediate frequency (I.F.). The latter is then amplified by means of one or more tuned stages, demodulated to give the required audio-frequency signal, amplified and finally fed into a loud-speaker. The selection of the particular station to be received is accomplished by adjusting the oscillator frequency so that the difference between it and the carrier frequency of the received station is equal to the intermediate frequency. Since the major part of the amplification is in the intermediate-frequency amplifier, both the selectivity and sensitivity of the set are essentially independent of the original station frequency. The advantages of the superheterodyne receiver were quickly recognized, but since the early sets required eight or ten expensive battery-operated tubes its use was limited to the more expensive models. Within 20 years. however, it had almost completely supplanted other types of broadcast receivers.

The accompanying block diagrams show the principal features of typical modern receivers. Starting at the input terminals, the signal is first amplified with one stage of tuned radio frequency in order to provide initial selectivity and thus to reduce so-called image and cross-modulation effects and mixer tube noise. The tuned-radio-frequency amplifier and local oscillator circuits are gang-tuned with a single control.

The mixer, converter or first detector tube, as it is called, changes the carrier frequency of the signal to the intermediate-frequency value. This was originally taken as 50 kc., but was later increased to 130–175 kc. Later it was further increased to 450–480 kc., with a tendency to standardize at 455 kc. in order to accommodate multiband receivers.

The intermediate-frequency amplifier usually consists of one or two transformer-coupled stages. The primaries and secondaries are permanently tuned, aside from small "trimmers" which are used for alignment purposes. The major portion of the high-frequency gain occurs in the intermediate-frequency amplifier. Remote cutoff pentodes are used to permit automatic gain control.

The function of the second detector is to convert the modulated intermediate-frequency signal into audio frequency. Square-law detection by means of a triode was used originally. This is preferable for weak signals, but since the percentage of second harmonic distortion increases rapidly with signal strength and percentage modulation, linear detection came to be used.

Among the advantages of high-level linear detection are the elimination of one stage of audio-frequency amplification, low harmonic distortion, reduction in tube noise and a lowering in cost of power pack filter because of the higher permissible hum.

The process of linear detection is essentially one of rectification and can be accomplished with either diodes or suitably biased grid-control tubes. Duplex tubes are often used, one part feeding into the audio-frequency amplifier, the other into the automatic volume-control system.

The audio-frequency amplifier may consist of one stage of voltage amplification and a power stage which utilizes two power

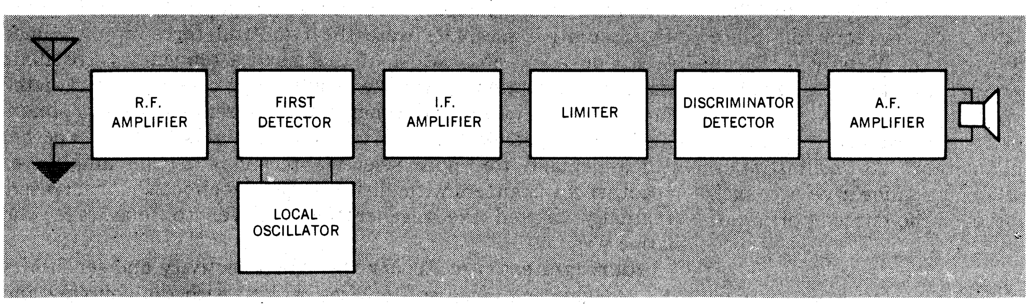


FIG. 3.—BLOCK DIAGRAM FOR FM BROADCAST RECEIVER

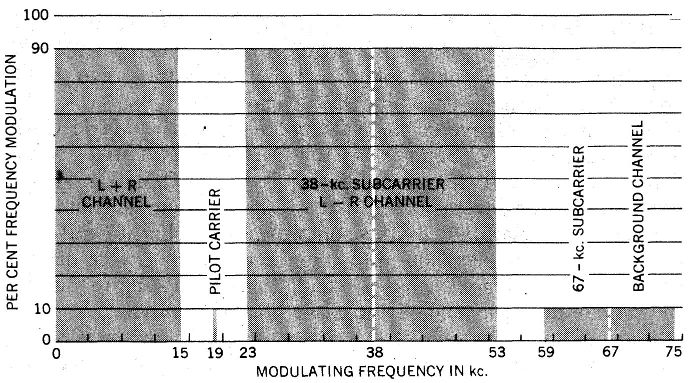


FIG. 4.—FREQUENCY SPECTRUM FOR FM STEREOPHONIC BROADCAST

pentodes in push-pull, when considerable output is demanded.

Automatic volume, or gain, control (AVC) was one of the most important developments in radio receivers. Its principal purpose is to maintain constant detector input. In this way the output of the receiver is unaffected by the strength of incoming signals. In brief, automatic volume control is accomplished by introducing an. extra bias in the remote-cutoff tubes in the tuned-radio-frequency and intermediate-frequency stages, which increases with the carrier input to the second detector. This automatically adjusts the gain of those stages so as to maintain nearly constant detector input as long as the incoming antenna signal exceeds a minimum threshold value.

The output of a receiving set is adjusted to suit the listener by means of a volume control, consisting of a potentiometer in the audio-frequency amplifier.

Since the sensitivity of the ear varies with frequency, some volume controls also include fixed coils or condensers such that the quality of the loud-speaker output will appear to be independent of intensity.

The purpose of the tone control is to allow the listener to vary the relative intensity of the high and low tones. The circuit for doing this often consists of a variable resistance connected in series with a fixed capacitor, its effect being to emphasize the bass notes by de-emphasizing the treble.

Receivers for FM Reception.—The block diagram in fig. 3 is schematic for a typical receiver designed for use in the 88- to 108-mc. FM broadcast band. In commercial sets, however, a converter stage replaces the local oscillator and the first detector mixer. Except that the intermediate frequency is 10.7 mc. instead of 455 kc., a change made necessary by the greater band-width requirements of FM, the functioning of the set is similar for receiving both AM and FM up to and including the I.F. amplifier. The output of the I.F. amplifier, however, instead of feeding into the detector as for AM, first goes through a limiter which levels off the signal to a fixed amplitude of a few volts. This is very effective in eliminating interference as well as noise due to static, ignition systems, etc., since it is estimated that only about 3% of such disturbances are of a frequency-modulation character. This results in a possible gain in the signal-to-noise ratio of as much as 30 db. by the use of FM.

The first step in the demodulation process is to convert the output of the I.F. amplifier into an AM signal. This is done with a frequency-sensitive circuit called the discriminator. A typical arrangement consists essentially of a coupling transformer with tuned primary and secondary. The desired shape of its frequency response curve is obtained by using coupling slightly less than critical. The output of the discriminator is fed into a detector and the resulting audio signal is further amplified and fed into a loudspeaker as in AM reception.

Receivers for Stereophonic Reception.—The U.S. Federal Communications commission on April 19, 1961. approved a multiplex system for broadcasting stereophonic programs in a single band in the regular 88 to 108 mc. FM broadcast spectrum. The approval became effective June 1, 1961. Previously. FM multiplexing had been utilized for several years by at least 200 stations in the U.S. as a means of broadcasting background music on a rental basis to factories, restaurants and other commercial establishments. The approved system for stereophonic broadcast made provision for continuing this special service. although—as in the case of monophonic broadcasting—background music signals are filtered out in home receivers.

The specified FM spectrum for stereophonic broadcasting, including the optional band for transmitting background music, is shown in fig. 4. With appropriate changes in the co-ordinates. this diagram also can be used to represent the upper sideband halves of both the radiated and received signals or. by omitting the background music portion, it can be used to portray the output of the FM limiter-detector stage in a stereophonic home receiver.

The transmitted signal consists of a main carrier that has been frequency-modulated as follows: (1) up to 90% (75 kc. constitute 100% modulation in FM broadcast) by L + R, the sum of the left- and right-hand audio signals; (2) 8% to 10% by a 19-kc. pilot carrier; (3) up to 90% by a 38-kc. subcarrier which has been amplitude-modulated, with carrier suppressed, by L − R, the difference between the left- and right-hand audio signals; and optionally. (4) up to 10% by a 67-kc. subcarrier amplitude-modulated by background music whose upper limit has been set at 8 kc. The standards of periormance are the same as for monophonic FM broadcasting.

The principal functions that must be performed by a stereophonic home receiver are portrayed in fig. 5. The first four sections in this are essentially the same as would be found in a similar diagram for a monophonic receiver? including 10.7 mc. for I.F. amplification. It is principally in the I.F. amplifier that background-music signals are filtered out in both monophonic and stereophonic home receivers; a specially adjusted receiver must be used to detect and amplify the background-music signal.

Starting with the output of the I.F. amplifier in fig. 5, channel A accepts and transmits L + R to the matrixing network, a network whose output is a linear combination of two or more input signals. Channel B_1 accepts the 38-kc. subcarrier that is amplitude-modulated by L − R. Channel B_2 accepts the 19-kc. pilot carrier, doubles its frequency and amplifies it so that it can replace the 38-kc. subcarrier that was suppressed in the transmitter. The outputs of B_1 and B_2 are then applied to an AM detector which delivers L − R to the matrixing network.

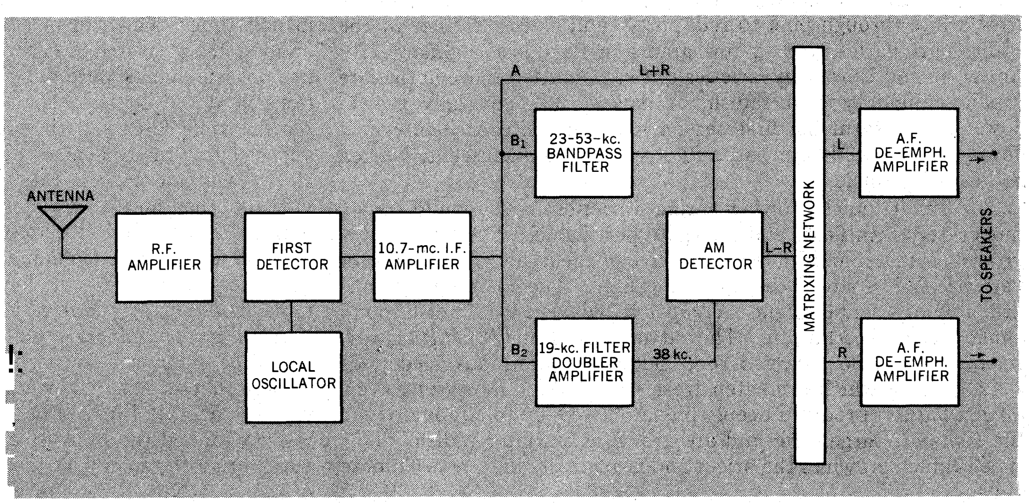


FIG. 5.—FUNCTIONAL DIAGRAM FOR STEREOPHONIC RECEIVER

The output of the matrixing network consists of the sum and difference of its two inputs, to give (L + R) + (L − R) = 2L. and (L + R) − (L − R) = 2R. respectively. After de-emphasis and amplification, these are fed into two loud-speakers so arranged as to give the proper stereophonic effect.

A stereophonic receiver can ordinarily be used for monophonic FM reception, although some interference may be heard if the received signal happens to include a background-music subcarrier that is at some point in the range of 20–53 kc. If a stereophonic signal is picked up by a monophonic receiver. a true monophonic reproduction. consisting of L + R. will be heard; the effect is the same as if two microphones were used in a monophonic broadcast. This is the reason for using L + R in place of either L or R as one of the original modulating signals for stereophonic broadcast. It is necessary to use an adaptor. as well as an additional amplifier and loud-speaker, with a monophonic receiver in order to obtain stereophonic reproduction.

Transistor Receivers. — The development of the transistor made it possible to construct a very small portable radio receiving set. In effect, the transistor permits the use of certain elements whose size is more commensurate with the amounts of useful power associated with the various parts of the receiver. This applies particularly to the replacement of thermionic vacuum tubes by transistors: since the latter require no cathode heating power. This removes the necessity of providing filament transformers and sufficient tube radiating surface to dissipate the cathode power.

See also BROADCASTING; ELECTRON TUBE; HIGH-FIDELITY SOUND SYSTEMS; LOUD-SPEAKER; RADIO; TELEVISION; TRANSISTOR.

BIBLIOGRAPHY.—Keith Henney (ed.), *Radio Engineering Handbook*, 5th ed. (1959) ; W. R. Maclaurin, *Invention & Innovation in the Radio Industry* (1949) ; William Marcus and Alex Levy, *Practical Radio Servicing* (1955) ; K. R. Sturley, *Radio Receiver Design* (1943–45) ; F. E. Terman *et al.*, *Electronic and Radio Engineering*, 4th ed. (1955); S. W. Amos and F. W. Kellaway, *Radio Receivers and Transmitters* (1948); J. A. Fleming, *The Principles of Electric Wave Telegraphy and Telephony*, 4th ed. (1919); J. H. Morecraft *et al.*, *Principles of Radio Communication*, 2nd ed. (1927); D. R. von Recklinghausen, "Stereophonic FM Multiplex System," *Electronics World* (July 1961).

(C. S. Rs.)

RADIOSONDE, an instrument sent aloft, attached to a freely rising balloon, for the purpose of obtaining information on the temperature, humidity and other properties of the upper atmosphere. It includes a radio transmitter which sends down signals representing the numerical values of these properties. See UPPER AIR SOUNDINGS. (W. E. K. M.)

RADIOTELEGRAPHY: *see* RADIO.

RADIOTHERAPY: *see* RADIOLOGY: *Therapeutic Radiology*.

RADISH, *Raphanus sativus* (family Cruciferae), an annual or biennial grown for its large. succulent root. The edible part of the root, together with some hypocotyl, form a structure varying in shape, among varieties. from spherical through oblong to long cylindrical or tapered. The outside colour of the root varies from white through pink to red, purple and black; the size of the edible part varies from a few grams in the most popular early American and European varieties to two pounds or more in the late Japanese field type of radish, or daikon. As generally grown, flower stalks form the first season, bearing white or lilac-veined flowers. The seeds are borne in a spongy, nondehiscent, beaked pod called a silicle.

The small, quick-growing spring varieties have a mild: crisp, moderately firm flesh, and are quite perishable. The large, slow-growing summer and winter types have pungent, firm flesh. Winter varieties can be stored through the winter. The common radish is probably of oriental origin. R. *raphanistrum* is a wild radish found along the Mediterranean. The rat-tailed radish (R. *sativus*, var. *caudatus*) has no enlarged root, but bears enormous seed pods 8–12 in. long which are eaten fresh or pickled. R. *sativus* (var. *longipinnatus*) produces deeply pinnate leaves up to two feet long; the roots are large, firm and are grown as a winter radish. This type is much grown in the orient and is generally known as Chinese radish. (V. R. B.)

RADIUM, the most familiar of the natural radioelements, is a metallic element belonging to the alkaline-earth group, of which it is the heaviest. The name, derived from the Latin *radius* ("ray"), originally applied only to the first discovered and most important isotope of the element, that of mass number 226, but is now used as a general name for the element.

Radium was discovered in 1898 by Pierre Curie, Marie Curie and an assistant, G. Bémont, at the Sorbonne in Paris. Mme. Curie had observed that the radioactivity of pitchblende, an ore of uranium, was several times that of the uranium it contained. By chemical separation of the constituents of the mineral, two highly radioactive elements—polonium and radium—were discovered. Prior to this discovery, it had been customary to discard the residue of pitchblende after extraction of uranium.

Radium was found to adhere closely to the common element barium, which it followed in the chemical treatment of the ore, indicating a very close chemical relationship of the two elements. Only after developing a complicated fractional precipitation procedure could the two elements be separated. Then. in 1902, Mme. Curie was able to prepare a pure salt of radium by working up several tons of pitchblende residues. The same general method of extracting radium is used commercially, a tribute to the genius of this pioneer in radiochemistry.

The pure element was first prepared in 1910 by Mme. Curie and A. Debierne; it is a shiny white metal.

The symbol of radium is Ra; atomic number 88; atomic weight 226.05.

Isotopes and Radioactive Properties — Several isotopes of radium, all radioactive, are known. Only Ra^{226} is stable enough to permit its isolation in visible and weighable amounts, and the name "radium" often refers simply to this isotope. Its half life is approximately 1,620 years, and it disintegrates with the emission of alpha particles. It is a member of the uranium, or radium! family of natural radioelements, following ionium in the series. Its immediate transformation product is radon, a noble gas of 3.825-day half life, which in turn changes into a series of shorter-lived radioelements, radium A, B, C, C′ and C″. It is rarely encountered in a radioactively pure form, for immediately after purification from its disintegration products they rapidly grow in again. Radium C emits penetrating gamma rays, so that, although radium itself emits only small numbers of gamma rays of low penetrability, a sample which has been sealed up to prevent loss of the gaseous radon is a source of strong gamma radiation. About a month is required for the gamma activity to reach its maximum, or equilibrium, intensity. The end product of the short-lived descendants of radium is radium D, which is also radioactive, and from this grow radium E and polonium, or radium F. Since the half life of radium D is 20 years it comes to equilibrium slowly in radium preparations.

The half life of radium is so great that it cannot be determined by directly observing the decay, and recourse must be had to indirect methods. Most of these involve the' determination of the specific activity, or the number of disintegrations per unit weight in unit time. This can be done by counting the alpha particles emitted in a measured interval by a sample of known weight. The first measurements were done by visual counting of the scintillations produced by the impact of the particles on a zinc sulfide screen, while later experimenters'have used electrical detection and counting instruments. Since alpha particles are helium nuclei, measurement of the rate of helium generation by radium provides another means of determining the specific activity. The half life also can be calculated from the rate of growth of radium in a sample of purified ionium relative to the amount in equilibrium with the same quantity of ionium in ancient and intact uranium minerals. Finally, from the equilibrium ratio of radium and uranium in such minerals the half life of radium can be calculated if that of uranium is known independently. The specific activity is close to 3.61×10^{10} alpha disintegrations per second per gram, whence the half life is 1,620 years. The disintegration rate of radium formed the basis of a standard unit of radioactivity, the curie, originally a rate of disintegration equal to that of a gram of radium. Now, a curie of any radioelement is by definition that amount undergoing 3.7×10^{10} disintegrations per second.

In the thorium series of radioelements occur two radium isotopes, mesothorium I (Ra^{228}) and thorium X (Ra^{224}), the former a beta emitter of 6.7-year half life and the latter an alpha emitter of 3.64-day half life. One of their descendants, ThC″, emits gamma radiation even more penetrating than that of RaC, and as a result of the complex sequence of half lives the gatnma activity of freshly purified mesothorium increases for about four years and then decays steadily. A fourth isotope, actinium X (Ra^{223}), occurs in the actinium series and is an alpha emitter of 11.7-day half life. *(See* RADIOACTIVITY, NATURAL.)

Several artificial radioactive isotopes of radium are also known. (See NUCLEUS.)

Natural Occurrence.—Although the half life of radium, 1,620 years, is long with respect to human experience. it is infinitesimal in the geological time scale, and any radium present at the time of the formation of the earth has by now completely disappeared. It is only because a new supply of the element is continually being generated by the disintegration of uranium that any is found at the present time, and its distribution in nature is practically identical with that of uranium. There is a constant ratio between radium and uranium, 0.00000034, in all sufficiently old minerals in which radioactive equilibrium has not been disturbed by weathering or leaching. In altered minerals the radium is generally relatively lower because of the greater solubility of its oxide. Springs, rivers, sea water and the ocean sediments contain small amounts of radium. Uranium, and consequently radium, are widely distributed in minute traces in nearly all common rocks, both igneous and sedimentary, the average concentration of radium in the earth's crust being about 1 part per 1,000,000,000,000. The bulk of the earth's radium is so accounted for, but in this form it is, of course, commercially unavailable. Only in uranium minerals is radium present in high enough concentrations to make its extraction feasible, and even the richest ores contain only about $\frac{1}{4}$ g. of radium per ton. Most deposits contain smaller amounts; and some which contain as low as 1% of uranium, or 1 g. of radium in 300 tons, have been exploited for the latter.

Radium was discovered in the mineral pitchblende, an oxide of uranium, which had been mined since about 1840 at Joachimsthal, Czech., for its uranium content. More extensive pitchblende deposits were later found at Katanga in the Belgian Congo and at Great Bear lake and Beaverlodge lake in Canada. Second in importance as a radium source is carnotite, a double vanadate of uranium and potassium found principally as a yellowish impregnation of sandstone in the western United States. Altogether several dozen different radium-containing minerals are known, and deposits of varying extent are found in many other places; some of these have been worked from time to time for radium. The increased importance of uranium, as a source of atomic energy, has resulted in intensive prospecting and the discovery of many more such deposits. *(See* URANIUM.)

Mesothorium is obtained principally from monazite. a mixed phosphate of thorium and rare earths occurring frequently in alluvial sands. *(See* THORIUM.) Thorium *X* and actinium X occur naturally in thorium and uranium minerals. respectively, but are usually obtained from their parents rather than from natural sources.

Industrial Production.—For a number of years following its discovery the only important source of radium was the Joachimsthal mines, operated by the Czechoslovakian government. Later some radium was produced in other European countries. The United States became the first major producer and from 1913 to 1923 was the chief world supplier, with carnotite from the western states being extracted principally at Denver. Colo.. and Pittsburgh, Pa. The rich Belgian Congo pitchblende deposits were discovered in 1913; and the refinery at Oolen, Belg.. began production in 1922. immediately dominating the world market. The extensive Canadian deposits were discovered in 1930; and the refinery at Port Hope. Ont., started producing radium in 1933. In the late 1930s the norld market was divided between the Belgian and Canadian producers on a 60:40 basis by a cartel agreement. After Belgium fell to the German army in 1940, the Congo ores were shipped to the Cnited States and Canada for refining. Following World War II, radium-bearing residues from these ores were shipped to Oolen for extraction of radium.

The following is a typical procedure for the commercial production of radium from pitchblende. The ground ore is digested with a mixture of nitric and sulfuric acids to which a little barium is added to act as a carrier for the radium. The uranium dissolves, and an insoluble residue of radium, barium and lead sulfates and siliceous gangue remains. This is separated by filtration and boiled with sodium hydroxide solution to leach out the lead sulfate and some of the silica. The residue is then autoclaved with sodium carbonate solution to convert the barium and radium sulfates to carbonates, which are dissolved in hydrochloric acid. After filtering off the remaining silica, the barium and radium are again precipitated as sulfates and converted to carbonates to effect a purification. The carbonates are now dissolved in hydrobromic acid and the bromides subjected to an involved fractional crystallization process. Since radium bromide is somewhat less soluble than barium bromide, the crystals are enriched in radium. After ten recrystallizations the ratio of radium to barium in the head crystals is changed from a few parts per 1,000,000 to a few parts per 1,000. At this stage, the bromides from several batches are accumulated, purified again and subjected to further crystallizations until radium of the desired purity, usually 95% or 99%, is obtained. This is sealed into small glass tubes to be measured and sold.

Variations in this process are dictated by differences in the nature and quality of the ores found in different locations. Canadian pitchblende contains considerable native silver, which is recovered by roasting the ore with sodium chloride to convert the silver to its chloride and subsequently leaching the latter out of the sulfate residue with sodium thiosulfate solution. With carnotite. the treatment can be altered by leaching the ground ore with hydrochloric acid to dissolve the radium, uranium and vanadium away from the siliceous matter before adding sulfuric acid. The sulfate precipitate can alternatively be heated with charcoal to reduce the sulfates to sulfides, which dissolve readily in hydrochloric acid. In the fractional crystallization the chlorides are often used instead of the bromides.

Newly developed methods for separating radium from barium involve cation exchange resins and precipitation from homogeneous solution.

Radium was originally interchanged freely among scientific and medical investigators, but when it became an item of commerce it became extremely expensive. However, as new and richer sources have become available. the price has steadily fallen. Typical market prices per gram were $10,000 in 1904, $80,000 in 1912, $120,000 in 1915, $135,000 in 1918. $90,000 in 1920. $70,000 in 1923, $50,000 in 1929, $25,000 in 1936, $20,000 in 1941, $25,000 in 1946. $20,000 in 1950, $16,000 in 1953 and $15,000 in 1957. The total world production in grams was approximately 50 by 1916, 300 by 1925 and 1,000 by 1940. Production was greatly accelerated during and shortly after World War II, but was declining in the early 19jos because of the competition of substitutes.

Chemical Properties.—Of the 88 electrons of the radium atom, the first 86 are strongly bound. whereas the outer two are readily lost leaving a divalent cation of noble gas structure. This property classifies it among the alkaline-earth elements, which include. in order, magnesium, calcium, strontium, barium and radium. There is a general gradation of properties in going from the lighter to the heavier members of the group. and radium continues this trend. It is very similar to barium, all of its known compounds being isomorphous with the corresponding barium compounds and differing so little in properties as to make the separation of the two elements a matter of great difficulty. The chemistry of radium. is. therefore, well understood.

Radium is divalent in all of its compounds. The sulfate. $RaSO_4$, is the most insoluble sulfate known and for this reason is important in the separation of the element from its ores. However, it is only because lead sulfate is also precipitated from the solution of the ore that quantitative precipitation of radium is obtained. for the amount of radium sulfate present is far too low to precipitate by itself. This principle, whereby an element present in quantity too small to permit manipulation by itself is caused to undergo certain chemical reactions by the presence of a larger quantity of a similarly behaving element, is called "carrying" and is important both in the isolation and in the chemical study of radium. The nitrate, $Ra(NO_3)_2$, chloride, $RaCl_2$, and bromide, $RaBr_2$, are soluble in water but highly insoluble in concentrated solutions of the corresponding acids, and are consequently of use in the purification of radium, including its separation from the last traces of barium. The chloride and bromide crystallize as hydrates, $RaCl_2 \cdot 2H_2O$ and $RaBr_2 \cdot 2H_2O$, but form the anhydrous salts on heating. The hydroxide, $Ra(OH)_2$, is the most soluble of the alkaline-earth hydroxides. The carbonate, $RaCO_3$, is insoluble in water but soluble in acids and the sulfide, RaS. is soluble in water.

Metallic radium melts at approximately 700° C. and has high chemical reactivity. It dissolves in water with vigorous evolution of hydrogen and darkens in air with the formation of the nitride. It is prepared by electrolysis from an aqueous solution of the chloride into a cathode of mercury, followed by volatilization of the mercury in a stream of hydrogen.

The optical spectrum of radium is similar to that of the other alkaline-earth elements, consisting of comparatively few relatively strong lines. The ordinary compounds of radium are all colourless but become coloured upon standing as a result of the continual bombardment by radioactive particles. Glass containers of considerable quantities of radium also become coloured, and sizable preparations can be seen to glow in the dark. Those properties are not peculiar to radium but are common to all strongly radioactive substances.

Analytical Methods.—The assay of radium is generally made not by the usual chemical procedures. such as weighing, but by methods based on its radioactivity. Strong samples, such as those for medical and radiographical use, are assayed by their gamma radiation by means of an ionization chamber and electrometer. The sample must be sealed for at least a month before the measurement so that the equilibrium quantity of radium C is present. For calibration of the measuring apparatus, standard preparations of radium have been made. The primary international standard was prepared by Mme. Curie by precise weighing and has been preserved at Sevres, France. Secondary standards, carefully checked against the international standard, are kept in the capitals of the principal nations. In using these standards allowance must be made for theirdecay, which amounts to 0.043% per year. Another assay method is the emanation technique, in which the gaseous radon generated by the radium sample in a measured time is collected in an ionization chamber and the intensity of its radiations measured. This method can be made extremely sensitive by electrically counting the individual alpha particles, and as little as 10^{-14} grams of radium can be so detected.

Uses.—The uses of radium all result from its radiations. The most important of these have been in medicine, principally for the treatment of cancer. For this purpose the element may be used directly. sealed in a tube, or the accumulated radon may be drawn off and compressed into a small capsule which may be used until it has decayed to a low intensity. (See RADIOLOGY.) Large amounts of radium have been employed for industrial radiography, particularly for the inspection of metal castings. Radium is mixed, in small concentrations, with a paste of zinc sulfide to make a luminescent paint for watch, clock and meter dials and signs ahich must be read in the dark. An intimate mixture of radium with beryllium is a moderately intense source of neutrons. Such neutron sources have been used extensively in scientific work and have found practical applications in well logging in geophysical prospecting for petroleum. Radium-bearing slime from uranium processing is used as a marking compound in oil-well casings.

Mention should be made of the hazards of handling radium, which result from the physiological effects of its radiations and which are enhanced by the gaseous nature of its decay product, radon. Before the dangers were recognized and adequate precautions taken a number of radium workers suffered serious injury or death. For physiological effects of radioactive substances see RADIOLOGY.

Mesothorium can be used in a manner similar to radium for all the purposes mentioned, but its greater expense and shorter lifetime limit its applications. It is superior to radium as a luminous paint activator because the intensity of its radiations increases for several years and thus compensates for the fatigue of the zinc sulfide. Except for scientific purposes, the other radium isotopes have no practical value.

For all the uses of radium, substitutes have become available. Artificial radioelements and high-voltage X-ray generators are supplanting radium in radiotherapy and radiography. Fluorescent paints activated by ultraviolet radiation are replacing radium paints in airplane panel meters. Cyclotrons and nuclear chain reactors provide much more intense neutron sources. Nevertheless, the use of radium is still important because of its special properties and its availability as a by-product of uranium.

BIBLIOGRAPHY.—M. Curie, *Recherches sur les substances radioactives* (1904) and *Radioactivité* (1935); S. Meyer and E. Schweidler, *Radioaktivitat* (1927); E. Rutherford, J. Chadwick and C. D. Ellis, *Radiations From Radioactive Substances* (1930); L. Gmelin, *Gmelin and Krauts Handbuch der anorganischen Chemie,* 8th ed., "Syst.-Nr. 1" (1926) and "Syst.-Nr. 31" (1928); U.S. Bureau of Mines, *Minerals Yearbook* (annual volumes). (T. P. K.)

RADNORSHIRE, an inland county of Wales, bounded north by Montgomery, northeast by Shropshire, east by Hereford, south and southwest by Breconshire and northwest by Cardigan. Its area is 471 sq.mi., and it is consequently the smallest of the six south Wales counties. Pop. (1961) 18,431. The county is a highland region grading eastward to the plain of the Severn. The western section is formed of Ordovician rocks which are succeeded eastward by the Llandovery. Wenlock and Ludlow beds of the Silurian. This region forms part of the central Wales plateau with a general level of nearly 2.000 ft. To the east of the mid-Wales railway that cuts the county diagonally from southwest to northeast the grits and shales of the Lower Palaeozoic rocks are overlain by the Old Red Sandstone which culminates in the rugged mass of Radnor forest (2.166 ft.). The railway follows the lower Ithon valley (a tributary of the Wye) from near Builth Road to Llanbadarn Fawr. The Wye forms the southwest boundary of the county between Newbridge and Three Cocks, and divides Radnor forest from the Epynt mountains of Breconshire. Between Llandrindod and Builth is a disturbed area of Ordovician strata with masses of andesitic and diabasic igneous rocks. The region has also saline, sulphurous and chalybeate springs. East of New Radnor in the eastern section of the county an inlier of Wenlock rocks is surrounded by Ludlow beds; while at Old Radnor a ridge of very ancient rocks appears. The eastern half of the county is characterized by the number of river valleys that open out to the English plain and consequently offer important ways into the county from the east. In the north the Teme opens out to Knighton and Ludlow and forms the northern boundary of the county for a part of its course. The Lugg flows eastward past Presteign, and the Arrow past Kington, while the vale of Wye leads down to Hereford.

History and Early Settlement.-he heavily forested nature of the county in early times made it unsuited for settlement. There are remains on the open higher ground, especially in the north of the county. of tumuli of uncertain date. Evidences of Bronze Age and Megalithic cultures are almost entirely absent. There are, however, a few good examples of hilltop camps, especially at Burfa, and Castle Ring in the parish of Evenjobb. The Roman interests in the region seem to have centred on Castell Collen, a focus of ways among the hills, and on the road running due north from Brecon to Caersws. The post-Roman centuries were naturally times of difficulty in this region and the outstanding memorial of the time is the remains of Offa's Dyke that traversed the county. The best preserved sections are in the hilly districts west of Knighton and Presteign. Church dedications show the influence of the Celtic saint movements of these centuries. Toward the close of the 9th century Maesyfed was absorbed into the middle kingdom of Powys, and in the 10th century it was included in the realm of Elystan Glodrudd, prince of Fferlys, or Feryllwg, who ruled over all land lying between the Wye and Severn. In the reign of William I, the Normans began to penetrate into Maesyfed, where, according to Domesday. the king already laid claim to Radenoure, or Radnor, in the lordship of Melenith (Moelynaidd), which was subsequently bestowed on the Mortimer family. The Domesday records are of interest in that they show evidences of cultural penetrations along the valley ways from the east (English place names west of Offa's Dyke, etc.). Influences from the plain have long been a feature of the social. religious and political life of the county. Later, the Norman invaders forced their way up the Wye valley, the de Braose family, lords of Elvel (Elfael), building fortresses at Painscastle and at Colmyn or Maud's Castle.

The Wye valley long formed one of the debatable districts between Welsh and Normans. After the annexation of Wales by Edward I, the district of Maesyfed remained under the jurisdiction of the Lords Marchers, represented by the families of Mortimer and Todenep.

The valley ways show evidences of compact settlements, in marked contrast to the single iarms of the upland west. The difficult nature of much of the county throughout medieval times, together with the weak Norman hold, meant that the manorial system was very late in establishing itself. The ravages of the Black Death, which were particularly severe in this region, brought manorial conditions to an early end and the county became almost entirely dependent on sheep rearing. The increase in the number of sheep and the development of the wool trade and the great wool markets of the Welsh border — Shrewsbury, Ludlow, Hereford and Gloucester — were features of 14th and 15th century England. There was only one monastic house of consequence in this pastoral county, the Cistercian abbey of St. Mary, founded by Cadwallon ap Madoc in 1143 in "the long valley" of the Clywedog, 6 mi. E. of Rhayader, and from its site commonly called Abbey Cwmhir. Its existing ruins are insignificant, but the proportions of the church, which was 238 ft. long, are still traceable. The churches of Radnorshire are mostly poor and small.

The political instability of the county continued throughout the 15th century and in 1402 Owen Glendower entered the Marches and raided the lands of the young Edward Mortimer, earl of March.

Radnorshire was created a county on the English model by the Act of Union (1536). It was parceled out of the suppressed marches lordships. Together with the rest of moorland Wales the county was conservative and royalist during the 17th century, the local clergy during the Commonwealth coming in for severe criticism under the administration of the Puritan Vavasor Powell (1617–70). The developments in the wool trade and local weaving attracted in the 16th and 17th centuries numbers of continental weavers, mostly religious reiugees, and the county is well known for the strong points of view it took later in religious matters. It was an old stronghold of the Quakers and later of the Baptists.

During the 20th century the rise of Llandrindod as a watering place and the construction of the Birmingham reservoirs in the Elan valley have tended to increase interest in the county. On Oct. 23, 1952, Queen Elizabeth II opened the Claerwen dam which completed the Birmingham water supply plan inaugurated in 1904.

Occupations. — Good hay and cereals are raised in the valleys, oats being by far the chief crop. The extensive upland tracts, which cover more than one-third of the total area of the county, afford pasturage for large flocks of sheep. The quality of the wool of Radnorshire has long been celebrated, and also the delicacy of the Welsh mutton from the small sheep that are bred. Sheep fairs are held at Rhayader.

The Central Wales branch of British railways enters the county at Knighton, traverses it by way of Llandrindod and passes into Brecknock at Builth Road Junction on the Wye. The western section follows the course of the Wye, by way of Builth and Hay. Two small branch lines connect New Radnor and Presteign with other sections.

There is no existing municipal borough, although New Radnor, now a mere village, was incorporated in 1561, and its municipal privileges were not formally abolished until 1883. The chief centres are Presteign, Llandrindod Wells, Knighton and Rhayader, all, except Rhayader, being urban districts. Radnorshire is included in the Wales and Chester circuit, and Presteign ranks as the county town. The whole county together with that of Brecon returns one member to parliament. Ecclesiastically. Radnorshire is divided into 46 parishes, the majority of which lay after 1923 in the diocese of Swansea and Brecon, hut, before that, had been for centuries included in the diocese of St. David's. After a 10% increase in population during World War II the county by the 1950s was as sparsely peopled as ever, with an average of 0.07 persons per acre.

RADOM, a town of Poland in Kielce province. about 64 mi. S. of Warsaw by rail. Pop. (1960) 131.000. Radom has several iron and agricultural machinery works and tanneries. In 1216 it occupied the site of what is now Old Radom. New Radom was founded in 1340 by Casimir the Great, king of Poland. There Jadwiga was elected queen of Poland in 1382; the first act relating to the union of Poland with Lithuania was signed in 1401; the *sejm* (diet) of 1505, where the organic law of Poland was sworn by the king, was also held there. Several great fires, and the Swedish war of 1701–07, ruined the old city. After the third partition of Poland in 1795 Radom fell under Austrian rule; it was in 1815 annexed to Russia and was returned to Poland in 1918. Germany conquered Radom after bitter fighting in Sept. 1939. It was again returned to Poland in 1945.

RADON, atomic weight 222, is the heaviest element of the noble gas group and an important radioelement. Its chemical symbol is Rn and its atomic number is 86. The name radon is used either for the most important isotope, that of mass 222, or for the element as a whole, although for the latter purpose the name emanation (symbol Em) is sometimes preferred. Other isotopes are thoron (Tn, mass number 220) and actinon (An, 219). Thoron was discovered in 1899 by R. B. Owens and E. Rutherford, who observed that some of the radioactivity of thorium preparations can be swept away by a current of gas. Radon was similarly discovered in radium samples by F. E. Dorn in 1900, and actinon was found associated with actinium in 1904 by F. O. Giesel and A. Debierne.

Radon is the immediate product of the decay of radium and undergoes alpha disintegration with a half life of 3.825 days. It yields several short-lived radioelements called the active deposit because of their tendency to adhere to solid objects. Thoron and actinon have similar properties, but because of their short half-life periods, 51.5 and 3.92 seconds respectively, are of less importance than radon. (See RADIOACTIVITY, NATURAL; RADIUM.)

Because of its transient existence, radon is found only in conjunction with a source of radium. The atmosphere contains traces of radon near the ground as a result of seepage from soil and rocks, all of which contain minute quantities of radium. For preparing intense samples a supply of radium is kept in a glass vessel in aqueous solution or in the form of a porous solid from'which the radon can readily effuse. At intervals of a few days the accumulated radon is pumped off. purified, and compressed into a small tube which is then sealed and removed.

Radium C rapidly grows into equilibrium with the radon and, since the former is the source of the intense penetrating gamma rays, the gamma activity is in effect transferred from the radium sample to the tube by this process. The radon can then be used for radiotherapy, radiography or other purposes, until its strength decays to too low a value. "Dead" radon tubes are often saved for the extraction of radium D and polonium.

Radon possesses a particularly stable electronic configuration which gives it a chemical inertness characteristic of the noble gas elements. Thus it is always found in the elementary state, and no true compounds are known. Its properties are similar to those expected by extrapolation from the other noble gas elements, helium, neon, argon, krypton and xenon. It is the most easily condensed and solidified of the group, the boiling point being $-62°$ C. and the freezing point $-71°$ C. It dissolves more readily in water than the other noble gases and is very soluble in a number of organic liquids.

For bibliography, see RADIUM. (T. P. K.)

RADOWITZ, JOSEPH MARIA VON (1797–1853). German statesman, first pursued German unification under the military leadership of Prussia. Born at Blankenburg in the Harz mountains, he became an artillery expert and a friend of the crown prince (who succeeded to the throne as Frederick William IV in 1840). Radowitz combined romantic conservatism with a strong will for military efficiency! and in the war crisis of 1840 he first preached the doctrine of German military union under Prussia, with the emperor of Austria enjoying only a titular supremacy. Radowitz was an isolated figure at the Prussian court and could rely only on personal influence with the king. He occupied only minor posts before the revolution of 1848.

In that year he sat in the Frankfurt parliament, where his combination of military knowledge and strict religious views earned him the name of "the warlike monk." In April 1849 Frederick William IV refused the imperial crown offered by the liberal politicians of Frankfurt. Radowitz then set out to achieve the same aim by conservative methods. that is, by agreement with the German princes instead of with the people. Though still without an official position, he became the principal director of Prussian policy. He founded the Union of Erfurt under Prussian control and was the chief figure at its parliament. This policy provoked Austrian opposition; and in 1850 a crisis blew up. Radowitz had neglected foreign relations. He hated the French republic and was also determined to exclude Russia from the Balkans and the near east Prussia was therefore isolated; and. what was worse, the Prussian Junkers disliked the policy of adventure into which Radowitz was leading them. Frederick William IV was still his only resource.

On Sept. 27, 1850, Radowitz was made Prussian minister of foreign affairs. This seemed to be the prelude to war with Austria. but the other Prussian ministers resisted his policy and at the end of October Frederick William IV agreed to a compromise with Austria, which followed at Olomouc. Radowitz resigned on Nov. 3. He was sent on a mission to London to secure an alliance with Great Britain in exchange for tariff concessions, but the British government refused to involve itself in German affairs. Radowitz seemed to have failed completely, but he had, in fact, anticipated the policy which Bismarck was to carry to success 16 years later. After 1850 Radowitz had no influence on Prussian policy. though he retained the personal friendship of the king. He died, a disappointed man, on Dec. 25, 1853. (A. J. P. T.)

RAE, JOHN (1813–1893). Scottish arctic explorer who surveyed and mapped new coast lines of arctic Canada. was born on Sept. 30, 1813, in the Orkney Islands. He studied medicine at Edinburgh university and was for 10 years resident surgeon at the Hudson's Bay company's station at Moose Factory. In 1846 he voyaged to Repulse bay, and the next spring surveyed 700 mi. of new coast line connecting the earlier surveys of J. C. Ross and W. E. Parry. He then joined Sir John Richardson's expedition in search of Sir John Franklin. During 1851 he traveled some 5.300 mi. and explored and mapped 700 mi. of new coast on the south side of Wollaston and Victoria Lands, a feat which gained him the gold medal of the Royal Geographical society. In 1853 he commanded another expedition which proved King William Land to be an island and elicited the first definite information as to the fate of Franklin. Subsequently he traveled across Iceland. and in Greenland and northern America. He died July 22. 1893, in London. He wrote *A Narrative of an Expedition to the Shores of the Arctic Sea in 1846 and 1847* (1850). (H. G. Kg.)

RAE-BAREILLY (Rae Bareli), a municipal town, *tehsil* (administrative subdivision) and district in the Lucknow division of Uttar Pradesh. India. The town is on the river Sai. 45 mi. S.S.E. of Lucknow. Pop. (1951) 24.958. It has many architectural features. chief of which is a large brick fort. Among other ancient buildings are the palace and tomb of Nawab Jahan Khan, governor in the time of Shah Jahan. and four fine mosques. It is an important trade centre, and cotton cloth is woven. Rae-Bareilly Tehsil (area 375 sq.mi.) had a population in 1951 of 250,065.

Rae-Bareilly District (area 1,758 sq.mi.) is slightly undulating and beautifully wooded. The soil is fertile. the main crops being rice, pulses. wheat, barley, millet and poppy. The principal rivers are the Ganges and the Sai. Pop. (1961) 1,316,753.

RAEBURN, SIR HENRY (1756–1823), the leading Scottish portrait painter after Allan Ramsay, was born at Stockbridge, near Edinburgh, on March 4, 1756. the son of a yarn boiler. He became a scholar of Heriot's hospital and in about 1771 was apprenticed to the goldsmith James Gilliland. He is said to have met the seal-engraver David Deuchar in 1773, and the leading Edinburgh portrait painter David Martin in 1773, but for the most part he was self-taught, progressing from miniature painting to full-scale portraiture. A full-length presentation portrait of George Chalmers of 1776 (Dunfermline town council) is Raeburn's earliest known portrait, and its faulty drawing and incorrect perspective suggest the artist's lack of formal training. By his marriage to Ann Edgar, a rich widow, early in 1780 he achieved financial security and during the next four years considerably improved his artistic skill. In London in 1785 he met Sir Joshua Reynolds, whose works were already familiar to him from Scottish collections and engravings, en route for a prolonged tour of Italy whence he returned to Edinburgh in 1787.

His reappearance was opportune; the rising professional classes of Edinburgh could support a gifted portrait painter and these, with members of the old Highland families, provided him enough sitters. Unlike Ramsay, he never needed to go south in search of patronage. The portrait of "The Archers" (trustees of the late Viscount Novar), of Robert and Ronald Ferguson of Raith, was probably painted soon after his return, and is an ingeniously composed group already showing something of the broad, assured style of his maturity. This concern with elaborate composition was afterward to give place to greater simplicity and directness of presentation. By about 1790 he had painted the outstanding portrait of his wife (Countess Mountbatten collection): a finely characterized work of expressive simplicity, and the double portrait of Sir John and Lady Clerk (Sir Alfred Beit collection), in which the artist experimented with an unusual lighting from behind the sitters' heads (they are in an evening landscape setting) to bring out the character of their faces.

During the years 1790–1800 Raeburn produced some of his most brilliant portraits, such as the dramatic full-length "Sir John Sinclair" (*c.* 1794–95, Viscount Thurso), a romantic composition of a uniformed Highland laird seen against a mountainous landscape background. This foreshadowed the famous "The MacNab" (c. 1803–13, John Dewar and Sons, Ltd.), in which the tonalities became darker and the lighting even more contrasted. It is significant that no drawings by Raeburn survive; he was essentially a painter rather than a draughtsman. This accounts for the weak drawing of the hands in several of his portraits; he is said to have begun his portraits with the brush, without any preliminary drawing on the canvas. After 1800, he concentrated upon the heads and hands of his sitters, reducing to the absolute minimum all accessories and preferring a dark background to set off his subjects. His technique broadened and he used a vigorous, square brushstroke with which boldly to model in the features of his sitters. Although this was often extremely effective, as in the "Lord Newton" (1806–11, earl of Rosebery collection) or "Mrs. James Campbell" (*c.* 1805–12. Colonel Thomas, Glasgow), in his less successful works it became brash and vulgar. Some softening of his brushwork appeared in the last ten years of his career.

In 1810, after the death of John Hoppner, he revisited London with the intention of seeing whether he could establish himself there. but did not pursue this plan. Two years later he was elected president of the Edinburgh Society of Artists, becoming a Royal Academician in 1815. Knighted in 1822, he was appointed His Majesty's limner for Scotland. He died at Edinburgh on July 8, 1823. In many ways Raeburn fulfilled in Scotland the position Reynolds had earlier achieved in London. A popular member of the new cultured Edinburgh society, he rarely associated with fellow artists; he was a man of many interests and a good conversationalist.

Bibliography.—William Raeburn Andrew, *Life of Sir Henry Raeburn, R. A.*, 2nd ed. (1894) ; Sir Walter Armstrong, *Sir Henry Raeburn*, etc. (1907) with catalogue; J. Greig, *Sir Henry Raeburn*, etc. (1911); *Ramsay, Raeburn and Wilkie*, exhibition catalogue, Scottish National gallery (1951) ; *Raeburn: Bicentenary Exhibition* catalogue, Scottish National gallery (1956). (D. L. Fr.)

RAEDER, ERICH (1876–1960), German naval officer, was born in Silesia, April 24, 1876, and entered the navy on April 1, 1894. He was promoted through the various ranks, becoming a rear admiral in 1922 and on April 1, 1939, admiral of the fleet, the first to hold that rank since Tirpitz. He was commander in chief of the German navy throughout the early part of World War II and until Jan. 30, 1943, serving thereafter, until the end of the war, as inspector general of the navy.

Raeder was an officer of marked ability, whose advice was generally disregarded by Hitler. After the defeat of Germany in 1945, the inter-Allied tribunal at Niirnberg sentenced him to imprisonment, from which he was released in 1956. He died at Kiel, Ger., Nov. 6, 1960.

Raeder was the author of a number of books on naval warfare, including Der *Kreuzerkrieg in den Auslandischen Gewassern* (1922) and *Die Tatigkeit der kleinen Kreuzer Emden und Karlsruhe* (1923). (J. B. Hn.)

RAEDWALD (d. *c.* 620), king of the East Angles, was the son of King Tytili. He became a Christian during a stay in Kent, but on his return to East Anglia he sanctioned the worship both of the Christian and the heathen religions. Very little is known about his reign, which probably began soon after 600. For a time he recognized the overlordship of Aethelberht, king of Kent, but he seems to have shaken off the Kentish yoke. He gained some superiority over the land south of the Humber with the exception of Kent and is counted among the Bretwaldas. Raedwald protected the fugitive Edwin, afterward king of Northumbria, and in his interests he fought a sanguinary battle with the reigning Northumbrian king, Aethelfrith, near the river Idle in the summer or autumn of 616, in which Aethelfrith was defeated and killed. He was followed as king of the East Angles by his son Eorpwald.

See Bede, *Historiae ecclesiasticae,* edited *by C.* Plummer (1896); and J. R. Green, *The Making of England* (1897–99).

RAEMAEKERS, LOUIS (1869–1956), Dutch cartoonist who gained international fame by his anti-German cartoons during World War I, was born at Roermond on April 6, 1869. He at first painted landscapes and portraits. His first political cartoons appeared in 1907 and he joined the *Amsterdam Telegraaf* in 1909. The sincerity and vigour of his wartime cartoons roused enthusiasm in England, France and the United States and after 1916 he lived for some years in England to supply the Allied press more easily. He was also a cartoonist during World War II. He died at Scheveningen near The Hague on July 26, 1956.

RAETIA (in inscriptions; in classical manuscripts usually RHAETIA), in ancient geography, a province of the Roman empire, bounded on the west by the country of the Helvetii, on the east by Noricum, on the north by Vindelicia and on the south by Cisalpine Gaul. It thus comprised the districts occupied in modern times by the Grisons, the greater part of Tirol, and part of Lombardy. The land was very mountainous, and the inhabitants chiefly supported themselves by cattle breeding and cutting timber, little attention being paid to agriculture. Some of the valleys, however, were rich and fertile, and produced corn and wine. Trade was also carried on in pitch, honey, wax and cheese. Little is known of the origin or history of the Raetians, who are described as one of the most powerful and warlike of the Alpine tribes. It is stated by Livy (v. 33) that they were of Etruscan origin At the time when the land became known to the Romans, Celtic tribes were already in possession of it and had amalgamated so completely with the original inhabitants that, generally speaking, the Raetians may be regarded as a Celtic people, although non-Celtic tribes (Lepontii, Euganei) were settled among them They retained their independence until their subjugation in 15 B.C. by Tiberius and Drusus At first Raetia formed a distinct province, but towards the end of the 1st century A.D. Vindelicia was added to it; hence Tacitus *(Germania,* 41) could speak of 'Augusta Vindelicorum (Augsburg) as "a colony of the province of Raetia." The whole province (including Vindelicia) was at first under a military prefect, then under a procurator; it had no standing army quartered in it, but relied on its own native troops and militia for protection In the reign of Marcus Aurelius it was governed by the commander of the *Legio iii. Italica.* Under Diocletian (*q.v.*) it formed part of the diocese of the *vicarius Italiae.* During the last years of the Western empire, the land was in a desolate condition, but its occupation by the Ostrogoths in the time of Theodoric, to some extent revived its prosperity. The chief towns of Raetia were Tridentum (Trent) and Curia (Coire or Chur). It was traversed by two great lines of Roman roads—one leading from Verona and Tridentum across the Brenner to Oenipons (Innsbruck) and thence to Augusta Vindelicorum; the other from Brigantium (Bregenz) on Lake Constance, by Coire and Chiavenna to Como and Milan.

BIBLIOGRAPHY.—J. Marquardt, *Römische Staatsverwaltung,* i. (2nd ed., 1881) p. 288; Smith's *Dict. of Greek and Roman Geography* (1873); *T.* Mommsen, *The Roman Provinces* (Eng. trans., 1886), i. pp. 16, 161, 196; Mary B. Peaks, *The General Civil and Military Administration of Noricum and Raetia* (1907).

RAETO-ROMANCE DIALECTS are spoken by about 450,000 persons in the Alpine regions of southeastern Switzerland and northern Italy, including the Friuli region. They do not cover a contiguous area; they do not now and never did belong to a single cultural, administrative or linguistic unit; and they are not written in any single standard language. They are also not founded upon the same pre-Latin linguistic substratum, nor do they have the same linguistic superstratum. Apart from being all Romance, that is, Neo-Latin dialects, they owe their being classified together under one name not so much to their similarities, which merely suffice to set them off from all other Romance dialects. as to their geographic location. The term Raeto-Romance (RR) has, therefore, been contested on various grounds; for example: it had little to do with the Latin province called Raetia, which covered a larger surface, though not so dispersed; it had even less to do with a pre-Roman population called Raeti, uhose dialect, imperfectly known, forms the substratum of only a small part of RR; all dialects concerned should be called Ladin in order to avoid Raetic connotations, and RR should be restricted to the dialects of Switzerland; the term RR should be abandoned altogether because all dialects concerned are really Italian: the western of the Lombard group and the eastern of the Venetian group. All these terminological disagreements bedevil the linguistic literature. which must, therefore, be used with proper caution. National animosities and disputes, many still alive, have penetrated (linguistic) research. particularly regarding the districts of northeastern Italy: the Alto Adige (the former Austrian South Tirol) and Friuli.

The RR dialects are spoken in three major areas: (1) In Friuli, the region between the Alps and the head of the Adriatic sea. with the capital at Udine. This idiom is called Friulian. It accounts for over 90% of the total number of speakers of RR. (2) In some valleys of the Alto Adige region, east and west of the city of Bolzano, and in some parts of the Dolomites. This idiom may be called Ladin. (3) In parts of the Swiss canton Grisons (Graubiinden), in particular in the valleys of the two confluents of the Rhine (the Vorderrhein and the Hinterrhein), and of the Inn (the Engadine, Upper and Lower), approximately as far as the Austrian border. These dialects are called Romansh (or, in the native tongue, Grishun) and may be subdivided into Surselvan (Vorderrhein), Sutselvan (Hinterrhein) and Engadinian (Inn)

There is no doubt that at one time the area of RR was much larger. But owing to the absence of documentation it is difficult to learn when a given district changed to another type of speech. Italian or German. In many areas, however, the switch is relatively recent. For example, the Inn valley between Finstermünz, Switz., and Imst, Aus., from the Swiss border haliway to Innsbruck, spoke RR until the 16th century; there were Romance minorities in the Vintschgau as late as the 18th century and in some villages into the 19th; Innsbruck did not become wholly German-speaking until the 13th century, and Vorarlberg, Aus., even later. especially the Montafon (valley of the Ill river'); the Rhine valley past Liechtenstein, and the Wallensee area west of it. were Romance until the 11th century; Chur, the capital of the Grisons, was prevalently of Romance speech until the beginning of the 15th century.

The retreat of RR before Italian and German continues under the impact of the national languages which have greater prestige and currency. Friulian will probably cede to standard Italian, as will all dialects of the state of Italy; whether Ladin will be replaced by German or Italian is not certain: it is spoken within the Italian state: but its nearest and most influential neighbouring language is German (Austrian-Bavarian) of Bolzsno-Merano. Romansh of Switzerland is in a slightly more favourable situation; it is spoken in a country where local dialects, both Germanic (Alamannic) and Romance, are not considered socially inferior but cultivated and cherished. Romansh has also been best describeti of all the RR dialects, has been codified in dictionaries. and grammars, has a literature (including a translation of the New Testament of 1560) and has in fact been the fourth official language of Switzerland since 1938.

Ethnically the area of RR has been mixed and unstable from prehistoric times. Because of its passes it has always served as the crossroads between east and west, and north and south; and because of its inaccessible valleys and heights it has likewise served as a refuge for populations driven in war from more hospitable surrounding regions. Preceding its Latinization it was most likely of Celtic and Raetic speech in its western parts, of Italic (Yenetic) speech in its eastern parts. But it is impossible to dram sure boundaries for these linguistic substrata or to give dates for their Latinization. The political conquest of the district of Friulian, a part of Gallia Cisalpina, occurred around 220 B.C., but the Alpine area of Ladin and Romansh was not conquered until 15 B C., when it became in part the province of Raetia.

All these beautiful but poor mountainous tracts, Raetia, Noricum, Vindelicia. seem to have interested the Romans mainly for logistic reasons, in order to keep open communications with Gallia Transalpina and other northern and western possessions. Hence these regions were neither as intensively nor as extensively Romanized in culture and speech as other parts of the Roman empire which are now Romance-speaking. Furthermore, the Alpine provinces were the first to fall before the onslaught of the Germanic tribes which invaded Roman soil in the 5th century: the Alamanni pushed south across Switzerland about the end of the 5th century; the Baiuwarii crossed the Brenner pass. reaching the upper Isarco valley about 600 and the Bolzano-Merano district around 765. Friuli was the territory through which the invading Ostrogoths and Visigoths moved into Italy; it became eventually a Langobardic possession, but it was no more Germanized by these German tribes than was the rest of Italy. If the Germans had been better organized and if they had pursued a common goal, such as a Germanic state on the soil of the Roman empire, the entire RR area, if not, indeed, large portions of Italy, might have become Germanic in speech. Or if the speakers of the different RR districts had formed a coherent political whole, the various RR idioms might eventually have brought forth a separate standard Romance language. In view of the extremely checkered history of the area throughout the middle ages and into the modern era, the linguistic situation has become difficult to analyze.

The few linguistic traits common to all RR languages are archaisms rather than common innovations. This testifies to a lack of communication among them and the absence of a common culture. The greatest amount of agreement is to be found in the vocabularies of the various dialects; but this is not very significant, since they are all of Latin origin. In phonology the retention of Latin final *-s* over large areas is important both phonemically and morphemically. In the latter respect it causes plural formations with *-s,* thus connecting RR with the western, Gallo-Romance languages. Otherwise the retention of *pl-*, *kl- (cl-)* and *bl-* (rather than palatalization, as prevails in Italian and Rumanian), the palatalization of *ka- (ca-)* and *ga-*, and the diphthongization of vowels in free (that is, syllable-final) position are widespread but far from ubiquitous. Of all the Romance idioms, the RR languages have been least studied because of the scarcity of records of the medieval and even modern period and the absence of any standard literary language or languages. Outside of Switzerland all RR speech is considered mere patois. The description of contemporary speech awaits modern scientific treatment; but it will have to be undertaken soon, lest RR go the way of other now extinct Romance speech forms.

BIBLIOGRAPHY.—G. I. Ascoli, "Saggi ladini," *Archivio glottologico italiano,* vol. i, pp. 1–326 (1873); C. Battisti, *Popoli e lingue dell'Alto Adige* (1931), *Storia della questione ladina* (1937); *R.* Brandstetter, *Ratoronzanische Forschungen* (1905); B. Gerola, *Correnti linguistiche e dialetti neolatini nell'area retica* (1939); G. Marchetti, *Lineamenti di grammatica friulana* (1952); *R.* von Planta, *Dicziunari Rumantsch Grischun* (1938), "Ueber Ortsnamen, Sprach- und Landesgeschichte von Graubünden," *Revue de linguistique romane,* vol. 7, pp. 80–100 (1931); G. A. Stampa, *Der Dialekt von Bergell* (1934). (E. PM.)

RAFF, JOSEPH JOACHIM (1822–1882). German composer and orchestral conductor. was born near Zurich. Switz., on May 27, 1822, and educated chiefly at Schwyz. He was encouraged and assisted by Liszt and von Bulow, his opera, *Konig Alfred,* being produced at Weimar under Liszt's direction.

Raff lived at Weimar until 1856. In 1859 he married Doris Genast, an actress of high repute, and thenceforward devoted himself with renewed energy to the work of composition, displaying an inexhaustible fertility of invention and great technical skill. He resided chiefly at Wiesbaden till 1877, when he was appointed director of the Hoch-Conservatorium at Frankfurt am Main, an office which he retained until his death on June 25. 1882. Raff's compositions included symphonies, quartets, concertos, sonatas and songs.

RAFFI (pseudonym of HAKOB MELIQ-HAKOBIAN) (1835–1888), the most celebrated Armenian novelist, was born in Phayajuk, in Iranian Azerbaijan. the eldest son of a merchant. After his father's bankruptcy in 1868. he worked as a schoolmaster and a journalist. collaborating nith the Russian-Armenian paper *Mshak* from 1872 to 1884. He died in Tiflis, where he is buried. His principal novels are *Jalaleddin* (1878), *The Fool* (1880; Eng. trans. 1950), *David Bek* (1880). *The Golden Cockerel* (1882), *Sparks* (1883–1890) and *Samuel* (1885). He wrote also a number of short stories and historical articles.

An ardent nationalist, he mas preoccupied with the lot of his fellow Armenians in Persia and Turkey, and his interest in history was that of a writer of the Romantic school. He had a fertile imagination and narrative skill, but the psychology of his characters tends to be shallow, and the construction and style of his nork uneven. (C. J. F. D.)

RAFFIA, a fibrous product obtained from the palm *Raphia pedunculata* of Madagascar. It is prepared from the leaves of the palm, which are cut before they begin to curl. The underpart is removed in strips and dried, after which the strips can be split easily from end to end in any desired width.

Raffia is used in connection with the tongue grafting method of tree or shrub propagation. A tongue cut on the face of the scion (cion) is fitted into a matching notch on the parent stock, and scion and stock are securely bound together with raffia.

Raffia is also widely used in basketry, particularly in the sewing of coiled reed or plaited rush baskets. It may also be woven in the conventional manner by passing it under and over warp strings on a loom.

Raffia can be satisfactorily dyed with vegetable colourings, such as those derived from barks, leaves, berries and flower petals. (E. L. Y.)

RAFFLES, SIR THOMAS STAMFORD (1781–1826), English administrator, founder of Singapore, was born on July 5, 1781, on board a merchantman commanded by his father, Benjamin Raffles, when off Port Morant, Jamaica. He became a clerk in the office of the East India Company, and in 1805 was sent out to Penang as assistant secretary to the first governor. In addition to his duties as secretary he acted as Malay interpreter. and in 1807 he became secretary.

In 1808 his health gave way, and he was ordered for a change to Malacca The East India Company had decided to abandon Malacca, and orders had been issued to dismantle it. Raffles drew up a report explaining the great importance of Malacca, and urging in the strongest manner its retention. Lord Minto was so impressed by the report that he at once gave orders for suspending the evacuation of Malacca. and in 1809 the company decided to reverse its own decision. In June 1810 Raffles, of his own accord, proceeded to Calcutta. where Lord Minto gave him the kindest reception. Raffles remained four months in Calcutta, and gained the complete confidence of the governor-general. He brought Lord Minto round to his opinion that the conquest of the island of Java, then in the hands of the French, was an imperative necessity. To prepare the way for the expedition, Raffles was sent to Malacca as "agent to the Governor-General with the Malay States." He did his work well and thoroughly—even to the extent of discovering that the short and direct route to Batavia by the Caramata passage would be a safe one for the fleet to take.

In August 1811 the expedition, accompanied by Lord Minto, and nith Sir Samuel Auchmuty in command of the troops (11,000 in number, half English and half Indian), occupied Batavia without fighting. On the 25th a battle was fought at Cornelis, a few miles south of Batavia. and resulted in a complete English victory. On Sept. 18 the French commander. General Janssens, formally capitulated at Samarang, and the conquest of the island was completed. Lord Minto's first act was to appoint Raffles lieutenant-governor of Java. From September 1811 until his departure for England in March 1816, Raffles ruled this large island with conspicuous success. He increased the revenue eightfold at the same time that he abolished transit dues, reduced port dues to one-third and removed the fetters imposed on trade and intercourse with the Javanese by Dutch officialdom. In his own words, his administration aimed at being "not only without fear, but without reproach." He had a still greater ambition, which was, in his own words, "to make Java the centre of an Eastern insular Empire," and to establish the closest relations of friendship and alliance with the Javanese, whom he described as "a highly polished people, considerably advanced in science, highly inquisitive and full of penetration." It is interesting to note that when another great Englishman, Rajah Brooke, began his career in Sarawak in 1838, he announced: "I go to carry Sir Stamford Raffles's views in Java over the whole Archipelago."

In November 1817 Raffles quitted England on his return to the East, where the lieutenant-governorship of Fort Marlborough (Sumatra) had been kept in reserve for him. His administration of Sumatra (1818–23) was characterized by the same breadth of view, consistency of purpose and energy in action that had made his government of Java remarkable. He had not, however, done with the Dutch, who, on their recovery of Java, endeavoured to establish a complete control over the Eastern archipelago, and to oust British trade. This design Sir Stamford set himself to baffle, and by a stroke of genius and unrivalled statecraft he stopped for all time the Dutch project of a *mare clausum* by the acquisition and founding of Singapore on Jan. 29, 1819.

In 1824 Raffles returned to England to vindicate his acts to the East India Company. The court exonerated him from the charges made against him, but censured him for "his precipitate and unauthorized emancipation of the Company's slaves," and after his death charged his widow to pay £10,000 for various items, which included the expense of his mission to found Singapore. Harassed by these personal affairs, he still found time to help in the foundation of the zoological society in London. His fine Sumatra collection formed its endowment. He died July 5, 1826.

See Lady Raffles, *Memoir of Sir Thomas Stamford Raffles* (1830); D. C. Boulger, *Life of Sir Stamford Raffles* (1897); Hugh Egerton, *Sir Stamford Raffles* (1899); J. Buckley, *Records of Singapore* (1903).

RAFFLESIA, a genus of plants of the family Rafflesiaceae with six species confined to Malaya. They are all parasitic on the roots of vines (*Vitis*). R. *arnoldi* has the largest flower known (18 in. across, weight 15 lb.) with a smell like decaying flesh. Pollinated by carrion flies, it is the only part of the plant above ground; the remainder is reduced to a funguslike mycelium.

RAFINESQUE, CONSTANTINE SAMUEL (1783–1840), a naturalist and early theorizer about the evolution of species, was born of French-German parents at Galata (Constantinople) on Oct. 22, 1783. He lived in Marseilles and after 1792 in Italy, studying in Leghorn, Genoa and Padua. In 1802 he went with his brother to the United States. He worked in Philadelphia and Germantown, Pa., visited Pres. Thomas Jefferson at Washington, and made many trips in search of natural history specimens. In 1805 he returned to Europe, spending the next ten years in Palermo. Sicily. In 1815 he returned to the United States, where he taught and made botanical collections. In 1819 be became professor of botany, materia medica and modern languages at the Transylvania university, Lexington, Ky., where he founded a botanical garden in 1825. In 1826 he moved to Philadelphia where he lectured at the Franklin institute. He died in poverty in Philadelphia on Sept. 18, 1840.

Rafinesque was a controversial figure in the history of U.S. botany. He was severely criticised by such an authority as Asa Gray (*q.v.*) for careless work and his passion for establishing new genera and species. On the other hand, he was lauded as a genius who had a definite idea about the theory of evolution long before Charles Darwin.

His publications numbered more than 950; the most important among his botanical works are: *Autikon botanikon* (1815–40, facs. ed.. 1942); *Florula ludoviciana* (1817); *Medical Flora,* 2 vol. (1828–30); *New Flora and Botany of North America,* 4 pt. (1836–38); *Flora telluriana,* 4 vol. (1837–38); *American Manual of the Mulberry Trees* (1839) and *Sylva telluriana* (1838, facs. ed., 1942). He also wrote *A Life of Travels and Researches* (1836, facs. ed. 1943).

See T. J. Fitzpatrick, *Rafinesque, a Sketch of his Life with Bibliography* (1911) and F. W. Pennell, *The Life and Wcrk of Rafinesque* (1942). (V. C. As.)

RAGGED ROBIN (*Lychnis floscuculi*), a perennial plant with pink, divided petals, belonging to the pink family, Caryophyllaceae (*q.v.*), native to Europe and Asia, common in Great Britain and naturalized in the eastern United States. It is a slender herb, about $1\frac{1}{2}$ ft. high, and is parasitized by a fungus, *Ustilago antherarum,* which forms its spores in the stamens, whence they are transported from plant to plant by insects.

RAGLAN, FITZROY JAMES HENRY SOMERSET, 1ST BARON (1788–1855), British field marshal, was the eighth and youngest son of Henry, 5th duke of Beaufort, by Elizabeth Boscawen, and was born on Sept. 30, 1788. Lord Fitzroy Somerset was educated at Westminster school, and entered the army in 1804. He served on the staff of Sir Arthur Wellesley in the expedition to Copenhagen (1807), and went with him to Portugal in 1808. During the whole of the Peninsular War he was at his right hand, first as aide-de-camp and then as military secretary. He was the first to mount the breach at Badajoz, and afterward showed great resolution and promptitude in securing one of the gates before the French could organize a fresh defense. During the short period of the Bourbon rule in 1814 and 1815 he was secretary to the English embassy at Paris. On the renewal of the war he again became aide-de-camp and military secretary to the duke of Wellington. About this time he married Emily Harriet, daughter of the 3rd earl of Mornington, and Wellington's niece. At Waterloo he was wounded in the right arm and had to undergo amputation, but on the conclusion of the war resumed his duties as secretary to the embassy at Paris. From 1818 to 1820, and again in 1826–29, he sat in the house of commons as member for Truro. In 1819 he was appointed secretary to the duke of Wellington as master general of the ordnance, and from 1827 until the death of the duke in 1852 was military secretary to him as commander in chief. He was then appointed master general of the ordnance, and was created Baron Raglan.

In 1854 he was promoted general and appointed to the command of the British troops sent to the Crimea (*see* CRIMEAN WAR) in co-operation with a strong French army under Marshal St. Arnaud and afterwards, up to May 1855, under Marshal Canrobert. Here the advantage of his training under the duke of Wellington was seen in the soundness of his generalship, and his diplomatic experience stood him in good stead in dealing with the generals and admirals, British, French and Turkish, associated with him.

For the hardships and sufferings of the British soldiers in the terrible Crimean winter before Sevastopol, owing to failure in the commissariat, both as regards food and clothing, Lord Raglan and his staff were at the time severely censured by the press and the government; but it afterward appeared that the chief neglect rested with the home authorities. He was made a field marshal after Inkermann. During the trying winter of 1854–55 his health was undermined. Disappointment at the failure of the assault of June 18, 1855, finally broke his spirit, and on June 28, 1855, he died.

RAGNAR LODBROK, Scandinavian ruler of the 8th or 9th century, supposed to have invaded England and France. It is nearly certain that such a person existed, but he has become a Scandinavian hero and the myths surrounding him are so extensive that it is difficult to separate the true from the fictional and to determine precisely what took place during his reign. One theory is that there were two men around whom the stories are woven: a prince named Ragnar Lodbrok, who died in 794; and another prince named Raginfrid or Regnier, who actually led the invasions of France and England, which did not take place until the 9th century, but who is known in Scandinavian history and legend as Ragnar Lodbrok also. In any case, the myths about the two men of the same name have become inextricably intertwined.

The story is that Ragnar Lodbrok sailed up the Seine river to Paris, which he captured and which was only redeemed by a ransom of 7,000 lbs. of silver. Later, the story runs, jealous of the reported achievements of his two sons, he planned to outdo them by invading England. He constructed two ships, the largest that had ever been built in Scandinavia, and sailed for Northumberland. He was captured by Aella, the Saxon king of Northumberland, after a valiant fight, and thrown alive into a pit of snakes, which stung him to death. His death song, the Lodbrokar-quida, has become a Scandinavian epic. His sons revenged him by killing Aella, and Northumberland ceased to be a Saxon kingdom and was looted and plundered by the Norsemen.

RAGNAROK, a Scandinavian myth telling of the death of the gods and the destruction of the world. The name is probably derived from the Old Norse words *regin* or rogn ("god") and rok ("reason, origin or history"), although it is sometimes thought that the word comes from the Icelandic ragna ("gods") and rokr ("twilight"). The story is contained in the Icelandic saga *Völuspá*. It tells of the war between the gods, led by Odin, and their evil opponents, led by Loki. The Ragnarok combines three common stories of the destruction of the world: the sinking of the earth into the sea and the devouring of the sun by a monster; a devastating winter; and the destruction of the earth by fire. In addition to the annihilation of the earth, the chief protagonists on each side are killed and there is a period of darkness and chaos. Afterward, however, some of the gods who were not destroyed return to the earth, which has risen from the sea, and with them return a human couple, Lif and Lifthraser (Life and Vitality), who are the progenitors of a new race. This is the story used by Richard Wagner, the German composer, in his opera *Götterdämmerung,* the German word for "twilight of the gods."

RAGUSA, a town and provincial capital of Sicily in the province of Ragusa, 70 mi. S.W. of Syracuse by rail and 32 mi. direct. It consists of an upper and a lower town united into one commune in 1926. Pop. (1951) 40,839. The city has an entirely new quarter, called Littorio. It has some churches with fine Gothic architecture, and is commercially important, a stone impregnated with bitumen being quarried and prepared for use for paving slabs by being exposed to the action of fire. Oil suited to diesel motors is extracted. On the hill occupied by the castle of the lower town (Ragusa Ibla) stood the ancient Hybla Heraea, a Sicel town, under the walls of which Hippocrates of Gela fell in 491 B.C.

During World War II Ragusa was severely bombed by the U.S. and British air forces prior to its occupation.

RAGUSA, Yugoslavia: see DUBROVNIK.

RAGWEED, any North American plant of the genus Ambrosia (family Compositae). The ragweeds are chiefly coarse annuals, with rough hairy stems: mostly lobed or divided leaves, and inconspicuous greenish flowers borne in small heads, the male in terminal spikes and the female in the upper axils of the leaves. The common ragweed (*A. artemisiifolia*), called also Roman wormwood, hogweed and bitterweed, found across the continent, grows from one to seven feet high, with thin, alternate or opposite, much-divided leaves. The great ragweed (*A. trifida*), called also bitterweed and horse cane! native from Quebec to British Columbia and southward to Florida, Arkansas and California, grows from 3 to 17 ft. tall, with opposite, entire or palmately three- to five-lobed leaves. Both the foregoing are annuals and often become pernicious weeds; their pollen, which is shed in great abundance in late summer, is a prolific source of hay fever (*q.v.*). Since these species are annuals, their eradication is easy if they are mowed well before they shed their copious seed. The western ragweed (*A. psilostachya*), found from Illinois to Alberta and southward to California, Texas and Mexico, is similar to the common ragweed, but is a shorter plant, perennial and with thicker leaves.

All the ragweeds; both annual and perennial, can be killed with 2,4-D; after low mowing, the plants are allowed to initiate low new top growth and sprayed with the herbicide.

In England, the tansy ragwort Senecio *jacobaea* (see SENECIO) is sometimes called ragweed. (N. TR.)

RAGWORT (Senecio jacobaea), a common plant in European pastures and wasteland, growing to a height of over 2 ft., with heads of bright yellow flowers. It is allied to the groundsel (*q.v.*) and is one of the five noxious weeds whose removal in Great Britain is enforced by law. This weed, known also as staggerwort, is sparingly naturalized in North America from Newfoundland to Ontario and southward to Pennsylvania. In the United States and Canada various other species of Senecio are called ragwort, *e.g.,* the golden ragwort or swamp squaw weed (*S.* aureus), a conspicuous wild flower of early summer, inhabiting swamps and wet meadows.

RAHAB, the name of two Old Testament figures.

1. Rahab was a Jericho woman who sheltered the spies sent by Joshua (Josh, ii), concealed them under flax on the roof and assisted them to escape by a rope from a window of her house on the town wall. By this act of friendship she secured the safety of her household when the Israelites took Jericho; by arrangement a scarlet cord was to be hung from a window for identification. Thus, she and her family were saved and became converts to the Hebrew religion. The Hebrew text describes her as a harlot (zonalz), and she is so regarded in Talmudic literature. Later Jewish commentators, however, prefer to associate zonah with an alternative root to procure the meaning "one who sells food." Rahab's beauty was proverbial, and from her profession she was reputed to be well informed on public affairs. After her conversion, according to tradition, she married Joshua and became the ancestress of Jeremiah, Huldah and Ezekiel among other prophets.

2. Rahab was the name of the sea monster inhabiting the primeval ocean (Ps. lxxxix, 10; Job ix, 13; xxvi, 12; Is. li, 9; comparable with Tiamat in Assyrian-Babylonian mythology); hence, in a figurative sense, a designation for Egypt (Ps. lxxxvii, 4; Is. xxx, 7).

RAHWAY, a city of Union county, New Jersey, U.S., is 20 mi. S.W. of New York city. Industrial establishments in Rahway produce drugs. chemicals, varnish, machinery, auto accessories, vacuum cleaners, office equipment, books, food products, rubber goods and textile goods. The city is also a residential ,centre. For comparative population figures see table in NEW JERSEY: Population.

The city was settled in the 1680s. During the American Revolution (when it was called Spanktown) it was temporarily an army supply base for General Washington's army and a skirmish was fought there in Jan. 1777. It became a township in 1804 (called Rahway after a local Indian Chief named "Rahwack") and a city in 1858. (W. L. CA.)

RAICHUR, a town and district of Mysore state, India. The town, 351 mi. N.W. of Madras, is a thriving trade centre and has cotton ginning and pressing factories; pop. (1951) 54,032.

The DISTRICT OF RAICHUR has an area of 5.591 sq.mi.; pop. (1951) 953.640. Low-grade iron ore is to be found in the district. Raichur gives its name to the doab or tract between the Kistna and Tungabhadra rivers, which was much fought over by Moslems and Hindus in the 16th century. (S. GL.)

RAIGARH, a town and district of Madhya Pradesh, India. Fine tussore silk is produced in the town; pop. (1951) 29,684. It is 363 mi. from Calcutta, to which it is linked by the Eastern railway.

The DISTRICT OF RAIGARH has an area of 5,150 sq.mi.; pop. (1951) 919.520. About a third of its area and population is accounted for by the absorption in 1948 of the former feudatory state of Raigarh. (S. GL.)

RAIKES, ROBERT (1736–1811), English philanthropist and pioneer of the Sunday school movement, was born at Gloucester on Sept. 4, 1736. His philanthropic work started with the prisoners in the local jail. Later, the lawless behaviour of Gloucester children on Sundays led him to experiment with a Sunday school in Sooty alley, where he engaged a number of paid women teachers to give instruction in reading and the church catechism. The experiment was so successful that in his newspaper, the Gloucester Journal (Nov. 3, 1783), he was able to record that the district had become "quite a heaven upon Sundays, compared with what it used to be."

The Sunday school movement spread to all parts of the country with great rapidity. In 1785 the Sunday School society was formed, and four years later Sunday schools were established in Wales. The Sunday School union (1803) was a direct result of Raikes's work.

Raikes died at Gloucester on April 5, 1811.

BIBLIOGRAPHY.—A. Gregory, *Robert Raikes* (1877); J. H. Harris, *Robert Raikes, the Man and his Work* (1899); G. Kendall, *Robert Raikes* (1939). (*S. J.* C.)

RAIL, the common name for marsh birds comprising the family Rallidae, of which there are more than 130 species recognized, world-wide in distribution except in high latitudes. They are somewhat chicken-shaped, aith short rounded wings and large feet with long toes. Rails are secretive in habit and infrequently seen; their loud, harsh calls, how-ever, give away their presence in dense vegetation. Many are excellent game birds; when flushed, they take to wing reluctantly, flying a short distance and then dropping to ground.

In the United States the king rail (*Rallus elegans*), a reddish-brown bird the size of a small chicken; clapper rail (*R. longirostris*), a gray form; and the Virginia rail (*R. limicola*), reddish brown and less than one-half as big, are hunted as game, as is the Carolina rail, or sora (*Porzana carolina*). The little yellow rail (*Coturnicops noveboracensis*) and the six-inch-long black rail (*Laterallus jamaicensis*) are too scarce to be of interest to the hunter.

HUGH M HALLIDAY FROM NATIONAL AUDUBON SOCIETY

VIRGINIA RAIL (RALLUS LIMICOLA)

The land rail, or corn crake (*Crex crex*), is found throughout Europe and western Asia and is a summer visitor to England. Brownish above and yellowish uhite below, it is inconspicuous except in flight, nhen it is recognized by its chestnut wings, barred flank and dangling legs. It nests on the ground and forages for food, chiefly insects, in long grasses. Eight to ten eggs are laid, of a cream colour blotched with red-brown. The young hatchlings are covered with black down. Less abundant but more widely distributed (extending to northern Africa) is the water rail (*Rallus aquaticus*). This is *a* slender bird of much the same habits as the corn crake. It is distinguished by darker plumage and a long, reddish bill.

The Rallidae includes also coots and gallinules (*qq.v.*) and, among a few flightless sorts. *Notornis,* a genus presumed to be extinct till small groups of N. *hochstetteri* were found in 1948 along some alpine lakes of New Zealand. Several rails live on tiny almost barren oceanic islands. (HT. FN.)

RAILWAY, a mode of land transportation the roadway of which consists of one or more tracks. each having two parallel steel rails. Over these rails move freight and passenger carrying vehicles, or cars, with flanged wheels. The cars are usually pulled or pushed by a locomotive, although they may be self-propelled.

TABLE I.—*U.S.-British Railway Terms*

United States	Britain
Baggage car	Luggage van
Boxcar	Goods van or box van
Classification yard	Marshaling yard
Caboose	Brake van
Crosstie or tie	Sleeper
Diaphragm (car)	Corridor connection
Dining car	Restaurant car
Engineer; engineman	Engine driver
Freight car	Goods wagon
Grade crossing	Level crossing
Gondola car	Open wagon
Interlocking plant	Signal box
Journal box	Axle box
Joint bars (rail)	Fishplates
Passenger car	Passenger carriage
Self-propelled car	Rail car
Self-propelled-car train	Train set
Signal tower	Signal cabin
Switching (of cars)	Shunting
Switcher (locomotive)	Shunting engine
Switch or turnout	Points
Tie plate	Baseplate
Truck, swivel car	Bogie

The development of railways is one of the great landmarks in the progress of human civilization. Coming early in the 19th century, railways provided an element that was essential to full realization of the promise of the surging industrial revolution — namely, a reliable, low-cost, high-volume system of land transportation.

It is the principle of flanged steel wheels rolling on steel rails that gives the railway its pre-eminence for heavy-duty transportation. The flanges guide the wheels of locomotives and cars, causing them to follow the line of the rails, and the rolling friction of the wheels on the rails is extremely low. In fact, if a 40-ton railway freight car of the type common in the U S were set rollihg on level track at 60 m.p h.. it would travel five miles or more before coming to a stop. In contrast, a highway truck of similar weight set free on level road at the same speed would roll only about one mile.

Because of this self-guiding characteristic and the low rolling friction, a locomotive of relatively modest horsepower can pull a long train of cars. This, basically, is the reason for the economy of railway transportation, an economy that is clearly evident in terms of manpower and fuel consumption. In 1952, for example. all other forms of transport in the United States used 11 times as much fuel as did the railways — yet the latter produced more than half the total gross ton-miles of transportation. In 1955, U.S. railways produced five times as much transportation per employee as did the intercity truck lines, despite the fact that the railways build and maintain their own roadways, which the highway carriers do not.

In this article, the discussion is divided into these principal sections:

Information on the economic aspects of railway operation may be found in the article INTERSTATE COMMERCE, while a general survey, from a historical viewpoint, of all forms of transport is presented in the article TRANSPORT. Forms of urban and inter-urban rail transport are described in ELECTRIC TRACTION and SUBWAY (UNDERGROUND RAILWAY).

I. HISTORICAL DEVELOPMENT

The railway as we know it originated in England, but the use of wheeled vehicles on rail lines came many years before the advent of mechanical traction. There is a reference to a railway in Europe as early as 1550. Before the end of the 16th century, mining railways were introduced in Britain. particularly in the northeast coal mining area. In the 18th century horse-drawn railways of this kind were to be found not only in England but in Wales and Scotland. Their application was increased with the introduction of cast iron for uheels and for the plateways over which the wagons ran. The earliest atmospheric steam engines, however, were too bulky and heavy for traction purposes.

In 1797 Richard Trevithick made three models, one of which may have represented a proposal for a self-propelled steam engine or locomotive. In Feb. 1804, a locomotive built by Trevithick ran on a tramroad in Wales, but these and subsequent experiments were unsuccessful, probably because the weight of the locomotive broke the rails. In 1808 Trevithick exhibited a locomotive and carriage on a circular track in London, but it was regarded as an amusement and not taken seriously.

Folloaing Trevithick's pioneering, the first practical and successful locomotive was built in 1812 to the instructions of John Blenkinsop, an inspector at Middleton colliery near Leeds. It ran on cast iron rails and had two vertical cylinders driving two shafts geared to a toothed wheel which engaged a rack rail. Three further locomotives were built in 1812 and 1813 and used between the colliery and Leeds, a distance of three and one-half miles.

In 1813, William Hedley built "Puffing Billy," a simple adhesion locomotive (*i.e.,* one that relied on friction between wheels and rails, dispensing with the toothed rack rail). It was used for hauling coal trucks between Wylam colliery and the wharves at Lemington-on-Tyne, a distance of about five miles. In the following year George Stephenson, pioneer railway and locomotive builder, completed his first engine, the "Bliicher." It was put to work at Killingworth colliery.

In 1823, Stephenson was invited by Edward Pease to build and equip a railway from Stockton to Darlington. This was completed in 1825 and ceremonially opened on Sept. 27 of that year. It was the first public railway in the world that employed locomotive traction and that was intended to carry both freight and passengers, and as such it marked the birth of the public service railway. It was not the first public railway, this honour going to the Surrey Iron Railway company, which was created through an act of parliament passed in 1801; it was opened in 1803 between Wandsworth and Croydon, using horses. In 1804 the Oystermouth railway was incorporated and this became the first railway to carry fare-paying passengers (March 1807), horse traction being used.

During the first two years of its existence, steam traction proved unreliable and expensive to maintain on the Stockton and Darlington railway. The first locomotive was "Locomotion" (now preserved at Bank Top station, Darlington). This and similar machines were only suitable for hauling low-speed mineral trains, and their tractive effort and weight were limited by the comparatively weak track. At times the railway reverted to horses, but the situation was improved with the introduction in 1827 of the "Royal George," a six-coupled locomotive designed by Timothy Hackworth. This and other locomotives eliminated the use of horses in rail freight service by 1833.

In 1829 the Liverpool and Manchester railway held a contest to decide upon the best kind of traction to use and it was won by Stephenson's "Rocket" (now preserved at the Science museum, London). The success of the "Rocket" mas due principally to the use of a multiple fire-tube boiler in place of the single-flue boilers previously used. The Liverpool and Manchester railway was opened on Sept. 15, 1830, and it became the first public railway on which all traffic was hauled by steam locomotives. At this time another great stride was made in track construction by Blenkinsop's patent for fish-bellied rolled-iron edge rails (1829). These were much stronger than cast iron rails and enabled heavier locomotives to be used.

A. Railways in the United States

Paralleling this early English development. interest in railways began to develop in the United States, as well as in other countries. One of several horse-drawn tramways built early in the 19th century was Gridley Bryant's Granite railway in Quincy, Mass. Horses supplied power for this three-mile, broad-gauge line, which carried the granite used in building the Bunker Hill monument.

By 1813, the inventor Oliver Evans was proposing a railway between New York and Philadelphia. Two years later, John Stevens received from the New Jersey legislature the first charter for a railway ever granted in America. However, Stevens was ahead of his time: the chartered line, between the Delaware and Raritan rivers, was never built. But in 1825, Stevens built and operated the first locomotive to run on rails in America. It ran on a half-mile circle of track at Stevens' home in Hoboken, N.J.

This was the year that the Stockton and Darlington line opened in England; the success of that pioneering enterprise helped overcome the opposition and apathy toward railways in the United States. On Feb. 28, 1827, the Baltimore and Ohio Railroad company (B. & 0.) was chartered (in the following, abbreviations or names in parentheses are those by which U.S. lines are commonly known). The line began carrying revenue traffic Jan. 7, 1830, and the first 13 mi. of line, from Baltimore to Ellicott's Mills (now Ellicott City) opened on May 24, 1830.

The B. & 0. was the first railway in the U.S. to be chartered as a common carrier of freight and passengers. Moreover, its promoters looked beyond purely local needs. They envisaged a line going all the way to the Ohio river to channel the commerce of the growing middle west through the port of Baltimore. By 1834 the B. & O. had built to Harpers Ferry, Va. (now W.Va.), and on Dec. 24, 1852, it reached the Ohio river at Wheeling. Subsequently the B. & 0. expanded, both through new construction and by acquiring other railways, until it reached Chicago, St. Louis and the Great Lakes.

Almost simultaneously, several other early U.S. railways came into being. Construction of the 5-ft. gauge line from Charleston to Hamburg, S C , by the South Carolina Canal and Rail Road company began in Feb. 1829. On Dec. 25, 1830, this line became the first in the United States to start scheduled passenger operations using a steam locomotive. When the entire line to Hamburg was completed in 1833, it was the longest then operating in the U.S. (136 mi.). Ultimately. the original Charleston-Hamburg route became one segment of the 8,000-mi. Southern Railway system.

Still other railway systems that later grew into giants of the U.S. railaay industry had their beginnings in the decade of the 1830s. The Mohawk and Hudson, first predecessor of the New York Central system, operated its first train between Albany and Schenectady, N.Y., on Aug. 9, 1831. Predecessors of both the Boston and Maine railroad and the New York, New Haven and Hartford Railroad company (New Haven) started regular service in the summer of 1835. Three local lines chartered in Virginia evolved into major rail systems. One was the Richmond and Petersburg, chartered in 1836, oldest element of the Atlantic Coast Line Railroad company. The Portsmouth and Roanoke, pioneer segment of the Seaboard Air Line Railroad company. dates from 1832. The Chesapeake and Ohio Railway company (C. & 0.) had its beginning in the little Louisa railway. chartered in 1836

The Richmond, Fredericksburg & Potomac Railroad company, which operates between Richmond, Va., and Washington, D.C., was incorporated Feb. 25, 1834. It is the oldest American railway that has continued to exist since the beginning under its original name. and without reorganization.

By 1840 there were 2,800 mi. of line in the U.S., and the country had entered its first great era of railway building. Twenty years later, on the eve of the American Civil War, the country had more than 30,000 route miles of track.

With but few exceptions (such as the B. & O.), early railways were purely local in character They mere designed to promote the commercial interest of local communities or areas. As growth progressed, houever, many of the small roads were consolidated, forming through routes that served fairly large territories, and new railway projects became more ambitious. The Pennsylvania Railroad company completed its line from Philadelphia to Pittsburgh in Dec. 1852, using ten inclined planes to climb over the Allegheny mountains. A little more than a year later, it completed an all-rail route.

1. The Westward Movement.—By the 1850s U.S. railways were taking on their historic role as civilizers of the western frontiers. The first locomotive in Chicago, the "Pioneer" of the Chicago and Galena Union, now the Chicago and North Western railway (North Western), made its initial run on Oct. 25, 1848—and Chicago was on the way to its ultimate destiny as the nation's largest rail centre.

Soon railways were pushing west from Chicago. The Chicago and Rock Island, now the Chicago, Rock Island and Pacific Railroad company (Rock Island). was the first railway to link Chicago with the Mississippi river (1854). It also built the first bridge across that river. Other pioneer lines built west from the Mississippi. The first locomotive to operate west of the river made a five-mile run from St. Louis in Dec. 1852. This was on a short railway that became part of the Missouri Pacific Railroad company. The Hannibal and St. Joseph, now part of the Chicago, Burlington and Quincy railroad (Burlington), reached the Missouri river in 1859.

The Civil War slowed, but did not stop, the headlong growth of railways in the U.S. After the close of that conflict, another era of intensive railway building began, and it continued into the early years of the 20th century. It reached its high point during the decade of the 1880s, when some 70,000 route miles were laid. In 1882, the greatest single year of railway building in the U.S., 11,569 mi of track were completed.

Highlighting this era was the completion of several lines—the transcontinentals—which, more than any other factor, helped *make the United States finally a truly united nation. On May 10, 1869, the first transcontinental route was created when the Union Pacific Railroad company, building west from Omaha, Neb., met the Central Pacific, now part of Southern Pacific (S.P.). which was built east from Sacramento, Calif. In 1881 the Atchison, Topeka & Santa Fe railway (Santa Fe) joined rail with the S P. at Deming, N.M., to form the second transcontinental route. Ultimately. there were about nine major routes leading from the middle west or south to the west coast. From Chicago, the Santa Fe and the Chicago, Milwaukee, St. Paul & Pacific (Milwaukee road) run all the way to the west coast over their own rails. The S.P. has its own trackage from New Orleans. La., to Los Angeles, Calif., and on up the coast to Portland, Ore.*

2. *Land Grants.— A feature of the post-Civil War railway building era was government aid to a number of lines through land grants, loans and other types of assistance. About 131,000,000 ac. of public land were granted to 29 railways for about 18,000 mi. of line. These grants (about 8% of the total U.S. railway mileage) made it possible for the railways to push their lines across prairies and mountains that were then almost entirely undeveloped and very sparsely settled.*

Actually, railway aid a-as, on balance. a profitable activity for the U.S. government. For instance. the government received about $167,000.000 in principal and interest from the $65,000.000 it loaned to the Union Pacific and Central Pacific. The original value of the land grants was about $130,000.000, but in return the railways agreed to carry government traffic at reduced rates. By the time this agreement was abrogated in 1955, the railways had paid back to the government. through these reductions, more than $1,000,000,000.

3. *Railway Regulation.— For almost 50 years after their beginnings, railways in the U.S. were subject to little governmental regulation. But after the Civil War, abuses such as rate wars, rate discrimination and financial piracy became more widespread. In these things railways were probably no worse offenders than many other businesses of that era, but since they had by then attained almost a monopoly over domestic transportation, the public could not tolerate these abuses.*

Regulation at first was largely at the state level, but public sentiment resulted in the passage, in 1887, of the Interstate Commerce act, which placed the railways under federal regulation. Later, other acts broadened and extended the areas of federal regulation so that the railways finally had to clear through the Interstate Commerce commission almost all proposals for changes in such matters as financing, equipment standards, signaling and rates.

4. *Labour Relations.— $ailways were one of the first U.S. industries in which employees became unionized. Today there are nearly two dozen "standard railroad labour organizations" which represent employees in various classes or crafts. In 1888 the U.S. congress passed legislation providing, among other things. for special presidential emergency boards to investigate disputes. Through the years, other legislation was added. Labour-management negotiations now are conducted under the complex provisions of the Railway Labor act. Enacted in 1926 and subsequently amended, it provides a national mediation board that has power to mediate disputes, and a national railway adjustment board, composed of management and union representatives. which considers grievances, interpretations and applications of the complicated labour-management working agreements.*

Over the years, relations between railway labour and management in the U.S. have been marked with few industry-wide work stoppages— although there were violent and bloody strikes in 1877 and 1894. A brief nationwide strike also tied up U.S. lines in 1946. (See also LABOUR LAW.)

5. **U.S.** *Developments to World War 11.—By the early years of the 20th century, railway building had slowed in the United States, and the network had reached about its fullest extent. This was a period of improvements in railway plant and equipment; emphasis was on standardization of equipment and operating techniques.*

After a brief period of government control during World War I, the U.S. railways entered an era of further operating refinements but of few spectacular advances, although several technological developments that later had vast impact, among them the diesel locomotive, were being tried. The first inroads of highway competition were being felt. The economic depression, beginning in 1930, dealt the railways a disastrous blow, and many companies went through bankruptcy proceedings. Emerging from this depression decade, U.S. railways faced their supreme challenge, the years of World War II.

6. **U.S.** *Railways in War.— Almost from the first, some military men recognized the value of railways. An early proposal called for a network of railways to be built in the U S. primarily for military purposes. In many other countries, some or all of the railways originally were constructed strictly for military reasons.*

Although some use was made of railways in the Crimean and Mexican wars, the American Civil War was really the first "railway war." Since then, nations in every major war have depended on railways as basic transportation either in the active theatres—as in Europe during the world wars—or to supply men and materials to seaports for overseas shipment, as in the case of the U.S. during those wars.

Experience has shown that railways can move huge quantities of supplies and troops over land with a tremendous economy of fuel and manpower—a vital advantage, of course, during a war emergency. Moreover, railways. while seemingly vulnerable to enemy action, can be more quickly restored to full-capacity operation than any other form of land transport. This was amply demonstrated in World War II and in the Korean mar of 1950–53.

At the very beginning of the American Civil War, railways played a key role. The Confederate victory at the first battle of Bull Run (Manassas) was due in considerable measure to the Manassas Gap railway. which was able to deliver a number of reinforcements to the battlefield just in time to turn the tide. Throughout the war, the Confederacy was able to use its railways to concentrate troops where needed and thus help to overcome its numerical disadvantage. However, the Confederacy was not able to exercise effective organized control of its railways so they could operate to best military advantage.

On the other hand, the Union side was able to organize its military railway operations more effectively. This, along with its better-developed railway network and the fact that most of the U.S. locomotive and car-building plants were in Union territory, played an important part in the final outcome of that conflict.

One of the important lessons learned in the Civil War mas that railway cars must be used only for the movement of troops and supplies— not for storage. By World War I this lesson had been forgotten, however. Cars were loaded and sent on their way with no place to unload them. As a result of this practice, congestion approaching paralysis hit the U.S. railway system in 1917. In order to unravel the tie-up, the U.S. government took over the operation of the railways on Dec. 28, 1917. The lines were restored to private operation March 1, 1920.

No such problem arose in R'orld War II. when the U.S. railways demonstrated how efficiently a well-run system can operate to handle extraordinary traffic movements. In the war year of 1944, freight ton-miles were two and one-half times the level of 1938; passenger-miles had increased fourfold. This tremendous traffic was handled with only relatively modest increases in the supply of locomotives and cars. Moreover, this wartime job mas done at a time when the railways had supplied some 40,000 officers and men for army transportation corps units and another 300,000 employees were in other branches of the armed services.

During the World War II period, U.S. railways carried almost 98% of all military personnel moving in organized groups and more than 90% of all military freight handled by inland transportation. In the Korean war of 1950–53, the railways performed a similar job on a smaller scale while at the same time handling normal civilian transport requirements.

In the Korean war, too, the flexibility of railways under front-line conditions was reaffirmed. Neither the U N or Communist forces could permanently disable the other side's strategic rail lines even under the impact of heavy air strikes.

B. Railway Growth in Canada

The growth of Canadian railways paralleled somewhat that of lines in the United States.

Construction of the first line, between Laprairie and St. Johns, Que., began in 1835; its first train operated on July 21, 1836.

By 1860 there were about 2,000 mi. of railway line in Canada. One of the terms on which British Columbia entered the confederation in 1871 was the construction of a transcontinental route. This line, the Canadian Pacific, was completed in 1885. It is literally the tie that bound Canada into a unified nation.

Two other transcontinental lines reached the Pacific coast in 1914 and 1915. They were the Grand Trunk Pacific, which reached Prince Rupert, B.C., in 1914; and the Canadian Northern, built into Vancouver in 1915. Both of these lines were built with government assistance.

The dislocations of World War I dashed the hopes of internal development that had sparked the construction of these two transcontinentals. They required further government financial help and were finally taken over by the dominion government. In 1923 both the Grand Trunk and the Canadian Northern, along with other railways always owned by the dominion, were unified, forming the present Canadian National railways (C.N.R.).

In normal years the Canadian Pacific operates at a profit; the Canadian National, which has many lines serving as yet sparsely settled areas, usually records a deficit. The C.N.R. also serves as an agency of national policy. As a result it has built a number of lines to open up new territory during the years since World War II.

Other Canadian railways were being built or extended as the dominion entered a period of rapid economic growth. The Quebec. North Shore and Labrador, a 320-mi. ore-carrying line from the iron ore deposits near Schefferville, Que., to the St. Lawrence river at Sept Iles. was opened in 1954. In 1958 the Pacific Great Eastern railway (P.G.E.) completed its line all the way from Vancouver, B.C., to Dawson Creek and Fort St. John, B.C., where it connects with the Alaska highway. Another new line was constructed from the P.G.E. near Prince George, B.C., to Whitehorse, Y.T.

C. United States and Canadian Railways After World War II

For about a century, rail ays were the dominant form of intercity transportation in the United States and Canada. Indeed, their monopoly was almost complete, with the exception of a fair volume of water transport—river, Great Lakes and intercoastal.

But the development of the internal-combustion engine and its application to highway vehicles (starting about the beginning of the 20th century) and the invention of the airplane were to have far-reaching effects on railway transportation. In the period between the two world wars, highway transportation of goods by motor truck and of people in buses and private automobiles was already seriously cutting into railway business, especially on branch and secondary lines.

The demands of war hastened the technological development of these new forms of transportation. and by the late 1940s their inroads had reached critical proportions from the railway point of view. Competing forms of transport were continuing to gain in relative volume at the expense of the railways in the early 1960s. This trend was especially pronounced in the United States, where the growth of highways, aviation facilities and pipelines was particularly intense, but the same trend was noticeable—though in its earlier stages—in most other countries except those that were still in the more primitive stages of economic development.

How did the railways react when confronted with this new competition? Accustomed to competing only with other railways, most found it hard to adjust their thinking—and their operations—to meet the challenge of competitors who could offer the public faster, more flexible or, in some cases, cheaper service; and who in most cases were burdened much less by government regulation. Thus for many years motor trucks, automobiles, buses, waterways, airplanes and pipelines took over increasing volumes of traffic against very little resistance from the rail lines. Only the overall growth of the U.S. economy prevented the railways from suffering a drastic absolute—as well as relative—drop in traffic volume.

Eventually. however, railways began to fight back against their new competitors. They took measures to improve the speed and regularity of their train services; offered passengers and shippers new types of equipment; and adjusted their rates to become more competitive—and to more fully reflect the advantages of railroad transportation for high-volume, long-haul service.

The substitution of diesel for steam locomotives in the U.S. and Canada allowed freight and passenger trains to operate at higher sustained speeds. Moreover, the running gear of modern freight and passenger cars (wheels, springs, journal bearings and brake equipment) allows greatly increased top speeds.

The big problem in freight service continued to be the delays encountered in classification yards and freight terminals through which cars must pass. Much has been done to alleviate yard delays by constructing classification yards that are largely automatic. These new yards can sort out freight cars and make up new trains in much less time than was possible in the past.

Railroads are offering their customers special types of freight cars, designed to permit them to load particular commodities quickly and at minimum expense. Typical are the automobile-parts cars with specially designed racks that allow fast loading of specific automobile components; or the covered hopper cars for bulk handling of commodities such as phosphates, cement or flour. Both special and conventional types of freight cars are becoming larger to take advantage of the economies of high-volume shipment.

Significant, too, was the increase in the use of highway trucks by railways. Under governmental restrictions, U.S. railroads could not (for the most part) operate truck lines except as supplements to or in substitution for railway service. Thus railways used trucks to deliver small-lot (less-than-carload, or L.C.L.) shipments from rail car terminals to consignees in nearby areas, and to pick up L.C.L. freight for subsequent rail movement. In some cases, also, railway-operated trucks substituted for trains in local freight service or on branch lines where the volume of business no longer justified train operations.

1. The "Piggyback" Development.—As early as the 1920s, a U.S. railway was carrying loaded highway trucks on flatcars (although the idea dates back to the 19th century). "Piggyback" combines the flexibility of truck pickup and delivery with the economy of rail movement between cities. Piggyback did not begin to grow rapidly until the later years of the 1950s, but some authorities estimated that piggyback traffic might eventually amount to one-half of the total volume of railway traffic.

Along with piggyback, there was increasing interest among railways and other modes of transport in "container" systems. Clearly, the trend was toward a system of freight transport in which merchandise could be loaded into standard containers or boxes, which then would move either via highway on a truck chassis, via rail on special container cars, in ships especially equipped to handle them, or even by air. A single shipment might use two or more modes of transport in the course of its trip. Railways in the U.S. used containers on a small scale in the 1920s, but not until the early 1960s did the technique meet with widespread acceptance.

Future development of piggyback, and containers, could result in a freight transportation system that was quite highly integrated. Each mode of transport might then perform the type of service for which it is best suited, and a single shipment might be moved by several different modes of transport at minimum extra cost.

2. Passenger Service.—In the United States and Canada, long-haul railway passenger service appeared in the 1960s to have a limited future. A vast network of paved highways and the fantastic growth in automobile ownership had diverted almost 90% of all intercity travel to the public automobile. The remaining travel volume was shared by railways, by buses on the public highways and by the rapidly growing air lines.

The greatest area of usefulness for intercity rail travel in the future appeared to be for trips ranging up to 300 mi. between large centres of population; for overnight sleeping car service between large cities 500 to 1,000 mi. apart; and for some commuter service centring on the larger cities. There also appeared to be a market for a limited volume of long-haul railway service in luxury "cruise" trains.

D. Railways of Mexico and Central America

The railway systems of Mexico and in Central and South American countries are less advanced than those in the U.S. and Canada. Except in Mexico. most countries have a predominance of narrow-gauge lines of relatively light construction.

The Mexican railways, almost all of which are owned by the federal government, have a route mileage of approximately 15.000. Of this approximately 8.400 mi. is operated by the National Railways of Mexico (Ferrocarriles Nacionales de México). The N. de M. was acquired both by purchase and expropriation, beginning in 1937. Prior to that time much of the railway development in Mexico had been by private interests.

Most of the Mexican railway mileage is standard gauge, and there are interchange connections with U.S. railways at several points. As a result, the Mexican railway network may be said to be integrated with those of the C.S. and Canada to a considerable extent. Since World War II a vigorous modernization program has been under way.

The railways of Central America are all narrow gauge and of light construction. Some of them are government owned; others are private railways owned and operated by banana companies. There is little integration: most of the lines are isolated and serve only small areas. Cuba has about 2,900 mi. of public service railnays and another 7,000 mi. of sugar mill railways operated by 175 different mills.

E. South American Railways

South America has about 66,000 route miles of railroad, of which about 62% is narrow gauge. The rest is either standard or wide gauge. Although early development of South American railways, beginning in the middle of the 19th century. was largely by private enterprise, there later was a trend toward government ownership and operation. This was particularly marked in Argentina, where in 1945 only about 31% of the trackage mas state owned; by the 1960s Argentina's 27.600 mi. of line were all under the jurisdiction of the Argentine State railways.

Brazil is a close second to Argentina in total track miles. Of its 23.253 track miles, all but 2,980 are owned by state or federal governments.

There is little integration of railways in the South American countries. This is due partly to the rugged terrain over which many of them operate but even more to the diversity of gauges, as well as equipment standards. Many early South American railways were built by British. French, U.S. and German concerns and this resulted in considerable variation in the types of equipment, methods of operation and even terminology.

Nearly all South American railway systems had improvement programs planned or under way in the 1960s, but most were handicapped by lack of funds.

F. European and Asian Railways

1. Great Britain. — The success of the Stockton and Darlington and the Liverpool and Manchester lines touched off widespread railway construction in Britain. In 1836, the opening of the London and Greenwich railway brought the first public passenger service to London. In 1838, the London and Birmingham railway was opened throughout its length and in 1840 the line from London to Southampton was completed. The Great Western railway's 7-ft. broad-gauge line from London to Bristol was opened to traffic in 1841.

Between 1844 and 1846 parliament authorized the construction of over 400 railways. This represented the height of what was known as the railway mania, and there followed a period of slower development and a growing number of consolidations. Early in the 1900s some systems realized that mergers could create a stronger economic position for them, but because of monopoly fears. acts sanctioning such moves were not passed by parliament.

Amalgamation of Lines — Following World War I, it was evident that large-scale consolidation was a financial necessity, and the government decided upon compulsory amalgamation. As a result of the Railways act of 1921. some 123 separate railway companies amalgamated into four main groups on Jan 1, 1923. The four systems were the London. Midland and Scottish railway; London and North Eastern railway (L. & N E R.); Great Western railway; and Southern railway. Certain minor railways and London's Underground retained their separate existence. The latter were amalgamated with London area bus and tramway systems in 1933 under authority of the London Passenger Transport board, a public body constituted by act of parliament.

The object of creating four large railway systems was to consolidate control and obtain more economical methods of operation. The consolidation also allowed the introduction of a new classification of rates and charges designed to enable the railways to earn a standard revenue.

During the 1920s the railways began to suffer from increased highway competition. To combat this, various new services were introduced. In 1928, an act of parliament authorized the railways to operate both passenger and freight road services, and they acquired extensive financial interests in existing undertakings, principally bus companies.

Despite competition and the general economic depression of the 1930s, the four railway companies mere responsible for some remarkable achievements between 1925 and 1939. In 1928 the L. & N.E.R began the nonstop running of its principal express train between London and Edinburgh, a distance of $392\frac{3}{4}$ mi. The high-speed running of streamlined passenger trains began in 1935 with the introduction of the "Silver Jubilee" between London and Newcastle. It was followed in 1937 with the "Coronation" (London-Edinburgh) and the "Coronation Scot" (London-Glasgow).

At the outbreak of World War II in 1939, the railways were placed under government control. So-ordination and direction nas through the Railway Executive committee appointed by the ministry of transport. During the period 1939–45 the railways operated 260.000 special troop trains and 280,000 matériel trains for the armed services. Over 9,000 incidents of enemy action were recorded on the railways and nearly 400 railway men were killed and 2.444 injured by enemy action. At the end of the war the state of the railways had deteriorated considerably due to lack of maintenance, abnormal wear and tear, shortage of personnel and damage through enemy action.

Railway *Nationalization*.—In 1946 a bill was introduced in parliament for setting up a publicly owned inland transport system. Under the Transport act, which became law on Aug. 6, 1947, the British Transport commission (B.T.C.) was established as the body responsible for taking over the railways, the railway owned docks. road haulage contractors, many road passenger undertakings and the inland waterways. On Jan. 1, 1948, the nationalization of the railways took effect and they became British railways. The Railway Executive committee became the body responsible to the Railway commission for the management and co-ordination of British railways. The latter mere divided. on a geographical basis, into six regions: Eastern, Northeastern, Western, Southern, London Midland and Scottish.

A transport bill which became law on May 6, 1953, provided for greater decentralization of the railways. The Railway Executive committee was abolished and the chief regional managers were made responsible to the commission. The greater degree of autonomy enabled the regional officers more closely to meet the needs of the local traveling public and trading interests.

On Jan. 24, 1955, the B.T.C. announced an extensive and ambitious modernization and re-equipment plan. The plan aimed at producing a really modern system that would be able to meet both current traffic requirements and those of the foreseeable future. It was intended that the main features of the plan would be started within 5 years and completed within 15 years. The main objective was to provide "an equipment, in the widest sense of the nord, of modern design and fit to give reliable and speedy transport service on a large scale." The plan involved an outlay of approximately £1,200,000,000.

The main features of the plan, as far as they affect British railways, may be summarized as follows:

Track and signaling improvements to make higher speeds possible; extension of colour-light signaling, track circuits and the introduction of an automatic warning system on locomotives; the introduction of more power-operated signal towers and the installation, where suitable, of centralized traffic control.

Steam traction to be replaced by electric or diesel traction.

Replacement of much of the existing passenger rolling stock, largely with multiple-unit electric or diesel trains; the remaining passenger stock to be modernized.

Freight services to be drastically remodeled and continuous brakes fitted to all freight cars, which will lead to faster operation; classification yards and freight terminal facilities to be relocated and modernized and the number of classification yards to be greatly reduced; larger cars for certain types of traffic to be introduced.

Expenditures to be directed to other activities including improvements to packet ports, staff welfare, office mechanization, etc.

The modernization plan began to show concrete results in 1958, although no large scale improvements had, by that time, been completed. In 1959 there was a reappraisal of the plan, aimed at accelerating certain portions of it. In 1958 there was a total deficit for the year of £89,000,000, covering all the commission's activities. To meet the situation the government agreed to increase the limit of deficit borrowing from £250,000,000 to £400,-000.000, as well as increasing the general borrowing powers.

British railways run some 23.000 passenger trains each weekday and carry over 1,000,000,000 passengers a year.

In 1957 the B.T.C. (railway merchandise) Charges Scheme came into force, allowing freight charges to be varied below the permitted maximum. This enabled the railway to charge on the basis of loadability, except for consignments of 100 tons or more, for which charges had to be reasonable.

Passenger Service. — Passenger train developments included the widespread introduction of diesel multiple-unit rail-car trains. At the beginning of 1960. 3,000 of these vehicles were in use and by the end of that year the total reached 4.000. Among the principal express trains were the "Elizabethan" (London-Edinburgh, nonstop, summer only) and the "Caledonian" (London-Glasgow). In 1955 a new type of service aimed at the motorist was launched. Called the "Car-Sleeper Limited," it carried automobiles in specially designed cars, their drivers and passengers traveling in sleeping cars. It operated between London and Perth.

British railways expected to rely increasingly on diesel and electric traction, although much traffic in the 1960s was still hauled by steam locomotives. By the end of 1961 the number of steam locomotives was to be reduced to less than 8.000. In 1960 there were 1,400 diesel switch engines and over 800 main-line diesel locomotives in use. Substantial numbers of diesel locomotives, some embodying hydraulic transmission but the majority having electric transmission, mere under construction.

Electric Traction. — Electric traction is used extensively in southeast England, together with suburban lines in various parts of the London area and around Manchester, Liverpool and Newcastle-on-Tyne. All these use direct current and all but one use current collection via a conductor rail mounted alongside the running rail. Electrification of the line connecting Manchester, Sheffield and Wath was completed in 1954. This uses the 1,500-v., D C. overhead conductor wire system. The same system was employed for the electrification of the London-Shenfield line, which was completed in 1949 and extended to Southend in 1956 (this, however, was later converted to A.C. to bring it into conformity with later electrification projects in the same area). The B.T.C. announced in 1956 that future electrification would be on the 25-kv.. 50-cycle, A.C. system. The first application of this form of electric traction was on the Colchester-Clacton-Walton line, some $24\frac{1}{2}$ route miles (inaugurated in 1959). The first trunk route to be electrified using 25-kv. power was to connect London, Manchester and Liverpool.

2. China.—Following creation of the People's Republic of China in 1949, an intensive program of rehabilitating war-damaged lines and constructing new ones was started. Among the new lines were the Chengtu-Chungking railway, opened in 1952, and a line connecting Mongolia and China, opened in 1955. There was some 5-ft. gauge line adjoining Russian territories and also some narrow-gauge mileage; however, the majority of the system was standard gauge. Through passenger train services were being operated between Peiping and Moscow; Peiping and Ulan-Bator; and Peiping and Hanoi.

3. France. — The first railway in France, from St. Étienne to Andrézieux. was officially opened on Oct. 1. 1828. although it was in unofficial use the year before. At first only freight was carried, passenger traffic commencing in 1832. Horse traction was employed until the adoption of steam locomotives in 1832. In 1830 the first section (between Givors and Rive-de-Gier) of the St. Btienne-Lyons railway was opened, and the line was completed in 1832. Both steam and horse traction were used, steam taking over completely in 1844. The first international line from Strasbourg to Basle, Switz., was completed in 1841, by which time France had 350 mi. of railways.

In the 1850s railways construction was at its height and there emerged six principal companies: Nord, Est, Paris-Orléans. Paris-Lyons-Méditerranée, Midi and Ouest. In 1878 the state took over a group of small companies in western France, thus creating the Btat system. By 1902, the railway network had grown to 28,400 miles.

The Ouest railway became state owned in 1908, and following World War I the Alsace-Lorraine railways also became French property. On Jan. 1, 1938. the five remaining privately owned railways were taken over by the government. They — and the existing État system — formed the French National railways (Société Nationale des Chemins de Fer Français [S.N.C.F.]), a joint stock company with 51% of its capital held by the government.

During World War II the S N C.F. suffered extensive damage and by 1944 some 82% of the motive power, 80% of the coaches and 64% of the freight cars had been damaged or destroyed. Extensive damage had been wrought on many other installations, but by mid-1946 nearly all track (24,800 mi.) was restored to use and by mid-1948, 2,491 bridges and viaducts had been rebuilt.

Following the immediate postwar restoration of basic facilities, the S.N.C.F. embarked on the modernization of its system. Initial recovery was aided by the supply of 1,340 steam locomotives from the U.S. and Canada and 48,000 freight cars from North America and Britain.

The principal features in the modernization of the system were the steady abandonment of steam traction, increased use of diesel power and large-scale electrification. Extensive improvements also were made to track and signaling, and large quantities of new rolling stock were introduced.

The initial postwar project was to electrify the main line from Paris to Lyons. and this was completed in 1952. The prewar 1.500-v., D.C system was adopted. Further sections from Lyons subsequently were dealt with. and electrification was being continued to Marseilles. The S.N.C.F. also developed the use of 25-kv. A.C. at the commercial frequency of 50 cycles for rail traction.

4. Germany. — The use of the steam locomotive in Germany began on Dec. 7, 1835, with the opening of a railway between Niirnberg and Furth. Both private companies and states built railways, but after 1876 the privately owned systems were gradually absorbed by the states. By 1909 the total route mileage was 35.625.

In 1920 there was a further change in ownership when the state systems were unified as the German State railways. Their status was changed in 1924 to that of a publicly owned company. but a few years later they again reverted to government ownership.

Following World War II and the partition of Germany, two railway systems emerged. In the German Federal republic (west Germany) there emerged the German Federal railway (Deutsche Bundesbahn or D.B.). while in the German Democratic republic the title of German State railway (Deutsche Reichbahn or D.R.) was retained. In west Germany, apart from the D.B., there were about 250 public railways owned by commercial concerns, municipalities and provincial governments.

After World War II a great deal of reconstruction was necessary and the opportunity was taken to introduce new equipment. There were improvements in track, signaling, communications, locomotives and rolling stock, and steam traction was being replaced by diesel locomotives and electrification.

5. India. — The most complex railway network in Asia, and also the oldest, exists in what was the dominion of India, now split into the republics of India and Pakistan. In 1849, the East Indian Railway company registered. and the first line to be opened was between Bombay and Thana in 1853. This early development was due to British influence, and the various networks gradually extended and increased in size and scope.

The control of the Indian systems comes under the ministry of railways at New Delhi. There are eight railways, which serve different areas of the country: Central, Eastern, Northern. North Eastern, Northeast Frontier. Southern, South Eastern and Western. The Central railway is principally 5-ft. 6-in. gauge, and the Eastern railway is entirely 5-ft. 6-in. gauge, except for 17 mi. of 2-ft. 6-in. gauge. The Northeast Frontier railway is mainly metre gauge, and the North-Eastern railway is entirely of this gauge. The Northern railway is largely 5-ft. 6-in. gauge, as is the South Eastern railway. The Southern railway is mainly metre gauge, and the Western railway has a majority of metre-gauge mileage, with some 5-it. 6-in., 2-ft. 6-in. and 2-ft, gauges. The total mileages for the various gauges of the entire network are: 5 ft. 6 in., 16,246; metre, 15,480; and 2 ft. 6 in. and 2 ft., 2,735.

6. Ireland. — The first railway in Ireland was opened Dec. 17, 1834, between Dublin and Kingstown (now Dún Laoghaire). It was originally constructed to the 4-ft. 84-in. gauge but was converted to the principal Irish gauge of 5 ft. 3 in. in 1857. The first line to be opened in Northern Ireland was the Ulster railway between Belfast and Lisburn in 1839, originally built to a gauge of 6 ft. 2 in., and converted in 1847 to 5 ft. 3 in.

On Jan. 1, 1925, the majority of all lines wholly within the Irish Free State were combined into the Great Southern railways, and on Jan. 1, 1945, this system and the Dublin United Transport company were merged into the Irish Transport company (Córas Iompair Eireann or C.I.E.). The Great Northern Railway board's facilities in the Republic of Ireland were merged with C.I.E. in 1958.

Under the 1948 Transport act (Northern Ireland), the Irish Road Transport board, the Belfast and County Down railway and the Northern Counties committee were all acquired by the Ulster Transport authority (U.T.A.), and in 1958 the portion of the Great Northern railway board in Northern Ireland was merged with the U.T.A.

7. Italy. — The first railway in Italy was between Naples and Portici, opened in 1839. Railway construction in other parts of the country followed, but it was not until the union of the states of Italy took place in 1861 that the idea of a national rail network could be put into practice. In 1885, the major systems were merged into three railways and in 1905–07 these networks, and other smaller lines, were taken over by the state.

During World War II the system suffered considerable damage and extensive reconstruction was necessary. The electrified network, which dates back to 1901, was restored and greatly extended. The majority of the electrification was 3,000-v. D.C., but there was some 3,600-v., $16\frac{2}{3}$-cycle A.C.; this was scheduled to be converted to D.C.

8. Japan. — Japan's first railway was projected in 1869, but construction did not start until 1870 and the first section, between Shimbashi (Tokyo) and Yokohama was not opened until 1872. The years 1885 to 1895 saw the rapid growth of privately built lines in various parts of the country. In 1906 and 1907. under the Railways Nationalization law, the government acquired 17 of the major private lines, boosting the proportion of government-owned mileage from 32% to 91%.

In 1949 the government railways were reorganized into a public corporation, the Japanese National railways (J.N.R.), which in the 1960s operated about 12,600 route miles of line, all of it 3-ft. 6-in. gauge. There were still about 4,600 miles of private railways, most of them short, but some carrying heavy traffic.

Japan's railways, largely built to high standards, carry a very heavy traffic. J.N.R.'s Tokyo-Osaka route (the Tokaido line) in the early 1960s carried the heaviest traffic density on the system (about 60 to 80 passenger trains and 50 to 60 freight trains each way daily). However, the capacity of the double-track, electrified 3-ft. 6-in. gauge line had almost been reached, and a new double-track, standard-gauge line was planned between Tokyo and Osaka, a line that would have no grade crossings and would be built to permit a top speed of 150 m.p.h. for passenger trains.

9. Norway.—Norway's first railway was completed in 1854 between Oslo (then Christiania) and Eidsvoll. Railway construction has always been difficult because of the mountainous nature of the country, the rigorous climate and the relatively small population. Main lines radiate from Oslo to Bergen, Trondheim, the Swedish frontier and Stavanger. A completely isolated section of the system is the electrified Ofoten railway from the Swedish frontier at Riksgransen to Narvik; this carries a heavy iron ore traffic. Some other lines are also electrified, the longest running from Oslo to Stavanger (370 mi.) and the total electrified mileage in 1958 was 951.

10. Pakistan. — The partition of India and Pakistan resulted in the latter having two territories, separated by the widest part of India. As a result Pakistan has two distinct railway systems. Eastern Pakistan is served by the Eastern Bengal railway, which has its headquarters at Chittagong. The majority of its route mileage is metre gauge, with some 5-ft. 6-in. gauge and 2-ft. 6-in. gauge. Western Pakistan is served by the North Western railway, which has its headquarters at Lahore. It is largely 5-ft. 6-in. gauge, with some metre gauge and 2-ft. 6-in. gauge. There is no electrification in Pakistan, but the use of diesel traction was growing in the 1960s.

11. Spain. — The first railway in Spain was the Barcelona-Mataro line, opened Oct. 28, 1848. The topography of the country made subsequent construction slow and expensive. From the many companies in existence there emerged, through a series of consolidations, four major systems. During the civil war of 1936–39, all the railways suffered damage and their position after hostilities was so difficult that the Spanish National railways (Red Nacional de los Ferrocarriles Españoles) was formed in 1941, taking control of 7,580 mi. of 5-ft. 6-in. gauge lines in 1943. There is also an extensive mileage of narrow-gauge track in the country, operated by about 50 privately owned systems.

12. Sweden. — The railways of Sweden were built partly by private companies and partly by the state. The first standard-gauge line was opened in 1856 and the first trunk line from Stockholm to Goteborg was inaugurated in 1862. As early as 1879 the state began taking over private companies and in 1939, the Swedish parliament decided that the majority of lines still privately owned should be taken over by the Swedish State railways. As a result some 95% of the railway network had come under state control by the 1960s.

One of the most important aspects of the system is the heavy traffic in iron ore between mines in Lapland and the ports of Narvik, Norway, and Lulea.

13. **U.S.S.R.**—A gauge of 6 ft. was selected for the first public railway in Russia, which was opened—with horse traction — in 1836. In the following year, steam traction was introduced, with locomotives supplied from Britain. The first line of any length was from Warsaw to the Austrian frontier, opened in 1848, followed by the 400-mi. Moscow-St. Petersburg (now Leningrad) line, opened in 1851; this was of the 5-ft. gauge, which became the standard in Russia. The network spread somewhat slowly at first, gathering momentum from the 1860s onward, until in 1900 there were some 33,000 mi. of line. At the time of the Russian Revolution, route length was 43,800 mi. and there were 25 state-owned and 13 privately owned systems.

Following the revolution, the railways were nationalized and by a series of five-year plans the system was rehabilitated and modernized. World War II resulted in the railways being worked to capacity and, in many areas, being extensively damaged. Postwar reconstruction and modernization included diesel traction, electrification, improved signaling and train control apparatus, and new rolling stock. The railway is the principal form of transportation in Russia and handles approximately 80% of all freight traffic.

The network is split up into 45 railways controlled by railway boards which, in turn, are under the supervision of the ministry of transport and communication.

An important development after World War II was the introduction of dual-gauge passenger coaches which can have the trucks of one gauge exchanged for those of another, using special lifting installations at the break-of-gauge point. This permits the through running of coaches between Russia and east and west Europe.

One of the most notable lines in Russia is the Trans-Siberian railway. 5.787 mi. long, which links Moscow and Vladivostock. Construction commenced in 1891, the work starting simultaneously from the east and west terminals. Originally, passengers could not make the entire journey by rail but had to travel by boat (or, in winter, by sleigh) across Lake Baikal. However, by 1916 a line had been laid around the lake, allowing the entire journey to be made without changing cars.

In 1960 a Trans-Siberian express left Moscow daily, requiring nine days to reach Vladivostock. There also was a through train three times a week between Moscow and Peiping.

G. African Railways

Construction of the first railway on the African continent was started in 1852 in Egypt. It was the Alexandria-Cairo line, the first section of nhich was opened in 1854. It was followed by the opening, in 1860 of a line betueen Durban and the Point in south Africa Development of railway mileage in Africa as a whole was slow until the turn of the century when a number of construction schemes were started. Some other early railway building took place in Tunisia (first line planned in 1875); the Sudan (first tracks of a military line laid in 1897–98); formerly French Equatorial Africa (construction started in 1880); and Tanganyika (construction started in 1891).

1. Union of South Africa. — In South Africa, the discovery of diamonds at the Cape gave considerable impetus to railway construction. By the time the Union was founded in 1910, some 7,570 mi. of track had been laid, of which the majority was state owned. There were three systems, the Central South African railways, the Cape Government railways and the Natal Government railways, all of nhich were merged in 1916. By the 1960s, the South African Railways and Harbours administration had the most extensive network on the African continent. Apart from the operation of the railroads, the administration operates road services, the principal harbours and the South African airways.

2. Central Africa. — The East African Railways and Harbours system was formed in 1948 by the amalgamation of the Kenya and Uganda Railways and Harbours and the Tanganyika Railways and Ports services. Construction of the original Uganda railway was begun at Mombasa in 1895; the site of the present city of Nairobi was reached in 1899 and Kisumu. on Lake Victoria, in 1901. Kampala, the commercial centre of Uganda, was linked with the coast (871 mi.) in 1931 following the completion of a line around the north shore of Lake Victoria and the bridging of the Nile at Jinja. Subsequently, extensions were made to Mityana (1953), Kabagole (1955) and Kasese (1956).

The first line in the Tanganyikan section was completed in 1911, between Tanga and Moshi. The Dar es Salaam line was constructed between 1905 and 1914. A branch from Tabora and Mwanza, on Lake Victoria. was built between 1925 and 1928, after the country came under British mandate. Steam traction predominates, although some diesel locomotives have been introduced.

In 1947 the Southern Rhodesian government purchased the railroad systems in Northern and Southern Rhodesia and the Bechuanaland Protectorate There are connections with the Congo railway, the Beira railway (Mozambique) and the South African railways. The railway was making grouing use of centralized traffic control and it also operated 2,000-h.p. diesel-electric locomotives, some of the most powerful units ever built for 3-ft. 6-in. gauge tracks.

In the Republic of The Congo the principal lines are operated by the Compagnie du Chemin de Fer du Bas-Congo au Katanga (B.C.K.). The first lines to be built were from Sakania to Bukama (1910 to 1918) and Port Francqui to Bukama (1923–28). The Tenke-Dilolo line was started in 1928 and completed in 1931. Another line from Kamina to Kabongo links the B.C.K. with the Compagnie des C. de F. du Congo Supérieur aux Grands Lacs Africains (C.F L.). The C F.L. has 596 route miles of 3-ft. 6-in. gauge track from Albertville to Kabalo and Kabongo and from Kabalo to Kindu. A separate 78-mi. metre-gauge line runs from Ponthierville to Stanleyville.

Other 3-ft. 6-in. gauge systems are to be found in Nigeria, Nyasaland, Sudan. Republic of Congo, Ghana and Angola. The majority of the remaining systems are of metre gauge. In former French West Africa ([1] Senegal to Mali; [2] Guinea; [3] Ivory Coast; and [4] Dahomey) there are four lines of this gauge, totaling 2,542 mi., all operated entirely uith diesel traction. The railway system in Ethiopia is also metre gauge. The building of the main line from Djibouti on the coast of French Somaliland began in 1897 and reached Addis Ababa in 1917.

3. Northern Africa. — Egypt, the scene of the first railroad in Africa, by the 1960s had an extensive standard-gauge system extending to 2.967 mi., with some narrow-gauge mileage as well. There was also a considerable amount of standard-gauge mileage in north Africa. Post-World War II developments included extensive modernization and the virtual replacement of steam traction by diesel and electric power. There were also other lines of narroner gauges in the country, some of which were being converted to standard gauge.

H. Australasian Railways

1. Australia. — The first railway to be operated by steam traction in Australasia was a 2-mi. line from Flinders street, Melbourne, to Sandridge (now Port Melbourne). It was built by the Melbourne and Hobson's Bay Railway company and opened on Sept. 12. 1854. In the following year a second line was opened in New South Wales. Construction was originally in the hands of two private companies, but mhen they experienced financial difficulties they were bought out by the N.S.W. government. The first steam railway in South Australia was opened in 1856. It was 74 mi. long, of 5-ft. 3-in. gauge, and ran between Adelaide and Port Adelaide. Other parts of Australia did not have the benefits of rail transportation until later.

Unfortunately, in the early days of development each state laid down tracks in whatever gauge it considered most suitable to its needs and finances. Only one state, New South Wales, chose the standard 4-ft. 84-in. gauge. Victoria and South Australia selected a broad gauge of 5 ft. 3 in. and Queensland and Western Australia chose the narrow 3-ft. 6-in. gauge. This means that freight often has to be transshipped and passengers transferred from a train of one gauge to that of another.

In later years the Commonwealth Government railways built several standard-gauge lines, the longest being the Trans-Australian railway from Port Pirie, South Australia, to Kalgoorlie, Western Australia, a distance of 1,108 mi. A feature of this line is one track length of 300 mi. without a curve, said to be unique in the world.

After World War II, efforts were made to standardize gauges, but progress was slow. Adding to the gauge problems were those of long distances, sparse population and large concentrations of population in a few large cities.

By 1960, all the principal railway systems were state or government owned, there being only one of any size (the Midland Railway company of Western Australia) which remained in private hands.

The Commonwealth Government railways was unusual in Australia in that it was operating profitably, largely because of the adoption of diesel-electric traction. Piggyback transport (road trailers and semitrailers carried on flat wagons) and container traffic also were introduced on the Trans-Australian route to overcome break-of-gauge delays.

2. New Zealand. — In New Zealand the first railway to be operated with steam traction was opened on Dec. 1, 1863, between Christchurch and Ferrymead. It had a gauge of 5 ft. 3 in.

Following the start of this line, numerous others were built by the different provincial governments. These were of various gauges, but in 1870 an act of the general government stated that all future construction should be of 3-ft. 6-in. gauge. In 1876 the provincial governments were abolished and their railways were taken over by the general government and the lines gradually converted to a uniform 3-ft. 6-in. gauge. Between 1885 and 1908 various private railways also were taken over.

The system was faced with strong competition from air and road transport, and in 1958 it had a working loss of £1,140,000. In the 1960s, emphasis was on increased use of diesel power. the installation of long welded rail, increased use of centralized traffic control and the completion (in 1955) of the $5\frac{1}{4}$-mi. Rimutaka tunnel. An unusual operation was the rail-air freight service between the two islands.

The general trend in Australasia was toward the adoption of more modern equipment (particularly diesel traction), electrification where traffic justified it, and improved passenger and freight rolling stock.

II. TRACK AND ROADWAY

1. Railway Location.—Ideally, a railway should be built in a straight line, over level ground, between large centres of trade and travel. In practice, this ideal is rarely approached. In planning. the location engineer must balance the cost of construction against annual maintenance and operating costs, as well as against the probable tonnage to be carried and the revenue it mill produce.

Thus, railways in areas of dense population and heavy industrial activity have generally been built for heavy duty—with minimum grades and curvature, heavy bridges and perhaps multiple tracks. This mas so in the case of most of the main-line railways of Britain and continental Europe. In sparsely settled country; as in much of the United States during the 19th century. as well as in Canada and South America, railways were built to minimize initial construction costs. As a result, the lines had sharper grades and curves, and were generally of lighter construction. As traffic grew, the main routes were later improved to increase their capacity and reduce operating costs.

2. Gauge.—One of the main cost determinants is the gauge, or distance between the inside faces of the running rails. Generally, the narrower the gauge the less costly is the line to construct and equip. This explains why many of the railways in underdeveloped, sparsely settled countries have been built to narrow gauges. On a narrow-gauge line, curvature can be more severe, less space is required and over-all construction can be lighter. Disadvantages are the limitation of speed because of reduced lateral stability and limitations in the size of locomotives and rolling stock.

Track gauges vary throughout the world from less than 2 ft. to 5 ft. 6 in., and in the past have been as wide as 7 ft.

About 60% of the world's railway mileage is of so-called standard gauge, which measures 4 ft. $8\frac{1}{2}$ in. It is not clear how this odd width originated. One of many suggested possibilities is that it evolved from the wheel spacing of vehicles used on early English wagonways or tramways, which were the predecessors of the modern railway.

Standard gauge got its foothold in North America through the English locomotives imported for some of the earliest U.S. lines. Today, nearly all the railway mileage in North America is standard gauge, although in the early years many lines were built in both wider and narrower sizes.

In Central and South America are to be found extremes ranging from 1 ft. $11\frac{5}{8}$ in. to 5 ft. 6 in. The majority is narrow gauge, although many countries have systems in different gauges—a legacy of unco-ordinated development. Standard gauge, or a width so nearly identical as to allow the through running of vehicles, is found in most of Europe, excepting Finland and Russia (5 ft.), Ireland (5 ft. 3 in.) and Spain and Portugal (5 ft. 6 in.). A considerable mileage of narrow gauges—including metre (39.37 in.), 2 ft. 6 in. and 1 ft. $11\frac{5}{8}$ in.—also exists on the continent of Europe, particularly in Germany, Austria, Spain and Switzerland.

In Africa the principal gauges are 3 ft. 6 in. and 1 m. India and Pakistan both have extensive 5-ft. 6-in. broad-gauge systems, together with a large metre-gauge mileage and narrow-gauge lines

TABLE 11.—Railway Systems of Selected Countries

Country	Service commenced	Ownership*	Gauge†	Mileage‡
Argentina	1857	state	5' 6"	27,200
			metre	
Australia	1854	state	5' 3"	7,501
			standard	5,998
			3' 6"	12,614
Austria		state	standard	3,691
Belgium	1835	state	standard	2,991
Brazil	1854	state	metre	23,253
Bulgaria	1866	state	standard	2,300
Burma	1877	state	metre	1,848
Canada	1836	state	standard	43,313
Ceylon	1865	state	5' 6"	898
China	1881	state	standard	19,000
Czechoslovakia		state	standard	8,118
Denmark	1847	state	standard	2,800
Egypt	1854	state	sfandard	2,967
Finland	1862	state	5	3,175
France	1828	state	standard	24,690
Germany	1835	state	standard	22,849
Greece		state	standard	927
			metre	125
Hungary	1846	state	standard	5,029
India	1853	state	5' 6"	16,246
			metre	15,480
			2' 6"	2,735
Indonesia		state	3' 6"	3,335
Ireland	1834	state	5' 3"	2,053
Italy	1839	state	standard	10,379
Japan	1872	state	3' 6"	12,600
		private	3' 6"	4,600
Jugoslavia		state	standard	5,592
			2' 6"	1,864
Malaya	1885	state	metre	1,028
Mexico	1850	state	standard	14,577
Netherlands	1839	state	standard	2,007
New Zealand	1863	state	3' 6"	3,466
Norway	1854	state	standard	2,841
Pakistan		state	5' 6"	5,181
			metre	1,464
			2' 6"	338
Poland	1845	state	standard	14,415
			narrow	2,000
Portugal	1856	state	5' 6"	1,760
			metre	475
South Africa	1860	state	3' 6"	13,435
Spain	1848	state	5' 6"	11,090
Sweden	1856	state	standard	7,716
Switzerland	1844	state	standard	1,280
		private	narrow	1,849
Turkey		state	standard	4,850
United States	1830	private	standard	217,700
U.S.S.R.	1837	state	5'	76,321

*Predominant ownership is given; most countries have both private and state-owned lines.
†Gauge of the principal mileage; most countries have lines of several gauges.
‡Data are for the late 1950s.

of 2 ft. and 2 ft. 6 in. The lines of the Japanese National railways, which make up most of the mileage in Japan, are all of 3-ft. 6-in. gauge. That country also has a number of short. privately owned railways, some of which are standard gauge, as well as 3 ft. 6 in. The Chinese railways, on the other hand, are laid largely to standard gauge, although there is some 5 ft. and narrow gauge as well. New Zealand employs a gauge of 3 ft. 6 in., but Australia has major networks in three different gauges: 3 ft. 6 in., 4 ft. $8\frac{1}{2}$ in. and 5 ft. 3 in.

The benefits of a uniform gauge were recognized early. It permits free interchange of cars between various railway lines, thus speeding the flow of commerce and, of course, greatly reducing the over-all cost of transporting goods and people. Only because of this virtual uniformity of railway gauge in North America was the railway able to play the dominant role in the settling and development of that continent. Conversely, in areas where uniformity of gauge has not been achieved, such as South America and Australia, development of the railways—and consequently the economic growth of the countries they serve—has been correspondingly slowed.

The principal gauges in use in major countries are shown in Table II. The total route length of all railways throughout the world is 781,000 mi., divided approximately as follows: North America, 36% ; Europe, 34% ; Asia, 12% ; Central and South America, 8% ; Africa, 6% ; Australia and New Zealand, 4%.

3. Rail.—Railway track as we know it originated in the plateways used in English coal mines, consisting of squared timbers on top of which iron plates were fastened. The earliest examples of iron rail were L-shaped, the upright portion keeping the flangeless wagon wheels running on the flat baseplate. From this developed the I-shaped rail which was carried in pedestals or chairs, these in turn being secured to stone blocks or, later, wooden sleepers or crossties. The rails were retained in position in the chairs with the aid of oak keys.

The I-shaped rail led to the bullhead rail, in which the head was of greater area than the foot. The use of this rail in conjunction with chairs attached to wooden ties became the standard for the British railway systems until 1949; the weight of rail for main lines was 95 lb. per yard arid the length 60 ft. After 1949, British railways were converting to a standard flat-bottomed rail weighing 109 lb. per yard.

In the 1830s a French engineer, Charles Vignoles, invented the flat bottomed rail, which was like an inverted T. It was spiked direct to the tie, which made for simple and inexpensive construction. A further refinement was the introduction, in 1847, of the fishplate nhich joined the outer ends of the rails together. This stopped the movement of the rail ends beyond the tie.

The majority of continental railways and those in other areas adopted the flat-bottomed rail from the beginning. The standard rail length in Europe is 30 m. (98 ft. 5 in.) and the weight, for main line use, is 118.8 lb. per meter, or about 109 lb. per yard.

Some of the earliest U.S. railways used iron rails shaped like an inverted U, but since iron had to be imported from England, it was very costly. A more common and much less expensive type of construction involved the use of iron straps fastened to the tops of longitudinal wooden stringers. The main problem with these iron straps mas their often-disastrous tendency to break loose and slash up through the floors of passing cars.

The modern type of track, using the flat-bottomed T rail on wood crossties or sleepers, was tried in the U.S. as early as 1831. The Camden and Amboy Railroad and Transportation company used iron T rails designed by its president, Robert L. Stevens. At first they mere attached, with spikes much like those used today, into wooden plugs inserted in stone blocks. Later, during a shortage of the stone blocks, the rails were spiked direct to wooden ties in order to keep the construction going. The emergency wood ties proved far superior. The track was more flexible; it held up better, gave a smoother ride and was much easier on the rolling stock.

It was not long before most of the railways in the U.S. began using this type of construction, although it did not become standard until about 1850 (as late as 1848 the Galena and Chicago Union railroad laid some strap-iron track). Iron rails were used in the U.S. until 1865. when rails of Bessemer steel made their appearance. By the early 1900s U.S. railways were using open-hearth steel rails, which soon largely supplanted Bessemer steel.

Although present-day rail is, in appearance. similar to the early designs of Stevens and Vignoles, it is actually a highly refined product in terms of both engineering and metallurgy. Much study and research have produced rail designs that minimize internal stresses under the neight of traffic, and thus prolong rail life. After they have been rolled at the steel mills, rails are allowed to cool slowly in special cooling boxes. This controlled cooling minimizes internal shatter cracks which at one time were a major cause of broken rails in track.

Hundreds of different rail cross sections were designed for U.S. and Canadian railways. and most of the larger lines used sections of their own design. Many of these rail sections are still in use, but there developed a strong trend toward standardizing on a few sections. The bulk of the new rail being purchased in the 1960s in North America was of sections weighing 100, 106, 115. 119, 132, 136 or 140 lb. per yard. The American Railway Engineering association was studying the possibility of standardizing on perhaps three or four rails of varying sizes for different traffic conditions. The standard U.S. rail length is 39 ft.

In general, lighter rail sections are used in countries outside the U.S. and Canada. This is partly because in most other countries the railways use lighter rolling stock; in some it is also due to traffic conditions or the need for economy in building the railways. Rail sections varying from 36 to 75 lb. per yard are common in South America. In Japan, 110-lb. rail, or heavier, is used on dense traffic lines, but there is much mileage of lighter rails in service.

Rail Fittings.—As rolling stock became heavier, railways found that under heavy traffic the rails tended to dig into the crossties, thus shortening the life of ties and making it difficult to maintain proper gauge and track alignment. To overcome this difficulty, tie plates are used between the base of the rail and the top of the tie. These plates (they may be up to 14 or 16 in. long on U.S. heavy traffic lines) distribute the load over more of the tie area. In some cases a resilient tie pad of rubber or a similar material is used between the tie plate and the tie.

The standard spike. with offset head, is still the most used fastening. It is driven through holes in the tie plates. In some cases railways have used special types of fastenings, including screw spikes and compression clips. These do an excellent job for critical locations, as on sharp curves or bridges, but they are considered too expensive for general use in the United States. Bolts or clips are used extensively in Europe.

Welded Rail.—One of the most important developments was the welding of rail into long lengths. This continuous welded rail increases travel comfort and saves maintenance. The rail is usually welded into lengths of up to a half-mile. In a few cases these lengths have, in turn, been welded together to produce rails several miles long without a break.

Welded rail was first tried in 1933 by the Delaware and Hudson railroad in the U.S. This line had laid 30-odd miles of continuous rail by 1939. It was not until the decade of the 1950s, however, that U.S. railways began to turn to melded rail in earnest. By 1960 about 1,000 mi. of long rails were being laid annually, and about 1% of all U.S railway mileage consisted of welded rail. In the 1950s. the French railways alone laid over 3,000 mi. of long welded track and it was also being standardized in Britain. Japan and other countries also were adopting melded rail.

Controlling the temperature expansion of long welded rails proved not so difficult as was first thought. It was found that the problem can be minimized by extensive anchorage of the rails against the ties to prevent them from moving when the temperature changes, and by laying the rails when the ambient temperature is close to the mean temperature prevailing in the particular locality. In France and some other countries, beveled expansion joints, in appearance somewhat like switch points, are sometimes provided at the ends of long welded rails.

4. Crossties (Sleepers).—Although timber is still the commonest tie material, both steel and concrete are also used. Steel ties are common in certain European countries, notably Switzerland, and they have also been adopted by a number of African and Asian systems. Concrete ties gained in popularity after initial stressing problems were overcome. Both prestressed and post-stressed types are in use, as well as concrete ties and concrete blocks joined by metal spacing bars. A combination of concrete ties and long nelded rail is said to produce an especially solid form of track.

With concrete ties, the resilience of wood, is, of course, lost. To avoid excessive pounding of both the tie and rolling stock, some form of cushioning pad, of rubber or similar material, is always used between the tie plate and the concrete ties. Bolts or clips are used to fasten the rail to the tie.

Methods of treating wooden ties with preservative chemicals (usually creosote) were improved to a degree that the average life of crossties in the U.S. increased to more than 30 years. Nevertheless, the cost of wooden ties rose steadily, thus creating some interest in ties made of substitute materials. In the early 1960s several U.S. railways, notably the Atlantic Coast Line railroad and the Seaboard Air Line railroad, placed in service experimental sections of track laid with prestressed concrete ties.

5. Roadbed.—Early U.S. railways often were constructed as cheaply as possible. This meant that they usually followed the contour of the ground; earth cuts and fills, where required, were minimized. Railways built in this way often have steep grades and sharp curves, features that greatly increase operating costs and restrict train length and speed. With the advent of modern high-capacity earth-moving machinery (developed primarily for highway construction) railways were able in many cases to eliminate the old adverse grades and curves through line changes. Graders, bulldozers and similar equipment make it practicable to dig deeper cuts through hillsides and to make higher fills where necessary in order to smooth out the profile of the track, and to do this at a

reasonable cost.

Modern equipment also helped railways improve their existing roadbeds, even where major changes were not required. For instance, a number of railways carried out ditching programs, in which the drainage ditches on each side of the right of way were deepened, thus improving drainage and increasing the stability of the roadbed. Where roadbed conditions are unstable, railways often find that it pays to remove the unstable material and replace it with filler material from another location. Stabilizing of the subgrade by injecting concrete grout under pressure is another widely used technique. In planning roadbed improvements, as well as in new construction. railways turned to modern soil engineering techniques (see SOIL MECHANICS).

The first step in building a new railway line, after the route has been surveyed and cleared of brush and trees, is to grade the right of may, much as is done in building a highway. Next. ballast (usually crushed rock, slag or volcanic ash) is applied and the track laid on top of this foundation. When the track has been laid the final ballasting is done and the track is carefully aligned in both the vertical and horizontal planes.

In Canada, where much new railway mileage was built in the years following World War II, track-laying machines are often used. A track-laying machine, mounted on rail cars, feeds ties and rails ahead of the working crew, moving forward over the new track as soon as it is spiked down.

6. Track Maintenance.— Until after World War II, the system of section maintenance—descended from the early days of railways—remained standard in the U.S. and Canada. The typical section was only a few miles in length. It was under the supervision of a section foreman and a gang which might vary in size from 4 to 12 men. They had only a few hand tools. However, because of rapidly rising labour costs. the pressure to develop more economical track maintenance methods became intense.

With modern techniques, a small mechanized force of men can maintain a long stretch of track to high standards. Machines are available to do all the necessary track and maintenance jobs: removing and inserting ties, tamping ballast. spiking rail, tightening joint-bar bolts and leveling and aligning the track. Mechanized forces also can renew rail. either in conventional bolted lengths or with continuous welded lengths; they use cranes to remove the old rail and lay the new. Gauging, spiking and bolt-tightening devices complete the installation.

Ballast-cleaning machines pick up old ballast, sift it, reject oversize or undersize stones, and replace it. Tamping machines consolidate ballast beneath the ties, thus improving running conditions. Scarifiers break up hard, compressed ballast. Complete sections of track—rails and crossties—may be prefabricated at a central shop and then laid on the site by mechanical means.

Rail grinding machines are used to even out irregularities that occur on the running surface of rails. For checking any irregularities in track alignment, other machines are capable of testing for gauge, curvature, etc., while in motion, the results being recorded on moving charts. So-called detector cars. equipped with electronic inspection apparatus, move over main-line tracks periodically to locate any internal flaws in the rails that might cause them to break under the stress of traffic.

Mechanization reduced the number of track and roadway maintenance workers in the U S by about one-half in 15 years following World War II. It constituted a major technological revolution. Improved and more automatic maintenance machines were constantly being developed, and U.S. railways were adopting new construction techniques that promised to reduce the amount of maintenance that the track structure requires. The trend to mechanization of track and roadway work was evident also in many other countries, but in most, mechanization was less advanced. largely because labour costs were not as high as in the United States.

III. LOCOMOTIVES

Although some of the earliest railways used horses for motive power, it was only the development of practical locomotives that permitted railways to become efficient arteries of volume transportation.

Normally the term locomotive refers to a separate unit incorporating nothing more than the machinery to generate (or, in the case of an electric locomotive, to convert) power. However, motive power can also be incorporated in a vehicle equipped with passenger or baggage accommodations, or both Broadly speaking, there are three sources of power for a locomotive: steam, oil and electricity. Steam was the earliest form of propulsion and was in universal use for over 100 years. but after World War II the popularity of the steam locomotive daindled in favour of diesel and electric traction, which are more efficient.

The steam locomotive is a self-sufficient unit, carrying its own water supply for steam generation and either coal, oil or wood for heating the boiler. The diesel locomotive also carries its own fuel oil supply, but because of the characteristics of the diesel engine, direct drive to the wheels is not employed. Instead, mechanical, hydraulic or electric transmission is used; with the last. the diesel engine drives a generator to produce electric power and this, in turn, is fed to traction motors that propel the vehicle.

With electric traction the locomotive is not normally self-sufficient. As the locomotive moves along the track, electric current is picked up from either an overhead conductor wire or a third rail mounted alongside the running rails. The only self-sufficient examples are battery-driven electric locomotives and rail cars, which are not widely used. The only other category of motive power is the turbine locomotive—either the turbo-diesel or the gas turbine. Both use oil fuel and have electric, hydraulic or mechanical transmission.

A. STEAM LOCOMOTIVES

It was George Stephenson's "Rocket"—winner of the Liverpool and Manchester railway's competition of 1829—that ensured a place for the steam locomotive as a means of propulsion and the railway as a means of transport. The success of the "Rocket" was attributed to its multitube boiler and its more efficient system for exhausting the steam and creating a draft in the firebox. basic features that continued to be used in the steam locomotive. The principal characteristics of the "Rocket" were a boiler pressure of 50 pounds per square inch (p.s.i.); cylinders $8 \times 16\frac{1}{2}$ in.; one pair of driving wheels, 4 ft. 83 in. in diameter; and a total weight of about 9,500 lb.

The number of coupled drive wheels soon increased. After the "Rocket," with its single pair of driving wheels, came the four-

TABLE *111.—Designations of Wheel Arrangements of Steam Locomotives*

Symbol U.S.-British	Symbol French	Symbol German	Wheel Arrangement (Front to Back)	Type name
0-6-0	0-3-0	C	OOO	Six-wheel switcher, Bourbonnais
0-8-0	0-4-0	D	OOOO	Eight-wheel switcher
2-6-0	1-3-0	1C	oOOO	Mogul
2-6-2	1-3-1	1C1	oOOOo	Prairie
2-8-0	1-4-0	1D	oOOOO	Consolidation
2-8-2	1-4-1	1D1	oOOOOo	Mikado
2-8-4	1-4-2	1D2	oOOOOoo	Berkshire
2-10-0	1-5-0	1E	oOOOOO	Decapod
2-10-2	1-5-1	1E1	oOOOOOo	Santa Fe
2-10-4	1-5-2	1E2	oOOOOOoo	Texas
4-4-0	2-2-0	2B	ooOO	American
4-4-2	2-2-1	2B1	ooOOo	Atlantic
4-6-0	2-3-0	2C	ooOOO	Ten wheeler
4-6-2	2-3-1	2C1	ooOOOo	Pacific
4-6-4	2-3-2	2C2	ooOOOoo	Hudson, Baltic
4-8-2	2-4-1	2D1	ooOOOOo	Mountain, Mohawk
4-8-4	2-4-2	2D2	ooOOOOoo	Northern, Niagara, Pocono
4-8-8-4	2-4-4-2	2D-D2	ooOOOOOOOOoo	Union Pacific "Big Boy"

coupled locomotive. followed by the six-coupled. The number of coupled wheels grew to a maximum of 14, a locomotive with this remarkable number being built in Russia. Additional wheels of smaller diameter are often provided ahead of and behind the coupled wheels. The pilot wheels ahead of the coupled wheels fulfill various functions, the principal one being to assist in guiding the coupled wheels around curves. The pilot wheels usually consist of two on a single axle or four on two axles. Those to the rear of the coupled wheels normally support the weight of the firebox, enabling it to be larger than if it had to be accommodated between the last pair of coupled wheels. (Common wheel arrangements, and methods of designating them, are shown in Table III.)

Steam locomotive driving wheels are of various diameters, usually larger on passenger locomotives and smaller on freight locomotives. In Europe the average is between 66 and 78 in. for express passenger engines and 54 and 66 in. for freight or mixed-traffic types. Typical locomotives built in the U.S. just before the end of the steam era had drivers ranging from 60 to 84 in. in diameter. At one time it was thought that locomotives with small coupled uheels could not be operated at high speeds, but this later was disproved; for example, 2-10-0's with 5-ft. diameter wheels have been run at 90 m.p.h.

Supplies of coal and water can be carried on the locomotive frame itself (in which case it is called a tank engine) or may be carried in a separate vehicle (the tender) attached to the locomotive; the latter arrangement allows far greater supplies of fuel to be carried. The average capacity of a tender of a European main-line locomotive is 10 tons of coal and 8,000 gal. of water. In Russia and on some African, Asian and Australian systems higher capacities are common. The tender for a typical large U.S. steam locomotive of the World War II period was carried on 14 wheels and had a capacity of 28 tons of coal and 25.000 gal, of water.

1. U.S. Locomotives. — In relatively short order, steam locomotives in the U.S. evolved to the general type that became known as the American Standard. It had horizontal fire-tube boiler, a four-wheel pilot truck to steady and guide the front of the locomotive, and four coupled driving wheels. This 4-4-0 type was used in the U.S. for all kinds of services; it dominated U.S. railroading until well after the American Civil War period. In fact, many 4-4-0's were still in service by the early years of the 20th century.

Nevertheless, to meet the needs of heavy freight traffic, other types of locomotives with more (and usually smaller) drive wheels were developed. Common were the Mogul (2-6-O), the Consolidation (2-8-0) and the Mikado (2-8-2). A type used by a few railroads was the 2-12-2, which had 12 coupled drive wheels. In the late years of steam locomotive development, still greater tractive effort was obtained by using two separate engine units under a common boiler. These articulated locomotives culminated in the Union Pacific's famous "Big Boy," said to be the largest steam locomotive ever built. Used in mountain freight service, "Big Boy" was an articulated 4-8-8-4 type which weighed nearly 600 tons. It could exert 133,575 lb. of tractive force and developed over 6.000 h.p. at 75 m.p.h.

2. Articulated Locomotives. — Articulated designs have also been produced in other countries. One of the best known is the Beyer-Garratt, in which there are two frames, each having its own driving wheels and cylinders, surmounted by water tanks. Separating the two chassis is a further frame carrying the boiler, cab and coal or fuel oil supplies. This type of locomotive is of particular value on tracks which permit only light axle loads, as the weight is spread over a considerable distance. Also, the Garratt can negotiate sharp curves. It is widely used in Africa.

Another form of articulation is the Mallet, in which there is a long rigid frame, below which are two sets of driving wheels each with its own set of cylinders. The rear driving wheels are frame mounted, but the leading ones are pivoted. The name Mallet is taken from the Swiss engineer, Anatole Mallet, who devised the layout for use with compound propulsion.

Simple-expansion steam locomotives can be equipped with two or more cylinders and. especially in Britain, three- and four-cylinder locomotives are common. For double expansion or compounding. more than two cylinders are mandatory. In this system, steam goes first to one or two small cylinders and then to two larger cylinders before being exhausted into the atmosphere; thus it is expanded or used twice, resulting in greater thermal efficiency. In Europe, compound locomotives were most popular in France, where for many years the majority of the designs were of this type.

3. Modern Types. — Typical of modern steam locomotives is the French railways 2-4-1 P class (4-8-2), a four-cylinder compound engine with 794-in. drivers, a boiler pressure of 290 p.s.i. and tractive effort of 45,084 lb. The South African railways class 25 (4-8-4) has two cylinders, 60-in. driving wheels and develops 51,400 lb. of tractive effort. The Indian Government railways class WG (2-8-2) has 614-in. driving wheels and develops 38,890 lb. of tractive effort. The British railways "West Country" class (4-6-2) has three cylinders, 74-in. drivers and can produce 27,720 lb. of tractive effort. Total weights of these engines, with tenders, range from 288,000 to 498,000 lb.

Typical of latter-day U.S. steam passenger locomotives were the Pacific (4-6-2) type and the Hudson or Baltic (4-6-4), which could haul heavy trains at high speeds. The Mountain (4-8-2) and Northern (4-8-4) types were logical further developments in passenger train power. The New York Central's Niagara 4-8-4 represented perhaps the highest state of development in passenger locomotives; this locomotive (also used in high-speed freight service) had a tractive force of 61,500 lb. and developed 4,850 h.p. at 65 m.p.h.

Various refinements gradually improved the reciprocating steam locomotive. Some of these included higher boiler pressures (up to 290 p.s.i. in France and up to 310 p.s.i. for some of the last U.S. locomotives), superheating, feed-water preheating. roller bearings and the use of poppet valves instead of the sliding piston valve. Nevertheless, the thermal efficiency of even the best modern steam locomotives seldom exceeds about 6%. Incomplete combustion, heat losses from the firebox, stack, boiler and cylinders, and other losses dissipate most of the energy of the fuel burned. In terms of modern technology, the reciprocating steam locomotive is obsolete. Yet it has its good points, not the least of which are its simplicity and ability to withstand abuse. See also STEAM.

B. ELECTRIC LOCOMOTIVES

The first challenge to the supremacy of steam came from the electric locomotive. Although efforts to propel railway vehicles using batteries date back to 1835, the first successful application of electric traction was in 1879, when a locomotive designed by Werner von Siemens mas operated at an exhibition in Berlin. In 1881 the first public electric railway commenced operation at Lichterfelde, near Berlin, while in 1883 the first part of Magnus Volk's electric railway at Brighton, Eng., was opened. Another early electric line was the City and South London railway between King William street and Stockwell. This was opened in 1890 and was the first electric underground railway. The initial applications of electric traction were for suburban or metropolitan railways such as those in Berlin, Budapest, Paris and London (see ELECTRIC TRACTION). In 1895 the B. & O. electrified a stretch of track in Baltimore to avoid smoke and noise problems in a tunnel, marking the first use of electrification by a steam railway in the U.S.

One of the first countries to use electric traction for main-line purposes was Italy, where a three-phase, 3,000-v. system was inaugurated in 1902. In the same year, some remarkable experiments were carried out on an experimental line near Berlin, where an electric train achieved a speed of 130.4 m.p.h.

By 1906, a number of electrified lines were operating all over Europe and a start had been made on major electrification schemes. Of these, the most extensive was in Switzerland, where large-scale electrification started at the end of World War I. Other countries that began extensive electrification in the 1920s were Sweden, Germany and Austria. All of these, together with Norway, made use of the same system: 15,000-v., 163-cycle, single-phase A.C. In other countries, direct current was preferred, although Italy electrified a considerable mileage with 3,700-v., 163-cycle, three-phase AC. The use of the overhead conductor wire was almost universal, except for suburban lines and the Southern railway in Britain. By the end of the 1920s nearly every European country had at least a small percentage of electrified track. Electric traction was also introduced in Australia (1919), New Zealand (1923), India (1925), Indonesia (1925) and South Africa (1926).

Following the pioneer B. & O. tunnel electrification, a number of other terminals in the U.S. (such as the New York Central's Grand Central terminal in New York city) and difficult mountain segments of main lines were electrified. Some of these relatively small electrifications were later removed with the advent of the diesel-electric locomotive.

In the 1960s, the only major line-of-road electrifications in the U.S. were on the Pennsylvania railroad (about 671 route miles between New York and Washington, D.C., and between Philadelphia and Harrisburg, Pa.) and on the Milwaukee road in Montana, Idaho and Washington (about 660 mi.). There were also a 134-mi. main-line electrification on the Norfolk and Western railway, and 106 mi. of electrified line on the New York, New Haven and Hartford railroad.

The suburban passenger services of several U.S. and Canadian railways were electrified, including the Canadian National at Montreal, the Long Island and the Erie-Lackawanna railways around New York city, and the Illinois Central at Chicago. Several South American countries have small mileages of electrified track. notably Brazil. About 11% of the route mileage of the Japanese National railways is electrified.

Following World War II, electrification was greatly extended in Europe in a comparatively few years, while there was also expansion in Africa, Asia and Australasia.

1. Advantages and Disadvantages.— Electric traction is generally accepted as the most economical and efficient means of operating a railway, providing that the traffic justifies the capital expenditure and that cheap electricity is available.

Being simply power-converting, rather than power-generating, devices, electric locomotives have several very real advantages. Since they draw on the resources of the central power plant, they can develop power greatly in excess of their nominal ratings to start a heavy train or surmount a steep grade. A typical modern electric locomotive rated at 4,000 h.p. has been observed to develop as much as 10,000 h.p. for a short period under these conditions.

Moreover, electric locomotives are quieter in operation than other types, they produce no smoke or fumes, they accelerate rapidly: and they are completely predictable in performance. Electric locomotives have a high availability factor (that is, they require little time in the shop for maintenance) and, because of their relatively simple construction, the cost of maintaining them is low. It also appears that electric locomotives have a longer economic life than do diesel electrics.

The greatest drawback to electrified operation is the high capital investment and the maintenance expense of the fixed plant—the trolley wires and structures, power substations and associated equipment. A less important disadvantage is the lack of flexibility of electric motive power: it cannot operate where there are no trolley wires.

Electric operation is most suited to railway systems carrying very dense traffic; this is the basic reason why it made rapid headway in many European countries. In Japan, too, further electrification seemed inevitable as a means of more economically handling the extremely heavy traffic that characterizes the Japanese railways.

2. Types of Systems. — Electric traction systems can be broadly divided into those using alternating current (A.C.) and those using direct current (D.C.). With D.C., the most popular line voltages are 1,500 and 3,000, although there is a large mileage in southeast England of 600 v., and several systems in the 600–700 v. range around New York city. The disadvantages of D.C. are that expensive substations are required at frequent intervals and the overhead wire or third rail must be relatively large and heavy. Thus, a very high density of traffic is necessary to justify the cost of this form of electrification.

However, the low-voltage, series-wound D.C. motor is well suited to traction purposes, being simple to construct and easily controlled. Typical of modern locomotives for D.C. operation is the French railways 1,500-v. 9200 series, weighing 82 tons and developing 5,200 h.p. It was on a line equipped with the 1.500-v. D.C. system that, in March 1955, two different types of French locomotives achieved a speed of 205 m.p.h.

Single-phase A.C. at $16\frac{2}{3}$ cycles per second (c.p.s.) is also widely used by a number of European systems. With this system, substations do not need to be so numerous nor does the power transmission equipment need to be so substantial. Its application has been bound up with the lengthy development of the A.C. commutator motor. Initial A.C. electrification was on the three-phase system and the first practical application was on the Burgdorf-Thun railway in Switzerland in 1899, using a line voltage of 750. The first trial with a single-phase supply was on the Seebach-Wettingen line in Switzerland in 1907. The Berne-Lötschberg-Simplon, another Swiss system, was the first railway to be operated on single-phase, 165-cycle A.C., at a line voltage of 15,000, throughout its length (1910–1913) and this type of power was subsequently adopted by the Swiss Federal railways.

In the United States, single-phase A.C. at 25 cycles was used on a number of the main-line electrifications. The Pennsylvania, the New Haven, and the Norfolk and Western (on the former Virginian railway) systems are of this type.

Quite early in the development of electric traction the question of using alternating current at the industrial or commercial frequency (50 c.p.s. in Europe, 60 in the U.S.) was considered. Use of commercial-frequency A.C. means that current can be obtained from the commercial supply network, eliminating the need for the railways to generate and distribute their own power. The overhead contact wire can be much lighter, far fewer substations are necessary, and therefore lines with a lower density of traffic can be electrified on a profitable basis. Initial experiments with 50-cycle A.C. were carried out in Hungary in 1933, using a line voltage of 16.000. In the same year the German State railways decided to experiment on the Hollental branch with this form of electrification, using a line voltage of 20,000.

TABLE IV.—Designations of Wheel Arrangements of Diesel and Electric Locomotives

Symbol	Wheel Arrangement (front to back)	Description
A1A-A1A	○ o ○–○ o ○	Single-unit locomotive with two six-vheel trucks, each with centre idler axle.
B-B	○ ○–○ ○	Single-unit locomotive with two four-wheel trucks, all axles driven.
C-C	○ ○ ○–○ ○ ○	Single-unit locomotive with two six-wheel trucks, all axles driven.
2+(B-B)	○ ○–○ ○ + ○ ○–○ ○	Two-unit locomotive, each with two four-wheel trucks, all axles driven, units joined with articulated connection.
2-C+C-2	o o ○ ○ ○ - ○ ○ ○ o o	Electric locomotive with four-wheel leading and trailing (idler) trucks; six driven axles in two frames with articulated connection between frames.

In 1945, Louis Armand, former president of French railways, set up a commission to study 50-cycle operation on the Hollental line. As a result, French railways pressed forward with the further development of 50-cycle electrification, converting a line between Aix-les-Bains and La Roche-sur-Foron for their first practical experiments. This was so successful that in 1952 it was decided to electrify a network of lines in northeast France using 25,000-v., 50-cycle? single-phase A.C. Subsequently, a number of other countries adopted 50-cycle electrification, including Britain, Turkey, Portugal, Russia, India, the Belgian Congo, China, Japan and Argentina.

With the commercial-frequency A.C. system, there are three ways of taking power to the driving wheels: (1) employ a rotary converter or static rectifier to convert the A.C. supply to D.C. to drive D.C. traction motors; (2) use a phase converter to produce three-phase, variable-frequency current to drive A.C. motors; (3) make direct use of A.C. traction motors. The first method, using mercury-arc, germanium or silicon rectifiers, is the most popular.

The problem of international operation of electric locomotives in Europe was increased by the variety of electrification systems there. It was partially overcome by the construction of multi-voltage and multi-frequency locomotives. A similar problem exists in New York city, where the New Haven railroad operates into Grand Central terminal via the New York Central's 660-v., D.C. electrified system. The New Haven electric locomotives can operate either on 660-v. D.C. or 11,000-v., 25-cycle A.C. The New Haven also operates unique electric-diesel electrics. When in Grand Central terminal these locomotives operate from the 660-v. third rail; at all other times their trection motors are supplied from a standard diesel-electric engine-generator set carried on the locomotive.

Although electrification had made little headway in the U.S. up to mid-century, several factors were at work that showed promise of resulting in further electrification in the future. These included the demand for faster freight trains, the rising costs of diesel fuel, and a trend toward mergers that would tend to increase traffic density on the surviving lines. There was also the possibility of reducing fixed-plant costs through the use of the high-voltage. commercial-frequency system that has proved so successful in Europe and in Japan.

C. Diesel-Electric Locomotives

By the 1960s the diesel-electric locomotive had almost completely superseded the steam locomotive as the standard railway motive power in North America, and it was gaining rapidly in most other parts of the world. As the decade began, the Norfolk and Western railway, the last major C.S. system to continue steam operation, had completed its dieselization and was retiring its great steam locomotives, said by many to have been the most efficient steam motive power ever operated. In short, the railways of the U.S. in just 25 years, completely replaced the steam locomotive—which had been standard for 100 years—with the diesel electric. Actually, most of this change was accomplished in an even shorter period: as late as 1951 U.S. railways had more steam locomotives than diesel-electrics in service.

What caused the diesel electric to supersede the faithful steam locomotive so rapidly? Briefly, the pressure of competition from other modes of transport, and the continuing rise in wage costs, forced the railways to improve their services and to adopt every possible measure to increase operating efficiency. Compared with the steam locomotive, the diesel electric (or simply, the diesel) has a number of major advantages. For instance:

It can operate for long periods with relatively little down time for maintenance. This high availability makes it possible for diesels to operate through on a run 2,000 miles or more in length and then, after brief servicing, to start the return trip. Steam locomotives must be serviced after only a few hours in operation, and thus they are limited to relatively short runs.

The diesel uses less fuel than a steam locomotive (its thermal efficiency is about four times as great).

It can accelerate a train more rapidly and run at higher sustained speeds with less damage to the track structure.

These are the major points at which the diesel excels. It is also superior to the steam locomotive because of its smoother acceleration, greater cleanliness, standardized repair parts and operating flexibility (a number of diesel units can be combined and run by one man under multiple-unit [MU] control). With diesels. too, there is no problem of supplying large quantities of boiler feed water; there is no loss of power capability in cold weather; and there is less stand-by cost, since the locomotive can be completely shut down when not in use.

Because of advantages such as these, most U.S. railways found that diesel locomotives quickly paid for themselves, despite their relatively high initial cost. It is no exaggeration to say that without the diesel locomotive the U.S. railways could not have continued solvent under private operation, as they had up to the beginning of the 1960s.

1. Early Diesel Development.— The earliest patent for an oil-engine using the compression-ignition principle was granted in 1890 to a British pioneer, Akroyd Stuart. A small locomotive incorporating an engine of Stuart's design was built by Hornsby and Sons in 1896. The first patent for a compression-ignition engine was granted to the German engineer Rudolf Diesel in 1894, and the first engine to be built in accordance with his designs was completed in 1897 (see Diesel Engine). The pioneer diesel-engine locomotive of any size was a 1,000-h.p. unit built by the Diesel-Klose-Sulzer company in 1912. It had a four-cylinder, two-stroke engine directly coupled to the driving wheels. This was followed in 1913 by the first diesel-electric rail car to operate in regular service, a Swedish design powered by a 75-h.p. engine coupled to a D.C. generator.

Gasoline-engine vehicles were in existence as early as the first compression-ignition engines. In 1891 two German firms jointly produced a small industrial locomotive with a 4-h.p. gasoline engine, and numerous other examples of gasoline-engine vehicles were produced in several countries following the turn of the century. Rail cars of various kinds, with gasoline engines, continued to be used up to the 1930s. In Europe, however, gasoline was too expensive to use for traction purposes, and its inflammability was a source of danger in the event of an accident.

The earliest ancestors of the modern diesel locomotive in the United States were the gasoline-driven rail cars used by the Union Pacific and other railways on branch-line passenger runs beginning early in the 20th century. The engines used in these cars were neither powerful nor reliable, nor were their mechanical transmissions suitable for such severe service. Next, gasoline-electric rail cars were developed, using larger engines and electric, rather than mechanical, transmissions. These proved more satisfactory, but they still did not fully solve the problem of branch-line passenger service.

After World War I, increased highway competition made the problem of money losing branch lines even more critical in the U.S., and led to renewed interest in gas-electric cars. The Electro-Motive company was formed in 1922 to build gas-electric cars, using engines supplied by the Winton Engine company and electrical equipment by General Electric company. Meanwhile, the American Locomotive company (Alco) had been experimenting with diesel engines, and in 1925 it produced the first commercially successful diesel-electric switching locomotive. This 300-h.p. 60-ton unit was sold to the Central railroad of New Jersey for service at its Bronx terminal in New York city. The locomotive went to work in Oct. 1925 and served continuously until its retirement in 1957 (this pioneer diesel unit is now preserved at the B. &. 0. transportation museum in Baltimore).

A little-remembered next step in North American diesel locomotive development was the delivery, in 1928, of "road" type locomotives to the Canadian National and New York Central railways. The C.N.R.'s locomotive, a 2,660-h.p., two-unit affair, was built by Canadian Locomotive company. Two smaller, single-unit locomotives, one freight, one passenger, were delivered to the New York Central by Alco and General Electric in the same year. These were not especially successful, but the C.N.R.'s two units were separated and continued in service, one until 1939 and the other until after World War II.

Diesel development continued in Europe during this period, also. There were rail car applications in several countries, as well as many examples of higher powered locomotives, notably in Germany and Italy. A Russian engineer, G. V. Lomonosoff, had been pressing the claims of diesel traction since 1910. The Russian government finally agreed to let him put his ideas into practice and in 1925, in conjunction with the German railways, a 1,200-h.p. diesel-electric locomotive was completed. This was followed by a similar unit equipped with mechanical transmission.

Much Eurooean develooment work in the 1920s centred on the transmission of power. Because of its characteristics, the diesel engine is very limited when equipped with direct drive because it cannot rapidly adapt to variable load requirements. Also, it cannot start from rest under load. Experiments were carried out with mechanical, hydraulic, pneumatic, compressed gas, compressed steam and electric transmissions. Gradually it was found that mechanical, hydraulic and electric transmissions were the most satisfactory. In 1928 a diesel-electric train was tested in Britain, and a diesel-hydraulic rail car was placed in service in Northern Ireland in 1933. However, it was in 1932 in Germany that the first really striking results with diesel traction were obtained. A two-car streamlined diesel-electric train, equipped with two 400-h.p. engines, commenced operation between Berlin and Hamburg. This train, the "Flying Hamburger," was soon on a 77-m.p.h. average speed schedule that called for the regular attainment of 100 m.p.h. Other units were built and a network of fast services was introduced all over Germany. In the 1930s diesel rail cars and diesel-engine multi-car train sets were brought into use in most European countries.

A turning point in U.S. diesel development came in 1930, when Electro-Motive company and Winton Engine company were acquired by General Motors corporation. This merger led to the development of a lightweight, two-stroke-cycle diesel engine suitable for general railway application. This was the engine used in the "Pioneer Zephyr" of the Chicago, Burlington and Quincy railway. Delivered in April 1934, this was the first train in the U.S. to use diesel-electric power successfully in main-line service. Together with the Union Pacific's "M-10000," later renamed the "City of Salina," the "Pioneer Zephyr" also inaugurated the modern era of streamlined lightweight passenger trains. The "Pioneer Zephyr" remained in service for more than 25 years and then was preserved in the Museum of Science and Industry, Chicago.

The "Pioneer Zephyr," the "M-10000" (which used gasoline as fuel) and a few other early diesel-powered passenger trains were actually modernized versions of the old gas-electric cars. They were articulated trains in which a single truck supported the adjacent ends of adjoining cars. This meant that cars could not be added or removed easily to meet traffic demands. In most cases the new trains mere so popular that the traffic soon outgrew them, and eventually most of them had to be relegated to lighter-traffic runs.

Logically, the next step was to build a nonarticulated diesel locomotive that could be used to pull any train. In 1935 Electro-Motive division delivered one 1,800-h.p unit to the B. & O and two to the Santa Fe. The latter two units, operated as a single 3,600-h p. locomotive, were used to begin the first high-speed passenger service between Chicago and Los Angeles, May 12. 1936. They covered the 2,226-mi. run, pulling the "Super Chief," in $39\frac{3}{4}$ hr.

After 1935, the diesel began to play an increasingly important role in passenger train operations in the U.S.. as well as in yard switching work, but it was not until 1939 that the first road freight diesel, a four-unit Electro-Motive demonstrator, mas built. This 5,400-h.p. locomotive could be split and operated as two 2,700-h.p. locomotives. The original demonstrator was eventually sold to the Southern railway. Meanwhile, the Santa Fe, in 1940, had become the first railway to operate diesel locomotives in regular freight service.

By the end of World War II the diesel locomotive had become a proven, standardized type of motive power, and it rapidly began to supersede the steam locomotive in North America. In 1943 there were nearly 40.000 steam locomotives and only 2,100 diesel units in service in the U.S. Less than 20 years later there were but a handful of steam locomotives in regular operation (mostly on short-line railways) and about 28,000 diesel-electric units. Because of its greater efficiency, this smaller number of units proved fully capable of performing as much or more transportation work than the larger steam locomotive fleet it replaced.

After World War II, the use of diesel traction greatly increased also in Europe, Africa, Asia and Australasia. Practically every major system in these areas used the diesel engine in some form, and there were some systems—especially in Africa—that became completely dieselized.

2. Elements of the Diesel Locomotive.—Although the diesel engine has been vastly improved in power and performance, the basic principles remain the same: drawing air into the cylinder, compressing it so that its temperature is raised and then injecting a small quantity of oil into the cylinder. The oil ignites without a spark because of the high temperature. The diesel engine may operate on the two-stroke or four-stroke cycle and may have cylinders arranged in line, in V formation, horizontally opposed or in vertical formation. Rated operating speeds are from 350 to 2,000 r.p.m. and rated output may be from 10 to 2,400 h.p.

In the United States, early road units, and most yard switchers, use diesels ranging from 600 to 1,200 h.p. Road units now commonly have 1,800-. 2.000-, or 2,400-h.p. engines. Most builders use V-type engines, although the in-line type is used on smaller locomotives (up to 1,200 h p.).

Electric transmission is the most popular, and is nearly universal in North America. With electric transmission, the diesel engine is directly connected to a main generator that converts the mechanical energy produced by the engine into electrical energy. Through the appropriate control equipment, this in turn is used to drive the traction motors. The traction electrical system operates at a nominal 600 v.. but there is great variation in the voltage under operating conditions. The traction motors are of the series-wound type, each geared to the axle it drives. Most locomotives have a traction motor on each axle, although some passenger locomotives or units designed for light branch-line service may have six-wheel trucks with the centre axle an idler.

Hydraulic transmission employs the principle of a centrifugal pump or impeller driving a turbine in a chamber filled with oil or a similar fluid. The pump. which is driven by the diesel engine, converts the engine power to kinetic energy in the oil impinging on the turbine blades. The faster the blades move. the less the relative impinging speed of the oil and the faster the locomotive moves.

Mechanical transmission is the simplest type and is mainly employed in the lower power range. Basically it is a clutch and gearbox similar to those used in automobiles. A hydraulic coupling, in some cases, is used in place of a friction clutch.

3. Types of Diesel Motive Power.—There are four broad classes of equipment using diesel prime movers:

The light rail car or rail bus (up to 180 h.p.) usually is four-wheeled and employs mechanical transmission; it often is powered by a standard motorbus engine or a horizontal or pancake engine. The vehicle may haul a light trailer car.

The rail car in the low horsepower range (up to 1,000 h.p.) usually is equipped with mechanical transmission; higher powered versions may have hydraulic or electric transmission. Nearly all rail cars are capable of hauling trailer vehicles, while the most powerful types are designed essentially for hauling additional vehicles, although they also have passenger or baggage space.

Train sets (500 to 2,000 h.p.) are formations of more than one vehicle, usually designed to be worked from a single set of controls. They include one or more powered vehicles in their formation and usually have hydraulic or electric transmission.

Locomotives (10 to 3,300 h.p.) may have mechanical, hydraulic or electric transmission, depending on power output and purpose. They frequently are designed to work in MU formations. In the lower power range (to 600 h.p.) the usual duties are switching and light freight traffic. Medium-power locomotives (600–1,200 h.p.) may be used for freight haulage, passenger work or heavy switching purposes. Locomotives over 1,200 h.p. are normally required for main-line duties in Europe and North America. The 1,500–2,000 h.p. range is the most popular class for express train haulage, and for freight service in North America.

4. Diesel Operations in the **U.S.**—In North America, diesel locomotives are built in three distinct types designed for switching, freight and passenger service. Freight and passenger types are very similar in appearance, but passenger units are usually geared to a higher top speed and are equipped with an automatic steam boiler for train heating.

Road locomotives may be of either the streamlined or cab type, an outgrowth of the early streamlined articulated train designs, or of the purely functional hood type. In the former the body conforms closely to the cross-sectional dimensions of modern passenger cars. In hood units the covering for the engine, generator and other components is smaller and is not streamlined. Yard engines are always of the hood type in the U.S. and Canada (with the exception of a few early box cab yard switchers).

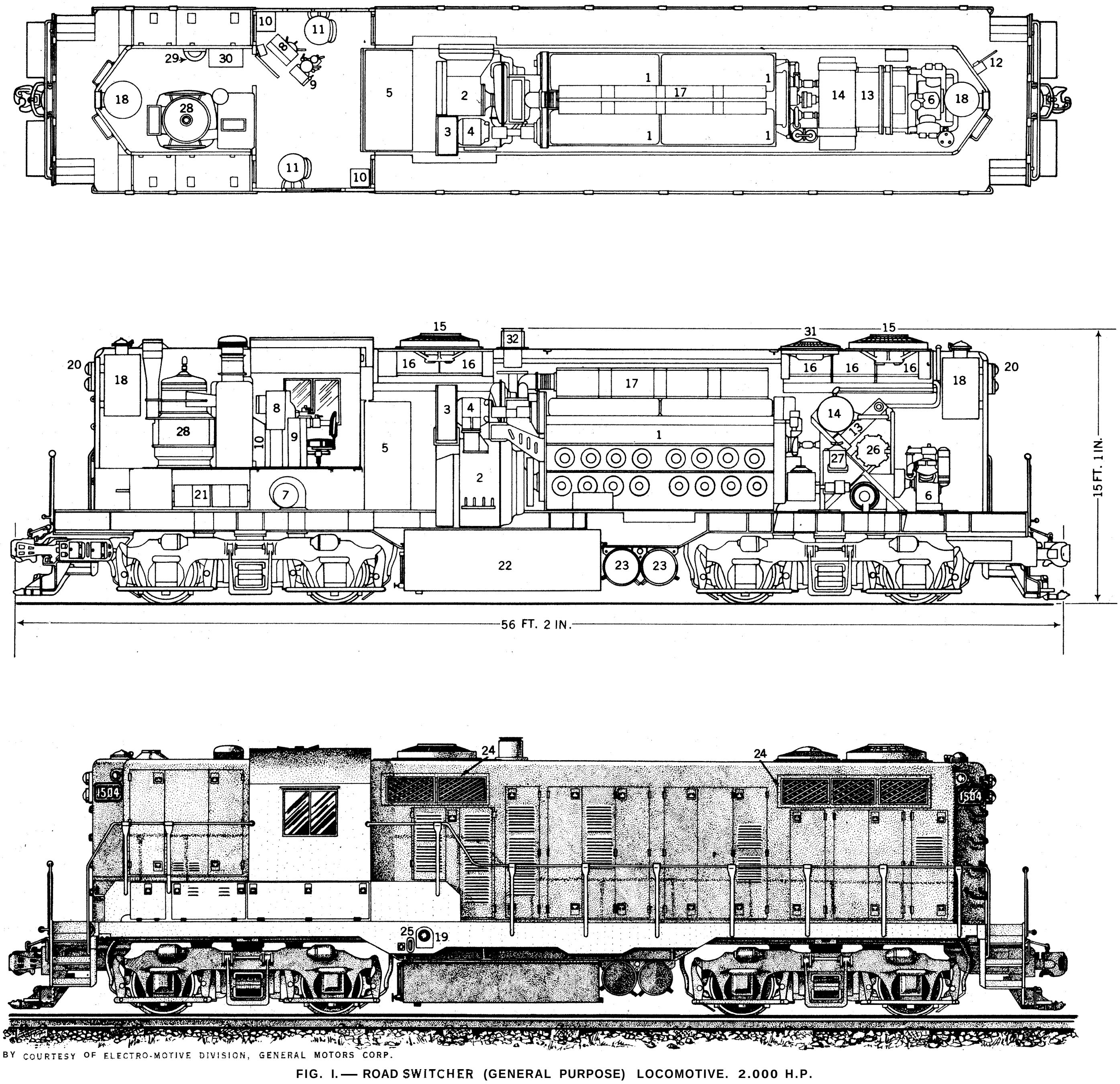
The so-called road switcher or general-purpose diesel has become almost standard in the U.S. and Canada. This hood-type unit is usually geared for medium top speeds and has an offset cab located between a short hood (which may contain a steam generator) and a longer hood covering the diesel engine, generator and control equipment. The road switcher can be used in either passenger or freight service interchangeably, and it can also be assigned to yard switching service as needed. Because of this versatility, the number of locomotives required may often be substantially reduced when road switchers are used.

5. Operating Methods.—It became almost universal practice in North America to equip diesels for MU control. This permits setting up a "building block" system in which two or more units can be combined and operated as a single locomotive from one control cab. This can be done on short notice to cope with fluctuations in traffic, for example, or to obtain extra power for a mountain grade. The electrical systems of the different builders' locomotives are sufficiently standardized so that it is possible to operate units of mixed makes together in a locomotive "consist."

In the early days of dieselization, railways tended to emulate the operating methods they had used with steam locomotives, but to take advantage of the diesel's special characteristics they soon found it necessary to change their techniques, and often their physical facilities. For one thing, the diesel closed many division-point roundhouses, since it could run across a whole continent, if necessary, without requiring any maintenance attention. Moreover, many railways found it necessary to pay increased attention to the scheduling of motive power operations. Rather than having locomotives assigned to a maintenance terminal on a first-in, first-out basis, some roads found it desirable to operate as many units as possible on definite cycles. Such a cycle may take a locomotive to all parts of the line, hauling a succession of different regular trains, before it returns to the maintenance point after perhaps 15 days on the road.

D. Special Locomotive Types

Although the diesel locomotive with electric drive is the present standard type in North America and over much of the rest of the world, railways are constantly experimenting with other types of locomotives. For example, on several occasions experiments have



BY COURTESY OF ELECTRO-MOTIVE DIVISION, GENERAL MOTORS CORP.

FIG. I.—ROAD SWITCHER (GENERAL PURPOSE) LOCOMOTIVE. 2,000 H.P.

(1) Engine; (2) main generator and alternator; (3) generator blower: (4) auxiliary generator; (5) control cabinet; (6) air compressor; (7) traction motor blower; (8) engineer's control stand; (9) air-brake valve; (10) cab heater; (11) seat; (12) hand brake; (13) lubricating oil cooler; (14) engine water tank; (15) ventiiatlno fan; (16) radiator; (17) exhaust manifold; (18) sand box; (19) fuel filler; (20) headlight; (21) batteries; (22) fuel tank; (23) main air reservoir; (24) air intake and shutters; (25) fuel tank gauge; (26) lubricating oil filter; (27) fuel filter; (28) steam generator; (29) lavatory; (30) clothes locker; (31) ventilating fan; (32) turbocharoer exhaust stack

been made to adapt the steam turbine for rail traction purposes. One of the first examples was built in Sweden in 1921. Other prototypes followed in Europe and there were also experimental turbine-electric locomotives, none of which met with success.

The first gas-turbine locomotive was developed in Switzerland and completed in 1941. Another Swiss-built gas-turbine locomotive developing 2,500 h.p. was supplied to British railways in 1949. The first British-built gas-turbine locomotive developed 3,500 h.p. and was completed in 1951 (it was later converted to 25,000-v., 50-cycle A.C. operation).

Shortly after World War II the Union Pacific railroad (UP.) acquired a total of 25 gas-turbine electric locomotives of 4.500 h.p. each to be used on main-line heavy-duty freight service between Omaha, Neb., and Ogden, Utah. Although the gas-turbine is not as efficient as the diesel engine, the U.P. found that the turbine locomotives can develop high sustained speeds with heavy trains, and that they cost less to maintain than diesel-electric iocomotives of comparable power. The original 25 units were subsequently supplemented by thirty 8,500-h.p. units.

Union Pacific also experimented with a coal-fired, gas-turbine electric locomotive. Work on a coal-burning gas-turbine locomotive began in the U.S. after World War II, and research and testing solved many of the problems inherent in using coal in a gas turbine. The coal-burning turbine was considered to have significant possibilities for railways which, like the U.P., serve areas rich in coal.

Also employing a turbine is the turbo-diesel or free-piston gasifier locomotive. In this design the turbine is driven by power gas from a free-piston diesel compressor. Pioneer work with this type of engine for rail traction purposes commenced in Sweden in 1933.

In 1955 another Swedish locomotive was produced, much. larger than the original example. It had a power-gas producer that worked on a two-stroke-cycle diesel principle (the power gas is exhaust gas leaving the producer under high pressure at a temperature of 900" F.). The locomotive was driven, via a reduction gear, by the turbine, fed by the power gas. It developed an output of 1,300 h.p. and used 20% less fuel than the equivalent diesel-hydraulic or diesel-electric locomotive.

E. Self-Propelled Rail Cars

Although the gas-electric and gas-mechanical cars of the 1920s and earlier evolved into the diesel-electric locomotive, they were not too successful in their intended role. In the U.S. especially, there was still a need for a self-propelled rail car that could be used on light-traffic lines.

In 1949 the Budd company introduced a modern self-propelled coach that it called the rail diesel car (R.D.C.). The 85-it. stainless steel car was powered by a pair of 300 h.p., 6-cylinder, in-line diesels, each of which drove one axle through a torque converter. The engines were mounted under the floor, leaving almost the entire car body available as revenue space. The car had a control compartment at each end, could be operated in MU trains with other R.D.C.'s, and was air-conditioned.

The R.D.C. found favour with many railways in the U.S. and other countries. Some, notably the Western Pacific and the B. & O. in the U.S., and the Commonwealth Government railways in Australia, began using these self-propelled diesel cars on long-distance runs.

Self-propelled cars have been widely used for many years for electrified commuter service serving larger cities, as well as on local subway and rapid-transit systems. Modern MU cars, as they are called, can accelerate and decelerate rapidly because of their lightweight construction and improved motors and control equipment. (See Electric Traction.)

In its Chicago-area commuter operations, the Chicago and North Western railway began using nonpowered cars equipped with MU control equipment, and a control cab, in conjunction with standard diesel-electric locomotives. By having one of these control cars at the rear of a train, it is possible to operate the train in either direction at normal speed, without turning the locomotive or cars at either end of a run.

IV. RAILWAY CARS

The ancestors of modern freight and passenger cars were the wagons and stage coaches of the early 19th century. Some of the earliest railway cars were, indeed, merely road vehicles fitted with flanged wheels.

After the first crude beginnings, railway car design took diverging courses in North America and Europe, partly because of differing economic conditions on the two continents and partly because of differing technological developments. Early railway cars on both continents were largely of two-axle design. but passenger car builders soon began building cars with three and then with four axles, the latter arranged in two four-wheel swivel trucks or bogies. Swivel trucks produce smoother riding qualities and allow the weight of heavy cars to be distributed over more axles—an important consideration, especially on some of the early, lightly built rail lines.

In North America, the two-truck design soon became the standard for freight as well as passenger cars. Over the years, American freight cars have become much larger than their European counterparts. A typical modern American boxcar is about $50\frac{1}{2}$ ft. long, weighs 53,000 lb. empty. and has a capacity of 100,000 lb. of lading and a cubic capacity of 4.860 cu.ft.

To a remarkable extent, the characteristics of rolling stock reflect the background of the early railway builders in each country. Thus, the cars used in Africa and most Asian countries reflect European origins; South American equipment favours North American or European practice, depending on who built the first lines. In Japan most freight cars are of the four-wheel type, but in Australia eight-wheel truck-type cars are more common. After World War II, there was a trend in European countries toward larger, eight-wheeled freight cars. but European railways are often handicapped by close clearances and sharp curves on factory loading tracks.

A. Freight Cars

Three basic types of freight cars have developed: the open-top car, the boxcar and the flatcar. Apart from these examples, many additional designs have been introduced to suit particular types of freight. In Europe, the freight vehicle usually runs on four wheels. Capacity varies: British cars are the smallest, having an average capacity of 12 long tons, although vehicles taking 16, 20 and $24\frac{1}{2}$ long tons are in use. On the continent capacities vary from 16 metric tons to 30 metric tons. In Russia, however, much larger two-truck vehicles are generally employed, having capacities of up to 90 metric tons. Two-truck cars having a capacity of up to 30 or 40 long tons are also used to a great extent in Africa, Australia and most Asian countries.

After World War II a number of new freight car designs evolved in Europe. These included double-deck vehicles for transporting automobiles; open cars with sliding roofs; pressurized tank cars for the transport of dry solids in bulk; boxcars with wide side doors for the easy movement of loads packed on pallets; and hydraulically operated tipping cars.

European railways also made great strides in the use of demountable containers carried on flatcars. These were first introduced in the 1920s to enable the railways to offer a door-to-door service and there came to be many examples in service for the transport of all kinds of merchandise from liquids to highly perishable commodities such as frozen food.

Of the approximately 2,500,000 freight cars operating on U.S., Canadian and Mexican railways, about 800,000 are boxcars—the standard house car with closed sides, a roof, and sliding doors on each side. Cars of 40- and 50-ft. lengths are common, but the trend is to larger units. American railways use an equally large number of open-top cars—so-called gondola and hopper cars, the latter having hoppers with doors for unloading through the bottom. Other common American freight car types include flatcars, tank cars and refrigerator and livestock cars.

Many thousands of cars are equipped with special internal fittings designed to accommodate specific products without the need for dunnage (*i.e.*, bracing or blocking of the load). Typical of these are the automobile parts cars, which are often designed to carry a certain automobile component, such as bodies, frames or engines, of just a single manufacturer. The internal loading equipment in these cars must be changed whenever the automobile manufacturer changes the design of his product.

Among other special types of boxcars are those with "long-travel" cushioned draft gear to prevent damage to fragile commodities; heated cars to protect commodities such as potatoes during winter; extra-long flatcars with two- or three-deck automobile racks, and so on.

As the 1960s began, still other types of specialized freight cars were becoming more and more important. Especially notable was the growing use of piggyback cars designed for efficient loading and hauling of highway trailers. A wide variety of piggyback cars was in use, ranging from converted standard 40-ft. flatcars to 85-ft. cars especially planned to carry two large or three small highway trailers or containers.

For the railways, the growing variety of specialized freight cars complicated the problem of keeping all shippers supplied with cars of the proper types. On the other hand, specialized cars usually ran more miles and earned more revenue than standard cars, and thus were a worthwhile investment. To supply special freight cars more efficiently, the private car companies played an increasing role. These companies buy the equipment and either operate it or lease it to shippers and often to the railroads themselves, a practice long followed in the U.S. with tank and refrigerator cars.

B. Passenger Cars

Cars with two four-wheel trucks were used in the United States almost from the beginning, but the two-truck coach was not introduced into Britain until 1874 and on the European continent until 1880. At about the same time the flexible gangway or corridor connection was adopted for main-line cars, enabling passengers to have access to any part of a moving train. Early American cars had open platforms at each end; it was not until around 1900 that closed-vestibule cars came into general use.

Sleeping cars were operated in the U.S. as early as 1837, and the first Pullman sleeper was placed in service in 1859; sleeping cars were introduced in Britain in 1879.

In Europe there was a gradual trend toward longer and lighter passenger vehicles. The standard British coach measures 67 ft. in length, while continental designs are up to 86 ft. 6 in. long. The introduction of steel, first for coach frames and later for frames and bodies, added to the weight of vehicles. An all-steel continental coach might weigh up to 45 metric tons, or 55 metric tons for a sleeping car. However, it was found possible to reduce these weights without loss of strength by using lightweight steels, stainless steels and light alloys. For example a modern lightweight steel coach of the Swiss Federal railways is 73 ft. long, seats 80 passengers and has a tare weight of only 26 metric tons. In contrast, typical U.S. passenger cars weigh from about 60 to 80 short tons, or even more.

Experiments have been carried out with ultra-lightweight trains. The Spanish railways operate a number of lightweight sets, called Talgo trains, consisting of several short coach units, each resting at one end on a single axle. At the other end the weight is carried on a pivot which forms part of the next vehicle, and the leading coach is supported on the diesel locomotive. The train is thus made up of a series of jointed units and, having a very low centre of gravity, it can traverse curves at high speed.

The interior accommodations of passenger cars vary widely. In Europe the six- or eight-seat compartment with the corridor along one side of the coach is still favoured, although the use of coaches with a centre aisle has increased, particularly for suburban service. Reclining coach seats were adopted by a number of systems for long journeys.

United States passenger cars use the centre-aisle arrangement almost exclusively, except for some sleeping cars. Besides the coach, with its two rows of seats, the modern U.S. passenger train may include several types of sleeping cars for overnight travel, a dining car and a lounge or observation car. In addition, "head-end" cars—for mail, express and baggage—are operated in most U.S. and Canadian passenger trains.

A typical modern sleeping car has six bedrooms (each with two beds) in the centre of the car, with six roomettes (each with a single bed) at each end. Thus the total capacity of the car is about 24 persons. This relatively low capacity produces low revenue, making necessary rather high fares to cover the cost of operating the car. The high fares, in turn, discourage patronage in competition with the much faster airlines. This is the basic problem of sleeping-car service under modern conditions.

As one answer to this problem, the Budd company in the U.S. developed the "slumbercoach," a sleeping car similar to the European compartment coach. It has eight small double rooms and 24 single rooms. The total capacity of 40 makes possible rates only slightly above the standard coach fare. In use on a few lines in the U.S., slumbercoaches proved highly successful.

The dome car, developed in the U.S. after World War II, enables passengers to ride under a raised, glassed-in roof section from which they have a wide-range view of the countryside. Below the dome section may be sleeping rooms, a lounge section or coach seats. Although costly to build and operate, dome cars without doubt helped attract patronage. They became widely used on railways having scenic routes in the western U.S. and Canada. The same type of service was adopted in other countries as well, notably in France and Italy.

With growing industrialization many countries began building their own rolling stock, whereas previously they had obtained their cars from European or American builders. Many of the cars in service have been designed to suit climatic and other special conditions of the countries in which they operate. *Narrow-gauge railways also impose restrictions as to weight and size. Even so, a 3-ft. 6-in. gauge coach of the South African railways, for example, may be up to 63 ft. 5 in. long and weigh up to $43\frac{3}{4}$ long tons. In Australia the trend has been to longer coaches, many of which follow the American pattern in design and appearance.

C. Standardization of Running Gear

Although U.S. and Canadian railways build many different types of cars to suit their own needs or whims, most of the cars may operate interchangeably among railways. Through the work of the mechanical division of the Association of American railroads (and its predecessors) the elements of the running gear—wheels, trucks, draft gear, couplers and brakes—have been standardized. Not only does this permit any car to operate over almost any railway on the North American continent, but it also allows any railway to repair or maintain any car it is using, regardless of who owns the car.

This mechanical standardization was an important factor in the growth of the American railway industry, yet it does impose some problems. Any improved type of coupler or brake, for example, must be compatible with existing older equipment if it is to be used on cars operated in interchange service. However, despite this limitation, mechanical progress has been steady. Roller bearings almost entirely replaced the traditional plain journal bearings on passenger cars and locomotives, and came into increasing use on freight cars. Several improved types of automatic couplers were adopted; an improved freight air brake, the type AB, became universal, and wheels were constantly improved. Truck or bogie spring systems were made more effective against vertical shocks and oscillations in moving cars, and the draft gear used in freight cars was refined to provide more cushioning against longitudinal jolts.

As a result of these changes, the mechanical standards of freight cars approached more and more those of passenger cars. This was a necessity, because longer trains were being operated at higher speeds, and it became even more urgently necessary to prevent damage to merchandise in transit.

1. Couplers.—European couplers originally consisted of nothing more than chains linking the vehicles, with solid buffers to help absorb the shock when one vehicle came in contact with another. Later, spring buffers were introduced, along with screw couplings that permit two vehicles to be brought together so that buffer faces are just touching; this helps to ensure smooth starting and stopping.

During their first half-century, U.S. railways used a crude link-and-pin coupler that was extremely dangerous to employees who had to couple cars. Beginning in 1882, American railways began to convert to the knuckle-type automatic coupler. This basic design, built heavier for today's larger cars and much improved in detail, is still the North American standard. Knuckle couplers are also used in many other countries, notably Japan, Russia and Australia. In fact, the majority of non-European railways use automatic couplers of one pattern or another.

In Britain, automatic centre couplings were tried out on the Great Northern railway in 1898. Later, automatic couplings were used on the main-line passenger coaches of the London and North Eastern and the Southern railways. In 1948 British railways adopted this type of coupler for all their main-line coaches. and experiments later began on an automatic coupler for freight cars.

Multiple-connection automatic couplings have been adopted by a number of railuays, principally for diesel rail-car trains or MU electric trains. This type of coupling incorporates connections for the continuous brakes, heating and electrical controls, as well as joining the vehicles together.

Instead of buffers, U.S. cars have draft gear, directly behind and attached to the couplers, which may employ spring, friction, rubber or hydraulic elements to help absorb coupling and operating jolts. The standard draft gear is mounted in a pocket 24- or 36-in. long, but a number of long-travel draft gears and cushioned centre sills have been developed to give greater protection to fragile commodities.

2. Brakes.—Two continuous braking systems are in general use —the vacuum brake and the compressed-air brake. Of the two, the more popular is the air brake, patented in 1869 by George Westinghouse and made compulsory in the U.S. by the Railroad Safety Appliance act of 1893. The vacuum brake is used principally in Britain, where continuous brakes have been compulsory on passenger vehicles since 1889. With either system, every vehicle is connected by a brake pipe; therefore, application of the brake on the locomotive applies brakes throughout the train.

Although virtually all passenger rolling stock throughout the world is equipped with continuous brakes, this is not the case with freight cars. The majority of British freight cars, for example, do not have continuous brakes, although steps have been taken to remedy this situation. In other countries the bulk of the freight stock is fitted with continuous brakes.

The brake itself takes the form of a single or double shoe which presses against the wheel tread. The disk brake also has been widely used on U.S. and Canadian passenger trains (see also BRAKE).

3. Dual-Gauge Vehicles.—Vehicles capable of running on more than one gauge are in use in Europe. The Spanish Transfesa company operates freight cars that can be used on the 5-ft. 6-in. broad gauge of Spain and on the standard 4-ft. 84-in. gauge of other European countries. Special apparatus at frontier yards enables wheel sets of one gauge to be exchanged quickly for those of the other. Similar arrangements, on a larger scale, are to be found at certain Russian frontier stations, so that 5-ft. gauge Russian passenger coaches can receive standard-gauge trucks and operate into east and west European countries.

In some countries special cars are used to carry cars of a different gauge in piggyback fashion. In Australia, for example, complete trains of specially adapted flatcars are in use to carry, in turn, entire trains of a narrower gauge, thus obviating the need for transshipment of freight.

V. CAR AND LOCOMOTIVE MAINTENANCE

The design, construction and maintenance of rolling stock is a responsibility of a railway's mechanical department. In steam locomotive days, some of the larger railways (both in the U.S. and elsewhere) built their own locomotives, as well as many of their own cars. However, U.S. railways did not build new diesel locomotives, although there was a trend toward building cars in railway shops rather than having them built by the commercial car manufacturers.

In terms of money spent for wages, materials and the operation of shops, rolling stock maintenance is a vast operation. In normal years U.S. railways, for example, spend about 18% of their income for this purpose.

Railway shops perform all the operations and contain much of the machinery common to a heavy manufacturing industry. Moreover, railway shop production was being organized more and more around assembly-line techniques. just as in other industries.

1. Locomotive Shops.—In contrast to the steam locomotive back shops that railways formerly required on each operating division, the dieselized railway usually needs only one heavy repair shop. Here the locomotives are more or less completely dismantled and their major components—engines, electrical equipment, running gear—are either completely overhauled or renewed. Under normal conditions, a diesel locomotive is given heavy repairs or rebuilding only after a period of perhaps five to seven years. Between these major overhaulings, a locomotive receives maintenance attention usually on the basis of mileage; that is, certain routine maintenance work is performed at specified mileage intervals (in the U.S., certain inspection and maintenance work is prescribed by the Interstate Commerce commission).

In addition, of course, locomotives also are given certain routine inspections at the end of each run. Although many railways still use converted roundhouses for much diesel maintenance, others have found that specially built diesel shops are more efficient.

2. Car Shops.—Freight car maintenance may be classified as running repairs, intermediate repairs and heavy repairs or rebuilding (the exact definition of each varies among railways). As trains enter terminal yards they are inspected for running gear or other defects. Any cars requiring attention are switched out of the train and sent to the "rip track," a shop equipped to do light repair work such as wheel changing, air-brake repairs and minor repairs to the car bodies.

If a car has been severely damaged, it may be sent to a heavy repair shop. Often, railroads rebuild an entire series of cars. This is most likely to occur after the cars have seen 15 or 20 years of service. The rebuilt cars may be equipped with entirely new bodies and emerge from the assembly-line car shop the virtual equivalent of new cars.

VI. BRIDGES, BUILDINGS AND TUNNELS

The fixed plant of a railway consists of much more than just the track itself. In the U.S. alone, about 4.000 mi. of line are on bridges. In mountainous country, tunnels must be built to avoid excessive grades or excessively roundabout routes. Where mountain railways are not in tunnels they must often be protected by snow sheds against drifting and avalanches. In addition, railway engineering departments are concerned with constructing and maintaining thousands of different buildings ranging from small watchman's shanties to huge passenger terminals.

1. Bridges.—The designer of a railway bridge faces some challenging problems. He must allow for the forces that result from the concentrated impact as a train moves onto the bridge, the pounding of wheels, the sidesway of the train, the drag or push effect as a train is braked or started on the bridge. These factors mean that a railway or rail-highway bridge must be designed more stringently than a highway bridge. The heavier construction of a railway bridge designed for main-line traffic, as compared with a highway bridge of similar length, is usually quite evident even to a casual observer.

As trains and locomotives became heavier, bridges had to be strengthened accordingly. In the past, newer, heavier steam locomotives usually caused the need for stronger bridges, but modern diesel-electric locomotives are less damaging to bridges than large steam locomotives. However, as freight loads became heavier and train speeds higher, railways still had to design and build their bridges to high standards.

Besides the need to strengthen bridges, there was another major objective in much modern railway bridge construction: reducing maintenance costs. This became evident in the widespread trend toward replacing timber trestles with concrete slab structures or with concrete or steel-pipe culverts. Prestressed concrete slab bridges came into use on an increasing scale. All-welded steel bridges, although remaining relatively rare on railways, became more common, as did the use of high-strength bolts rather than rivets for field assembly of bridge spans.

Under the spur of rising labour costs, U.S. railways sought ways to mechanize the maintenance of bridges and other structures. Typical of solutions to the problem were the bridge sprayer machines used to apply protective coatings, as well as special types of derrick equipment for replacing bridge ties and stringers. *(See* also BRIDGES.)

2. Buildings. — Railway buildings in the 20th century became fewer and more functional. The newer types of motive power, for instance, required only a few maintenance shops. Car shops, too, were being consolidated into fewer but usually more modern structures. In North America, the declining importance of passenger traffic resulted in the elimination of many passenger stations, and some local freight stations were removed, too, since with paved highways almost everywhere, it became more economical to concentrate freight terminal operations at a few large stations.

Only a few really modern passenger stations have ever been built in the U.S. One is the Los Angeles Union Passenger terminal; one of the latest is the New Orleans Union Passenger terminal, completed in 1954. Grand Central terminal in New York city, completed in 1913, is perhaps the best-known railway station in the world: approximately 150,000 passengers use it daily. In contrast, however, approximately 580,000 use the Tokyo station of the Japanese National railways daily.

Europe, however, has a number of large, modern passenger stations. One of the most striking is Rome Termini, the construction of which started in 1938, although it was not completed until 1951. Of prewar construction is the Central station, Milan, one of the largest in Europe. Opened in 1931, it has 22 platforms, of which 18 are 1,051 ft. long.

3. Tunnels. — Although it is a highly expensive form of construction, tunneling provides the most economical means for railways to traverse mountainous terrain and to gain access to the heart of a crowded city. However, railway tunnels confront the construction engineer with some unique problems, particularly in matters of ventilation on nonelectrified lines. Some examples of famous tunnels and methods of construction may be found in the articles TUNNEL and SUBWAY (UNDERGROUND RAILWAY).

VII. COMMUNICATIONS AND SIGNALING

A. COMMUNICATIONS

Modern railways have operating and service problems as complex as those of a major manufacturing concern — in some respects even more so. The railway's plant and its operations may be spread out over thousands of miles of line serving hundreds of communities. Quick communication between stations is usually essential in the operation of trains. It is also required in order to give service information to the public and to carry on the vast amount of routine correspondence and accounting data that a railway enterprise generates.

1. Telegraph and Telephone. — Railways were among the first to adopt the electric telegraph and the telephone. The railway telegraph dates back to 1837, when it was tried on the London and Birmingham line. In the U.S., the telegraph was first used for dispatching trains in 1851; the telephone was first tested in 1877.

Modern railways are among the larger operators of electrical and electronic communications facilities. For example, the dial telephone network of the S.P. system covers the entire western area of the U.S. It allows personnel anywhere on the railway and its affiliates to dial direct to offices anywhere on the 14,000-mi. rail system serving 12 states. Other railways have similarly extensive telephone systems.

The Morse telegraph, originally used in North America for all railway business messages as well as train dispatching, eventually was relegated to use only on some secondary and branch lines, and train dispatching was done almost entirely by telephone, or by centralized traffic control signaling.

For message communication other than that. involved in dispatching of trains, most U.S. railways came to rely heavily on the printing telegraph (Teletype) as well as the telephone. Many railways installed teleprinter networks to connect all stations, engine houses, yard offices and general offices.

The teleprinter is used for many purposes beyond the exchange of routine messages. One of the more noteworthy developments is the transmission of the complete train "consist" (or list of cars in the train) by teleprinter from the origination point of a train to the next terminal on its route. By having the exact train consist, the destination terminal can plan switching operations well in advance of a train's arrival.

Simultaneously, the same train consist list may be transmitted to the railway's general headquarters, where it can be used to inform customers of the whereabouts of their shipments. The consist can also go to the car records office, which records the movements of individual cars, and to the accounting department.

More and more, railways in the 1960s moved toward the concept of integrated data processing, which requires a data-processing centre usually located at company headquarters. Operations and accounting data of many types may be fed into this centre direct from outlying points on the railway. Often, one or more large electronic computers may be included in the complement of business machines.

Central data processing requires a large number of communications circuits. The capacity of a single pair of telegraph lines may be increased many times by superimposing on it a number of electronic "carrier" circuits, each operating in a different frequency range. But modern demands for circuits in some cases even exceeded the capacity available through carrier equipment. Thus, some railways turned to broad-band radio beams (microwave) to supply the many channels needed for direct telephone dialing systems and teleprinter and data processing circuits.

2. Radio. — In 1959 the Pacific Great Eastern railway, between Vancouver and Dawson Creek-Fort St. John, B.C., became the first railway to use microwave radio for all line-side communications, doing away almost entirely with line wires. Other major North American carriers, notably the Santa Fe, S.P. and U.P., also installed extensive microwave systems. Microwave has the additional advantage of minimizing communication failures in areas subject to heavy sleet and snowfalls, which might bring down conventional open-line wires.

American railways also began to use very high-frequency (VHF) radio on a large scale after World War II. In freight operations VHF permits communication between the locomotive and caboose of a long train, between two trains, and between the train dispatcher and wayside stations and trains.

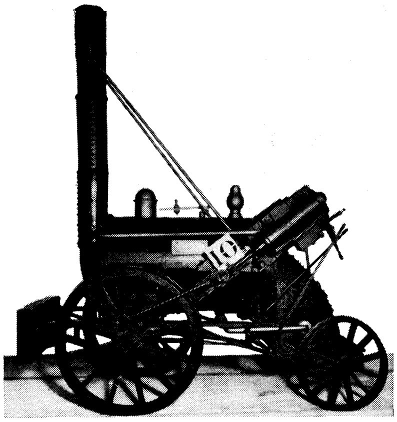
In terminals, radio greatly speeds yard switching work, because it allows the yardmaster to keep in close touch with the yard engines. Through VHF radio, too, widely separated elements of mechanized track maintenance crews can maintain contact with each other and with oncoming trains. Supervisory personnel use radio in their automobiles to keep in touch with activities under their jurisdiction.

To some extent, train radio took over some of the communication functions formerly reserved for the locomotive whistle. Enginemen commonly use standard combinations of long and short whistle sounds to communicate with the rest of the train crew and with wayside stations. On U.S. passenger trains, an intra-train air whistle system allows the conductor or trainmen to signal the engineman.

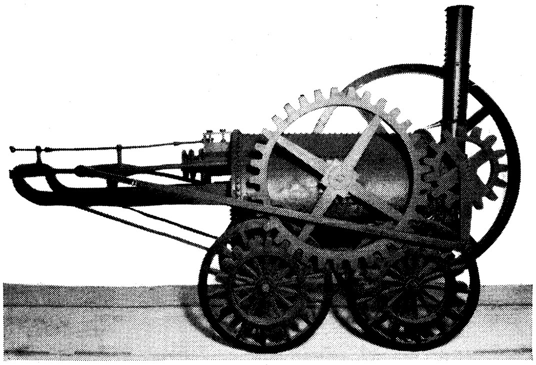
B. SIGNALS

Railway signals are a form of communication designed to inform the train crew (in particular, the engine crew) of track conditions ahead and to instruct it in the operation of the train.

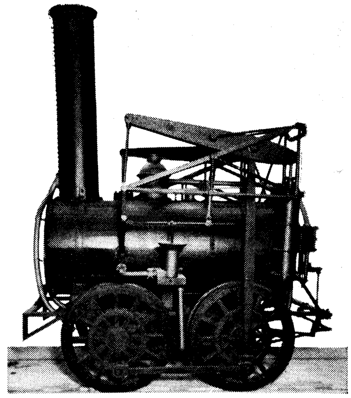
The earliest form of signaling consisted of a lamp by night or a flag during daylight. The first movable signal was a revolving board, introduced in the 1830s and followed in 1841 with the semaphore signal, which provided "stop," "proceed with caution" and "all clear" indications. Among the widely used early types of signals in the United States was the highball signal, consisting of a large ball, hoisted to the top of a pole, to inform the engineman that the train might proceed.



The "Rocket," built by George Stephenson. It was the winner of the 1829 trials by the Liverpool and Manchester railway, England



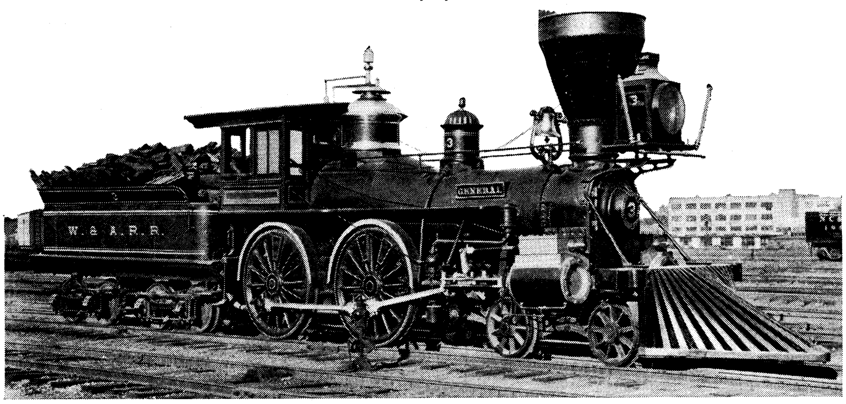
Richard Trevithick's "New Castle," 1803, the first locomotive in the world to do actual work



The "Stourbridge Lion," built in England and shipped to the U.S. where it was placed in operation in 1829

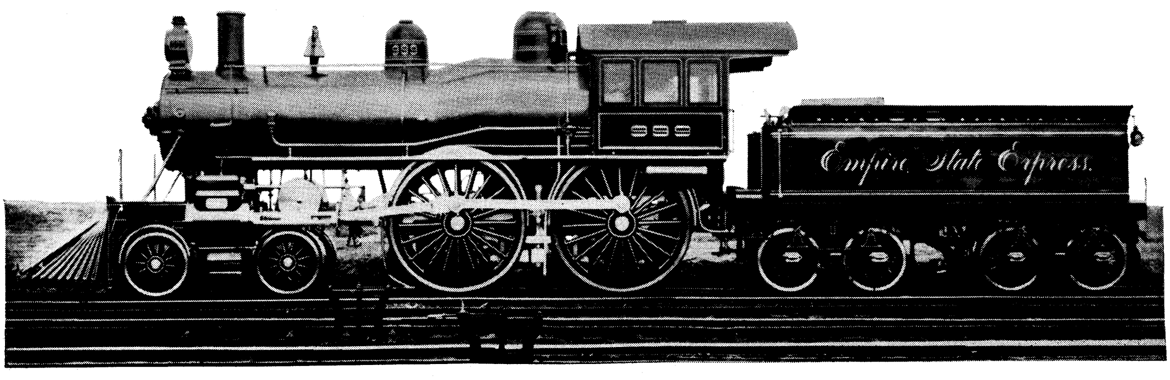
The "Best Friend of Charleston," first locomotive built in the U.S. for regular service on a railway. It began scheduled passenger service in 1830 from Charleston, S.C., over a route which eventually became part of the Southern Railway system

HISTORIC LOCOMOTIVES OF ENGLAND AND THE U.S.



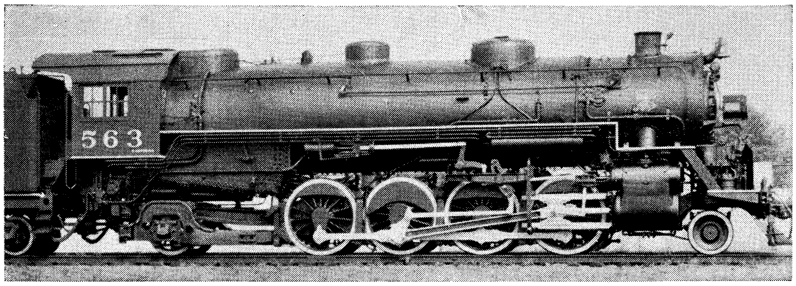
Tl "General,' active during the American Civil War. h locomotive 'a the basic type of the American class (4-4-0 wheel arrangement), a design which continued in service until the 20th century

Engine 999 of the Empire State Express, New York Central railroad, a somewhat later version of the 4-4-0 type. It set a speed record of 112.5 m.p.h. in 1893

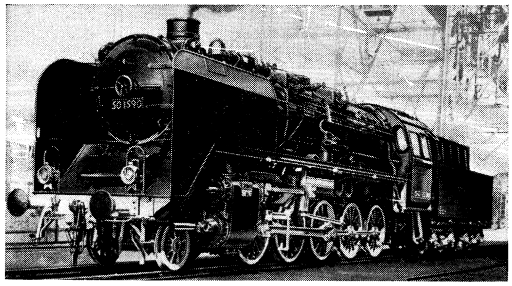


BY COURTESY OF (TOP LEFT, TOP CENTRE, TOP RIGHT) BALTIMORE AND OHIO RAILROAD COHPANY, (CENTRE ABOVE) SOUTHERN RAILWAY SYSTEM, (CENTRE BELOW) LOUISVILLE & NASHVILLE RAILROAD COMPANY, (BOTTOM) THE HEW YORK CENTRAL RAILROAD COMPANY

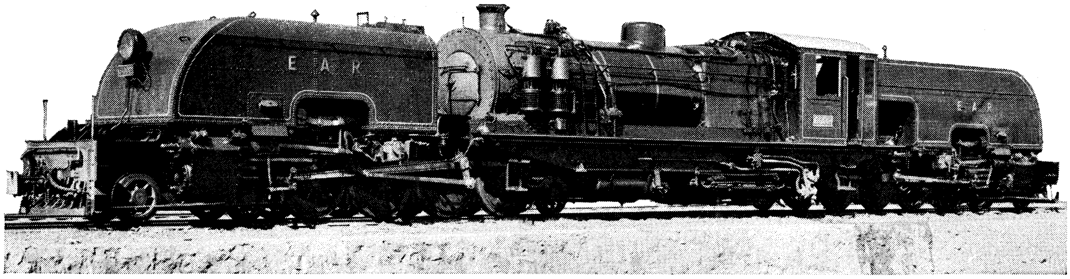
RAILWAY



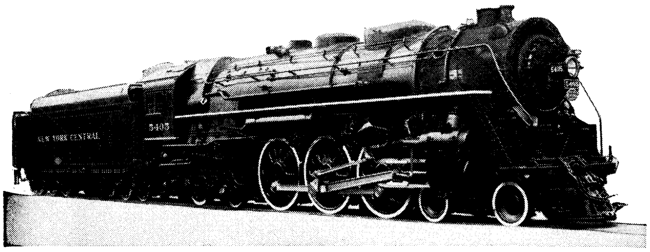
Mikado (wheel arrangement 2-8-2), a heavy-duty freight locomotive of the U.S.



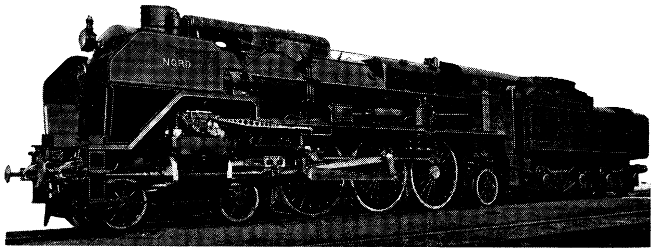
Decapod class (2-10-0) locomotive of Germany, a typical freight engine widely used in Europe



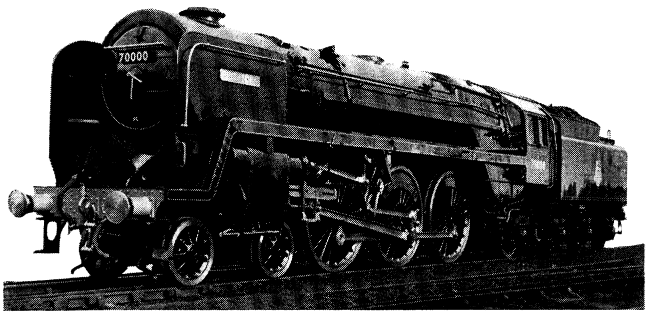
Beyer-Garratt articulated type (4-8-2-2-8-4), a unique design with its weight spread over considerable length and also capable of operating over railroads with sharp curves. Used in Africa, Asia and Australasia



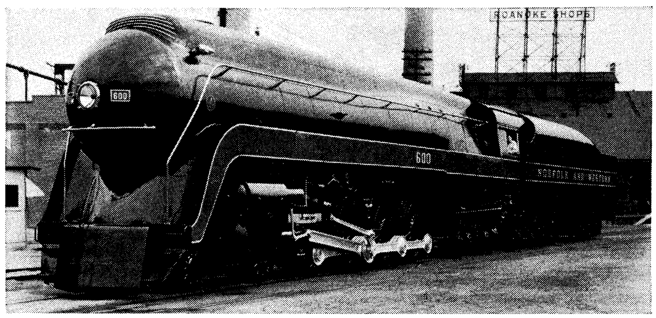
Hudson or Baltic type (4-6-4), used extensively on U.S. lines for high-speed, heavy-duty passenger hauling during the steam locomotive era



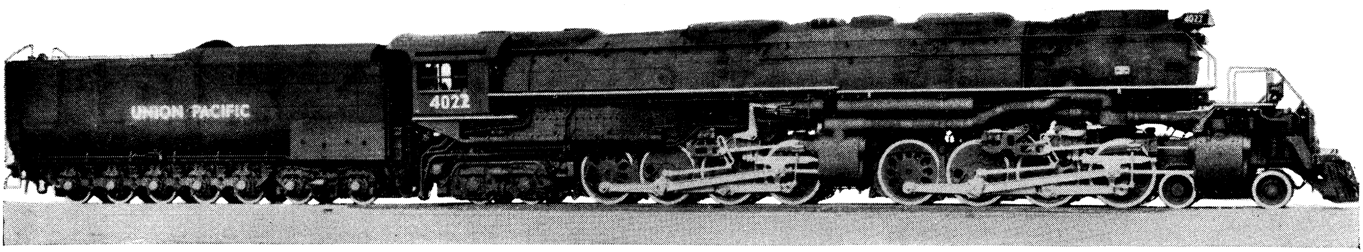
Pacific (4-6-2) of the French railways, typical locomotive of the years between World War I and World War II



Another Pacific, the British "Britannid" class, a standard type used after World War II



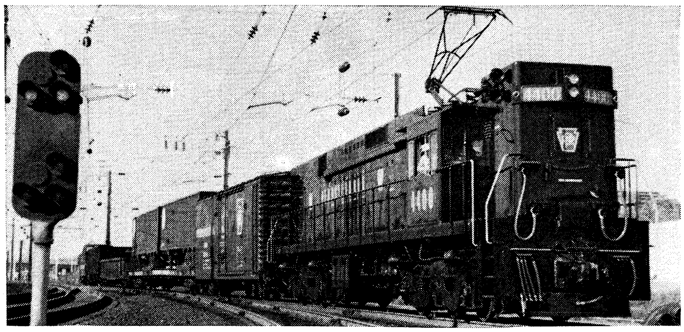
A U.S. "streamliner," a modification of the Northern or Niagara (4-8-4), a final stage of development of steam locomotives for passenger service



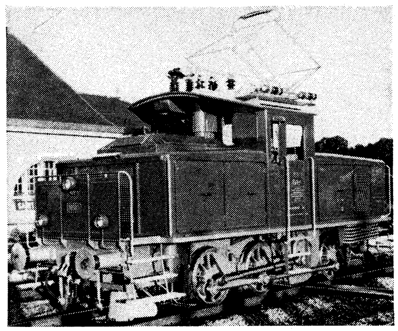
The "Big Boy" (4-8-8-4) of the Union Pacific railroad (U.S.), considered to be the largest steam locomotive ever built. Used for hauling freight in mountainous areas

STEAM LOCOMOTIVES

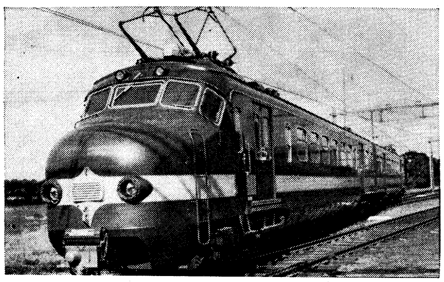
BY COURTESY OF (TOP ROW LEFT) LOUISIANA & ARKANSAS FROM ASSOCIATION OF AMERICAN RAILROADS, (TOP ROW RIGHT GERMAN FEDERAL RAILROAD, (SECOND ROW) EAST AFRICAN RAILWAYS & HARBOURS, (THIRD ROW LEFT NEW YORK CENTRAL RAILROAD (THIRD ROW RIGHT) NORD FROM FRENCH NATIONAL RAILROADS (FOURTH ROW LEFT) BRITISH RAILWAYS, (FOURTH ROW RIGHT) NORFOLK & WESTERN RAILWAY FROM ASSOCIATION OF AMERICAN RAILROADS, (BOTTOM) UNION PACIFIC RAILROAD



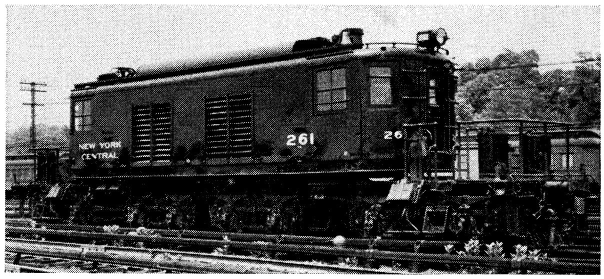
Rectifier locomotive of the Pennsylvania railroad (U.S.), a large, post-World War II model of the C-C type



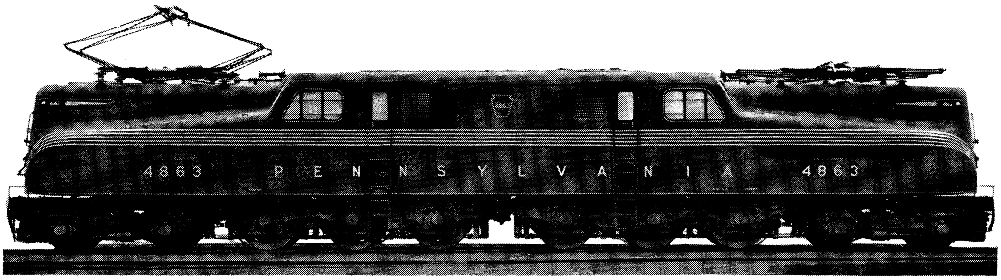
Variable frequency switching engine of the Swiss Federal railways. Operates on either 15,000-v., $16\frac{2}{3}$-cycle or 25,000-v., 50-cycle A.C.



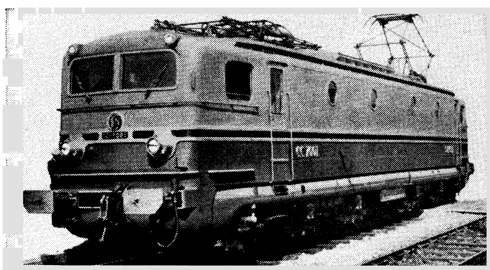
Dual voltage "Benelux," a passenger train operating in Belgium and the Netherlands



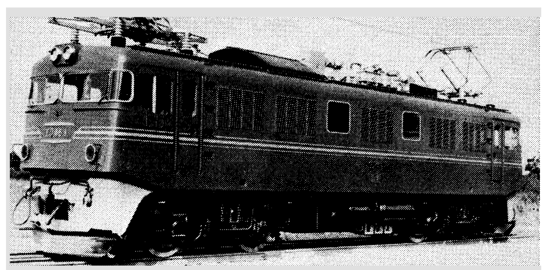
Class T type of electric locomotive ot the New York Central railroad



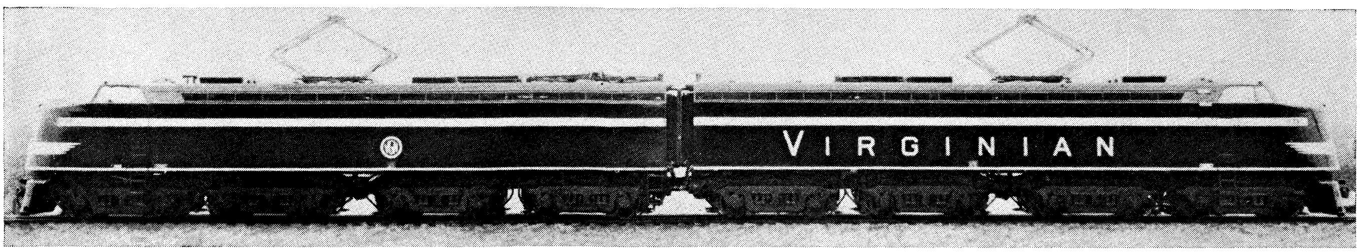
Pennsylvania railroad (U.S.) GG-1, a 2-C+C-2 electric used for high-speed passenger and freight operations



French C-C type which operates on 1,500-v. D.C. Set a world speed record of 205 m.p.h. in 1955



Japanese B-B unit which can operate from commercial-frequency A.C. (50 c.p.s.) or 1,500-v. D.C.

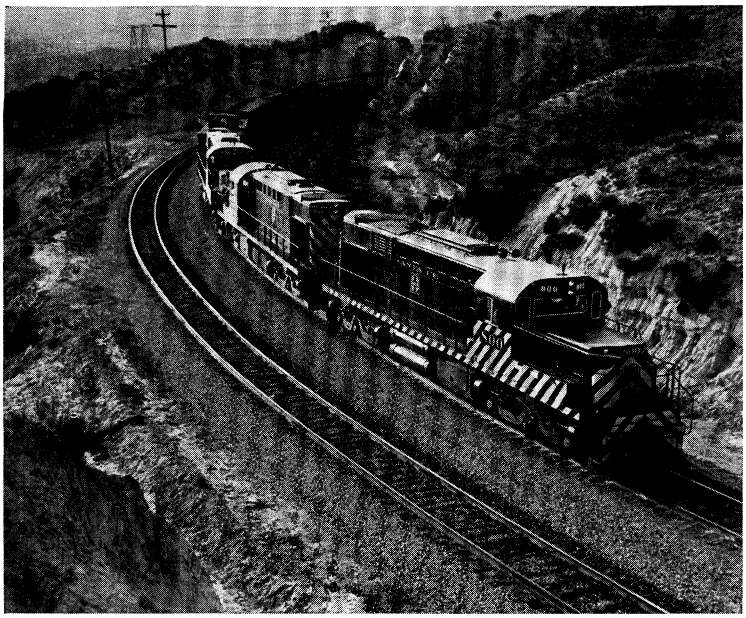


Large electric locomotive of the U.S., a two-unit type developed for the Virginian railway, later absorbed into the Norfolk and Western. The locomotive operates on 11,000-v., 25-cycle A.C. power, converted to D.C. by equipment carried on board

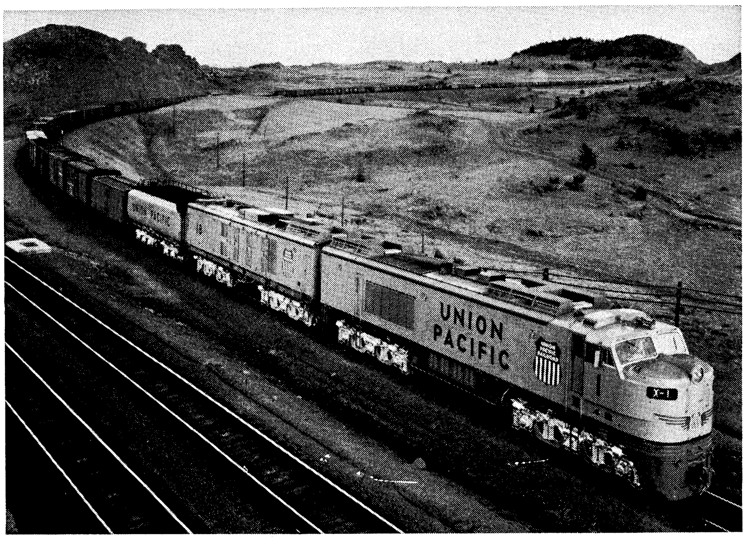
ELECTRIC LOCOMOTIVES

BY COURTESY OF (TOP ROW LEFT AND THIRD ROW) PENNSYLVANIA RAILROAD, (TOP ROW RIGHT) SWISS NATIONAL TOURIST OFFICE, (SECOND ROW LEFT) NEW YORK CENTRAL RAILROAD, (SECOND ROW RIGHT) N.V. NEDERLPNDSCHE SPOORWEGER, (FOURTH ROW LEFT) FRENCH NATIONAL RAILROADS, (FOURTH ROW RIGHT) JAPANESE NATIONAL RAILWAYS, (BOTTOM) THE VIRGINIAN RAILWAY FROM ASSOCIATION OF AMERICAN RAILROADS

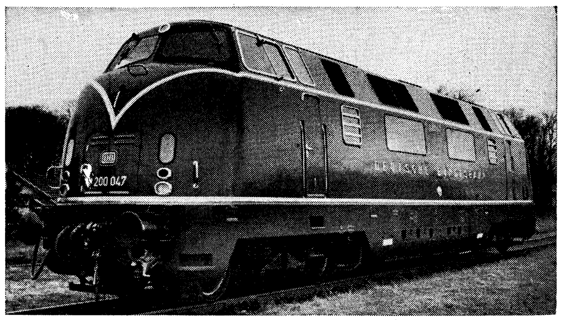
RAILWAY



Three DL-600 locomotives, 2,400-h.p. modern diesel-electric units powered by 16-cylinder engines. Sante Fe, U.S.

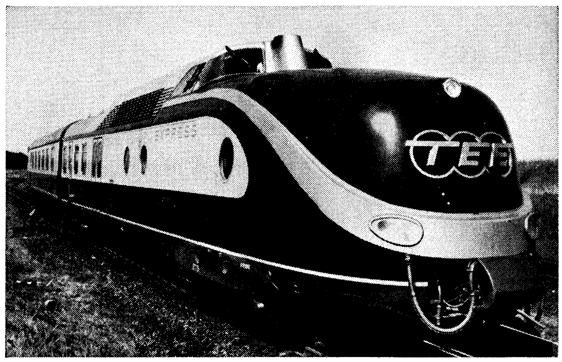


Gas-turbine locomotive of the Union Pacific railroad, an 8,500-h.p. unit which can develop high speeds with heavy trains such as the long freight shown in the photograph

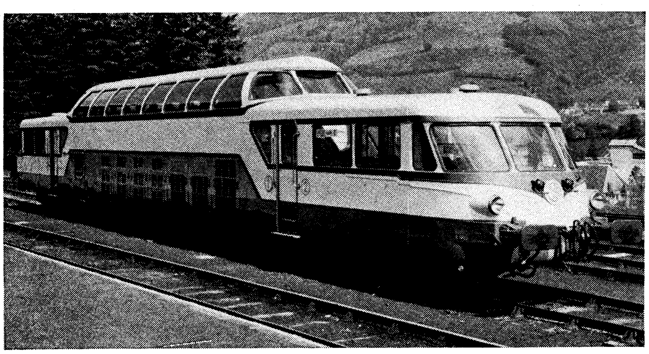


Diesel-hydraulic type, the V200, a 2,000-h.p. locomotive of the German Federal railroad

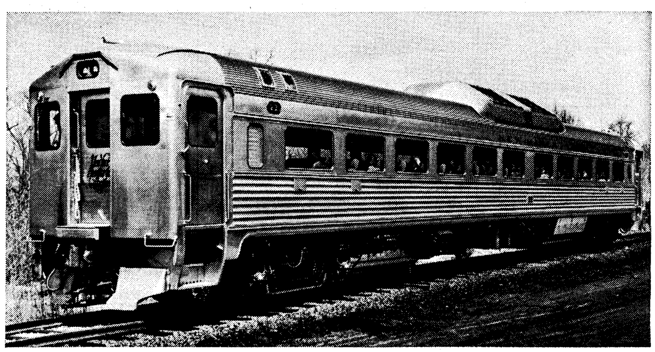
TE-3, part of a twin-unit diesel-electric of the Soviet railways. Each of the C-C type articulated units is equipped with a 2,000-h.p. engine



Diesel locomotive unit of a Trans-Europ express (T.E.E.) train. T.E.E. trains serve eight nations on international runs. They are operated jointly by the Dutch, Swiss, German, French and Italian railways



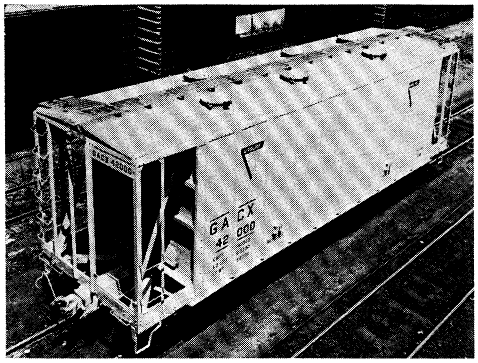
Diesel rail car of the French railways, a self-propelled passenger unit equipped with a domed observation section



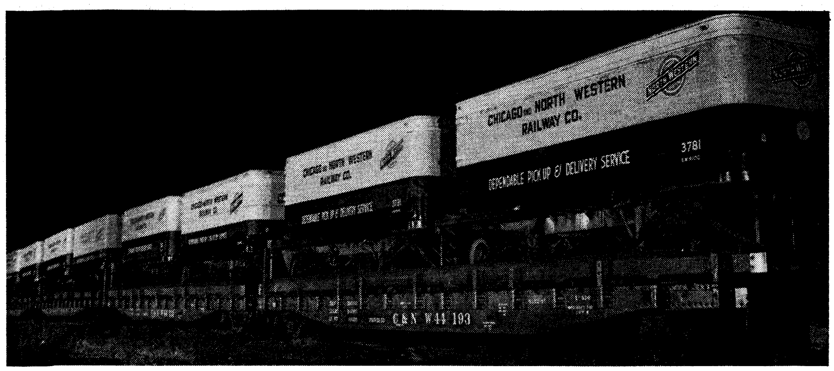
Self-propelled rail diesel car (R.D.C.) powered by a pair of 300-h.p., 6-cylinder diesels. Individual units can be joined to make up longer trains

DIESEL, GAS TURBINE AND OTHER SELF-PROPELLED UNITS

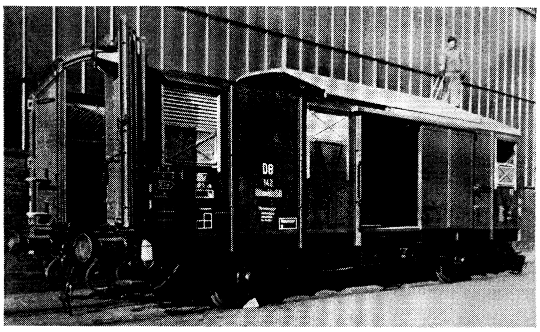
BY COURTESY OF (TOP LEFT) ALCO PRODUCTS, INC. (TOP RIGHT, CENTRE RIGHT BELOW) GERMAN FEDERAL RAILROAD. (CENTRE LEFT) UNION PACIFIC RAILROAD, (BOTTOM RIGHT) NEW HAVEN RAILROAD FROM ASSOCIATION OF AMERICAN RAILROADS; PHOTOGRAPHS, (CENTRE RIGHT ABOVE) SOVFOTO, (BOTTOM LEFT) AUTHENTICATED NEWS



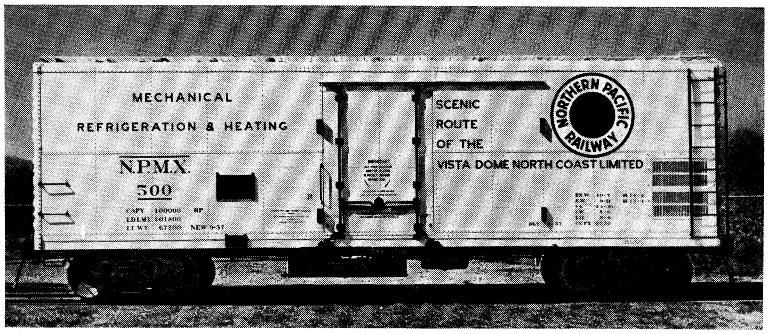
Covered hopper car for bulk shipment of dry products. **U.S.**



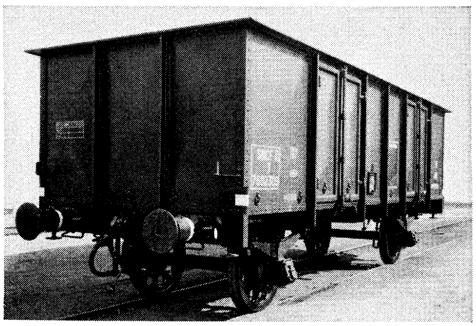
Flatcars equipped for "piggyback" service, the transporting of motor truck trailers, an innovation in railway service that grew rapidly in the **U.S.** after World War II



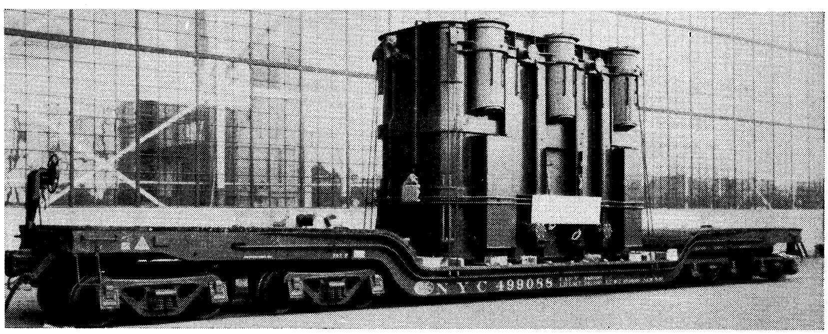
Sliding-roof boxcar permitting loading and unloading from the top as well as from the sides. German Federal railroad



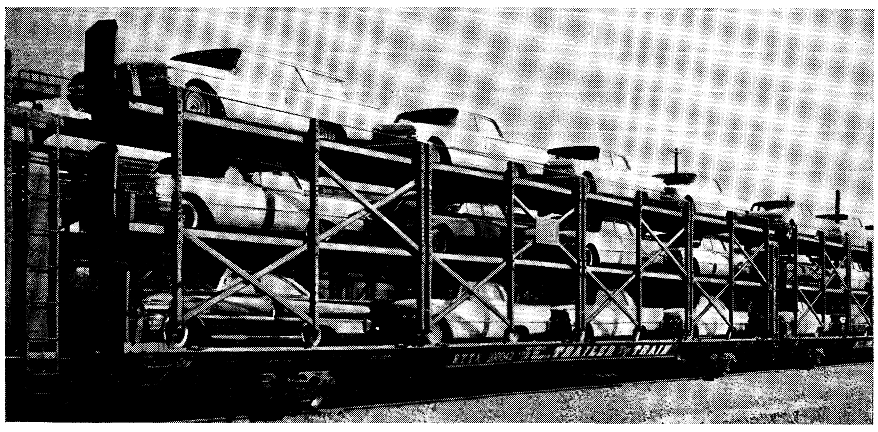
Car for transporting perishable goods, equipped with both refrigeration and heating facilities. **U.S.**



Gondola car owned by the French National railroads, but operated as a unit in the Europ freight car pool, co-operative plan of the International Union of Railways



Specialized flatcar with low central section designed to carry electric power transformers and maintain clearance in tunnels and under low bridges. The car is also unusual in its arrangement of 8 axles



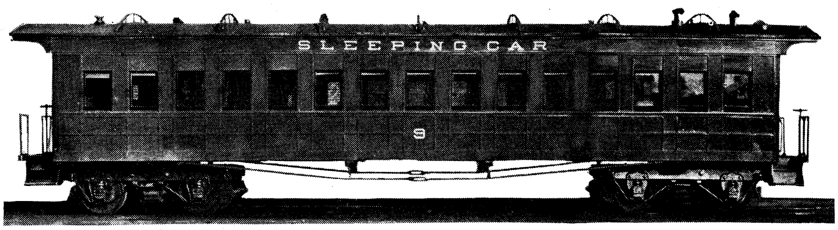
Modern automobile carrier of the **U.S.** railways, a flatcar equipped with two extra decks to accommodate a total of 12 automobiles

Gerrnan automobile carrier, a two-decked, five-axle type which will hold 10 compact cars

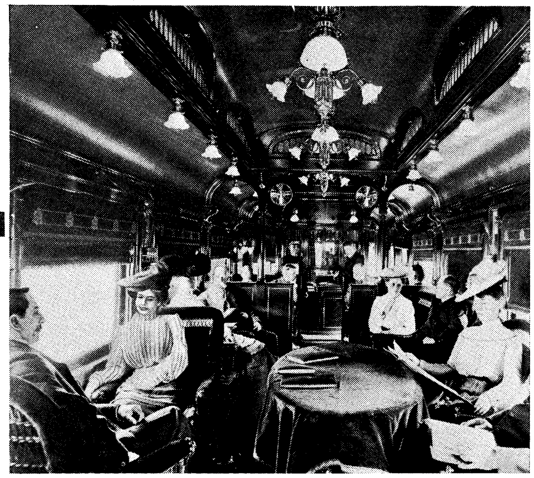
FREIGHT EQUIPMENT

BY COURTESY OF (TOP LEFT) ASSOCIATION OF AMEYICAN RAILROADS, (SECOND ROW LEFT, BOTTOM RIGHT) GERMAN FFDERAL RAILROAD, (SECOND ROW RIGHT) NORTHERN PACIFIC RAILWAY FROM ASSOCIATION OF AMERICAN RAILROADS, (THIRD ROW LEFT) FRENCH NATIONAL RAILROADS. (BOTTOM LEFT1 PULLMAN-STANDARD; PHOTOGRAPHS, (TOP RIGHT, THIRD ROW RIGHT) UNITED PRESS INTERNATIONAL

RAILWAY

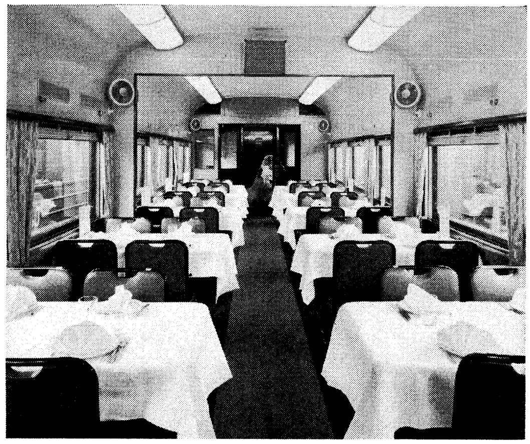


First Pullman sleeping car, a converted day coach which went into service in Sept. 1859

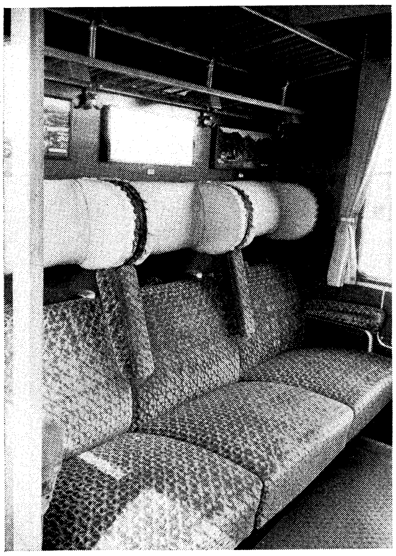


Interior of the "North Coast Limited," a luxury train of 1900, Northern Pacific railway. It was the first electric-lighted train of the U.S. northwest

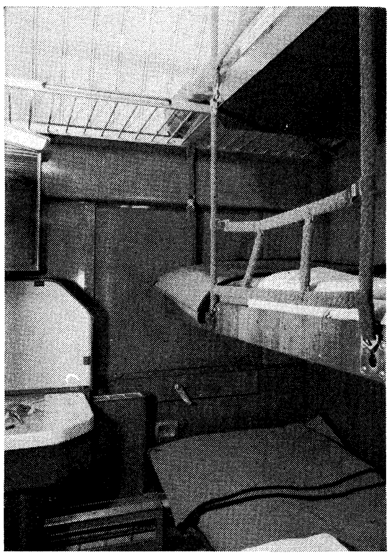
ETR 300 "Settebello," a high-speed electric passenger train of the Italian State railways. Unique design provides passengers with an observation area in the first car while the engineer operates the train in a "blister" cabin above



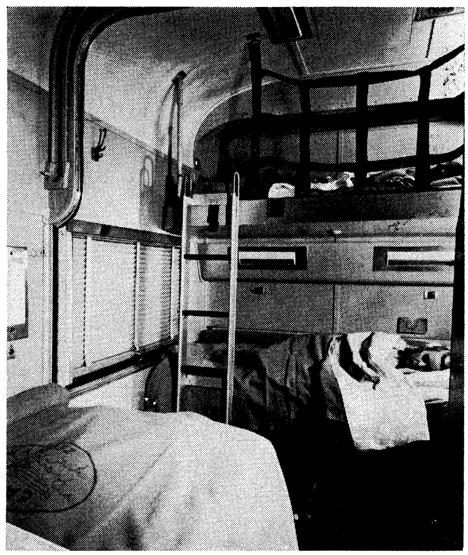
interior of an air-conditioned dining car of the Swedish national railways



First-class compartment, express train of the German Federal railroad



Three-bed sleeping compartment, tourist class. of the Wagon-Lits company which operates passenger equipment on railways of Europe, Africa and the middle east



Master bedroom of the "California Zephyr" of the Chicago, Burlington and Quincy railroad. It accommodates six passengers by day and has four beds (one not shown)

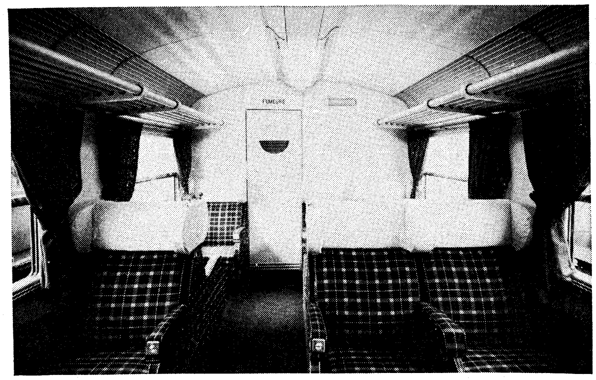
PASSENGER SERVICE, EARLY AND RECENT

BY COURTESY OF (TOP LEFT TOP RIGHT) ASSOCIATION OF AMERICAN RAILROADS, (CENTRE LEFT) ITALIAN STATE RAILWAYS. (CENTRE RIGHT) KUNGL JARNVAGSSTYRELSEN. (BOTTOM CENTRE) FRENCH NATIONAL RAILROADS, (BOTTOM RIGHT) CHICAGO, BURLINGTON & QUINCY RAILROAD COMPANY FROM ASSOCIATION OF AMERICAN RAILROADS: PHOTOGRAPH, (BOTTOM LEFT) AUTHENTICATED NEWS

Lounge car equipped with a full-length observation dome. in service on the "Empire Builder," Great Northern railway. U.S.

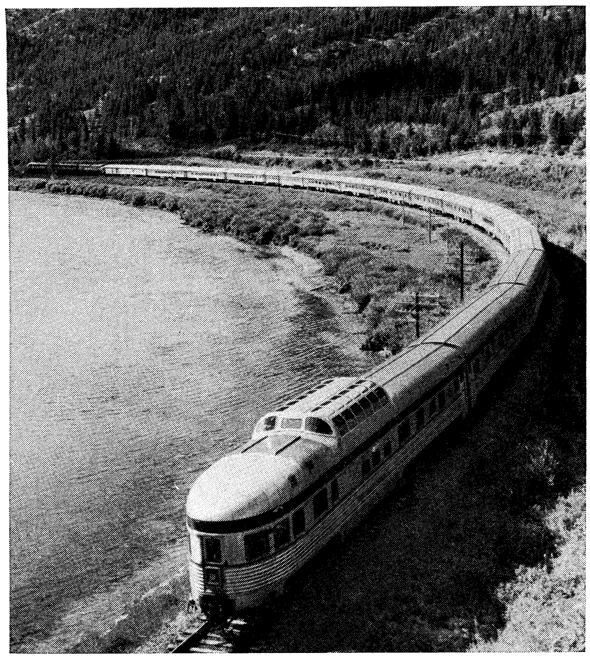
Modern passenger station at Rotterdam, the Netherlands

Remodeled ticket counter in the Pennsylvania station, New York city. Electronic devices, including television, were added to facilitate reservation handling



Reclining seats in a first-class coach of the French National railroads

Double-deck coach for commuters on the suburban divisions of the Chicago and North Western railway



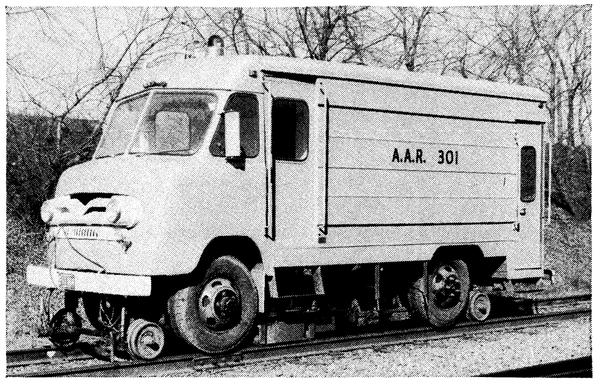
The "Canadian," a high-speed transcontinental passenger train equipped with two domed observation cars. Canadian Pacific rail. way

PASSENGER SERVICES

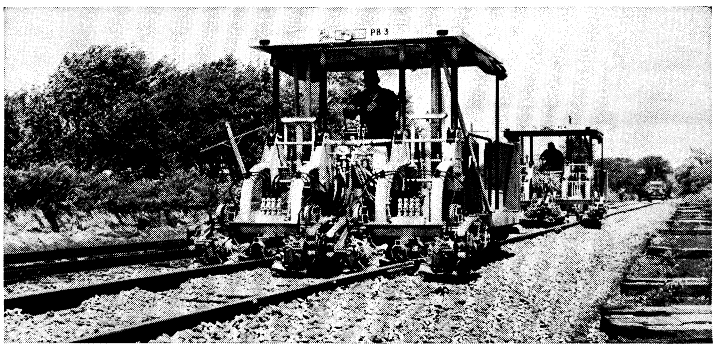
BY COURTESY OF (TOP LEFT) GREAT NORTHERN RAILWAY. (TOP RIGHT) FRENCH NATIONAL RAILROADS, (CENTRE LEFT) N.V NEDERLANDSCHE SPOORWEGEN, (BOTTOM RIGHT) CANADIAN PACIFIC; PHOTOGRAPHS, (CENTRE RIGHT) UNITED PRESS INTERNATIONAL, (BOTTOM LEFT) "ST. LOUIS POST-DISPATCH" FROM BLACK STAR

Rail-laying gang in action on a U.S. railway. Rails are lifted into place on wooden ties by derrick. Other units following align the rails, join rail sections and drive spikes into tie plates

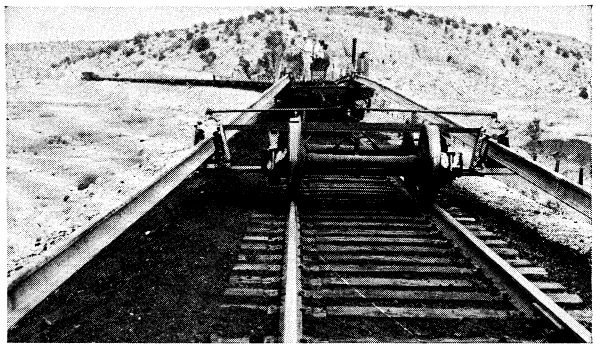
Adzing machines, which cut a uniform seat for tie plates before new rail is laid



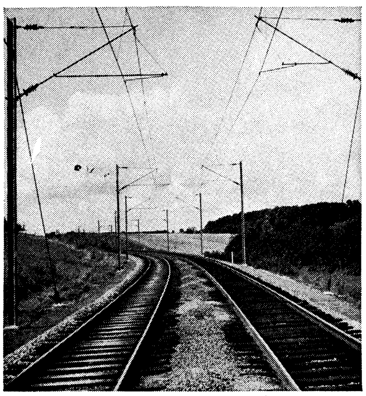
Rail inspection car equipped with electronic devices which detect the presence of flaws in rails. Rubber tires permit car to be driven off the rails onto highways



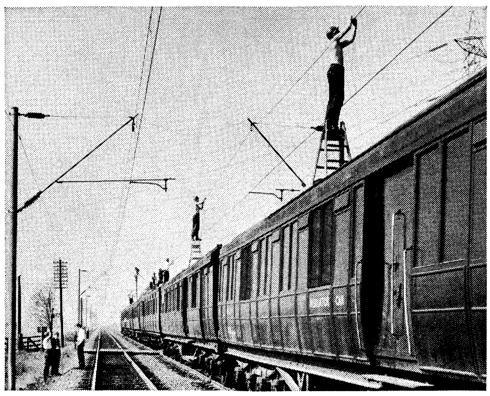
Track maintenance machines which tamp crushed rock roadbed ballast



Laying continuous rail sections. Steel rails are pressure welded into long units (in this case 1,440 ft.) and unloaded from flatcars



Lightweight wiring of 50-cycle, commercial-frequency electrification of French National railroads



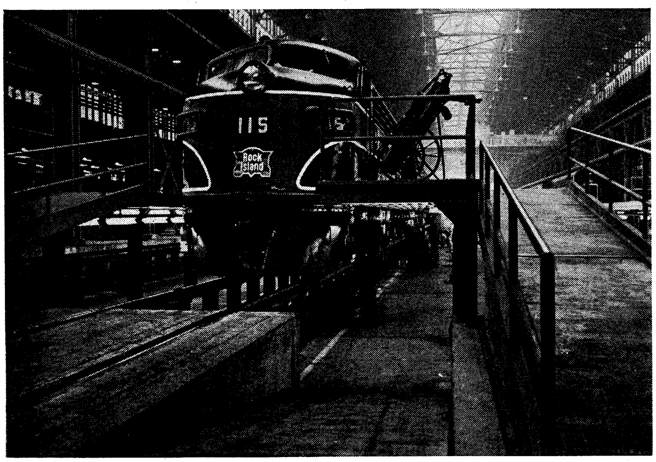
Installing an overhead electrical system on a division of the British railways

A modern roadbed: long welded rails set into concrete and steel crossties (sleepers)

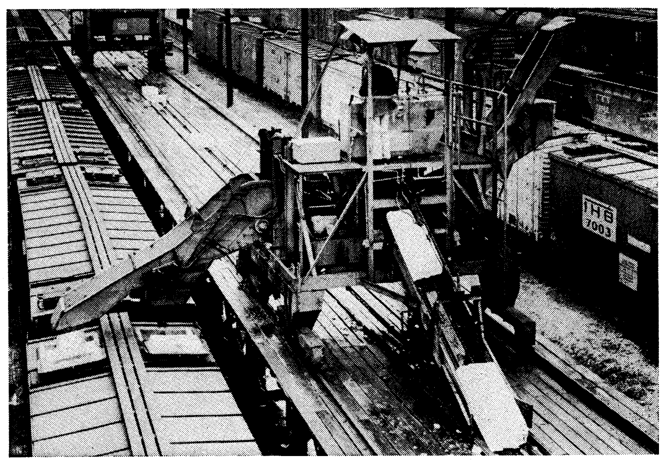
TRACK MAINTENANCE AND ELECTRIFICATION

BY COURTESY OF (TOP LEFT) NORFOLK & WESTERN RAILWAY FROM ASSOCIATION OF AMERICAN RAILROADS, (TOP RIGHT ABOVE) ERIE RAILROAD FROM ASSOCIATION OF AMERICAN RAILROADS, (TOP RIGHT BELOW, AND BOTTOM RIGHT) ASSOCIATION OF AMERICAN RAILROADS. (CENTRE LEFT) DELAWARE & HUDSON RAILROAD, (CENTRE RIGHT) SANTA FE RAILWAY. (BOTTOM LEFT) FRENCH NATIONAL RAILROADS. (BOTTOM CENTRE) BRITISH RAILWAYS

Turntable and roundhouse where locomotives receive cleaning and light repairs. Dieselization of American railways eliminated many such roundhouses originally built to provide the frequent maintenance required by steam locomotives

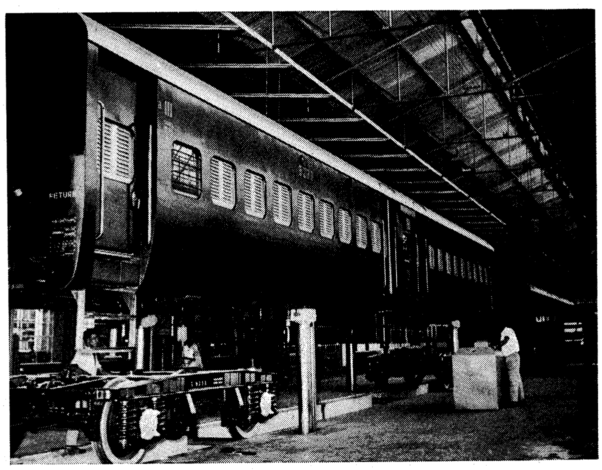


Diesel shop for light and heavy repairs. Work pits and platforms at three levels provide easy access to all parts of the locomotive



Modern re-icing unit which provides ice and salt for refrigerator cars. Cars can be re-iced by the unit in less than one minute each

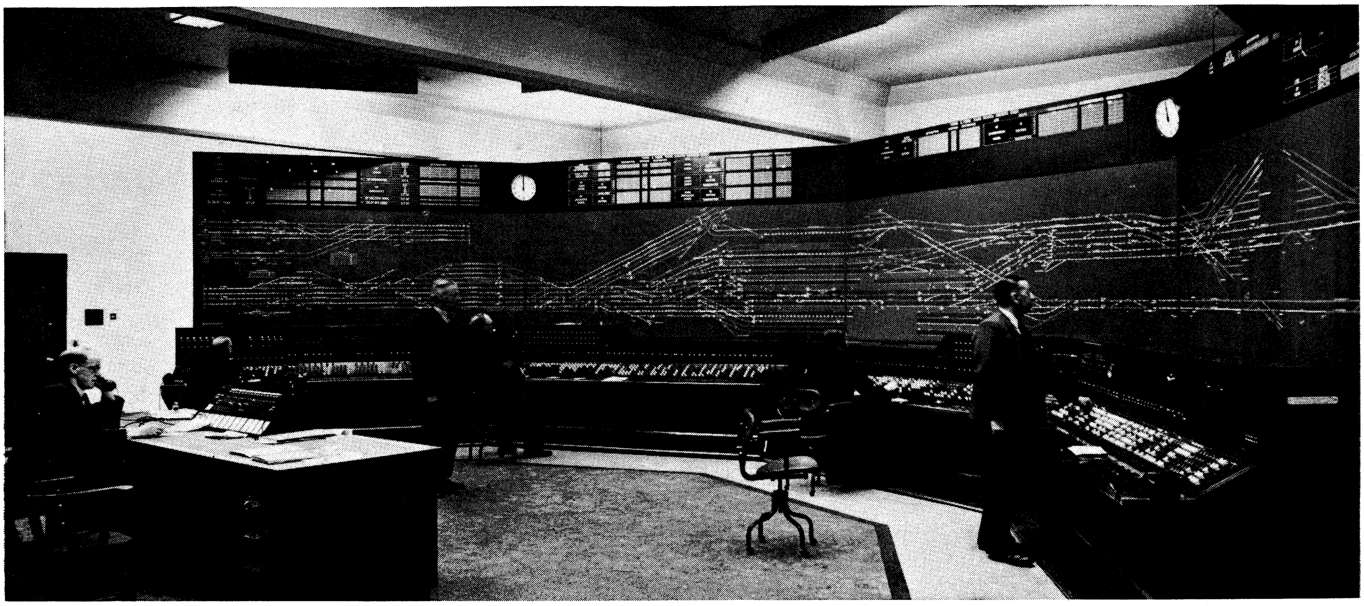
Car repair shop where all types of freight rolling stock are refurbished or rebuilt and modernized



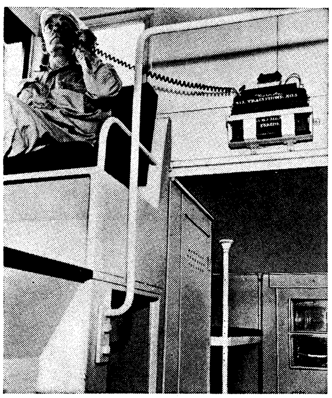
Assembling passenger cars at Madras, India. The coach shell is shown being lowered onto the wheel trucks or bogies

LOCOMOTIVE AND CAR MAINTENANCE

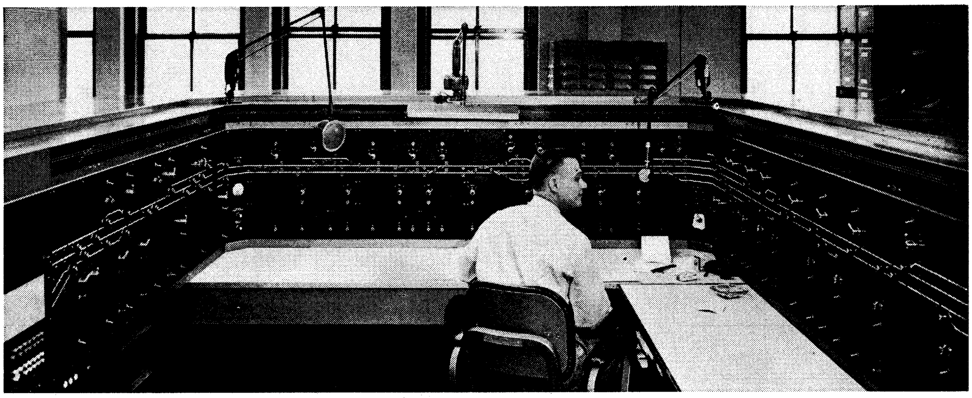
BY COURTESY OF (TOP) ASSOCIATION OF AMERICAN RAILROADS. (CENTRE LEFT) CHICAGO. ROCK ISLAND AND PACIFIC RAILROAD FROM ASSOCIATION OF AMERICAN RAILROADS, (CENTRE RIGHT) LINK-BELT COMPANY, (BOTTOM LEFT) GREAT NORTHERN RAILWAY FROM ASSOCIATION OF AMERICAN RAILROADS. PHOTOGRAPH. (BOTTOM RIGHT) AUTHENTICATED NEWS



Electronic program machine, York, Eng., signal station. Trains passing through the more than 30 mi. covered by this station are controlled by signal and switch changes dictated by electronic scanning of a punched plastic tape

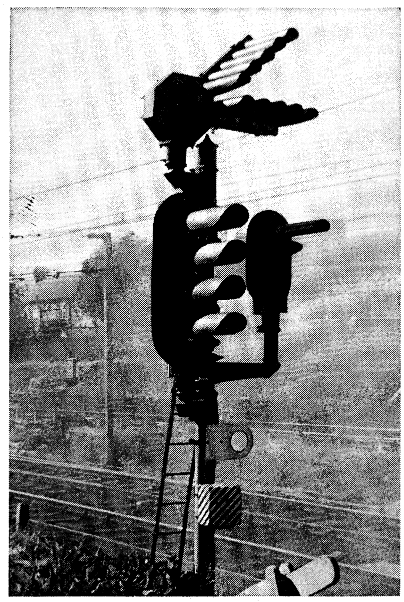


Two-way radio installed in the caboose of a freight train enables the conductor to communicate with the engineer or with operators of other passing trains



Train dispatcher at the console of a centralized traffic control (C.T.C.) board of the New York Central railroad at Erie, Pa. The dispatcher controls the movements of all trains between the cities of Erie and Buffalo, N.Y., (80 mi.) by operating a series of push buttons and levers which activate signals and switches on the right of way

Control tower in the Markham, Ill., yard of the Illinois Central railroad. As freight cars roll down a hill, operator punches buttons to direct each car or group of cars to its appropriate classification track. Electronically controlled retarders regulate speed of the roiling cars



Four-aspect colour light with double junction indicator, a modern trackside signal of the British railways for block traffic control

TRAIN OPERATION AND CONTROL

BY COURTESY OF (TOP, BOTTOM RIGHT) BRITISH RAILWAYS, (CENTRE LEFT) SEABOARD AIR LINE RAILROAD FROM ASSOCIATION OF AMERICAN RAILROADS, (CENTRE RIGHT) NEW YORK CENTRAL SYSTEM FROM ASSOCIATION OF AMERICAN RAILROADS; PHOTOGRAPH. (BOTTOM LEFT) HEDRICH-BLESSING

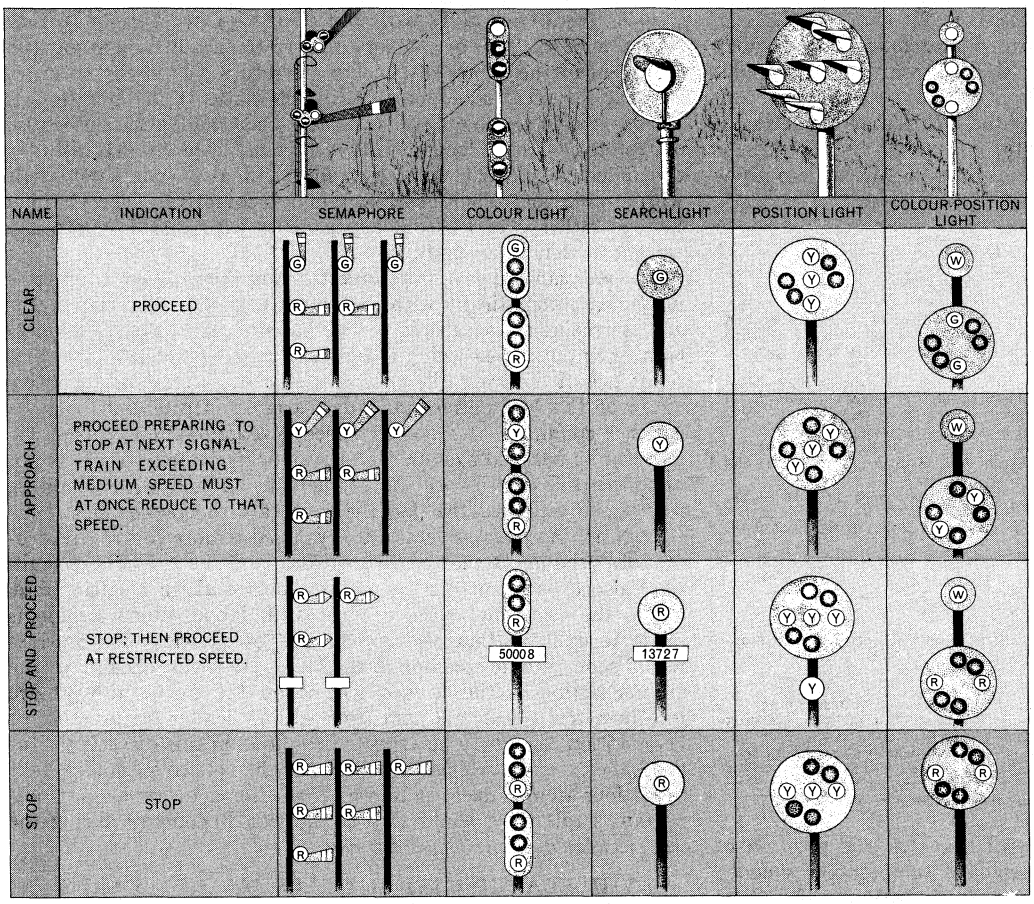


FIG. 2.— STANDARD AMERICAN SIGNAL INDICATIONS AND ASPECTS

Lamp colours: G, green; Y, yellow; R, red; W, white. The three columns under "Semaphore" show how the same indication may be given with one, two or three signal heads on the same mast (any of the other types of signal may also be combined in the same fashion); two- and three-head signals ordinarily are used at junctions, passing sidings, e t ~ . A stop-and-proceed signal is designated by a number plate on the mast below the signal head, by a marker light, by a pointed semaphore blade or by a combination of these features

The first attempts at interlocking switches and signals were made in France in 1855 and in Britain in 1856. Interlocking at crossings and junctions prevents the signalman from displaying a clear signal for one route when clearance has already been given for a conflicting route.

Another forward stdp was the introduction of train operation on the distance interval or block system. The electric tablet machine (1878) for the safe operation of traffic over a single track was another note orthy development.

The next major step forward was the application of power to signaling. Experience gained with large power interlocking frames having mechanical interlocking between levers led to the development of all-electric interlocking. This, in turn, led to relay interlocking in which interlocking and controls are effected by electrical relays.

A development in the design of the signal itself was the introduction of the colour-light type in addition to the semaphore pattern. The colour-light signal uses a separate bulb and lens for each aspect. By the 1960s it was being generally superseded in the U.S. by the searchlight type, which uses only a single lens and bulb, the different colours being displayed by means of roundels or colour filters that are rotated in front of the lamp. Two other types of signals are used in the U.S.: the position light, in which rows of yellow lights duplicate the positions of semaphore arms, and the colour-position signal, which uses coloured lights arranged in rows.

Most lines in Europe are controlled from wayside signal towers, or cabins at stations, in conjunction with fixed signals. Block signaling is usual, the track being divided into sections, and a train is not permitted to enter a section until the train ahead has left it. This manual block system was once much used in the United States also, and is still found there on some lines. Electric interlocking improves this system by making it impossible for the "line clear" indication to be given for a section already occupied by a train.

Of more recent introduction is automatic block signaling. This uses track circuits which are short-circuited by the axles oi a train, putting the signals in the rear of the train (and. on single track, in front of it as well) at the danger aspect. A track circuit is made by the two rails of a section of track, insulated at their ends. Electric current, fed into the section at one end, flo s to a relay at the opposite end and the wheels of any vehicle will then short-circuit the current supply and energize the relay.

Signaling on African, Asian and Australian systems usually follows European practice in areas of heavy traffic. On lines of lighter traffic, control is often via the telegraph or telephone.

In the early years of U.S. railways. it was common to program operations on the basis of a strict timetable, which set up all the places where trains were to meet. If one train were delayed, others would also be held up, since it was impossible to change the meeting points.

By using the telegraph it became possible for the dispatcher to issue orders to keep trains moving in unusual circumstances, or to operate extra trains when required. This "timetable-train order" system is still used on about 100,000 mi. of lighter-traffic line in the U.S. and on much Canadian mileage. It is widely supplemented by automatic block signals, which provide an additional safety factor.

TABLE V.—Standard U.S. Locomotive Whistle Signals

Sound	Meaning
□	Apply brakes; stop
—	Release brakes; proceed
	Flagman protect rear of train
— — — —	Flagman return from west or south*
— — — — —	Flagman return from east or north*
• •	Engineman's answer to any signal not otherwise provided for
, • •	When standing: will back up. When running: will stop at next passenger station
• • • •	Call for signals (usually to request towerman or operator to clear a signal so train can proceed)
— • •	Another section of this train is following
— — • —	Approaching public crossing at grade
————	Approaching station, junction or railway crossing at grade
— — •	Approaching a meeting or waiting point

*Followed by one or more short sounds to designate which track is meant, when train is in multiple-track territory

The earliest function of signaling was to advise the engineman when it was unsafe to proceed and to indicate where a train should stop. In contrast, the aim of modern signaling is to keep trains running to the best advantage. Route-setting is one of the developments that helps accomplish this. With it, a complete route can be set up by operating push buttons on an electrical control panel. Equipment of this kind allows a large area to be controlled from one point, thus reducing the number of signal towers and personnel required.

1. **Centralized Traffic Control.—A** logical extension **of** the

route interlocking principle is centralized traffic control (C.T.C.). This is a system in which trains are operated entirely through remote control of the switches and signals from a central point by an operator, who sees the track layout in miniature on his control panel. Lights on the panel show the location and progress of all trains at all times. By pushing buttons and turning levers, the operator directs the movement of trains over distances from a few miles to several hundred miles.

Table VI.—*British* **Locomotive** *Whistle Signals*

Sound	Meaning
—	Approaching signals at "danger" or to indicate when ready to proceed on same track (on main or fast lines)
— —	As above, when on slow, or freight, track next to main line
— — —	As above, when on track next to slow or freight line (one additional long iound is given for each additional line farther away from the main line)
— •	On main line and requiring to proceed to the left
— • •	On main line and requiring to proceed to the right
— — •	On slow or freight line and requiring to proceed to the left
— — • •	On slow or freight line and requiring to proceed to the right
• • • • •	Requiring to pass between slow line or loop and main line
▪ ▪ ▪ ▪	Requiring to cross from main to main
(crow)* —	Requiring to pass between bay and platform lines
• • ▪	Train ready to leave siding
• • ▪ ▪	Shunt from sidinns to main line
▪ ▪	To or from locomotive
(three crows)	Express train requiring fresh locomotive at next stopping place
(crow) — (crow)	Fire on trackside
— • ▪ ▪	Locomotive requires water
	Locomotive clear of switch which requires turning
(crow) ▪	Train or locomotive shunted clear of switch leading from one running line to another
▪ ▪ ▪	Train or locomotive shunted clear of all running lines
(2 crows)	Preparing to start train assisted by locomotive in rear

'Crow: the traditional "cock crow" indication, thus: — ▪ — ▪ —

In C.T.C., track circuiting is essential so that the position of every train is known. Switches and signals are operated by coded electrical circuits which reduce the wiring required. C.T.C. is being used on an increasing scale in Africa, Asia and New Zealand as well as in certain European countries. Over long distances, C.T.C. substantially increases track capacity by making more effective use of the line.

Since C.T.C. eliminates any need for written train orders or manual operation of block signals, it permits closing of telegraph or signal stations — another major economy. On lines of light traffic, most of the benefits of C.T.C. can be obtained at less cost by having the signals controlled from the central office and the switch points operated manually by the train crews.

2. New Forms of Signaling. — Completely automatic signaling, activated by electronic program machines, had been introduced by the 1960s on some of London Transport's subway lines. The program machine has a plastic band incorporating a complete timetable translated into a series of punched holes. The line of holes is positioned for each train by a photoelectric cell. A comb with steel "feelers" scans the line of holes, causing a series of electrical contacts to be closed; these in turn carry out all signal, switch and interlocking movements.

In Germany, experiments were being conducted with train control by radio signals to the enginemen, instead of by fixed wayside signals Signal indications are given on a panel in the self-propelled car or locomotive and are accompanied by tone signals. Orders are acknowledged by a train recognition signal and the position of the train on the line is visually presented to the control operator on a track panel. In addition, all locomotives and self-propelled cars are linked to the controller by radio telephones.

3. Automatic Train Controls. — Automatic train control (A.T.C.) provides the engineman in the locomotive cab with audible (and sometimes visual) information on track conditions. Should a restrictive indication be ignored, the brakes are applied automatically to stop the train. Several U.S. railways use automatic speed control, a refined form of A.T.C. A miniature signal in the cab repeats the wayside signal aspects (or it may take the place of wayside signals). Should train speed exceed that indicated by the aspect being displayed, the brakes are automatically applied to reduce the speed below the permissible level.

4. Automation of Train Operations. — Only a slight further extension of this type of control is needed to permit fully automatic operation of the train — dispensing entirely with the engine crew. From a technical standpoint, fully-automatic train operation is entirely feasible, and experiments have been made with automatic or remote control of locomotives and trains. The French railways controlled an electric train by radio and also conducted trials with a radio-controlled diesel s itching locomotive. The German Federal railways carried out experiments with a radio-controlled electric switching locomotive.

The Russian railways were investigating the problem of operating trains automatically with the object of saving electric current and increasing track capacity. The basis of the system is an electronic computer into which is fed data relating to the weight and resistance of the train, the characteristics of the line, the tractive effort of the locomotive and any variable information such as weather conditions, temporary speed restrictions, etc. The system can be adapted to both diesel and electric traction. It is not intended to dispense with the engineman, but his work would be reduced to watching the line ahead in case of emergencies.

In North America, several railways tried remote control of locomotives used in classification yard work, and the New Haven railroad also experimented with remote control of an electric train. While the experiments were successful, labour-union problems made it unlikely that widespread use of crewless locomotives would soon become common in the U.S. However, because of the guiding action of the flanged wheels on the rails, railways are ideally suited to fully automatic operation. Under the pressure of competition, they may be expected to move in this direction. Indeed, the extent to which railways would be able to automate their operations seemed likely to be a major factor determining how important a role they would play in the world economy during the last decades of the 20th century.

VIII. CLASSIFICATION (MARSHALING) YARDS

A freight train starting on its run usually consists of cars moving to a number of different destinations. Somewhere en route, the cars going to each destination must be sorted out and transferred to other trains going to the proper terminals. This is done in classification or marshaling yards. In the years following World War II, railways made much progress in improving the efficiency of these yards — mainly through the use of automatic equipment.

Most large classification yards have a hump over which cars are pushed. The cars then roll down the hump by gravity and each is routed into a classification track corresponding to its destination. The principle is similar to that of sorting letters into pigeonholes at a postoffice.

The speed of a car rolling down the hump siding can be controlled by retarders — electric or electropneumatic clamps that grip the wheels of the car as it passes over them. The degree of retardation can be controlled automatically by an electronic computer which takes into account such factors as the weight, speed and rolling friction of the car. Equipment of this kind enables more cars to be handled, reduces human error, lessens the risk of damage to cars and their loads, and reduces delays.

However, modern improvements involve more than just the automatic humping of cars. The modern electronic yard is usually blanketed with a local radio network, as well as telephone, teleprinter and pneumatic tube communication circuits. Television may be used to scan trains entering or leaving the yard. Infrared detectors scan the wheels of incoming trains to pick out any journal bearing that may be overheated. Repair shops adjacent to the yard are mechanized to speed the repair of cars found to be in bad order as they move over the hump. In a fully modern hump yard it is not unusual to classify a train and have the cars moving in outbound trains in less than two hours.

Because modern classification yards can sort cars with such efficiency, they eliminate the need to do this work at other, smaller, intermediate yards. Thus, one modern hump yard may permit curtailing or closing a dozen or more other yards. Most of the modern yards built in North America have paid for themselves in operating savings in three or four years, and this takes no account of the benefits of improved service to shippers.

IX. CO-OPERATION AMONG RAILWAYS

In both North America and Europe, close working relations among different (and often competing) railway systems developed almost from the earliest years. It was found desirable, for instance, that connecting railways agree on such basic elements as the gauge of track and the type of couplings to be used on cars. This mas done to such an extent that a shipper can send a carload of his goods from almost any railway point in North America to any other point, including, via car ferries, Cuba; and a passenger may buy, at his local railway agency, a ticket for a trip that may cover thousands of miles in the cars of many different railways.

1. North American Organizations. — The principal element for co-ordination among North American lines is the Association of American Railroads (A.A.R.), with headquarters in Washington, D.C. Members of the A.A.R. include about 185 of the principal railways in the U.S., Canada, Mexico and Cuba. The American Short Line Railroad association is a similar organization serving 275 smaller lines. In addition, railways and the companies that supply them with materials and equipment work together through numerous regional groups and trade associations.

Through its several divisions and their numerous working committees, the A.A.R. co-ordinates the operations of the individual companies that make up the North American rail network. Among results of this joint activity (by the A.A.R. and its various predecessor groups) are standard items of car equipment, such as couplers, brakes and safety appliances; standard time; standard train operating rules; standard rules governing the interchange of cars among railways; and rules covering the collection and division of revenues for interline movements of freight and passengers.

Through its research centre at Chicago, the A.A.R. also carries on technological research and testing; this is in addition to the testing and research work done by many individual railway companies. The A.A.R. also represents the U.S. railway industry in connection with legislative proposals in congress that may affect the railways, and it carries on an extensive public relations program for the industry as a whole.

Although the Canadian and several U.S. railways operate their own sleeping cars, most cars of this type are operated by the Pullman company, which is jointly owned by the principal railway companies. A similar jointly owned company, the Railway Express Agency, Inc., handles most express package traffic. This agency uses both railways and other types of transport; it has an active air express division.

A number of companies also own large fleets of freight cars but do not actually operate any railway line. These so-called private car lines were formed usually to meet the need for certain specialized types of equipment that could be better supplied in this way than by the individual railways.

Railways also co-operate throughout the western hemisphere through the Pan American Railway Congress association, which has its headquarters at Buenos Aires, Arg. It operates much like the International Railway Congress association (which has world-wide membership), that is, through the exchange of technical information among railways in the different North and South American countries.

2. European Organizations. — In Europe, too, the gradual spread of railway routes led to the need for some form of co-operation and uniform regulations relating to the movement of equipment. From this need came the Convention Internationale sur le Transport des Marchandises, or International Convention for the Transport of Freight (C.I.M.), which was established in 1890.

Later came the Convention Internationale sur le Transport des Voyageurs, or International Convention for the Transport of Passengers (C.I.V.). These were followed by the Regolamento Internazionale Veicoli, or International Wagon union (R.I.V.), and Regolamento Internazionale Carrozzi, or International Carriage and Brake Van union (R.I.C.). They succeeded earlier arrangements concerning the international movement and interchange of passenger and freight vehicles. From these arrangements also came annual passenger and freight train timetable conferences.

In 1885 the International Railway Congress association was formed for the purpose of exchanging technical information between administrations, and in 1922 the Union Internationale des Chemins de Fer, or International Union of Railways (U.I.C.), was created. Its original aim was to improve international services. During the interwar years it was also concerned with technical measures and joint regulations for improving international traffic.

After World War II, European railway co-operation made great strides in many different spheres and, in particular, the scope of the U.I.C. was considerably enlarged. From the U.I.C. sprang a number of other organizations that made important contributions to the economy and progress of the European railway systems.

The Europ freight car pool came into being in 1953. Previously, freight cars entering another country had to be returned to the owning system as quickly as possible after unloading, subject to efforts being made to find a return load. Europ cars are not bound by this requirement, which saves millions of empty car miles a year.

Interfrigo was created in 1949 with the object of developing the international transport of perishable traffic at controlled temperatures. It is owned jointly by 11 railway systems, and there are agreements with nonmember administrations. Interfrigo has a fleet of 900 vehicles and, in addition, operates in international traffic some 10,000 refrigerated vehicles belonging to members and their subsidiaries.

The Office for Research and Experiments (O.R.E.) was created by the U.I.C. in 1949. Its purpose is to conduct research and tests for the benefit of members. Unlike the Association of American Railroads, O.R.E. does not have its own research establishment. Instead, it uses the laboratories and testing plants of its members. Financing is handled by a common fund, the cost being divided among the 29 members in proportion to the operated track mileage of each.

Eurofirma is a financing company that was established in 1955 with about 16 administrations as members. It finances the purchase of locomotives and rolling stock.

Trans-Europ express (T.E.E.) services are operated jointly by the Dutch, Swiss, German, French and Italian railways. They consist of a network of international express trains linking important cities in eight countries. Operations commenced in 1956. The trains are owned by the different administrations but must conform to accepted standards of comfort, speed, etc. The first trains were all diesel-powered, but in 1959 the Swiss ordered trains capable of running on four different electric traction systems for operating T.E.E. services.

Although it is a private company, the Compagnie Internationale des Wagon-Lits (C.I.W.L.) occupies a unique position in the field of international passenger services in Europe. It has been engaged in the operation of sleeping cars on international services since 1876. It also operates dining cars, Pullman cars, buffet and light refreshment facilities, restaurants at stations and airports, a motel, and restaurant and cabin facilities on river steamers. The company is registered in Brussels and has its operational and administrative headquarters in Paris. Its activities, although concerned principally with Europe, also extend to Africa and the middle east.

X. CONCLUSION

The railways can look back over a proud history. They were a vital element in the industrial revolution. They helped make Britain an industrial power, played similar roles in countries such as France and Germany, and went on to do much the same in Russia. Railways literally built the United States and Canada, and they remained the economic backbone of most of the major world powers.

But the railways in a number of countries — especially in Britain and the United States — were in serious trouble by the 1960s: they were steadily losing traffic to other modes of transport. In most countries, the railways had long since come under state control. and the remaining privately owned lines were finding it difficult to operate at a profit. Railway mileage mas shrinking in many countries. Did this foretell the end of this great form of transportation?

Technology was evolving so rapidly that it was probably unwise to say that this could not happen. However, as of the 1960s, it seemed unlikely. No other form of transportation had yet been developed to the point where it could challenge the railway as an all-around carrier.

Railways still otier two major advantages: (1) At distances of more than 100 or 200 mi.. they can haul any kind of freight. as well as passengers, at a true cost lower than any other form of transportation on land or air; (2) They are all-purpose land carriers. Pipelines may carry liquids and some solids economically: airplanes may produce savings on very high-value commodities; trucks offer speed and flexibility for relatively short hauls; overland conveyor belts may prove of value for certain bulk commodities. But only railways can carry anything, almost anywhere —and do it with little regard for weather conditions.

In sum. the railway is one of the earliest and greatest material achievements of the industrial era. It seemed likely to continue serving man's evolving civilization for many years to come.

See also Index references under "Railway" in the Index volume.

BIBLIOGRAPHY.—*General: World Railways* (at intervals); *Overseas Railways* (annually).

United States: T. W. van Metre, *Trains, Tracks & Travel,* 8th ed. (1950); R. S. Henry, *Trains* (1954); *Moody's Transportation Manual* (annually); S. H. Holbrook, *The Story of American Railroads* (1947); W. W. Hay, *Railroad Engineering* (1953); F. H. Hubbard, *Railroad Avenue* (1945); B. A. Botkin and A. F. Harlow (eds.), *A Treasury of Railroad Folklore* (1953); G. E. Turner, *Victory Rode the Rails* (1953); A. W. Bruce, *The Steam Locomotive in Anzerica* (1952); *Modern Railroads* (monthly); *Railway Age* (weekly); *Trains* (monthly).

Association of Western Railways, *Railroad Facts* (annually) Interstate Commerce Commission, *Annual Reports, Statistics of Railways in the United States* (annually); Association of American Railroads, *Quiz on Railroads and Railroading* (at intervals), *A Review of Railway Operations* (annually).

Canada: Board of Transport Commissioners, *Annual Reports; Canadian Transportation* (monthly).

Latin America: National Railways of Mexico, *Ferronales* (monthly); Pan American Railway Congress Association, *Bulletin* (monthly).

Great Britain: British Transport Commission, *Annual Report;* R. Bell, *History of British Railways during the War, 1939–45* (1946); *Concise Encyclopaedia of World Railway Locomotives* (1959); E. A. Binney, *Electric Traction Engineering* (1955); *Railway Gazette* (weekly); *Modern Transport* (weekly); *Journal of the Institute of Transport* (bi-monthly); *Diesel Railway Traction* (monthly); *Railway Magazine* (monthly).

Europe: Bulletin of the International Railway Congress Association (monthly); *Revue Generale des Chemins de Fer* (monthly); *Ingegneria Ferroviaria* (monthly); *Jahrbuch des Eisenbahnwesens* (annually); *European Railways* (quarterly); *Railway Electrification in Switzerland* (1954).

South Africa: Railway Engineering (monthly).

Japan: Japanese National Railways, Facts and Figures (annually); *Japanese National Railways at a Glance* (JNR).

Australasia: Railway Transportation (monthly).

(TH. C. S.; R. B. S.)

TUBE: *see* SUBWAY (UNDERGROUND RAILWAY).

RAIMONDI, MARCANTONIO (called MARCANTONIO) (*c.* 1480–*c.* 1534), Italian engraver, outstanding Italian master of engraving of the Renaissance and the first who practised it to reproduce designs of other artists rather than his own. He received his training in the workshop of the famous goldsmith and painter Francesco Raibolini, called Francia. There, according to Vasari, "he made waist buckles and many other things in *niello* . . . being in truth most excellent in that craft."

The real fame of Raimondi was to be founded on his attainments in that particular development of the goldsmith's art which consists of engraving designs on metal plates for printing. About 80 engravings can be attributed to the first six years of his career (1505–11). They include many subjects from mythology and some of religious character. Figures, drapery and composition bespeak the influence of Francia, but the landscape backgrounds and the expression of form by light and shadow indicate German traditions as well. Perhaps for commercial reasons or to improve his style, he produced a series of counterfeits of copper engravings from Albrecht Durer's woodcuts. There are 69 of these: 17 from the "Life of the Virgin," 37 of the woodcut "Little Passion" and a few others. The "Life of the Virgin" was copied in 1506 and signed with Durer's signature. Durer, traveling in Italy in the same year, complained to the Venetian senate and Raimondi added his own signature to the copies he subsequently completed in 1510 of Durer's "Little Passion." Raimondi profited greatly by these studies of Durer's energetic line and his use of crosshatching in modeling. He was to make brilliant use of these under another influence. Until this time he had lived only in Bologna, with the exception of a visit or visits to Venice.

Soon he was attracted to the circle that surrounded Raphael in Rome. Where or when he met Raphael is uncertain. His passage to Rome by way of Florence was supposedly marked by an engraving (1510) known as "The Climbers" (*Les Grimpeurs*), in which he reproduced part of the design of Michelangelo's cartoon of soldiers surprised while bathing, he added behind the figures a landscape imitated from the young Dutch engraver Lucas van Leyden. The piece in which he is recorded to have first tried his hand after a work of Raphael is the "Lucretia." From that time until he disappears in the sack of Rome in 1527, Raimondi was almost exclusively engaged in engraving the designs of Raphael or of his immediate pupils. Raphael, the story goes, was so delighted with the print of the "Lucretia" that he later personally trained and helped Raimondi.

A printing establishment was set up under the charge of Raphael's colour grinder, Baviera, and profits in its early days were shared by the engraver and the printer. The sale soon became very great; pupils gathered about Raimondi, of whom the two most distinguished were Marco Dente, known as Marco da Ravenna, and Agostino De Musis, known as Agostino Veneziano. During the last 10 years of Raphael's life and for several years following his death, the group produced a great number of engravings after the master's works. They did not usually copy his finished paintings, but worked up (with the addition of simple backgrounds and accessories) his sketches, which often gave the composition in a ditierent form from the finished work, and are all the more interesting on that account.

Raimondi's best engravings (*e.g.,* "Massacre of the Innocents") were done during the first years after he had attached himself to Raphael. In them he entered into the genius of his master and lost little of the chastened science and rhythmical purity of Raphael's contours. In the parts where he was left to himself (the rounding and shading, the background and landscape) he managed his burin with all the skill and freedom he had gained by the imitation of northern models, while dispensing with the northern emphasis and redundance of detail. Raimondi's engravings after the works of Raphael's later years were colder and more ostentatious. Still more so, as is natural, were those which he and his pupils produced after the designs of the followers of Raphael and Michelangelo, such as Giulio Romano, Polidoro Baccio or Bandinelli.

Raimondi's association with Giulio Romano (*q.v.*), was the cause of his first great disaster in life. He engraved a series of obscene designs by that painter in illustration of the *Sonnetti lussoriosi* of Pietro Aretino which caused his arrest. Marcantonio's ruin was completed by the calamities attendant on the sack of Rome, by the German troops of the emperor Charles V of Spain in 1527. He had to pay a heavy ransom to escape the Spaniards, and fled, to quote Vasari, "all but a beggar." It is said he took refuge in his native city of Bologna, but he never again emerged from obscurity. All that is known with certainty is that in 1534 he was dead.

See H. Delaborde, *Marc-Antoine Raimondi* (1887); A. M. Hind, *Great Engravers* (1911) and *A Short History of Engraving and Etching*

(H. Es.)

RAIN: *see* METEOROLOGY; RAINFALL.

RAINALDI, CARLO (1611–1691), Roman baroque architect, noted particularly for his works of the 1660s, was born in Rome in 1611 and died there in 1691. He collaborated with his father, Girolamo Rainaldi (1577–1655), a distinguished architect who transplanted to Rome the north Italian mannerist tradition of Pellegrino Tibaldi. After his father's death, Rainaldi evolved a monumental grand manner, without entirely discarding his paternal heritage.

The final building of his masterpiece, Sta. Maria in Campitelli (1663–67), showed a north Italian rather than a Roman pedigree. The use of many freestanding columns gave the building a scenographic quality which had neither past nor future in Rome but influenced late baroque north Italian church design. Nor was the facade, closely set with columns, rooted in the Roman tradition. Again, its basic motif—two enormous aediculae, one set into the other—was current in northern Italy.

Rainaldi's last important work was the grand façade uniting the old apse of Sta. Maria Maggiore with the chapels of Sixtus V and Paul V (1673). Thenceforth his practice was confined to a number of smaller enterprises. (RF. W.)

RAINBOW, a name for a set of coloured arcs seen against the sky whenever falling water droplets (from a rain cloud or in a spray of a waterfall or fountain) are illuminated by a strong light source (the sun or the moon).

The bows appear as concentric arcs, with the common centre on the line connecting the eye of the observer and the light source. Most frequently only one bow is clearly visible. It appears on the opposite side from the source; its angular radius of the red border is about 42°. Other colours of the spectrum can be seen inside of this border, ending with the violet. Occasionally another, secondary rainbow is observed above the primary rainbow. Its angular radius is about 54°, and the sequence of the colours is reversed: the red is inside and the violet on the outer border of the bow. The space between these two bows seems to be relatively dark. The centre of these bows is, angularly, as far below the horizon as the source (the sun) is above. Hence, usually less than a semicircle of these coloured arcs is visible. However, if the droplets are illuminated by a reflected source from a large water surface, the rainbow will appear as arcs of circles, with the centre above the horizon. Such a reflected rainbow will intersect the ordinary rainbow at the horizon.

Inside of the outer border of the primary rainbow, additional coloured bows can be sometimes seen, called (improperly) supernumerary bows. The appearance of these bows depends primarily upon the size of the droplets; thus it varies quite considerably. When superposed on the ordinary rainbow, these supernumerary bows cause eventually a broadening or disappearance of any particular colour in the rainbow, which then results in a great variety in the brightness and purity, as well as in the angular width of coloured bows. In particular, if the water droplets are very small (of a diameter of 0.1 mm. or less), the superposition of the ordinary and supernumerary bows leads to an almost white rainbow, sometimes known as Ulloa's ring or a fogbow.

The rainbow was first correctly explained by M. A. de Dominis in 1611. The primary bow is formed by two refractions and one internal reflection in the water droplets, the secondary bow by one more additional internal reflection. This explanation was further developed and experimentally confirmed by Descartes (1637). The explanation of the colours in the rainbow was given later by Sir Isaac Newton. The supernumerary rainbows were explained much later by Thomas Young (1803) as the interference effect of two ray systems in the inner space of the bows; the mathematical theory was given by Sir George Biddell Airy (1838).

The original explanation of the rainbow by De Dominis and by Descartes is based on tracing the path of a light ray falling on

n	Minimum deviation (D)	
	Red (.656μ)*	Violet (.397μ)
Primary rainbow	137°.6 ($\pi-42°.4$)†	139°.4 ($\pi-40°.6$)
Secondary rainbow	230° ($\pi+50°.4$)	233°.6 ($\pi+53°.6$)
Tertiary rainbow	317°.5 ($2\pi-42°.5$)	322°.1 ($2\pi-37°.9$)
Quarternary rainbow	402°.8 ($2\pi+42°.8$)	408°.6 ($2\pi+48°.6$)

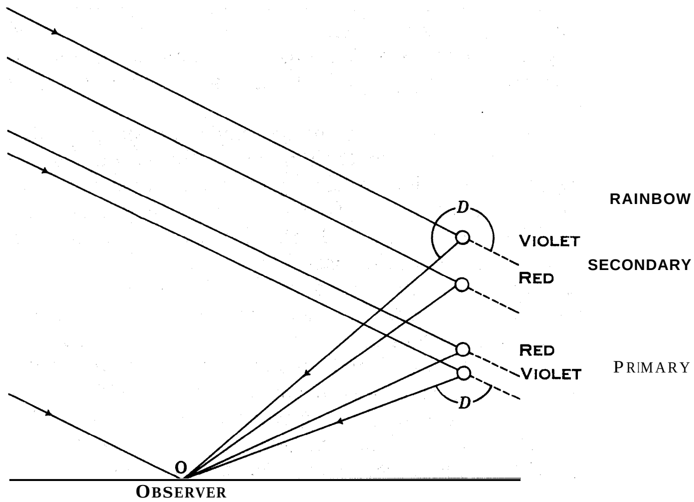
*$\mu=10^{-4}$ cm. †$\pi=180°$.

a transparent sphere with the use of the laws of geometrical optics. From the law of refraction and reflection it is easy to determine the deviation of the emerging ray from its original direction of incidence.

The angle of this deviation depends upon the angle of incidence, the number of internal reflections n and the index of refraction of the medium inside the sphere. For a particular angle of incidence the deviation has a minimum, given in the table.

The light emerging from the sphere reaches a high intensity around the direction of minimum deviation; the intensity then gradually decreases as the deviation increases. There are, however, no rays, hence no intensity on the other side of this direction (for smaller deviations). The observer will then see the highest intensity looking against the rays having minimum deviation, called sometimes Descartes rays. The Descartes rays from all individual droplets will form a cone with the vertex in the observer's eye and with the axis in the direction from or toward the source—the sun.

The light emerging from the droplets after one internal reflection will have the greatest intensity in the directions forming such a cone with the angle of 42°.4 in the red and of 40°.6 in the violet. The observer will see bright arcs of all spectral colours from the red over yellow, green, blue to violet. Since the angle for the red is greater, the red arcs will form the outer border, the violet arcs the inner one. The display fits the description of a primary rainbow. Similarly the secondary rainbow can be explained as consisting of Descartes rays from two internal reflections; the



SCHEMATIC DIAGRAM OF THE ORIGIN OF THE PRIMARY AND SECONDARY RAINBOW. *D* IS THE ANGLE OF MINIMUM DEVIATION OF EMERGING RAYS

angle between the axis of the corresponding cones and the rays is 50°.4 for the red and 53°.6 for the violet. The secondary bows appear above the primary, and the sequence of the colours is reversed. (*See* fig.) The rays from the droplets above the primary and below the secondary bow would have to have the deviations smaller than the corresponding Descartes rays if they were to reach the observer's eye. This explains the dark space between these two bows. The tertiary and quarternary bows are quite faint and thus difficult to see against the bright sky in the vicinity of the sun.

The rays incident on the sphere on either side of the Descartes rays emerge only on one side of the minimum deviation. In this region the two systems of rays are crossing each other. Their superposition leads necessarily to interference patterns, with alternative maxima and minima of intensity in different directions. For a particular colour the positions of these maxima and minima are strongly dependent upon the size of the sphere, being closer for larger diameters of the sphere. The main maximum is usually close to the primary rainbow.

The superposition of the secondary maxima and minima are responsible for the great variation in the brightness and in the width of individual coloured arcs in the rainbow. If, for example, the secondary maximum in the red falls in the direction of the green arc in the primary rainbow, the mixture of these two colours produces an additional yellow arc; in the rainbow the yellow arc has enlarged width compared to that of other colours. For smaller droplets the secondary maximum in the red may be shifted beyond the blue or violet of the primary rainbow, thus giving rise to a supernumerary bow.

Bibliography.—More detailed description and the theory of rainbow can be iound in J. M. Pernter and F. M. Exner, *Meteorologische Optik*, 2nd ed. (1910); W. J. Humphreys, *Physics of the Air*, 3rd ed. (1940); H. C. van de Hulst, *Light Scattering by Small Particles* (1957).

(Z. S.)

RAINBOW TROUT (Salmo irideus): see Salmon and Salmoxidae.

Average Rainfall and Melted Snow Water

(in inches)

	London	Paris	Berlin	Rome	Moscow	Tokyo	Bombay	New York	Capetown	Sydney
Jan.	1.9	1.5	1.9	3.6	1.6	2.3	0.1	3.5	0.7	3.9
Feb.	1.6	1.2	1.3	2.7	1.4	3.0	0.1	3.1	0.6	3.2
March	1.6	1.6	1.5	3.1	1.4	4.3	0.0	3.6	0.8	4.4
April	1.6	1.7	1.6	3.1	1.4	5.3	0.0	3.2	1.9	5.6
May	1.8	2.1	1.9	2.4	1.9	5.9	0.6	3.5	3.7	5.0
June	2.0	2.3	2.3	1.8	2.5	6.8	19.8	3.7	4.4	3.7
July	2.2	2.2	3.2	0.8	3.1	5.6	23.9	4.2	3.6	4.9
Aug.	2.2	2.2	2.2	1.0	2.8	7.1	14.1	4.3	3.3	2.4
Sept.	1.9	2.0	1.9	3.0	2.4	10.1	10.6	3.7	2.3	2.8
Oct.	2.6	2.3	1.7	5.3	2.5	7.9	2.1	3.0	1.6	2.8
Nov.	2.3	1.8	1.7	4.5	1.8	3.5	0.5	3.1	1.0	2.5
Dec.	2.3	1.7	1.9	4.1	1.6	2.2	0.1	3.1	0.8	3.6
Year	24.0	22.6	23.1	35.4	24.4	64.0	71.9	42.0	24.7	44.8
Days of rain	164	173	171	106	184	148	75	126	97	143
Days of snow	13	12	32	2	91	16	0	16	0	0

RAINFALL or snowfall usually occurs from fairly thick cloud systems fed by ascending moist air. In its ascent the air expands as a result of the decreasing pressure with height and cools adiabatically (see Adiabatic Processes in Atmosphere). Water-vapour saturation is reached and maintained, accompanied by the production of great quantities of liquid water droplets or ice crystals.

In such active clouds the physical processes required for growth of the cloud droplets or crystals to raindrops or snowflakes are accomplished easily. Meteorological evidence indicates that the ascending motion is far more important than the minutia of precipitation physics in determining when and where the precipitation will occur. Radiation, conduction and mixing are relatively inefficient atmospheric cooling processes. producing the less spectacular forms of condensation, such as dew, frost, fog and drizzle. Air cooled by lifting may be internally stable and require forced lifting, such as produced by mountains. or it may be potentially unstable and require only an initial impulse to establish free convection.

Raindrops have limited fall velocities and may be deposited some distance downwind from their point of formation, but, in general, rates of precipitation are closely related to rates of ascent. Rapid and extensive lifting by free convection in unstable air masses produces the intense rainfalls associated with showers and, in the warmer, more humid air masses. thundersho~vers.

Lifting processes are represented by air gliding upward over mountain slopes or over wedges of cooler air, free convection, underrunning by cooler wedges of air and large-scale net horizontal inflow of air at lower levels. The last is the most effective natural lifting process, since large masses of air are forced upward. Any or all of the lifting processes may operate on stable or unstable air within the life cycle of one major rainstorm. Orographic lifting of stable air gliding upward over gently sloping cooler wedges of air produces the typical winter rains. which are uniformly light, steady and extensive. The flash floods of the southern United States represent the other extreme, in that highly unstable and very moist maritime air is lifted by the combined effects of horizontal convergence, upglide over cooler continental air and orographic lifting.

Forced lifting of maritime westerlies produces more than 100 in. of rainfall a year on many windward points on western mountain ranges, leaving some leeward continental areas with ten inches or less per year. Rainfall is greatest on windward coastal slopes. near warm tropical waters and in areas of marked cyclonic activity. Rainfall is least near the centre of continents, in colder higher latitudes, leeward of mountain ranges and within areas of persistent anticyclonic activity.

Mt. Waialeale, Hawaii, with a 20-year average of 460 in. from tropical easterlies, is the wettest known point. The nearest competitor is Cherrapunji. Assam, with an annual average of 426 in. from the moist tropical monsoon. Less than 10 in. and more than 60 in. per year represent approximate extremes of rainfall for all of the continents. Rainfall is slight in the central regions of the subtropical anticyclones, which are therefore the desert regions of the earth. In parts of the desert no appreciable rain has ever been observed.

Over most of Europe. South America, eastern North America and central Africa the annual rainfall exceeds 20 in., while over most of Asia. excluding India. Tibet and China. the annual rainfall is less than 20 in.. being less than 10 in. in a long tongue extending from Arabia across to northeast Mongolia. The central regions of Australia, most of northern and a part of southwest Africa. portions of the intermontane area of the United States, portions of the west central coast and southern east coast of South America also have less than ten inches of rain in the year. Portions of the west coast of Africa, between the equator and 10° N., a strip of the west coast of India, parts of Assam, a coastal strip of Burma, windward mountain slopes in the temperate latitudes of North and South America and many isolated tropical stations average more than 100 in. of rain in the year. Rainfall intensities greater than 1 in. in five minutes. 4 in. in one hour or 20 in. per day are quite rare, but these intensities on occasion have been more than doubled for the respective durations.

The measurement of rainfall over an area by means of a network of rain gauges is often unsatisfactory because large variations in the amount of rainfall occur between adjacent gauges. This defect can be partly remedied by the use of a 3 to 10 cm. radar, which can give an areal picture of relative rainfall intensities at any moment as far as 200 mi. away. This is possible because the amount of radar reflection from raindrops is very sensitive to their size and number. (See Radar Meteorology.)

Average annual rainfall plus melted snow water is given in the table for some of the chief cities of the world. Data for other places will be found in standard textbooks on climatology. Detailed rainfall data for specific areas is best obtained by inquiry directed to any of the more prominent national meteorological services.

See W. G. Kendrew, *Clinzates of the Continents* (1942); *U.S.* Department of Agriculture, *Climate and Man* (1941). (A. *K*. s.; *E. M.* Bs.)

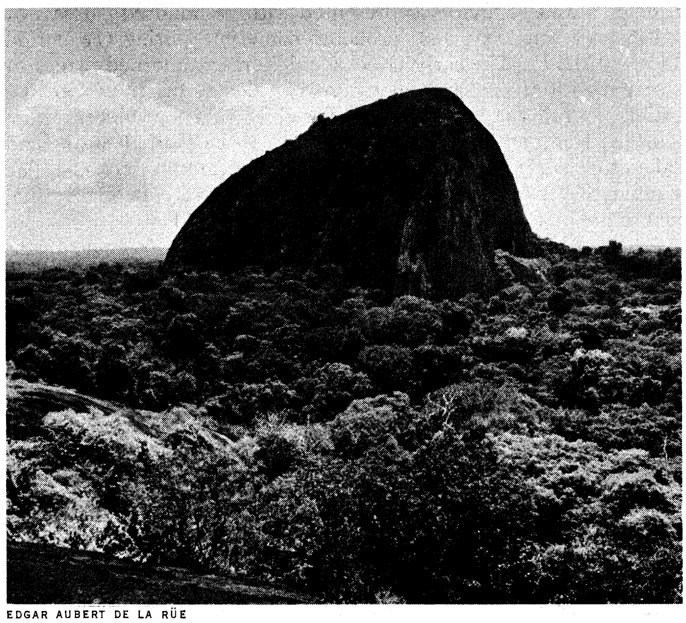
RAIN FOREST. The name rain forest is commonly applied to the luxurious evergreen forest typical of wet tropical lowlands (tropical rain forest). Some authors have chosen to broaden the term to include certain forest types found in subtropical and temperate climates. Factors favourable to the development of the true tropical rain forest are annual rainfall amounts in excess of 80 in. (nith no pronounced dry season) and mean temperatures between 68" and 8j° F.

The term rain forest was first employed in 1898 by A. F. W. Schimper, who described the formation as "Evergreen, hygrophilous in character, at least 30 m. high, but usually much taller, rich in thick-stemmed lianas and in woody as well as herbaceous epiphytes." This definition came to be the one most commonly accepted by ecologists.

A characteristic feature of the climax tropical rain forest is the storied or stratified layering of the dense tree canopy. The crowns of the trees usually form three distinguishable stories, but occasionally they form only two. The trees themselves are remarkably uniform in general appearance even though the number of separate species may be large (often as many as 100 distinct species of trees per acre); trunks are usually straight and slender, bases often flanged by plank buttresses; foliage consists most frequently of large. leathery, dark-green leaves with entire or nearly entire margins; flowers are usually inconspicuous. As P. W. Richards stated, "So uniform is the foliage that the non-botanical observer might easily be excused for supposing that the forest was predominantly composed of species of laurel" (P. W. Richards, Tropical Rain Forest, Cambridge University Press, 1952).

Contrary to popular belief, the tropical rain forest is not an impenetrable jungle of undergrowth, creepers and rotted vegetation. Such a description applies only along edges of clearings or banks of waterways, where the strong tropical sunlight can penetrate to the forest floor. In most cases, herbaceous ground flora is sparse and the soil bare or only thinly covered by dead leaves. An abundance of climbers is characteristic of the forest, however, in addition to almost unbelievable numbers of epiphytes, which grow on trunks, branches and even the leaves of the trees. The latter group of flora include some of the most exotic flowering plants found in any plant community.

The tropical rain forest forms an irregular belt around the earth, bisected unequally by the equator and interrupted by seas,



EDGAR AUBERT DE LA RÜE

EQUATORIAL RAIN FOREST NEAR THE SOUTHERN BORDER OF FRENCH GUIANA. A GRANITE INSELBERG, LIKOUTOU, RISES FROM THE FOREST TO A HEIGHT OF 1.650 FT.

mountains and, in a few cases, "tongues" of dry subtropical climates which here and there extend into equatorial regions. Ecologists recognize three distinct formations of tropical rain forest. These correspond to the three primary regions of the earth which possess equatorial rainy climates, and may be described as follows:

American rain forest: tropical portions of Central and South America from the Gran Chaco on the south to southern Mexico on the north.

Indo-Malayan rain forest: this formation extends from Ceylon and western India to Thailand, Indochina, the Philippines and through the Malay archipelago to New Guinea. In Australia the rain forest occupies a narrow strip along the northeastern coast.

African rain forest: this formation is quite irregular; the largest portion lies within the Congo basin and along the coast of the Gulf of Guinea.

Related Types. — The changes in vegetation with increasing altitude within the tropical rain forest are as marked as in the forests of temperate latitudes. As greater altitudes are reached, the typical forest of the equatorial lowland begins to change character: trees are lower, the number of species becomes less, and finally the typical tropical flora is replaced by a mountain vegetation, where many of the species are temperate. Richards refers to this formation type as the "montane rain forest." The altitude at which this transition occurs varies markedly from region to region depending upon temperature, rainfall, exposure to winds, soil and perhaps other factors. The base of the montane rain forest in some areas occurs at altitudes as low as 800 ft.; in others it is as high as 4,000 ft.

In eastern Australia, southeast Asia and on the east coast of South America, the evergreen rain forest extends far into subtropical latitudes. These forests differ from the true tropical rain forest and should be considered a distinct formation type — subtropical rain forest. The species of trees decrease in number with increasing distance from the equator, and subtropical and temperate species occur together in increasing proportion. Features such as buttressing and cauliflory tend to disappear. Nevertheless, the forest retains much of the true tropical aspect.

One of the important subtypes of the tropical rain forest is the mangrove swamp forest found along tropical seacoasts. The marine muds of coastal tidal zones provide ideal conditions for mangrove formations. These formations, however, may also occur far inland along brackish estuaries. Standing upon stilt roots which lift the main trunk of the tree above high-water level, the mangrove forest at low water presents an impenetrable tangle of roots and knees. Mangroves are of considerable economic importance because of their role in reclaiming land from the sea and also because they are an important source of firewood, timber and tanbark. Mangrove vegetation extends to about 32° N. and even farther from the equator in the southern hemisphere, but it reaches its greatest luxuriance where the tropical rain forest is the climax forest formation.

The term temperate rain forest is reserved to describe certain subantarctic broadleaf evergreen forests of southeastern Australia, New Zealand and southern Chile which are dominated by such temperate trees as *Nothofagus*. Rainy temperate forests of other regions, such as those of the coasts of Washington and Oregon, are occasionally referred to as rain forests, but such a usage of the term has not gained general acceptance among ecologists.

See Paul Westmacott Richards, *The Tropical Rain Forest* (1952); A. F. W. Schimper, *Plant-Geography Upon a Physiological Basis* (1903). (W. C. Js.)

RAINIS, JOZSEF, pseudonym of JAN PLIEKSANS (1865–1929), Latvian poet and dramatist, was born on Sept. 12, 1865, at Tadenava, in the district of Illukst, Courland. He was educated at the Riga *Gymnasium,* and from 1884 to 1888 studied law at St. Petersburg (Leningrad). He then practised as a barrister at Mitau, Courland. From 1891 to 1895 he edited in Riga a democratic Latvian paper, *Dienas Lapa* ("Daily Paper"). He was arrested by the Russian government on political grounds and remained in exile, first at Pskov and then at Viatka, until 1903. Among Latvian poets he may be considered the chief exponent of democracy. He translated plays from Shakespeare. Goethe and Schiller. His principal historical tragedies are *Uguns un nakts* ("Fire and Night"), *Put vejini* ("Blow Breeze") and *Daugava* ("The Dvina"). *The Sons of Jacob* was translated into English and was produced on May 22, 1925, at the New Scala theatre, London, by the International Theatre society. For several years Rainis was director of the Latvian National theatre and in 1920 he became a member of the Latvian *saeima* (parliament).

Rainis died at Riga on Sept. 13, 1929.

RAINPROOF FABRICS. Rainproof fabrics can be divided into two general classes — apparel fabrics and nonapparel fabrics. Included in the first group are fabrics used in raincoats, slickers, umbrellas, etc. Among those in the second group are fabrics employed in making tents, tarpaulins, etc. Rainproof fabrics may be actually waterproof or merely water repellent. Waterproof fabrics are impervious to water, the interstices or pores in the cloth being completely covered or filled by the waterproofing agent or sufficiently stopped up that water will not pass through them at the maximum pressure to which the fabric is exposed under conditions of use.

Water-repellent fabrics, on the other hand, are not impervious to water, the repellent effect being obtained not by closing or materially reducing the size of the interstices or pores, but by treating the cloth with a compound which increases the surface tension between the fibres and the water and thus makes it more difficult for the water to penetrate into and through the fabric.

Thus, a raincoat made from a lightweight water-repellent fabric may withstand a light shower but not a heavy, driving rain. The degree of water repellency depends on the type and twist of yarn, weight and closeness of weave and efficacy of the water-repellent compound. In general, heavy, closely woven fabrics are more water repellent than are light, loosely woven fabrics.

Other important applications of waterproof and water-repellent fabrics, in addition to those mentioned above, include shower-bath curtains, spotproof table covers and sheetings for hospital use. Fabrics which are both waterproof and chemical resistant find use in such applications as protective clothing for workers engaged in the handling of chemicals. Fabrics which are both waterproof and gasproof or airtight are employed as a protection against noxious gases. (W. W. CH.; X.)

RAIN TREE (Samanea saman), a tropical South American tree, so called from the fact that the ejection of juice by cicadas (*q.v.*) upon it causes it to appear to be always raining under its branches.

Andira inermis, which belongs to the same family (Leguminosae), is also called rain tree for the same reason.

RAINY LAKE lies 150 mi. W. of Lake Superior, partially on the international boundary between Ontario and Minnesota. The lake is 1,108 ft. above sea level and covers an area of 345 sq.mi. It is 56 mi. long and has an average width of 5 mi. (maximum, 27 mi.). There are over 500 islands in it. The shores, characteristic of lakes on the Canadian shield, are irregular and deeply indented. Drainage is westward through Rainy river to Lake of the Woods.

Fort Frances, Ont., and International Falls, Minn., on the river at the lake's southwestern extremity, manufacture pulp.

(W. G. DN.)

RAIPUR, a municipal town, a tehsil and district in Madhya Pradesh, India. The town (pop. [1951] 89,804) lies 188 mi. E. of Nagpur. The former Rajkumar college, where the sons of the chiefs of the Chhattisgarh and Orissa states were educated, has been thrown open to the public and there are four colleges in Raipur all affiliated to the university of Saugar, viz., the Chhattisgarh college, the College of Science, the Law college and the New Arts college. In the late 1950s the erection of a steel plant at Bilai in the neighbouring Durg district was projected, with a mines and metallurgy college to be established.

Raipur tehsil (area 1,115 sq.mi.) had a population (1951) of 384,269.

RAIPUR DISTRICT (pop. [1951] 1,640,006) covers an area of 8,214 sq.mi. and occupies the south and centre of the Chhattisgarh rice plain. It includes a large area of forest.

RAIS (or RETZ), **GILLES DE** (1404–1440), marshal of France, the central figure of a 15th-century cause *célèbre,* was born at Machecoul in Sept. or Oct. 1404. He joined the Montforts, supporting John V of Brittany against the house of Penthièvre. He helped to release Duke John from Oliver of Blois, count of Penthièvre, and was rewarded by extensive grants of land. In 1426 he raised seven companies of men-at-arms and, under Richemont (Richmond) (see ARTHCR III of Brittany), began active warfare against the English. He accompanied Joan of Arc to Orléans, fighting by her side there and afterward at Jargeau and Patay. He had advocated further measures against the English on the Loire before carrying out the coronation of Charles VII at Reims. On July 17. 1429, he was made marshal of France at Reims. He was a munificent patron of literature and of music. He ran into financial difficulties and began to sell his estates for small sums, but in 1436 his kinsfolk appealed to Charles VII, who proclaimed further sales to be illegal. John V refused to acknowledge the king's right to promulgate such a decree in Brittany. Gilles hoped to redeem his fortunes by alchemy and also spent large sums on necromancers, seeking to guarantee himself from evil consequences by extravagant charity and splendid celebration of the rites of the church. The abominable practices of which he was really guilty seem to have escaped the notice of his equals or superiors, though suspected by the peasantry. His servants kidnapped children. generally boys, whom he tortured and murdered. In 1440 he came into conflict with the church by an act of violence which involved sacrilege and infringement of clerical immunity and in the autumn he was arrested and cited before the bishop of Nantes on various charges, the chief of which were heresy and murder. With the latter count the ecclesiastical court was incompetent to deal, and Gilles refused to accept its jurisdiction (Oct. 8).

A parallel inquiry was made by Pierre de l'Hôpital, president of the Breton parliament, by whose sentence he was hanged (not burned alive as is sometimes stated) on Oct. 26, 1440, with two of his accomplices. In view of his confessions his guilt seems certain, but the irregularities of the proceedings, the fact that his chief accomplices went unpunished, together with the financial interest of John V in his ruin, have left a certain mystery over the trial. His name is connected with the tale of Bluebeard (*q.v.*).

RAISIN, the dried fruit of certain varieties of grape (*q.v.*). Raisin grapes were grown as early as 2000 B.C. in Persia and Egypt. Dried grapes are mentioned in the Bible (Num. vi, 3) during the time of Moses. David was presented with "a hundred clusters of raisins" (I Sam. xxv, 18), probably sometime during the period 1110–1070 B C. The early Greeks and Romans adorned places of worship with raisins, and they were awarded as prizes in sporting events. Until the 20th century the chief raisin producers were Turkey, Iran and Greece; by mid-century the United States had taken the lead in production, with Australia ranking second. The United States raisin industry is located entirely in California, where the first raisin grapes were planted in 1851.

The word raisin is a contraction of the French raisin *sec,* meaning dried grape. However, by common usage only a few varieties of grapes are said to yield raisins upon drying. The three most important varieties of raisin grapes are the Thompson seedless, a pale yellow seedless grape, also known as sultana (Australia), white or oval kishmish (Turkey, Iran), sultanina (California); the muscat or Alexandria, a large-seeded variety also known as gordo blanco (Australia), white hanepoot (South Africa); the black corinth, a very small, black seedless type, also called zante currant, staphis (Greece) and panariti. Other varieties of local importance are the round kishmish, rosaki, dattier, monukka and cape currant.

The trade name applied to a raisin may also signify the method of drying (natural, golden-bleached, sulfur-bleached, lexia), the form in which marketed (seeded, loose, layers), the principal place of origin (Vostizza, Smyrna, Malaga), the size grades or the quality grades. Natural raisins are dried in the sun in their natural condition; they are grayish-black or grayish-brown with the natural bloom intact and with a rather tough skin. Golden-bleached raisins are produced from Thompson seedless grapes dipped in 0.5% lye, exposed to fumes of burning sulfur for two to four hours and dried in a tunnel dehydrator. They are lemon-yellow to golden-yellow in colour, used chiefly in baked goods. Sulfur-bleached raisins are pretreated the same as golden-bleached, but are dried by exposure to direct sunlight. The grapes are spread on trays and left in the sun for three to four hours. The trays are then stacked and the drying is continued for several weeks in the shade. The finished product appears waxy, and cream to faintly reddish-yellow. Soda-dipped or soda-bleached raisins are from Thompson seedless grapes hot-dipped in dilute lye but not sulfured, then dried in the sun or in a dehydrator. If dried rapidly they are light amber to medium brown, moderately tender and mild-flavoured. Oil-dipped and lexias are dipped in a dilute solution of lye upon which a thin film of olive oil is floated; they are dried on trays in direct sunlight, are medium to dark brown, tender and mild in flavour.

The values below represent a composite of several reports on the nutrient content of Thompson seedless raisins containing about 17% moisture: carbohydrate 68%–71%, protein 2%–3%, fat 0.5%–3%, 1,300–1,600 calories per pound; milligrams in 100-g. portions: calcium 55–78, phosphorus 33–130, iron 1.5–3.3, potassium 700–900, sodium 52–87; vitamin **A,** 50 I.U. per 100 g., small amounts of vitamins B_1, B_2, B_6, niacin, biotin and a trace of vitamin C. Natural fruit acids contribute to the pleasant tartness of this delicacy. (Jo. E. B.)

RAJAH, a Hindu title for a chief, or prince, derived from the same root as the Latin *rex.* Other forms are rao, rana and rawal, while chiefs of high rank are styled maharaja, maharao and maharana. The Hindustani form is rai, and the title of the Hindu emperor of Vijayanagar in south India was raya.

RAJAHMUNDRY, a city in the East Godavari district of Andhra Pradesh, India. Pop. (1961) 130,030. It is on the left bank of the river Godavari, at the head of the delta, 360 mi. N. of Madras, and has a station on the Southern railway, which is there carried across the river by a bridge of 56 spans.

Tradition divides the merit of founding Rajahmundry between the Orissa and Chalukya princes. In 1470 it was wrested from Orissa by the Mohammedans, but early in the 16th century it was retaken by Krishna Raja. It continued under Hindu rule till 1572, when it yielded to the Mohammedans of the Deccan under Rafat Khan. It passed into the possession of the French in 1753, but they were driven out by the British in 1758.

RAJASTHAN, a state of India in its northwestern part, occupying most of the Rajputana region (*q.v.*) and formed by the union of most of the princely states of the old Rajputana agency. It is bounded on the north by Punjab state and Pakistan, on the east by Uttar Pradesh and Madhya Pradesh, on the south by Bombay state and on the west by Pakistan. Area of Rajasthan, 132,-150 sq.mi.; pop. (1961) 20,146,173. The capital is Jaipur, pop. (1961) 402,760; other important towns are Jodhpur, Bikaner, Udaipur, Kotah and Alwar. The union was formed on March 25, 1948, by the former princely states of Bundi, Dungarpur, Jhalawar, Kishangarh, Kotah, Tonk, Udaipur (*qq.v.*), Banswara, Kushalgarh (chiefship), Partabgarh and Shahpura; on March 30, 1949, Bikaner, Jaipur, Jaisalmer and Jodhpur (*qq.v.*) were absorbed; the short-lived Matsya union (founded March 18, 1948)—Alwar, Bharatpur (*qq.v.*), Dholpur and Karauli states—was absorbed on May 15, 1949; and in Jan. 1950 part of Sirohi was added.

Largely desert in the west, the soil becomes more fertile toward the east. Grain, oilseeds, fruit and vegetables are cultivated, mainly in the east; camels, cattle and sheep are tended in the desert region. Marble, sandstone and limestone are found in abundance, and a large quantity of salt is processed, mainly from the famous salt lake at Sambhar. Weaving, dyeing and printing of cotton cloth, manufacture of carpets and other woollen fabrics, pottery, enamelling and work in ivory, lac and stone, and in brass and other metals, are the important industries.

The administration of the merged states was integrated, and the union divided into five divisions. The *rajpramukh* (the maharaja of Jaipur from 1949) governs on the advice of a ministry and there is a state assembly of 160 members. The government resettled 400,000 refugees and initiated measures to develop the water resources of the union. On April 1, 1950, the federal financial integration of the union was completed and certain items of expenditure transferred to the central government.— (S. GL.)

RĀJASTHĀNĪ LANGUAGE is a group of Indo-Aryan dialects bordered by Western Hindi on the one side and by Gujarati and Sindhi on the other—an area roughly that of Rājpūtānā and adjoining parts of central India.

Rājasthānī has many dialects which can be assigned to four main groups: northeastern, southern, western and east-central. The northeastern form, Mēwātī, approximates most closely Western Hindi. It is a transitional dialect and sometimes classified with Hindi. The southern, Mālvī, spoken in Mālwā and neighbouring areas, shares characteristics with Western Hindi to the east and with Gujarati to the west. The western. Māṛwāṛī, spoken in Māṛwāṛ and neighbouring districts. is geographically more extensive than all the other dialects combined. Jaipuri, the language of Jaipur, is the standard east-central dialect. It has affinities with Gujarātī, whereas Māṛwāṛī resembles Sindhi. None of the Rājasthānī dialects is recognized in the Indian constitution. *See* also GUJARATI LANGUAGE; HINDUSTANI LANGUAGE.

Phonology.—With few exceptions, the Rājasthānī system agrees with other modern Indo-Aryan languages (*q.v.*). Long *ā* is sometimes pronounced like *au* in English "Paul," *ē* and *ai* like a in "hat" and *nu* like o in "hot." In the west and south especially, *s* is replaced by h—in northern Gujarati and in a number of the Bhil dialects. An original aspirate h and the aspiration of aspirated consonants are often lost; *ch* is replaced by *s*. In contrast with Western Hindi, Rājasthānī (like Gujarati and Sindhi) retains the cerebrals *ḷ* and n. Otherwise Rājasthānī shares a common ancestry with Gujarātī in Śaurasēnī Apabhraṁśa.

Morphology.—Rājasthānī has two genders: masculine and feminine. There are sporadic instances of the neuter, less in the subdialects toward the midland, more to the west and south to the borders of Gujariiti, which has three genders. A special agent form of noun is used instead of the oblique form with the postposition *ne*, though this construction is often encountered in Mēwātī and Mālvī.

A strong adjective agrees in gender, number and case with its noun; weak adjectives remain unchanged. The pronouns correspond generally with those of Hindi. In common with Gujarātī, Rājasthānī uses the inclusive pronoun *ap* "we." In conjugation a passive stem is formed with the suffix ij; Sindhi and Lahndā have a similar formation. The simple present indicative often functions as a subjunctive. The simple future stem is made by means of the suffix *s* (or h); a periphrastic future is formed by adding *gō*, *16* or *lā* to the subjunctive, of which *gō* and *lō* agree in gender and number with the subject, while *lā* never changes. Compound tenses are formed from participles plus auxiliaries. (See *Linguistic Survey* of *India*, vol. ix, pt. ii. 1908.)

The literature of Rajputana, chiefly in manuscript form, includes a number of bardic chronicles. In Māṛwāṛ, premodern literature falls into two categories: *Ḍiṅgal* (composed in Māṛwāṛī) and *Piṅgal* (composed in Braj Bhāshā). Modern literary activity is sparse.

BIBLIOGRAPHY.—S. H. Kellogg, *Grammar of the Hindi Language*, 3rd ed (1938); *Rām Karn Śarmā, Māṛwāṛī Vyākaraṇa* (1901); G. Macalister, *Specimens of the Dialects Spoken in the State of Jaipur* (1898); L P. Tessitori, "Notes on the Grammar of Old Western Rājasthānī," *Indian Antiquary*, vol. xliii–xlv (1914–16); S. K. Chatterji, *Rājasthānī Bhāṣā* (1949); *Sītārām Lāḷas, Rājasthāṁnī Vyākarana* (1954). (ET. B.)

RAJGARH, a town and district of Madhya Pradesh, India. The town had a population of 7,408 in 1951.

RAJGARH DISTRICT (area. 2,383 sq.mi.; pop. [1961] 517,837) is comprised in part by the former princely state of the same name (area 926 sq.mi.; pop., 1941, 148,609) and some adjacent territory formerly under princely jurisdiction, all absorbed into Madhya Bharat on June 15, 1948. Madhya Bharat was merged into Madhya Pradesh on Nov. 1, 1956. The ruler of Rajgarh was a Ponwar Rajput. His state and Narsingarh resulted from a partition in the 17th century. Rajgarh later became tributary to Scindia, but fell under the general settlement of Malwa (*q.v.*) in 1818.

RAJGIR HILLS, a range of hills in the south of the Patna district of Bihar, India. They form part of a range extending northeast for 40 mi, from the neighbourhood of Bodh Gaya; at one place they rise to 1,272 ft., but elsewhere they seldom exceed 1,000 ft. in height. The hills in Patna district consist of two parallel ridges. In the valley between, south of the village of Rajgir, was built the old city of Rajagriha, "the royal residence." Legend ascribes it to Jarasandha, king of Magadha (south Bihar), who had his capital at Giribraja, "the city of hills." The outer fortifications can be traced on the crests of the hills for more than 25 mi.; they are 17½ ft. thick, built of massive undressed stones without mortar. These ruined walls are generally ascribed to the 6th century B.C. The remains of New Rajagriha, the reputed capital of Bimbisara (*c*. 520–490 B.C.), lie two-thirds of a mile north of the valley.

The Rajgir hills are associated with the life of Buddha, who often taught there. Chhatagiri is the old Gridhrakuta, or vulture's peak, which was one of his favourite resorts. One of the towers on the Baibhar hill (Vaibhargiri) has been identified as the Pipara stone house in which Buddha lived. The Sattapanni, the cave in which after his death the council of his disciples was held to record the tenets of the faith, has been identified with different sites on this hill and with the Soubhandar cave at its foot; the latter is now believed to have been excavated by Jains in the 3rd or 4th century A.D. A brick mound, topped by a Jain shrine, stands in the centre of the valley. Rajgir is a place of pilgrimage. There are modern Jain temples on the hills around the valley. There are also hot springs in the valleys surrounded by Hindu shrines.

RAJKOT, chief city of Bombay state, India, and former headquarters of the old Western India States agency and the two Kathiawar subagencies; pop. (1961) 194,510. It is an important rail centre for north-central Saurashtra, and is the seat of Dharmendrasinhji college, Kotak Institute of Science (Gujarat university) and a museum.

The former princely state of RAJKOT, a taluka (subdivision) (area 344 sq.mi.; pop., 1951, 181,619), was within the Western Kathiawar subagency of the combined Baroda, Western India and Gujarat administration before absorption into Saurashtra on Feb. 1, 1948. Saurashtra was absorbed into Bombay state Nov. 1, 1956.

RAJMAHAL, a former capital of Bengal, now a village in the district of Santal Parganas, Bihar state, India, situated on the right bank of the Ganges, where that river makes a turn to the south. Pop. (1951) 4,896. Rajmahal was chosen for his capital by Man Singh. Akbar's governor, in 1595–96, but in 1608 the seat of government was transferred to Dacca. It was again made the capital by the prince Shah Shuja in 1639, and was a second time superseded by Dacca 20 years later.

Even in 166j Manucci found that it had fallen into ruin, being full of dilapidated palaces, great fallen mansions and neglected gardens. Rajmahal has given its name to a range of hills, comprising an area of about 2,000 sq.mi., which rise to a height of about 2,000 ft. They are inhabited by an aboriginal race known as Maler (the Malli of Megasthenes) or Sauria Paharias; *i.e.*, "hillmen." The valleys are inhabited and cultivated by the Santals, a different aboriginal race.

RAJPRAMUKH (Hindi *raj[a]* "prince" + *pramukh* "chief official." "president," etc.). the title given to those Indian princes who were appointed in place of governors in certain constituent states of the dominion — later republic — of India where it was thought expedient to retain some of the traditional polity of princely jurisdiction and to employ the administrative ability of the princes. The states concerned are Hyderabad and Mysore, large territories capable of continued provincial autonomy within the federal framework; and five unions of former princely states —Madhya Bharat. the Patiala and East Punjab states union, Rajasthan. Saurashtra and Travancore-Cochin. The *rajpramukhs* of Hyderabad and Mysore are those princes recognized by the president of the republic as respectively nizam and maharaja of the two states; in the states unions the *rajpramukh* is elected for life by a council of the rulers of the covenanting states. and is usually the ruler of the most important of them. He is assisted by one or more *up-rajpramukhs* or vice-presidents. The *rajpramukh* and *up-rajpramukhs* are answerable to the state and republican legislatures and to the president of India, and retain none of the autocratic powers of the old princes; their position is rather that of a constitutional monarch. Vindhya Pradesh was set up as a *rajpramukh* state when India became independent, but after certain legislative difficulties, was administered centrally through a chief commissioner from Jan. 1, 1950. Kashmir (*q.v.*), under dispute between India and Pakistan after the political partition of the subcontinent. was regarded in the 1950 Indian constitution as a *rajpramukh* state within the republic.

See Ministry of States, *White Paper on Indian States* (Delhi, 1950).

RAJPUT (Sanskrit *raja-putra,* "son of a king": also known as *Thakur*, "Lord," and *Chhatri*), a generic term for a number of land-owning and military endogamous subcastes and hypergamous lineages spread over India, mainly in Rajputana and other parts of central and northern India. They have been described as the main obstacle to complete Moslem domination of Hindu India during the years of Islamic supremacy. Traditionally regarded as the descendants of the Rajanya warriors of the Rig-Vedic era and putative successors of the ancient Kshatriyas, the Rajput groups vary greatly in status from princely lineages such as the Sesodiya and Kachwaha down to lowly cultivators. They are divided into three major lines: the Solar line, the Lunar line and the "Fire-descended" line. Most authorities agree that they are of mixed origin. V. A. Smith *(Oxford History of India,* Oxford University Press! 1919) described them as "essentially an occupational caste composed of all clans following the Hindu ritual who actually undertook the act of government." E. A. H. Blunt (The *Caste System* of *Northern India,* Oxford University Press, 1932) concluded that in ancient India "a Hindu or Hinduized ruler *de facto* obtained recognition as a Rajput *de jure*." Sir Denzil Ibbetson regarded Punjab Rajputs simply as the royal families of a common Jat and Rajput stock. The fact that Rajputs are of mixed origin and that entry into Rajput rank could be obtained by political or military success probably accounts for the fact that today this caste title has become the goal of many *jatis* wishing to rise in status. Patrician lineages in tribal groups tend to sever commensal and marital relations with their natal groups and establish themselves as endogamous subcastes of Rajputs, often inventing an origin myth to justify their new position. Another ladder of entry into Rajput groups is provided by the custom of hypergamous marriage, which has led to much stratification into status levels of which the higher will take wives from, but not give wives to, the lower. The Rajputs are a proud caste with high traditions of courage and honour. Their social structure is feudal in character, and they are less constrained by caste restrictions on behaviour and diet than most castes.

See James Tod, *Annals and Antiquities of Rajasthan* (1829–32; Oxford ed., 1920). (H. N. C. S.)

RAJPUTANA, a region of the northwestern part of the Indian subcontinent, formerly occupied by the Rajputana states agency and now largely falling within Rajasthan (*q.v.*), a constituent state of the republic of India. The Rajputana agency's area was 132,559 sq.mi. and its population (1941) 13,670,208 (13,282,105 in areas subsequently taken into Rajasthan), compared with Rajasthan's area of 130,207 sq.mi. and population (1951) of 15,290,797. The difference of area arises from the incorporation into Bombay of the states of Danta, Idar, Palanpur and Vijayanagar and part of Sirohi. The former agency had headquarters at Abu in Sirohi state and was divided into four subagencies — the Jaipur, Western Rajputana, Eastern Rajputana, and the Mewar and Southern Rajputana states agencies. All the Rajputana states were under Rajput rulers except Tonk (Moslem), Bharatpur and Dholpur (Jat).

Physical Features. — The Aravalli range of mountains intersects the country from southwest to northeast. About three-fifths of Rajputana lies northwest of the range and comprises the Rajasthan districts of Bikaner. Jaisalmer and Jodhpur. With the exception of the parts of Jodhpur which lie immediately below the Aravallis, this area is sandy, ill-watered and unproductive, improving gradually from a desert in the northwest and west to comparatively fertile land in the east. The country to the east and southeast of the Aravallis includes fertile lands, hill ranges and long stretches of forest, where fuel and fodder are abundant. The chief rivers are the Luni, the Chambal and the Banas. The Chambal rises in the highlands of the Vindhyas and discharges itself into the Jumna after a course of 560 mi. There are several important artificial lakes, constructed for storing water. The only basin of any extent is the Sambhar salt lake, of about 50 mi. in circuit.

From the geological point of view, the country may be divided into three regions — the central and largest, comprising the whole width of the Aravalli system, formed of very old submetamorphic and gneissic rocks; an eastern region, with a sharply defined boundary, along which the most ancient formations are abruptly replaced by the great basin of the Vindhyan strata or are overlaid by the still more extensive spread of the Deccan trap, forming the plateau of Malwa; and a western region, of ill-defined margin, in which, besides some rocks of undetermined age, it is more or less known or suspected that Tertiary and Secondary strata stretch across from Sind, beneath the sands of the desert, toward the flanks of the Aravallis. Rajputana produces a variety of metals. Ore of cobalt and zinc blende are peculiar to it. Copper and lead are found in several parts of the Aravalli range and of the minor ridges in Alwar and Shaikhawati, and iron ores abound in several areas. Alum and blue vitriol (sulphate of copper) are manufactured from decomposed schists at Khetri in Shaikhawati.

The climate over the whole of Rajputana is very dry and hot during the summer — Sri Ganganagar, where 122° F. has been recorded, is the hottest place in India — whereas in the winter it is much colder in the north than in the lower districts, with hard frost and ice on the Bikaner borders. The rainfall is unequally distributed.

Social Structure. — The territory became known as Rajputana because it was politically possessed by the Rajputs (*q.v.*). The whole number of this race was only about 620,000 at the beginning of the 20th century, and nowhere did they form a majority of the whole population in a state; but they are strongest, numerically, in the northern areas and in Udaipur. The Brahmans rank first; with them may be classed the Bhats, the keepers of secular tradition and of the genealogies. Next come the mercantile castes, mostly belonging to the Jain sect; these are followed by the powerful cultivating tribes, such as the Jats and Gujars, and then come the so-called aboriginal tribes, chief of whom are the Minas, Bhils and Meos. Rajasthani (and its dialects) is the chief language, being spoken by more than 70% of the population.

History.— Before the invasion of upper India by the Mohammedans. Rajputana was subject for the most part to two or three powerful tribal dynasties. Chief of these were the Rathors, who ruled at Kanauj; the Chauhans of Ajmer; the Solankis of Anhilwara, in Gujarat; the Gehlots with the Sisodhyia sept, which remained in Mewar or Cdaipur; and the Kachwaha clan, which remained in Jaipur. These tribal dynasties of Rajputs were gradually supplanted by the Moslem invaders of the 11th century and weakened by internal feuds. The clans were finally either conquered, overawed or conciliated by Jalal ud-Din Mohammed Akhar—all except the distant Sisodhyia clan, which, however, submitted to Jahangir in 1616. The Marathas, having been called in by the Rathors to aid them, took possession of Ajmer about 1756; thenceforward Rajputana became involved in the general disorganization of India. By the end of the 18th century nearly the whole of Rajputana had been virtually subdued by the Marathas. On the outbreak of the Pindari War in 1817, the British government offered its protection. The Pindaris were put down, Amir Khan submitting and signing a treaty which constituted him the first ruler of the existing state of Tonk. By the end of 1818 similar treaties had been executed by the other Rajput states with the paramount power. The political history of Rajputana then became comparatively uneventful. The great storm of the mutiny of 1857 was short, as most of the rajahs remained loyal. For later political history of the region *see* AJMER and RAJASTHAN.

Rajputana is of great archaeological interest, possessing some fine religious buildings in ruins and others in excellent preservation. Among the latter are the mosques at Ajmer and the temples on Abu. But the most characteristic features of architecture in the country are shown in the forts and palaces of the chiefs.

RAJSHAHI (formerly RAMPUR BOALIA), a municipality, district and division of East Pakistan. The municipality of Rajshahi (pop., 1951, 39.662 mun.), on a branch of the Eastern Bengal railway (whose main line crosses the district from north to south), is the divisional and district headquarters and a steamer station on the Ganges.

The municipality is the seat of Rajshahi university, founded in 1953 to affiliate about 20 colleges formerly connected with Dacca university, and of the Varendra Research society's museum.

RAJSHAHI DISTRICT (pop., 1951, 2,214,172) comprises a marshy alluvial plain seamed with old river beds, but to the north and west a slightly elevated area is found in the Barind. Rice is the staple crop; pulses. oilseeds and jute are also grown. Indigo cultivation has disappeared and the silk industry is moribund. The hemp grown on a small tract in the north supplies all the ganja (see HEMP) consumed in this region. District area 3,639 sq.mi.

RAJSHAHI DIVISION comprises Rajshahi, Bogra, Dinajpur, Jessore, Khulna. Kushtia, Pabna and Rangpur districts (total area, 21,958 sq.mi.); *i.e.,* East Pakistan west of the line of the Jamuna (Brahmaputra) and Madhumati rivers. Pop. (1951) 14,064,239.

RAKOCZY, the name of a noble Magyar family, settled from early times in the county of Zemplen (from 1919 in Slovakia).

SIGISMUND RAKOCZY (1544–1608) was one of the foremost supporters of Stephen Bocskay (*q.v.*) in his rising against Jesuit encroachment in northern Hungary, and succeeded him for a brief period in 1607 as prince of Transylvania, resigning the throne in 1608 in favour of Gabriel Bathory.

GEORGE RAKOCZY I (1591–1648), the youngest son of Sigismund, was like him a staunch Protestant. He took a leading part in the rebellion of Gabriel Bethlen (*q.v.*) against Bathory, and was made commandant of Kassa (Kosice). After Bethlen's death Rakoczy was elected prince of Transylvania by the diet of Segesvar (Sighisoara) on Nov. 26, 1630. Following Bethlen's national Hungarian policy he declared war in 1644 with Sweden as ally on Emperor Ferdinand III on behalf of the oppressed Protestants of northern Hungary. By the Peace of Linz (1644) he secured the return of some territory to Transylvania and the confirmation of Hungarian religious liberties. His capital Gyula Fehervar (Alba Iulia) became a great Protestant centre.

GEORGE RAKOCZY II (1621–1660) was the eldest son of George I and Susannah Lorantffy. In 1643 he married Sophia Bathory, who embraced Calvinism for the purpose. Succeeding his father in 1648 as prince of Transylvania George II sought like him alliances with the neighbouring hospodars of Moldavia and Wallachia. Hoping to realize his father's abortive Polish ambitions he joined in 16 j6 with Gustavus Adolphus of Sweden in attacking Poland; an expedition undertaken in defiance of the Turks, to whom Transylvania still owed tribute. Rakoczy was forced to retreat on humiliating terms. He was deposed by the diet on Turkish orders in 1657, but was reinstated a year later; whereupon the Turks invaded Transylvania in force. Rakoczy died at Nagyvarad (Oradea Mare) of wounds received at the battle of Gyula (May 1660).

FRANCIS RAKOCZY I (1645–1676) never succeeded to his father's throne. His mother, disregarding his father's last wishes, procured in 1662 his conversion to Catholicism to which she had herself reverted. He kept a splendid court on the family estates at Sarospatak and Makovica. In March 1666 Francis married Helen Zrinyi (Zrinski). a Catholic and Hungarian patriot. Francis joined in 1670 the Zrinyi-Frankopan conspiracy, led by his wife's father Peter, who was executed in 1671. Rakoczy escaped death through the influence of his mother with the Jesuits, on the payment of a ransom. He died in 1676 at Makovica.

FRANCIS RAKOCZY II (1676–1735), losing his father in infancy, was brought up, together with his sister Juliana, by their mother Helen Zrinyi in an atmosphere of fervent Magyar patriotism. Her marriage in 1682 to Imre Thokoly, leader of the Hungarian Protestants and organizer with Turkish assistance of abortive anti-Habsburg risings, did much to dissipate the family fortunes. Defeated, Thokoly went into exile, leaving his wife to organize alone the defense of Munkacs (Mukachevo, Ruthenia). After its surrender in 1688 the boy Francis, violently torn from his mother and sister, was taken to Vienna to be brought up in Austrian ways, and put in the charge of Cardinal Leopold Kollonic, sworn enemy of Magyar patriotism. The cardinal placed him in the Jesuit college of Neuhaus (Bohemia). Francis however resisted and continued his studies at Prague. His emancipation from the cardinal was helped by the marriage of his sister to a Belgian nobleman in Austrian service, Ferdinand d'Aspremont-Linden, count of Reckheim. The couple encouraged Francis in his marriage to Charlotte Amelia of Hesse-Rheinfels, solemnized at Cologne in 1694.

Rakoczy now settled on his Hungarian estates. His birth, wealth and brilliant personal qualities made him the natural leader of the Magyar nation, a role in which he was encouraged by other magnates. On the eve of the War of the Spanish Succession they sought help for the Hungarian cause from Louis XIV. Their intermediary Longueval. a Belgian captain in the Austrian service, betraying his trust, Rakoczy was arrested and imprisoned at Wiener-Neustadt, where his grandfather Peter Zrinyi had met his fate. Escaping certain death with his wife's help by leaving his cell in the disguise of a dragoon officer, he took refuge in Poland where he remained for two years. In 1703 he was actually offered the crown of that country, but returned instead to Hungary, putting himself at the head of the peasant revolt, known as the Kuruc (crusader) rising. He had some initial success, but the Magyar gentry stood aloof and the battle of Blenheim destroyed hopes of help from France. On June 13, 1704, the Kuruc army of 7,000 was routed by the imperialists at Koronczo and later at Nagyszombat. Want of arms, money, native officers and infantry made any permanent success in the open field impossible, yet Rakoczy drilled his little army into some degree of efficiency, and even after the rout of Pudmerice (Aug. 11, 1705) disposed of 100,000 men.

Meanwhile the Transylvanians were looking to Rakoczy to restore their independence; he was elected prince on July 6, 1704, and he set up a council of state of 24 members. The following year he was made dux of a Hungarian confederation. His efforts to secure toleration for his Calvinist followers alienated the Holy See, and peace negotiations with the emperor during 1705 came to nothing, the latter refusing to acknowledge the independence of Transylvania. France would not recognize the rebels officially unless they formally proclaimed the deposition of the Habsburgs, a desperate measure actually adopted by the diet of Onod on June 13, 1707. In spite of this Louis XIV sent no effective help. Efforts to secure the tsar's help against Austria failing and his peasant armies suffering further heavy defeats, Rakoczy left his country forever on Feb. 21, 1711, a few months before the signing of the Peace of Szatmar. After two years in Poland. Rakoczy took refuge in France in 1713 on the invitation of Louis XIV. After a time at court he withdrew as an oblate to the Camaldule monks of Grosbois (his marriage had proved unhappy) but in 1717 accepted a Turkish offer to help organize an army in Turkey against the Austrians (he was to have a new principality as prize). Before Rakoczy reached Constantinople Sultan Ahmed III had determined on peace-making and had no use for his services. Exiled in 1719 to Rodosto (Tekirdag), near Istanbul, Rakoczy remained there till his death on Good Friday, 1735. His remains were solemnly transferred to Hungary in 1906.

His two sons lacked character. The Turks for a time played with the elder, Joseph, and in 1737 he was recognized by the sultan as prince of Transylvania, but died the following year, thus bringing the history of the Rakoczy family to a close.

See *Histoire des révolutions de Hongrie,* containing memoirs of Francis Rakoczy II (The Hague, 1739); Émile Horn, *François Rakoczi II* (Paris, 1906). (B. Br.)

RAKOVSKY, CHRISTIAN GHEORGHYEVICH (1873–?), Soviet politician and diplomat, of Bulgarian descent and Rumanian nationality, was born on Aug. 13, 1873, at Kotel, Bulgaria. His father's home in the Dobruja passed after the Russo-Turkish war to Rumania, and the family became Rumanian. Rakovsky's Bulgarian ancestors, especially his grandfather, had organized risings against the Turkish rule, and the revolutionary traditions of the family were revived in Christian Rakovsky. In 1890 on account of his socialist activities all appointments in Bulgarian schools were closed to him. He therefore went to Geneva, where he joined the international social democratic student movement, and came in contact with G. V. Plekhanov and other Russian social democrats; and also to Germany, where he met Karl Liebknecht. He graduated as a doctor of medicine at Montpellier, and wrote his thesis on *The Etiology of Criminality and Degeneration* (1897). Returning to Bulgaria, he recommenced revolutionary activities, and in *Russia* in *the East* (1898) denounced tsarist politics. In 1900 he served as an officer in the Rumanian army. During the peasant riots of 1907 he was expelled from Rumania, his title to Rumanian citizenship not being considered adequate, and his civil rights were only restored in 1912.

After Rumania entered World War I, Rakovsky was arrested and imprisoned in various places, and finally at Jassy, where he was released by the Russians on May 1, 1917. After the Soviets came into power in November he became a member of the central executive committee of the Union, and in 1919 he became a member of the central committee of the Communist party. Rakovsky was well known as a writer on political and economic subjects under the pen name of "Insarov," and a number of his books were written and published in Russia *(Modern France,* 1900; *Metternich and His Time,* etc.).

Rakovsky's diplomatic career began with his appointment as head of the delegation entrusted with the peace negotiations with the Ukrainian central *rada.* In 1919 he was appointed president of the soviet of people's commissars of the Ukraine, and in 1922 represented the U.S.S.R. at the conference of Genoa. In 1924 he was the Soviet chargé d'affaires in London, and in 1926–27 Soviet ambassador to France. His support of Trotsky led, in 1928, to his expulsion from the Communist party and exile to Stalingrad. He was readmitted in 1934, and was a departmental chief in the commissariat of health until 1937, when he was dismissed. He was among the 21 members of the "Right Trotskyist bloc" arrested in February and tried in March 1938. Rakovsky was sentenced to 20 years' imprisonment.

RALEIGH, SIR WALTER (*c.* **1552–1618**), British explorer, was born about 1552, the son of Walter Raleigh, of Farhell, and Catherine, daughter of Sir Philip Champernown of Modbury. He was born at the farmhouse of Hayes near Budleigh Salterton Bay. In 1568 he was entered as a commoner of Oriel College, Oxford. In 1569 he followed his cousin Henry Champernown, who took over a body of English volunteers to serve with the French Huguenots and was perhaps present at the battle of Jarnac (Mar. 13, 1569) Nothing is known with certainty of his life until February, 1575, when he was resident in the Temple. In June 1578 his half-brother Sir Humphrey Gilbert obtained a patent for six years authorizing him to take possession of "any remote barbarous and heathen lands not possessed by any Christian prince or people." During 1578 Gilbert led a piratical expedition against the Spaniards. Raleigh accompanied his half-brother as captain of the "Falcon," and was perhaps with him in an unsuccessful voyage in 1579. In 1580 Raleigh was twice arrested for duels, and he attached himself to the earl of Leicester, and to the earl of Oxford. Late in 1580 he was serving as captain of a company of foot in Munster. He took an active part in suppressing the rebellion of the Desmonds; he advocated a ruthless policy against the Irish, and recommended assassination as a means of getting rid of their leaders.

In December 1581 he was sent home with despatches and his great fortune dates from his arrival at court, where he was already known through his correspondence with Walsingham. He had corresponded with Walsingham for some time. It is possible that Raleigh did throw his mantle on the ground to help the queen to walk dry-shod over a puddle, and that he scribbled verses with a diamond on a pane of glass to attract her attention. His tall and handsome person, his caressing manners and his quick wit certainly pleased the queen, and the stories in Sir Robert Naunton's *Fragmenta Regalia* and in Fuller's *Worthies* represent at least the mythical truth as to his rise into favour. The rewards showered on him were out of all proportion to his services in Ireland. In February 1583 he accompanied the duke of Anjou to Flanders. In 1583 he received the grant of Durham House, Strand, and in the same year the queen's influence secured him two beneficial leases from All Souls, Oxford, which he sold to his advantage, and a patent to grant licences to "vintners"—that is, tavern keepers, which he subleased. In 1584 he had a licence for exporting woollen cloths. He was knighted in 1584. In 1585 he succeeded the earl of Bedford as Warden of the Stannaries. He made good use of his powers in the mining districts of the west. He reduced the old customs to order, and showed himself fair to the workers. In 1586 he was given 40,000 ac. of the forfeited lands of the Desmonds, on the Blackwater in Ireland. He endeavoured to establish English colonies, and introduced tobacco into England. In 1587 he received a grant of part of Babington's forfeited land.

Raleigh was now at the height of his favour; Queen Elizabeth always had several favourites at once, lest any one might be supposed to influence her. She treated Raleigh exclusively as a court favourite, but never gave him any great office, nor admitted him to the council. Even his post of captain of the Guard, given in 1587, was mainly ornamental. The patent given to his half-brother Sir Humphrey Gilbert ran out in 1584. To avert this loss Raleigh, partly out of his own pocket, provided the means for the expedition to Newfoundland in 1583, in which Gilbert died. The patent was renewed in Raleigh's favour in March 1584.

Raleigh now began the series of ventures in the colonization of Virginia. His patent gave him and his heirs the proprietary right over all territory they occupied on payment of one-fifth of the produce of all mines of precious metals to the crown. In April 1584 Raleigh sent out two captains, Philip Amadas and Arthur Barlowe, on a voyage of exploration. They sailed by the Canaries to Florida, and followed the coast of North America as far as the inlet between Albemarle and Pamlico sounds in modern North Carolina. The name of Virginia was given to a vast and undefined territory, but none of Raleigh's captains or settlers reached the state of Virginia. In the same year he became M.P. for Devonshire. His first body of settlers, sent out in 1585 under Sir Richard Grenville, landed on what is now Roanoke Island in North Carolina. The settlers got on bad terms with the natives, and deserted the colony when Drake visited the coast in 1586. Attempts at colonization at the same place in 1586 and 1587 failed *(see* North Carolina), and in 1589 Raleigh resigned his rights to a company of merchants, preserving to himself a rent, and a fifth of whatever gold might be discovered.

After 1587 Sir Walter Raleigh's position as favourite was challenged by the earl of Essex. *(See* Essex, 2nd Earl of.) In 1588 he was in eclipse. He was in Ireland for part of the year with Sir R. Grenville, and as vice-admiral of Devon looked after the coast-defences and militia levy of the county. In 1589 he was again in Ireland, visiting Edmund Spenser at Kilcolrnan. It was by Raleigh's help that Spenser obtained a pension, and royal aid to publish the first three books of the *Faerie Queen.* In 1589 Raleigh accompanied the expedition to the coast of Portugal which failed to raise a revolt against Philip II. In 1591 he was at the last moment forbidden to take part in the voyage to the Azores, being replaced by his cousin Sir R. Grenville. In 1592 he was again at sea with an expedition to intercept the Spanish trade, but was recalled by the queen, having seduced one of her maids of honour, Elizabeth Throgmorton. Raleigh denied the stories in a letter to Robert Cecil. On his return he was put into the Tower, and if he was not already married was married there. To placate the queen he made a fantastic display of despair at the loss of her favour. The maids of honour could not marry without the queen's consent, which Elizabeth was always reluctant to give and would be particularly unwilling to give when the husband was an old favourite of her own. Raleigh proved a good husband and his wife was devoted to him through life. He superintended the distribution of the booty from the Portuguese carrack "Madre de Dios." He had provided large sums for the expedition, but the queen left him barely enough to cover his expenses.

Raleigh now retired to an estate at Sherborne in Dorsetshire, which he had extorted from the bishop of Salisbury by unscrupulous use of the royal influence. A son was born to him here in 1593. But a retired life did not suit Raleigh, and in 1595 he sailed on a voyage of exploration to the coast of South America. The object was undoubtedly to find gold mines, and Raleigh had heard the wild stories of El Dorado. His account of his voyage, *The Discoverie of Guiana,* published on his return, is brilliant, but contains much manifest romance and was received with incredulity. He was now the most unpopular man in England for his greed, arrogance and scepticism in religion. In 1590 he was named with Marlowe and others as an atheist. The share he took in the capture of Cadiz in 1596, where he was wounded, was followed by a return to favour, and he was apparently reconciled to Essex, whom he accompanied to the Azores in 1597. This co-operation led to a renewal of the quarrel, and Raleigh became still more unpopular. In 1600 he obtained the governorship of Jersey, and in 1601 took a part in suppressing the rebellion of Essex, at whose execution he presided as captain of the Guard. In 1600 he sat as member for Penzance in Elizabeth's last parliament. He was a steady friend of religious toleration, and a bold critic of the fiscal and agrarian legislation of the time.

James I., who regarded Essex as his partisan, had been prejudiced, and Raleigh's desire for war with Spain was against James's peace policy. Raleigh sold his Irish estates to Richard Boyle in 1602. He was expelled from Durham House, which was reclaimed by the bishop, dismissed from the captaincy of the Guard, deprived of his monopolies and of the government of Jersey. He was concerned in the complication of conspiracies of the first months of James's reign, and was committed to the Tower on July 19, 1603. Here he tried to stab himself, but only inflicted a small wound. His trial at Winchester, November 1603, was conducted with outrageous unfairness, and his gallant bearing in face of the brutality of the Attorney-General, Sir Edward Coke, turned public opinion in his favour. Raleigh was probably cognizant of the conspiracies, though the evidence against him was insufficient to prove his guilt. Much was kept back by the council, and the jury was influenced by knowing that the council thought him guilty.

The sentence of death passed on Raleigh was not carried out, but he was sent to the Tower, where he remained till March 19, 1616. His estate of Sherborne, which he had transferred to his son, was taken by the king. A sum of £8,000 offered in compensation was only paid in part. Raleigh's confinement was easy, and he turned to chemical experiments and literature. He had been known as a minor poet, and in prison he composed the only volume of his vast *History of the World* published. He invented an elixir, a very formidable quack stimulant. Hope of release never deserted him, and he secured his freedom in a way discreditable to all concerned. He promised the king to find a gold mine in Guiana without entrenching on a Spanish possession. It must have been obvious that this was impossible, and the Spanish ambassador, Gondomar, warned the king that the Spaniards had settlements on the coast. The king, who was in need of money, replied that if Raleigh was guilty of piracy he should be executed on his return. Raleigh gave promises he obviously knew he could not keep and sailed on March 17, 1617, relying on the chapter of accidents, and on vague intrigues he had entered into in Savoy and France. The ill-equipped expedition reached the mouth of the Orinoco on Dec. 31, 1617. Raleigh was ill with fever, and remained at Trinidad. He sent five small vessels up the Orinoco under Lawrence Keymis, with whom went his son Walter and a nephew. The expedition found a Spanish settlement on the way to the supposed mine, and a fight ensued in which Sir Walter's son and several Spaniards were killed. Keymis returned to Sir Walter with the news of his son's death and his own utter ruin, and killed himself as a result of Raleigh's reproaches. After a miserable scene of recriminations and mutiny, the expedition returned home. Raleigh was arrested, and in pursuance of the king's promise to Gondomar was executed under his old sentence on Oct. 29, 1618.

BIBLIOGRAPHY.—An edition of his *Works* in eight volumes was published in London in 1829. It contains a *Life* by Oldys and Birch, written with all the knowledge then available. A *Life of Sir Walter Raleigh* (1806, 2nd ed) was much used by Southey in his biography of Sir Walter Raleigh in vol iv of *The British Admirals* in the *Cabinet Cyclopaedia* (1837) Two biographies appeared simultaneously, *Life of Sir Walter Raleigh* by J. A. Saint John, and *Life of Sir Walter Raleigh* by E Edwards (1868) E. Edwards's work is in two volumes, of uhich the second contains the correspondence, and is still the best authority. Smaller lives, which in some cases contain new matter, are those by E W Gosse, "Raleigh" in *English Worthies* (1886); *W.* Stebbing, *Sir W Raleigh* (1891 and 1899); Martin Hume, *Sir Walter Raleigh* (1897): *H.* de Selincourt, *Great Ralagh* (1908); and M Waldman, *Sir Walter Raleigh* (1928). For special episodes *ree* Sir John Pope Hennessy, *Sir Walter Raleigh in Ireland* (1883), and *T* N. Brushfield, *Raleghana* (Ashburton, 1896). Two separate editions of Raleigh's poems have been published, *Poems, with biography and critical introduction* by Sir *F.* Brydges (1813), and *Poems of Raleigh with those oj Sir H. Wotton, etc.,* edited by J Hannah (1892). S. R Gardiner made a careful examination of the events of Raleigh's life after 1603 in his *History of England from the Accession of James I to the Outbreak oj the Civil War* (1883–84).

RALEIGH, SIR WALTER (1861–1922), English man of letters, born on Sept. 6. 1861. in London. was educated at University college. London, and King's college, Cambridge. He was professor of modern literature at University college. Liverpool, and professor of English literature at Glasgow In 1904 he was appointed professor of English literature at Oxford. He was knighted in 1911. and elected to a fellowship at Merton college in 1914. He died on May 13. 1922

Raleigh was a good critic and a stimulating teacher. He was not bound by the accepted judgments on individual writers, but brought a fresh and original mind to bear on literature. He did as much as any man of his time to break with what may be called the "dry-as-dust" school. His publications include *The English Novel* (1894). *Style* (1897), *Wordsworth* (1903), *The English Voyagers* (1904). *Shakespeare* (1907), *Six Essays on Johnson* (1910), *Romance* (1917) and many essays on literary subjects.

RALEIGH, the capital of North Carolina, U.S., located 23 mi. S.E. of Durham, has four major characteristics: politics, education, trade and manufacturing. Politically, as the state capital (and the seat of Wake county), the city is much like other state capitals of similar size The general assembly meets there regularly every odd-numbered year. The state capitol, completed in 1840, stands in the middle of a 4 ac. square and is considered a gem of Greek Revival architecture. Capitol square is surrounded by various state buildings (Labor, Library, Agriculture, Revenue, Education, Justice. Highway and others), all of which have been held to a height not exceeding five or six stories so as not to dwarf the capitol. Various state institutions are in or near Raleigh, including the hospital for the insane (1856), the prison (1869) and schools for the deaf and blind.

The city has four senior colleges: the State College of Agriculture and Engineering (1887); Shaw university (Baptist, 1865); St. Augustine's college (Protestant Episcopal, 1867); and Meredith (Baptist. 1891); and two junior colleges for women, St. Mary's (Protestant Episcopal. 1842) and Peace (Presbyterian, 1872). Within a 30-mi. radius are the University of North Carolina, Duke university, North Carolina College at Durham and the Southeastern Baptist Theological seminary. To take advantage of this concentration of institutions of higher learning, there has been established near Raleigh the Research triangle, a centre of industrial research. The large number of colleges and universities in the area has resulted in a heavy percentage of college graduates and a high level of cultural interest and activity. The North Carolina Museum of Art in Raleigh is one of the finest institutions of the kind in the area.

Raleigh has long been the major retail shopping centre for eastern North Carolina but in the middle part of the 20th century,. due largely to rapid transportation, the volume of trade grew enormously. The city also developed as a wholesale distributing centre, especially for chain food stores.

Industrial volume was small up to the beginning of World War II, but thereafter the city attracted a considerable number of factories producing a wide variety of products. It also became the home office or regional headquarters of a number of insurance companies. In a short period Raleigh changed from a small, slowgoing southern town to a modern, bustling, rapidly expanding city. Its population in 1960 was 93,931; for comparative population figures see table in NORTH CAROLINA: Population. The population of the standard metropolitan statistical area (Wake county) was 169,082 in 1960.

Raleigh was laid off from a tract of forest soon after the American Revolution (in 1792) when North Carolina, like several other of the original states, moved its capital westward from the seaboard. It was named for Sir Walter Raleigh and was incorporated in 1793. During the Civil War Gen. William T. Sherman's army entered the city without opposition in April 1865, and occupied it for the remainder of the war. During the late 19th and early 20th centuries Raleigh shared in the industrial development of the state but its major growth did not take place until during and after World War II. The city has a council-manager form of government, in effect since 1947. Pres. Andrew Johnson was born in Raleigh. (C. CR.)

RALPH (d. 1122), archbishop of Canterbury, called Ralph de Turbine, or Ralph d'Escures from his father's estate of Escures, near Séez in Normandy, entered the abbey of St. Martin at Séez in 1079, and ten years later became abbot of this house. After Anselm's death in April 1109 Ralph acted as administrator of the see of Canterbury until April 1114, when he himself was chosen archbishop at Windsor. Claiming authority in Wales and Scotland, he refused to consecrate Thurstan as archbishop of York because the latter prelate declined to profess obedience to the archbishop of Canterbury. This step involved him in a quarrel with the papacy, and he visited Rome, but was unable to obtain an interview with pope Paschal II, who had left the city. In spite of peremptory orders from Paschal's successors, Gelasius II and Calixtus II, the archbishop still refused to consecrate Thurstan, and the dispute was unsettled when he died on Oct. 20, 1122.

RAM. A male sheep, one kept for breeding purposes in domestication and not castrated, as opposed to the castrated wether. (See SHEEP.) For the ram as one of the signs of the zodiac, see ARIES. The word may be connected with O.Nor. *ramme,* "strong," or with Skt. ram, "to sport." The butting propensities of the ram have given rise to the many transferred senses of the word, chief and earliest of which is that of a battering implement used before the days of cannon for beating in the gates and breaching the walls of fortified places. (See ENGINES OF WAR.) Many technical uses of the term have been developed from this, *e.g.,* the weight of a pile-driving machine, the piston of a hydraulic press and other machines or portions of machines worked by water power. (See POWER TRANSMISSION.) The ancient war vessels were fitted with a beak projecting from the bows, and used to ram or crush in the sides of an opposing vessel. For the development of this in the modern battleship, see SHIP.

RAMADAN (the "Scorcher"), the fifth month of the Moslem year. Already sacred to the pre-Islamic Arabs, it became in Islam the holy month of fasting, selected because it was in this month that "the Koran was sent down as a guidance for the people" (Koran ii, 181). Tradition has it that the *lailat* al-qadr, the "Night of Power" (or "of the Decree"), in which the first revelation occurred is to be identified with the 27th of Ramadan. During this night the angels and spirits descend to earth and "it is peace until the rising of the dawn" (xcvii, 3, 5). Ramadan parallels Yom Kippur in its religious function; it, too, constitutes a period of atonement. But whereas the Jewish festival imposes a strict fast of 24 consecutive hours, the Moslem ordinance prescribes abstention from food, drink, sexual intercourse (indeed. any avoidable change of the body's composition) from the moment when "so much of the dawn appears that a white thread may be distinguished from a black" until with nightfall the two become indistinguishable once more (ii, 183), this abstention to be continued throughout the 29 days of Ramadan. Only the very young and the very old, the sick, pregnant and nursing women and persons on an extended journey may be excused.

Beginning and end of Ramadan are announced when one trustworthy witness testifies before the authorities that the new moon has been sighted; a cloudy sky therefore may delay or prolong the fast. The five daily prayers continue in Ramadan but the addition of the supererogatory prayers, or *tarawih,* at night is considered meritorious, particularly during the last ten days, which are regarded as especially sacred.

In the Koran the development of the Ramadan fast (one of the five "pillars" or absolute requirements of Islam) may be followed from the injunction to fast on Ashura, the Day of Atonement of the Jews (later identified with the tenth of Muharram, the first month of the Moslem calendar), to the command to fast "a certain number of days" during Ramadan (ii, 180) and finally to the month-long fast. The last may have been structured on the Christian Quadragesima (Lent) or comparable Manichaean practices. Fasting has come to be regarded as a most important religious act, and it is observed by many who will neglect their daily prayers. Psychologically a part of it is the Lesser festival or the Festival of Breaking Fast on the first three days of Shawwal when the strain of Ramadan is released.

See BAIRAM.

See G. E. von Grunebaum, *Muhammadan* Festivals (1951).

(G. E. V. G.)

RAMADI, a town in Iraq in 33° 30' N.. 43° 30' E. about 80 mi by road from Baghdad. Pop. (1957) 17,747. The town lies on both sides of the Euphrates, which is there crossed by a bridge of boats, and in the 20th century became of some importance as an airport and as the point at which the overland mail leaves the cultivated area and starts its journey over the desert.

RAMAKRISHNA (1836–1886), perhaps the best-known Hindu saint of modern times. While his background and training were intensely Hindu, his teaching was spiritual in character and universal in quality. While religion appealed to him temperamentally, he felt to the full the difficulties of faith and the force of modern criticism. He brought peace of mind to many doubters and dissenters in India and outside India. In a world giddy with material power and achievements, callous to human suffering and misery and indifferent to the higher life of spirit, he presented an ideal of holiness and compassion.

Ramakrishna was born in the village of Kamarpukur in Hooghly district. Bengal, on Feb. 20. 1836. His father. Khudiram Chattopadhyaya, was an orthodox Brahman. respected in his village for his integrity and ability as a teacher. His mother, Chandramani Devi. was a simple woman of character and piety. Of his parents, Ramakrishna said: "My mother was the personification of rectitude and gentleness. She did not know much about the ways of the world; innocent of the art of concealment, she would say what was in her mind. People loved her for her openheartedness. My father, an orthodox Brahman, never accepted gifts from the Sudras [lowest varna or caste]. He spent much of his time in worship and meditation and in repeating God's name and chanting his glories. Whenever in his daily prayers he invoked the goddess Gayatri, his chest flushed and tears rolled down his cheeks. He spent his leisure hours making garlands for the family deity, Raghuvir." Ramakrishna, who was originally named Gadadhar Chatterji, was the youngest child of a family of three sons and two daughters. From the beginning, he was attracted by the lives of religious heroes and did not pay much attentidn to the subjects usually taught in schools.

When he was seven years old he had his first experience of spiritual ecstasy. It is said that, on a summer day, as he was walking along a narrow path between paddy fields he saw a beautiful dark thundercloud. As it spread, rapidly enveloping the whole sky, a flight of snow-white cranes attracted his attention. The beauty of the scene overwhelmed him and he fell to the ground unconscious. Some villagers who happened to be in the vicinity took him back to his home. Ramakrishna said later that in that state he had experienced great joy.

When Ramakrishna was seven years old his father died, and this event plunged him into grief. He became more helpful to his mother in the discharge of her household duties. When he mas 13 his eldest brother Ramkumar left for Calcutta to improve the financial position of the family. Ramkumar was appointed a priest in the Kali temple at Dakhineswar 6 mi. north of Calcutta. The temple was founded by Rani Rasmani, a Sudra by caste. Ramakrishna's orthodoxy was so strict that he protested against his brother taking service in the temple and refused to take any cooked food on the day when the temple was opened and thousands were sumptuously fed. He left the temple and returned to Calcutta, leaving his brother there. But brotherly love prevailed and Ramakrishna returned to the temple and stayed there cooking his own food. A few months later his brother fell ill and Ramakrishna took charge of his duties and served as a priest in the temple His worship was quite different from that of the professional priests. He performed the duties of the office with ardent devotion and sincerity. His worship intensified his yearning for a vision of Kali, who for him was the mother of the universe. He would sit in the temple for hours, praying and weeping till he lost all consciousness of the outer world. While meditating he would lay aside his cloth and Brahmanical thread. Explaining his conduct, he said to Hriday, his boyhood friend and now his attendant: "Don't you know that when one thinks of God one should be freed from all ties. From our very birth we have the eight fetters of hatred, shame, lineage, pride of good conduct. fear, secretiveness, caste and grief. The sacred thread reminds me that I am a Brahmin and therefore superior to others. When calling on the Mother one has to set aside all such ideas."

When he was 23, to get him back to the world, his people married him to a girl of five, Saradamani Devi. (Such an early marriage is only a betrothal, the marriage being consummated years later when both the boy and the girl are mature.) The marriage did not tone down his fervent devotion but enhanced it. He became restless and excited and panted for a vision of Kali. "I felt as if my heart were being squeezed like a wet towel. I mas overpowered with a great restlessness and a fear that it might not be my lot to realise her in this life. I would not bear separation from her any longer. Life seemed to be not worth living. Suddenly my glance fell on the sword that was kept in the Mother's temple. I determined to put an end to my life. When I jumped up like a madman and seized it, suddenly the Blessed Mother revealed herself. The buildings with their different parts, the temple and everything else vanished from my sight, leaving no trace whatsoever, and in their stead I saw a limitless, infinite, effulgent ocean of consciousness. As far as the eye could see, the shining billows were madly rushing at me from all sides with a terrific noise. to swallow me up! I was panting for breath. I was caught in the rush and collapsed unconscious. What was happening in the outside world I did not know; but within me there was a steady flow of undiluted bliss, altogether new. and I felt the presence of the Divine Mother." With his visions and trances, he was not able to attend to the temple service.

A Brahman lady, who was slightly over 50 years of age and well versed in scriptural lore, helped him in his spiritual life. Ramakrishna described to her his experiences, which many people regarded as symptoms of madness. She replied: "My son, everyone in this world is mad. Some are mad for money, some for creature comforts, some for name and fame, and you are mad for God." Under her instructions Ramakrishna completed the spiritual exercises associated with the worship of Sakti and Vishnu.

About 1864, there came to Dakhineswar a wandering Vaishnava monk whose chosen deity was Rama. Ramakrishna took to the worship of Rama and realized that Rama was the spirit of the universe. He also practised the worship of Krishna and had a vision of him. He practised Vaishnava love to the highest point, where the human soul loves God as a devoted wife loves her husband. Its great example is the love of Radha for Krishna. To realise this ideal Ramakrishna dressed himself as a woman and behaved like one. He saw the beautiful form of Krishna in a trance and was satisfied. "After this vision," he said, "I realise that Bhagavan, bhakta, and Bhagavata — God, devotee and scripture — are in reality one and the same."

Ramakrishna next came under the influence of Totapuri, who initiated him into the truths of Advaita Vedanta and taught him the way to *nirvikalpa samadhi,* where a state of consciousness is reached which goes beyond all dualities of subject and object. Totapuri advised him to renounce the world. Ramakrishna had no objection to renouncing the world, but stipulated that his admission into the monastic order should be kept a secret, as he did not wish to hurt the feelings of his old mother who had been living with him for some years at Dakhineswar. Totapuri agreed. When Ramakrishna tried to withdraw his mind from all objects of the empirical world, he found it difficult to take his mind away from Kali, the divine mother of the universe. "In spite of all my attempts I could not altogether cross the realm of name and form and bring my mind to the unconditioned state. I had no difficulty in taking the mind from all the objects of the world. But the radiant and too familiar figure of the blissful Mother, the embodiment of the essence of pure consciousness, appeared before me as a living reality. Her bewitching smile prevented me from passing into the great Beyond." When Ramakrishna explained his difficulty to Totapuri. the latter took a piece of glass, stuck it between his eyebrows and said. "Concentrate the mind on this point." Ramakrishna did so. "My spirit at once soared beyond the relative plane and I lost myself in ecstasy."

Ramakrishna, after attaining the experience of *advaita* or nonduality, remained, however, in relative consciousness and found no incompatibility between the Absolute and personal God. "When I think of the Supreme Being as inactive — neither creating nor preserving nor destroying — I call him Brahman or Purusa or the superpersonal God. When I think of him as active — creating, preserving and destroying — I call him Sakti or *maya*[1] or *prakrti*[2], the personal God. But the distinction between them does not mean a difference. The Personal and the Superpersonal are the same thing, like milk and its whiteness, the diamond and its lustre, the snake and its wriggling motion. It is impossible to conceive of the one without the other. The Divine Mother and Brahman are one."

The realization of absolute Brahman convinced Ramakrishna that the gods of the different religions are but different ways of looking at the Supreme and that the ultimate reality could not be adequately expressed in human language. All religions led their adherents by different paths to the same goal. He wished to explore the non-Indian religions from the inside.

Toward the end of 1866 he started practising the disciplines of Islam under the guidance of a Moslem teacher. He dressed as a Moslem and repeated the name of Allah. He gave up visiting Hindu temples. He had a vision of God as Allah and lapsed into the ocean of the Absolute.

In 1874 Ramakrishna became eager to learn the truth of the Christian religion. One day his eyes became fixed on a painting of the Madonna and the Child. The figures in the picture took on life and the rays of light emanating from them entered his soul. He saw Jesus in a vision and for three days he could think of nothing, speak of nothing except Jesus and His love. Thus he had visions of Rama, Krishna, Siva, Kali, Allah and Jesus and these experiences became a part of his life. He came to the conclusion that all religions are one though each of them stresses a different aspect of the undivided life of spirit. He said: "I have practised all religions, Hinduism, Islam. Christianity, and I have also followed the paths of the different Hindu sects. I have found that it is the same God toward whom all are directing their steps, though along different paths. . . . He who is called Krishna is also called Siva, and bears the name of the Primal energy, Jesus and Allah as well—the same Rama with a thousand names. A lake has several *ghats*. At one the Hindus take water in pitchers and call it *jal;* at another the Muslims take water in leather bags and call it *pani;* at a third the Christians call it water. Can me imagine that it is not *jal* but only *pani* or water? The substance is one under different names, and everyone is seeking the same sub-

[1]Power of self-expression of the personal God. [2]Nature.

stance; only climate, temperament and name create differences. Let each man follow his own path. If he sincerely and ardently wishes to know God, peace be unto him! He will surely realize him."

Lost in his spiritual efforts, Ramakrishna forgot completely that he had a wife. She had by then grown up, and went to him in 1872. Ramakrishna received her kindly and said that the old Ramakrishna was no more, that he could no longer look upon any woman as his wife, and that he saw in her the divine mother She begged him to let her stay with him and serve him to the best of her ability and asked that he should teach her the way to perfection. She stayed within the temple compound and practised whatever Ramakrishna taught her. The first lesson she received from him was: "God is everyone's beloved, just as the moon is dear to every child. Everyone has the same right to pray to him. Out of his grace he reveals himself to all who call upon him. You too will see him if you but pray to him." Saradamani Devi said of her husband: "I have no words to describe my wonderful exaltation of spirit as I watched him in his different moods. Under the influence of divine emotion, he would sometimes become perfectly motionless in ecstasy. This would continue throughout the night. There was such an extraordinary divine presence in him that now and then I would shake with fear and wonder how the night would pass. Months went by in this way. Then one day he discovered that I had to keep awake the whole night lest, during my sleep, he should go into ecstasy—for it might happen at any moment—and so he asked me to sleep in the music room."

Those who have the personal experience of the Supreme, according to the Indian tradition, return to the worldly life, live, move and act in it for the welfare of humanity. Many earnest seekers, the leaders of the different religious movements, approached Ramakrishna for spiritual instruction and guidance, and were impressed by the purity of his character, his childlike simplicity and perfect unselfishness. All who approached him benefited a great deal and acknowledged him as their guru or spiritual preceptor. He explained profound truths in homely parables and pithy sayings. To Ramchandra Datta, who was sceptical about God, Ramakrishna said: "God really exists, you don't see the stars in the daytime, but that doesn't mean that the stars do not exist. There is butter in milk. But can anybody see it by merely looking at the milk? To get butter you must churn milk in a quiet and cool place. You cannot realise God by a mere wish, you must go through some mental disciplines."

One of the pupils asked him: "Why are there so many divergent opinions about the nature of God?" Ramakrishna answered: "Really they are not contradictory. As a man realises him, so does he express himself. If somehow one attains him, then one finds no contradiction. . . . Kabir (Kabitpanthis) used to say, 'The formless Absolute is my Father, and God with form is my Mother.' " When the question was raised whether the rites and ceremonies were not the mere husk of religion, Ramakrishna said: "Yes, but without the husk, paddy will not grow in the field. You eat rice but you sow paddy." To the question, "When shall I be free?", his answer was "When 'I' shall cease to be. The sun can give heat and light to the whole world, but it can do nothing when the clouds are in the sky and shut out its rays. Similarly so long as egoism is in the soul, God cannot shine upon the heart." Man cannot be content with a conceptual knouledge of God, he must burn to possess him: "The vulture soars high up in the air, but all the while he is looking down into the chamel-pits in search of putrid carcasses. So the book-read pandits speak glibly and volubly about divine knowledge, but it is all mere talk, for all the while their mind is thinking about how to get money, respect, honour, power, etc., the vain guerdon of their learning." He who is really great is meek and humble: "A tree, laden with fruit always bends low. So if thou wantest to be great, be low and meek." The responsibilities of the truly spiritual are heavy: "If a white cloth is stained with a small speck the blackness appears very ugly indeed by the contrast; so the smallest fault of a holy man becomes painfully prominent by his surrounding purity."

Ramakrishna spent the remaining years of his life in the unselfish service and spiritual education of his fellow men. His work, along with the trances he had experienced frequently, affected his health and early in 1885 he suffered from throat trouble which developed into cancer. He died of it on Aug. 16, 1886. As his famous disciple Swami Vivekananda said: "It was no new truths that Ramakrishna came to preach, though his advent brought old truths to light. In other words, he was the embodiment of all the past religious thought of India."

Bibliography.—F. Max Müller, *Ramakrishna: His Life and Sayings* (1898); "M." [Mahendranath Gupta], compiler, *Life of Sri Ramakrishna* (1924); Romain Rolland, *The Prophets of the New India*, Eng. trans. *by* E. F. Malcolm-Smith (1930); Ramakrishna, *The Gospel of Sri Ramakrishna*, Eng. trans. *by* Swami Nikhilananda (1942); D. S. Sarma, *Studies in the Renaissance of Hinduism in the Nineteenth and Twentieth Centuries*, ch. vi (1944). (S. Ra.)

RAMALHO ORTIGÃO, JOSÉ DUARTE: see Ortigão, Jose Duarte Ramalho.

RAMAN, SIR CHANDRASEKHARA VENKATA (1888–), Indian physicist, received the Nobel prize for physics in 1930 for his work on the diffusion of light. Raman discovered that the light scattered by any medium contains frequencies differing from that of the incident light by amounts which are characteristic of the scattering medium. These characteristic Raman frequencies are equal to the infrared frequencies of the substance and are caused by energy interchanges between the incident light and the scattering substance. However, some frequencies appear in the Raman spectrum which are "forbidden" in the infrared, and vice versa, so that studies of infrared and Raman spectra complement as well as confirm one another.

Less well known than the Raman effect (*q.v.*), but perhaps more important. was Raman's influence in stimulating interest in, and securing support for. scientific research in India. He contributed to the building up of nearly every research organization in India; he founded the Indian *Journal* of Physics and the Indian Academy of Sciences; he trained hundreds of students and sent them to important posts in universities, colleges and government work throughout India and Burma.

Raman was born at Trichinopoly (Tiruchirapalli), Nov. 7, 1888. He graduated from Presidency college in Madras and received a master's degree in 1907. He had already completed researches in optics and acoustics; but since there was at that time no opportunity for a scientific career in India, he entered the finance department of the Indian government, securing his position by competitive examination at the age of 19.

Continuing his researches in his spare time, he finally came to the attention of the authorities of the University of Calcutta, who offered him a professorship of physics in 1917. Raman was knighted in 1929. In 1933 he moved to the Indian Institute of Science at Bangalore as head of the department of physics. In 1947 Raman was named director of the Raman Research institute at Bangalore.

See L. Lorenz, *Chemikerzeitung*, 54:947 (1930); B. S. Mond, Proc. *Indian Acad. Sci.*, 8A:243 (1938). (*P.O.*)

RAMAN EFFECT. When a beam of monochromatic light passes through a transparent substance, a certain amount of light is scattered from the path of the original beam with altered wave length. This effect was discovered by Sir Chandrasekhara Venkata Raman (*q.v.*) in 1928 and is known by his name. The effect may be observed visually in favourable cases by directing a spectroscope toward a sufficient volume of a substance, such as a large bulb containing benzene, illuminated transversely by the light of a mercury arc lamp. Additional lines are then seen in the spectrum of the scattered light, which are not present in the spectrum of the incident beam. The effect is, however, more conveniently studied by photographing the spectrum of the scattered light, since the record thus obtained is permanent and can be examined at leisure and accurately measured.

In general, there is also a strong scattering of the incident beam without change of wave length. This records itself as a line or lines in the same position as in the incident light; while the Raman lines appear, for the most part, shifted with respect to them toward greater wave lengths. Lines shifted toward shorter wave lengths may also be recorded in the spectra, but these are usually much weaker than those shifted toward greater wave lengths. As many sets of Raman lines appear in the spectrum of the scattered light as there are monochromatic radiations in the incident beam of an intensity sufficient to give an observable effect.

The changes of wave length observed in the Raman effect owe their origin to the movements of the molecules of the scattering material. The translatory movements give rise to shifts of wave length which are usually small and irregular and therefore unobservable. The rotations of the molecules in gases give more readily observable effects, viz., a set of closely spaced but nevertheless discrete Raman lines located on either side of the incident line. In liquids, only a continuous wing or band is usually observed in the same region, indicating that the rotations in a dense fluid are hindered by molecular collisions. The internal vibrations of the molecules. on the other hand. give rise in all cases to large shifts of wave length. The Raman lines attributed to them appear well separated from the parent line and are therefore easily identified and measured.

A proper interpretation of the effect can only be based on the quantum theory (*see* QUANTUM MECHANICS), though certain classical analogies (namely, combinational tones in acoustics and frequency modulation in radio) may be invoked to aid its comprehension. The simplest view of the phenomenon is that it results from the exchange of energy between the light quanta and the molecules of the substance on which they impinge. If the energy $h\nu$ of the light quantum is in part taken over by the molecule in the form of vibrational or rotational energy $h\nu_m$, the residue $h\nu - h\nu_m$ appears as scattered radiation of lower frequency $\nu - \nu_m$. If, on the other hand, the molecule parts with energy $h\nu_m$ to the light quantum, the latter has its energy increased to $h\nu + h\nu_m$ and appears as scattered radiation of increased irequency $\nu + \nu_m$. In either case, the difference between the irequencies of the incident and scattered radiations is ν_m, which is a characteristic frequency of the molecule. The correctness of this explanation is proved by the fact that the positions and strengths of the lines recorded in the spectra are correctly predicted by considerations based on it. In particular, the lines oi frequency $\nu + \nu_m$ and $\nu - \nu_m$ are not recorded with equal strength, but have an intensity ratio $e^{-h\nu_m/kT}$ which is a function of the temperature T and also depends on the energy-quantum $h\nu_m$ which is transierred in the process of light scattering.

A thorough understanding of the subject of Raman spectra would involve further considerations regarding the optical properties of molecules as well as the dynamical theory of their rotations and vibrations. It should, however, be remarked that molecular rotations and vibrations do not in every case give Raman lines. Methane gas (CH_4), for instance, does not give an observable effect, because oi the rotation of its molecules. The molecules of benzene (C_6H_6) have no fewer than 20 distinct frequencies of possible vibration, but less than half this number are observed as frequency shifts in its Raman spectrum. Such cases of nonactivity have, however, been satisfactorily explained. The symmetry of form and structure of the molecule and the symmetry of the particular modes of vibration play an important role in the more complete theory. The vibration frequencies are themselves determined by the atomic masses and the interatomic forces which hold the atoms together in the molecule.

The applications of the Raman effect have been many and varied. Several of them depend on the fact that the nature oi the spectrum is characteristic of the molecule and indicative oi its structure. For example, X-ray measurements and other data indicate that in nitrous oxide (N_2O) the atoms are aligned, but the Raman spectrum shows that the arrangement of these atoms is asymmetrical rather than symmetrical, that is, N-N-O not N-O-N. Further, the study of the spectra may he used as a basis of qualitative identification or quantitative estimation where the usual methods of chemical analysis are too laborious or fail altogether. Raman spectroscopy has also been used to follow chemical or physicochemical processes of a progressive nature occurring in the substance under study. Electrolytic dissociation, molecular association, polymerization and chemical reactions have been studied by its aid with notable success.

Raman effect studies have also aided theoretical chemistry by providing numerical data regarding the nature and magnitude of the interatomic forces in molecules and molecular complexes. They have also enabled disputed questions regarding the symmetry or structure of molecules to be decisively settled. The substitution of atomic isotopes (for instance, deuterium for hydrogen) in molecules of known structure resulting in a change of the vibration frequencies has been employed extensively in such studies. In addition, the rotational and vibrational frequencies of molecules determined from the Raman spectra are fundamental requisites for elucidating their optical and thermodynamic behaviours.

The study of the Raman spectra of crystals and especially of the simpler ones, such as diamond, rock salt and quartz, is of exceptional interest because the facts observed throw light on the nature and properties of the solid state of matter. Theory indicates that a perfect crystal free from internal imperfections and inclusions should scatter no light except that which appears with changes of irequency due to internal vibrations in the solid These vibrations are found to be oi a fundamentally different nature in the lower and upper parts of the frequency range. In the former part of the range, the vibrations resemble those in an elastic solid which would result from longitudinal and transverse waves travelling in opposite directions and forming stationary wave patterns within its volume. In the upper part of the frequency range, there is a different kind of disturbance, namely atomic vibrations on a fine scale which represent periodic changes in the structure of the crystal. These vibrations are restricted at any one time to volume elements of extremely small dimensions. Raman effect studies have shown that the spectral characters of the two types of vibration are wholly different. The elastic vibrations have a continuous spectrum of frequencies; the atomic vibrations appear as a set of sharply defined lines in the infrared region of the spectrum. Their frequencies are determined by the geometry of the crystal structure as well as by the atomic masses and the interatomic forces.

BIBLIOGRAPHY.—The discovery of the Raman effect was first announced by Sir C. V. Raman in the *Indian Journal of Physics,* ii, 387 (Calcutta, 1928). Since then, an extensive literature has grown up around the subject. A useful summary of the work done up to 1942 is found in an article by G. Glockler in the *Reviews of Modern Physics,* xv, 111 (New York, 1943). The following treatises published in English. besides others in French and German, deal fully with particular aspects of the subject: J. H. Hibben, *The Raman Effect and Its Chemical Applications* (New York, 1939); S Bhagavantam, *Scattering of Light and the Raman Effect* (Brooklyn, 1942); G. Herzberg, *Infrared and Raman Spectra of Polyatomic Molecules* (New York, 1945).

(C. V. R.)

RAMANUJAN, SRINNASA (1887–1920), Indian mathematician who worked on the theory of numbers. mas born at Erode, southern India, on Dec. 22. 1887 His full name was Srinivasa Ramanuja Ayengar. He was educated at the town high school and at the Government college at Kumbakonam. He obtained a scholarship from the University of Madras, but after his marriage. in 1909, became a clerk in the Madras Port trust. Correspondence with G. H. Hardy of Cambridge led to his obtaining a further scholarship from Madras university. and a grant from Trinity college, Cambridge. In spite of religious difficulties arising from the fact that he was a Brahmin he came to England in April 1914, where Hardy. by private teaching. helped to provide the necessary mathematical background for his original work. His mathematical work is on the theory of numbers. theory of partitions and the theory of continued fractions. He became ill in 1917, returned to India in 1919, when he resumed some of his mathematical work, but died on April 26. 1920, at Kumbakonam. He was elected a fellow of the Royal society in 1918 and a fellow of Trinity college later in the same year.

Ramanujan's notebooks were published in 1957.

See G. H. Hardy, P. V. Seshu Aiyar and B. M. Wilson (eds.), ***Collected Papers of Srinivasa Ramanujan*** (1927); G. H. Hardy, ***Ramanujan*** (1940). (O. OE.)

RAMANUJAS, followers of Ramanuja, a southern Brahmin of the 12th century. Sri Vaishnavas, as they are usually called, worship Vishnu (Narayana) with his consort Sri or Lakshmi (the goddess of beauty and fortune), or their incarnations Rama with Sita and Krishna with Rukmini. Ramanuja's doctrine is essentially based on the tenets of an old Vaishnava sect, the Bhagavatas or Pancharatras, who worshipped the Supreme Being under the name of Vasudeva (later identified with Krishna, as the son of Vasudeva). They established shrines at Srirangam near Trichinopoly. Mailkote in Mysore, Dvaraka (the city of Krishna) on the Kathiawar coast, and Jagannath in Orissa; all of them were decorated with Vishnu's emblems, the tulasi plant and salagram stone. While Sankara's mendicant followers were prohibited to touch fire and had to subsist entirely on the charity of Brahman householders. Ramanuja, on the contrary, not only allowed his followers to use fire, but strictly forbade their eating any food cooked, or even seen, by a stranger. On the speculative side, Ramanuja met Sankara's strictly monistic theory by another, recognizing Vishnu as identical with Brahma, the Supreme Spirit animating the material world as well as the individual souls which have become estranged from God through unbelief, and can only attain again conscious union with him through devotion or love (bhakti). His tenets are expounded in various works, especially in his commentaries on the Vedantasutras and the Bhagavadgita. The followers of Ramanuja split into two sects, a northern one, recognizing the Vedas as their chief authority, and a southern one, basing their tenets on the Nalayir, a Tamil work of the Upanishad order.

RAMBAUD, ALFRED NICOLAS (1842–1905), French historian, was born at Besançon on July 2, 1842. After studying at the École normale supérieure, he completed his studies in Germany. He was appointed *répétiteur* at the École des Hautes Etudes on its foundation in 1868. His earlier historical work was done in Byzantine and Russian history. Probably his study of Russia was motived partly by his sense of the desirability of a Franco-Russian entente. Rambaud was *chef de cabinet* to Jules Ferry (1879–81), and in 1883 became professor of contemporary history at the Sorbonne.

He now wrote his *Histoire de la civilisation française* (2 vol., 1885, 1887; 9th ed., 1901) and his *Histoire de la civilisation contemporaine en France* (1888; new ed. entirely revised, 1906), and undertook the general editorship of the *Histoire générale du IV^{e} siècle jusqu'à nos jours.* The plan of this great work had been drawn up with the aid of Ernest Lavisse, but the entire supervision of its execution was carried out by Rambaud. Rambaud held the position of minister of Public Instruction from 1896 to 1898, and sought to carry on the educational work of Jules Ferry. He died in Paris on Nov. 10, 1905.

See the notices by E. Lavisse in the *Revue de Paris* for January 15th, 1906, and G. Monod in the *Revue historique* (vol. xc., pp. 344–348).

RAMBOUILLET, CATHERINE DE VIVONNE, MARQUISE DE (1588–1665), French *salonnière,* was the daughter and heiress of Jean de Vivonne, marquis of Pisani, and Giulia Savelli. She was married at twelve to Charles d'Angennes, vidame of Le Mans, and afterwards marquis of Rambouillet. The young ,marquise found the coarseness and intrigue that then reigned in the French court little to her taste, and after the birth of her eldest daughter, Julie d'Angennes, in 1607, she began to gather round her the circle afterwards so famous. She established herself at the Hôtel Pisani, called later the Hôtel de Rambouillet. Almost all the more remarkable personages in French society and French literature frequented it, especially during the second quarter of the 17th century. Madame de Rambouillet's natural abilities had been carefully trained, but were not extraordinary. She had genuine kindness and a lack of prejudice that enabled her to entertain on the same footing princes and princesses of the blood royal, and men of letters, while among her intimate friends was the beautiful Angélique Paulet. The respect paid to ability in her salon effected a great advancement in the position of French men of letters. The almost uniform excellence of the memoirs and letters of the period may be traced largely to the development of conversation as a fine art at the Hôtel de Rambouillet, and the consequent establishment of a standard of clear and adequate expression. Mme. de Rambouillet was known as the "incomparable Arthénice," the name being an anagram for Catherine, devised by Malherbe and Racan. Among the famous incidents in the story of the Hôtel are the sonnet war between the Uranistes and the Jobistes—partisans of two famous sonnets by Voiture and Benserade—and the composition by all the famous poets of the day of the *Guirlande de Julie,* a collection of poems on different flowers, addressed in 1641 to Julie d'Angennes, afterwards duchesse de Montausier. Julie herself was responsible for a good deal of the preciosity for which the Hôtel was later ridiculed.

The *Prkcieuses,* who are usually associated with Molière's avowed caricatures and with the extravagances of Mlle. de Scudéry, but whose name, it must be remembered, Madame de Sévigné herself was proud to bear—insisted on a ceremonious gallantry from their suitors and friends, though it seems from the account given by Tallemant des Réaux that practical jokes of a mild kind were by no means excluded from the Hôtel de Rambouillet. They especially favoured an elaborate and quintessenced kind of colloquial and literary expression, imitated from Marini and Gongora, and then fashionable throughout Europe. Molière's attack was probably levelled not at the Hôtel de Rambouillet itself, but at the numerous coteries which in the course of years had sprung up in imitation of it. But the satire did in truth touch the originators as well as the imitators,—the former more closely perhaps than they perceived. The Hôtel de Rambouillet continued open till the death of its mistress, on Dec. 2, 1665, but the troubles of the Fronde diminished its influence.

The chief original authorities respecting Madame de Rambouillet and her set are Tallemant des Réaux in his *Historiettes,* and Antoine Baudeau de Somaize in his *Grand Dictionnaire des Précieuses* (1660). Many modern writers have treated the subject, notably Victor Cousin, *La Société française au xvii^{e} siècle* (2 vols., 1856), and C. L. Livet, *Précieux et Précieuses . . .* (1859). There is an admirable edition (1875) of the *Guirlande de Julie* by O. Uzanne.

RAMBOUILLET, a town of France, capital of an arrondissement in the department of Seine-et-Oise, 30 mi. S.W. of Paris on the railway to Chartres. Pop. (1946) 7,169. Rambouillet derives its interest from the associations connected with the ancient chbteau. Originally a royal domain, the lands of Rambouillet passed in the 14th century to the D'Angennes family, who held them for 300 years and built the chbteau. Francis I died there in 1547; and Charles IX and Catherine de Medici found a refuge there in the Wars of Religion, as Henry III did after them. The title became a marquisate in 1612, and a dukedom under Louis XIV. It was here that in 1830 Charles X signed his abdication. The shooting of the famous coverts of Rambouillet was resewed for French presidents of the republic.

RAMEAU, JEAN PHILIPPE (1683–1764), French musical theorist and composer, was born at Dijon, the son of an organist, on Oct. 23, 1683. His father wished him to study law, but the boy's head was full of music, which he could only pursue in haphazard fashion. In 1701 his father sent him to Milan to break off a foolish love-match. But he learned little in Italy, and soon returned in company with a wandering theatrical manager, for whom he played the second violin. He next settled in Paris, where he published his *Premier livre de pièces de clavecin,* in 1706. He succeeded his father as organist of Notre Dame, Dijon, in 1709, and in 1714 removed to Lyons, where he was organist at the Jacobins. In 1715 he was organist at Clermont-Ferrand and working on his *Trait6 de l'harmonie.* There he remained until 1722. He studied the writings of Zarlino, Descartes and other theorists.

Rameau's keen insight into the constitution of certain chords, which in early life he had studied only by ear, enabled him to propound a series of hypotheses, many of which are now accepted. While the older contrapuntists were perfectly satisfied with the laws which regulated the melodious involutions of their vocal and instrumental parts, Rameau demonstrated the possibility of building up a natural harmony upon a fundamental bass, and of using that harmony as an authority for the enactment of whatever laws might be considered necessary for the guidance either of the contrapuntist or the less ambitious general composer. And in this he first explained the distinction between two styles, which have been called the "horizontal and vertical systems," the "horizontal system" being that by which the older contrapuntists regulated the onward motion of their several parts, and the "vertical system" being that which is built up perpendicularly from the bass. From fundamental harmonies he passed to inverted chords, to which he was the first to call attention; and the value of this discovery fully compensates for his erroneous theory concerning the chords of the eleventh and the great (Angl. "added") sixth. *(See* HARMONY.)

Rameau first set forth his new theory in his *Traité de l'harmonie* (Paris, 1722), and followed it up in his *Nouveau systkme* (1726), *Génération harmonique* (1737), *Dkmonstration* (1750) and *Nouvelles réflexions* (1752). After his return to Paris in 1722 he produced some light dramatic pieces, and then showed his real powers in his opera, *Hippolyte et Aricie,* founded on Racine's *Phkdre* and produced at the Académie in 1733.

Rameau wrote more than 20 operas, the most successful of which were *Dardanus, Castor et Pollux, Les Indes galantes* and *La princesse de Navarre.* Honours were showered upon him. He died in Paris on Sept. 12, 1764. Rameau was undoubtedly the greatest French musician of his day.

BIBLIOGRAPHY.—Biographies by Charles Poisset (1864), Nisard (1867), Pougin (1876) and L. de la Laurencie (1908); also Chabanon, *Eloge* (1764); Paul-Marie Masson, *L'Opéra de Rameau* (1926). His *Oeuvres complètes,* ed. by Saint-Saens (1894 *et seq.),* had reached the 18th volume in 1924.

RAMESES or RAMESSES (Gen. xlvii, 11; Ex. xii, 37: Num. xxxiii, 3), or, with a slight change in the vowel points, RAAMSES (Ex. i, 11), the name of a district and town in Lower Egypt, is notable as affording the mainstay of the current theory that King Rameses II was the Pharaoh of the oppression and his successor Merneptah the Pharaoh of the exodus. The first three passages cited above are all by the priestly (postexile) author and go together. Jacob is settled by his son Joseph in the land of Rameses and from the same Rameses the exodus naturally takes place. The older narrative speaks not of the land of Rameses but of the land of Goshen; it seems probable, therefore. that the later author interprets an obsolete term by one current in his own day. just as the Septuagint in Gen. xlvi, 28, names instead of Goshen Heroopolis and the land of Rameses. Heroopolis lay on the canal connecting the Nile and the Red sea, and not far from the head of the latter, so that the land of Rameses must be sought in Wadi Tumilat, near the line of the modern fresh-water canal. In Ex. i, 11, again. the store-cities or arsenals which the Hebrews built for Pharaoh are specified as Pithom and Raamses, to which the Septuagint adds Heliopolis. Pithom also takes us to the Wadi Tumilat. It is possible that these names were added by a writer who knew what fortified places were in his own time to be seen in Wadi Tumilat, for the form of the story of the Hebrews in Egypt is throughout deficient in precise geographical data The postexile or priestly author indeed gives a detailed route for the exodus (which is lacking in the older story), but he, we know, was a student of geography and might supplement tradition by what he could gather from traders as to the caravan routes.

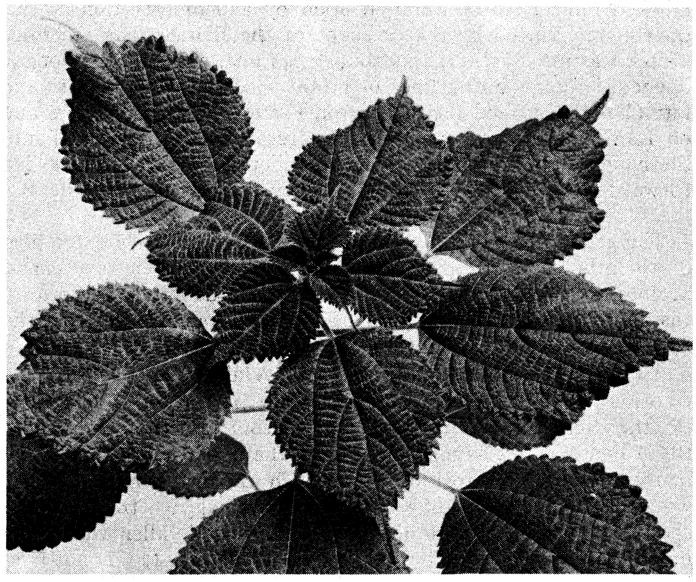
It appears, however, from remains and inscriptions that Rameses II did build in Wadi Tumilat, especially at Tell Maskhuta, which Lepsius therefore identified with the Raamses of Exodus. But E. Naville's excavations found that the ruins were those of Pithom and that Pithom was identical with the later Heroopolis. F. Petrie found sculptures of the age of Rameses II at Tel Rotab, in the Wadi Tumilat west of Pithom, and concludes that this was Rameses. The biblical city is probably one of those named Prameses, "House of Ramesses," in the Egyptian texts.

RAMESWARAM, a town in Ramanathapuram district, Madras state, India, on Rameswaram Island, in Palk strait. 93 mi. S E. of Madura, with which it is connected by a railway bridge. Pop. (1951) 5,419. Its great temple commemorates Rama's crossing over to Ceylon by Rama's or Adam's bridge (*q.v.*).

RAMIE. Ramie is a textile fibre of the soft or bast fibre group, which occur as longitudinal strands in the inner bark of dicotyledonous (broadleaf) plants. The individual cells of the fibre bundles are botanically true fibres—elongated and thick walled with characteristic pitting. These cells are tenaciously gummed one to the other to form the cablelike strands which become commercial fibre when once freed from other bark tissues. The ramie or "China grass" plant is a many-stemmed shrub, *Boehmeria nivea,* of the nettle family (Urticaceae). The variety *tenacissima* is called Rhea. Slender stems as much as eight feet long bear heart-shaped leaves with a whitish underside along the upper third of the stalk. At their base the stems may be nearly an inch thick and contain there the most abundant fibre. The ramie plant is perennial, new stems arising from the crown after the old are cut. A planting should endure for several years. with about three harvests annually. The species prefers warm humid climate and rich soils and should be fertilized generously to maintain good stands.

Ramie has been under cultivation from time immemorial. It was grown in ancient Egypt. where it was used to wrap mummies. Presumably it is native to China and Formosa and is mentioned in Chinese literature as early as 2200 B.C. Since 1855 it has been planted sporadically in the southern United States. Several attempts at European culture have been unsuccessful.

Fibres.—The fibres themselves are strong (eight times more so than cotton), durable and of fine texture and good colour. The cells are among the longest of natural fibres—up to one foot long but only $\frac{1}{750}$ in. in diameter. Ramie is superior in many respects to flax, hemp and jute. Its chief liability, however. has been the difficulty of freeing the fibre bundles from the gummy ensheathing tissues and inability to adapt the crop to large-scale mechanized handling. Production lagged behind major fibres, running only about 20,000 or 25,000 tons annually, produced mostly in China, with exports largely to Japan and Europe. In the United States it has continued as a minor crop in Florida, Louisiana, Texas and California.



WALTER SINGER

RAMIE (BOEHMERIA NIVEA) LEAVES

Retting.—Retting is the process of freeing stem fibres by bacterial decomposition (rotting). The thin-walled cells of softer tissue decompose more readily than thick-walled resistant fibres. Immersing the stems or exposing moistened stems to air usually fails to decompose the cementing gums of ramie, so that the fibre must be separated by pounding and scraping and even then contains up to one-fourth its weight as resin. Eventually the resin or gum must be dissolved chemically. The fibres then become flexible and smooth—so smooth, in fact, that spinning becomes difficult on machinery developed for other fibres. In the far east harvest is by hand a stalk at a time. Each stem can be selected for proper maturity. The limited production in the U.S. is harvested by machine. Much ramie is homespun in the east, with little final cleaning. This gives a coarse, although enduring, fabric. Adhesive gums can be removed by procedures such as boiling in lye, or sometimes an acid treatment, bleaching or induced retting. Degummed fibre is washed, then "softened" with glycerin, waxes or soaps. Spinning is usually on machinery designed for silk or other fibre. Most ramie fabric includes a percentage of some other fibre, such as wool or cotton. It has been used in fire hose, fishing nets. propeller-shaft packing, hats, upholstery and various fabrics. Clothing made of ramie cloth wears well and is said to be mothproof. (R. W. SY.)

RAMILLIES, a village of Belgium, in the province of Brabant, 13 miles N. by E. of Namur, between the sources of the Little Gheete and of the Mehaigne. Pop. (1955 est.) 606. It is famous for the victory of the Allies under the duke of Marlborough over the French commanded by Marshal Villeroi on May 12–23, 1706, in the War of the Spanish Succession (*q.v.*). The position of the French on the high ground about Ramillies was marked by the villages of Autréglise (Anderkirch) on the left, Offuz on the left centre, Ramillies on the right centre and Taviers on the right close to the river Mehaigne. In front of the last was a smaller village, Franquenay, which was held as an advanced post. Between these *points d'appui* the ground was mostly open upland, and the position as a whole was defective in so far that the villages were barely within cannon shot of each other. It was particularly strong on the flanks, which were protected by the marshy beds of the Mehaigne and the Little Gheete. Ramillies stands almost on the watershed of these adjacent valleys, and here Marlborough decided to deliver his main attack. The forces were about equal and were at first equally distributed along the whole line of each army. Marlborough's local concentration of force at the spot where the attack was to be pressed home was made not before, but after the action had opened. Villeroi's left wing of cavalry and infantry was secure — and at the same time immobilized — behind the upper course of the Little Gheete, and the French commander allowed himself to be imposed upon by a demonstration in this quarter, convinced by the presence of the British that a serious attack was intended. It was about 1:30 P.M. when the cannonade opened. Soon the first lines of infantry of the Allied centre and left (Dutch) opened the attacks on Franquenay and Taviers and on Ramillies, and, when after a severe struggle Taviers fell into the hands of the Dutch, their commander, Marshal Overkirk, led forward the whole of the left-wing cavalry and fiercely engaged the French cavalry opposed to it.

The ground was open, both parties had placed the greater part of their horse on this side and it was only after a severe and prolonged engagement that the Allies were definitely victorious, thanks to the arrival of a force of cavalry brought over from the Allied right wing. Meanwhile the principal attack on Ramillies had been successfully pressed home. While Villeroi was trying to bring up supports from the left to take part in the cavalry battle, the French in Ramillies were driven out into the open, where the Allied cavalry, having now gained the upper hand, rode down many battalions. Most of the French cavalry from the other wing, having to force its way through the baggage trains of the army arrived too late, and once Ramillies had fallen the whole line of the Allies gradually took up the offensive. It was not long before the French line was rolled up from right to left, and the retreat of the French was only effected in considerable confusion. Then followed for once a relentless pursuit carried on by the British cavalry to Louvain, 20 mi. from the field of battle.

RAMMED EARTH (PISÉ DE TERRE) is a building material resulting from the application of compaction to certain soils. Of the forms of earth building used by civilizations of varying technical development, rammed earth is the most durable. Since World War II it has been especially studied as an economic technique for underdeveloped regions. Its use is limited to soils with high sand and low clay contents, 70%:30% being a usual proportion, with the sand graded to various particle sizes. The mix, with about 10% water added, is compacted in molds by iron-headed rammers weighing 5 to 20 lb. (See SOIL MECHANICS.)

The mold may be a box for individual wall blocks or a long wooden form, about 2 ft. high, consisting of two sides separated by spacer bolts, which is placed on the wall. The soil is rammed into this in about 3-in layers. the form being removed when it is filled and again superimposed. Special angle, 'T' and stopped-end forms are used for corners, junctions and openings. Roller-mounted forms, pneumatic rammers and hydraulic, mass-production block presses are available.

The moisture content at compaction is critical to the ultimate strength and shrinkage of the wall, the optimum falling between narrow limits. Compressive strengths vary from 100 lb. per square inch to 500 lb. per square inch, while densities average 130 lb. per cubic foot and increase with sand content. Minimum wall thicknesses are usually 12 in.; this mass results in a high thermal capacity, the wall thus acting as a thermal flywheel. The time lag in its temperature changes maintains uniform internal conditions in climates with large day-night temperature variations. The wall surface is often given increased weather resistance with plaster, bitumen or linseed-oil treatment. Strength and weather resistance can be increased by small additions of soil stabilizers. Portland cement and bitumen are the most commonly used.

(T. A. M.)

RAM MOHAN ROY (1772–1833), the founder of Brahmo Samaj (*q.v.*) in India, was not only a great religious leader and social reformer but also a far-seeing statesman who indicated the lines of progress for India under British rule. Hence he is sometimes called the father of modern India. He was born in 1772 in a village in Burdwan district in Bengal. During the first 30 years of his life he seems to have traveled widely outside his province and mastered several languages — Sanskrit, Persian, Arabic, Hebrew, Greek and English, in addition to Bengali, his mother tongue. In 1803 he secured an appointment under the East India company, served its administration in various capacities until he retired in 1815 and settled in Calcutta. There he began his great agitation against the rite of suttee (*q.v.*) and vigorously kept it up until suttee was abolished by law by Lord William Bentinck in 1829.

During 1815–19 Ram Mohan published his translations of the Upanishads and his papers on Hindu theism. His object in these and similar writings was to wean his countrymen from what he regarded as the corruptions of medieval Hinduism and the evils of Hindu society, *viz.,* idol worship, animal sacrifices, polygamy and the caste system, and to draw their attention to the original purity of the teachings of Vedanta (see INDIAN PHILOSOPHY: The Vedanta). It was for achieving this object that he also later founded the Brahmo Samaj (1828).

Ram Mohan next turned his attention to the problem of education, and in a famous letter to Lord Amherst (1823) made a vigorous plea for scientific and English education for India in preference to the traditional Sanskrit education. He was as great a champion of political freedom as he was of scientific education; his memorial for the repeal of the Press ordinance of 1823 has been hailed as the Areopagitica of Indian history. Ram Mohan's letters show that he greatly admired the progress of freedom in Europe and hoped that India through its British connection would grow in knowledge and freedom and ultimately claim equal partnership with Britain.

In 1830 he went to England on behalf of the titular emperor of Delhi to plead his cause before the British government. He fell ill there and died at Bristol on Sept. 27, 1833. (D. S. SA.)

RAMNAD (RAMANATHAPURAM), a town and district of Madras. India. The town (pop. [1951] 24.053) is at the base of the peninsula that juts out toward Rameswaram Island. in Palk strait. It was the seat of the head of the Maravar caste: his title was setupathi, "lord of Ramasetu" or Rama's causeway (Adam's bridge, the chain of shoals across Palk strait).

RAMNAD DISTRICT (area 4,849 sq.mi.; population [1961] 2,420,-943) is a desolate tract crossed by the Southern railway branch running from Madura to the Palk strait ferry. Fishing is carried on.

RAMÓN Y CAJAL, SANTIAGO (1852–1934), Spanish histologist and with Camillo Golgi (*q.v.*) joint winner of the 1906 Nobel prize for medicine in recognition of their work on the structure of the nervous system, was born May 1, 1852, at Petilla de Aragon. He was a wild youth and so backward in his studies that his father, a struggling country surgeon, took him away from school and apprenticed him first to a barber and then to a cobbler. He was eventually allowed to enter the medical school of Saragossa (Zaragoza) and after obtaining his medical licence in 1873 served for a year as an army surgeon in Cuba.

In 1875 he was appointed an assistant in the Saragossa medical faculty and having at last found his natural bent he devoted himself to the study of anatomy. In 1877 he was promoted extraordinary professor and two years later he became director of the medical museum of Saragossa university. In 1883 he went to the University of Valencia as professor of descriptive anatomy and in 1887 to the University of Barcelona as professor of histology and pathological anatomy.

From 1892 until his retirement in 1922 he held the chair of histology and pathological anatomy at the University of Madrid. He died on Oct. 17, 1934.

Ramón y Cajal won world-wide fame by his researches on neuroanatomy. Having adapted Golgi's silver-stain method of staining nervous tissue, he began to explore the then unknown world of the cerebellum and the cerebrum and to publish the results of his researches in a flood of books and papers. One of his most fundamental achievements was the establishment of the neuron or nerve cell as the basic unit of the nervous system. Among his best-known writings are the great Manual de *histologia* normal y *técnica micrográfica* (1889; Eng. trans., 1933), Textura del sistema nervioso del hombre y de *los* vertebrados (1897–1904) and Estudios *sobre* la degeneracidn y regeneracidn del *sistema nervioso* (1913–14; Eng. trans. 1928). He was also the author of a fascinating autobiography, *Recuerdos de mi vida* (1901; Eng. trans., 1937), and of the earlier *Charlas de Cafe'* (1920), containing anecdotes and thoughts on a wide variety of subjects.

See D. F. Cannon, Explorer of the Human Brain: The Life of Santiago Ramdn y *Cajal* (1949). (W. J. Bp.)

RAMPION (*Campanula rapunculus*), a biennial plant of the Campanulaceae family, native to Europe, that is sometimes cultivated as a vegetable for its first-year roots and radical leaves for use as a salad. The white roots are about a foot in length and spindle shaped. Horned rampion is the common name applied to species of the genus *Phyteuma* of the same family. Several of these are used as rock-garden plants. (J. M. Bl.)

RAMPOLLA, COUNT MARIANO DEL TINDARO (1843–1913), Italian cardinal: was born on Aug. 17, 1843, at Polizzi, in the Sicilian diocese of Cefalù. Having completed his studies in the Capranica college, at Rome, and having taken holy orders, he studied diplomacy at the College of Ecclesiastical Nobles and in 1875 was appointed councilor to the papal nunciature at Madrid. Two years later he was recalled to Rome and received high office. After another brief stay in Madrid as nuncio he was created cardinal and became papal secretary of state. New to the Sacred College and free from traditional preconceptions, he was admirably fitted to carry out the papal policy under Leo XIII. (*See* Papacy.) Rightly or wrongly, he was held personally responsible for the rapprochement with France and Russia and the opposition to the Powers of the Triple Alliance; and this attitude had its effect on his career when Leo XIII died. Rampolla was not selected as pope, owing to the veto of Austria, and resigned his office as secretary of state. He died in Rome on Dec. 17, 1913.

RAMPUR, a town and district in the northwestern part of Uttar Pradesh. India, between Moradabad, Naini Tal. Bareilly and Budaun districts. The town (pop. [1951] 134,277), on the left bank of the Kosi river, is a centre for damask, light steelwork, pottery and sugar manufacture. It is the seat of Raza college. connected with Agra university.

Rampur District (area 895 sq.mi.; pop. [1951] 543,324) corresponds with the former princely state of Rampur (Gwalior residency). After the achievement of independence by India. Rampur was at first centrally administered from Delhi through a commissioner, but on Dec. 1. 1949, it was merged into Cttar Pradesh. The former ruler. the nawab. was a Rohilla Pathan, representing the family that established its power over this area in the 18th century. When the Kohillas were subjugated by the nawab of Oudh, with the help of a force lent by Warren Hastings, one of them. Faizullah Khan, was allowed to keep Rampur, and from him the modern ruling family descended. During the Mutiny of 1857 the nawab of Rampur rendered important services to the British.

The country is level and in general fertile, being watered in the north by the Kosi and Nahul rivers and in the south by the Ramganga. The chief crops are wheat, barley, maize, rice and sugar cane.

RAMSAY, ALLAN (c. 1685–1758), Scottish poet. His publications made available to Robert Fergusson and Robert Burns the work of earlier Scottish poets and he also preserved, though in a polished and possibly inferior form, many Scottish folk-songs and with them their tunes. His own poetry varies with some uncertainty of tone and taste between Augustan polish and the rougher freshness of Scottish vernacular poetry. Born at Leadhills, Lanarkshire, Oct. 15, 1684 or 1685. he was probably educated at the parish school of Crawford, and about 1700 left for Edinburgh, where in 1704 he was apprenticed to a wigmaker. He became a burgess in 1710, establishing himself as a wigmaker, and married Christian Ross in 1712. He was one of the founders of the literary Easy club in 1712, adopting the pseudonym first of Isaac Bickerstaff and later of Gawin Douglas. He began by writing occasional verse, the first piece of which was published in 1713: some of his poems were published as broadsheets. In 1718 he published a version of the old Scots poem, Christ's Kirk on the Green, with additional verses of his own, and a collection, Scots Songs; and he turned bookseller. The success of these ventures prompted him to publish his collected poems in 1720, and in 1721 to issue them as a quarto volume by subscription. The subscription brought in 400 guineas, and a similar edition of volume two of his *Poems* in 1728 was an even greater success. He thus achieved financial independence and about 1740 was able to retire to his house on Castle hill.

Meanwhile he had issued The Ever Green (2 vol., 1724) in which he was inspired by nationalist feelings to edit some of the older Scots literature: following the example of James Watson's Choice Collection (1706–11) he transcribed poems of Dunbar, Henryson and others from the 16th-century Bannatyne manuscript. The Tea-Table Miscellany (4 vol., 1724–37), in some editions subtitled "A Collection of Choice Songs Scots and English," contains some by Ramsay and some by his friends, several genuine folk ballads and songs and some 17th-century verse. In 1725 he published his dramatic pastoral The Gentle Shepherd, which had immense popularity. Ramsay wrote little afterward, though new editions of his work continued to appear during his lifetime.

His other activities were to set up what was apparently the first circulating library in Great Britain (before 1728), to encourage the fine arts, and against opposition to help attempts to set up a theatre in Edinburgh. In 1736 he opened a theatre in Carrubber's close, but this was closed by authority a year later.

Ramsay's place in literary history owes less to his merits as a poet than to his immense influence on two much greater men, Fergusson and Burns.

Bibliography.—Ramsay's *Works*, ed. by Burns Martin and J. W. Oliver, 4 vol. (1951–); A. Gibson, New Light on *Allan Ramsay* (1927); B. Martin, *Allan Ramsay*, a Study of His Life and Works (1931). (M. J. C. H.)

RAMSAY, ALLAN (1713–1784), Scottish portrait painter, the son of Allan Ramsay, author of *The Gentle Shepherd*, was born in Edinburgh on Oct. 13, 1713. After rudimentary training in Edinburgh he went to London and worked under the Swedish portrait painter Hans Hysing (1734), but his style was really formed by his studies in Italy (1736–38) under Francesco Imperiali and Francesco Solimena. On settling in London he soon became popular, although George Vertue in 1739 noted with distress that his style differed from the "valuable Manner" of Sir Godfrey Kneller and others and was "rather lick't than pencilled" (*i.e.*, his brushwork was smooth, not free).

His "Dr. Mead" of 1747 (Foundling hospital, London) is in the Italian grand manner, preceding Sir Joshua Reynolds' grand portraits by several years; but perhaps the rise of Reynolds induced Ramsay to return to Italy in 1755–57. During the 1760s Ramsay painted little but royal images on government commission: most of this hack work was done by assistants and Ramsay devoted himself to political pamphleteering, classical studies and conversation — Dr. Johnson said to Boswell: "I love Ramsay. You will not find a man in whose conversation there is more instruction, more information, and more elegance . . ." Ramsay died at Dover on Aug. 10, 1784. while returning from his fourth visit to Italy.

Ramsay's best works are in the National gallery of Scotland, including important drawings, and the National Portrait gallery, Edinburgh; but there are also pictures in London (National Portrait gallery and Tate gallery) and Liverpool. His "Youth With Cap and Gown" was acquired by the Huntington gallery. San Marino, Calif.. and his portrait "Mary Lillian Smith" by the Ringling museum, Sarasota, Fla.

See Alastair Smart, Life and Art of *Allan Ramsay* (1952). (P J. My.)

RAMSAY, SIR BERTRAM HOME (1883–1945), British naval officer,commander in chief of the Allied naval forces during the landings in Normandy in 1944, was born in 1883 and entered the Royal Navy in 1898. As a rear admiral he became chief of staff of the home fleet in 1935, going on the retired list three years later. He was flag officer commanding at Dover, 1939–42, and naval commander of the eastern task force, in the Mediterranean, in 1943. Reinstated on the active list in 1944 and promoted to admiral, Ramsay was placed in command of the Allied naval component, including more than 5,000 ships, that landed Allied soldiers on the Normandy beaches on June 6 and supported them with naval gunfire. He displayed outstanding qualities of leadership in that operation. Admiral Ramsay was created a knight commander of the Bath in 1940 and knight of the British empire in 1943. He died Jan. 2, 1945. (J. B. Hn.)

RAMSAY, SIR WILLIAM (1852–1916), British chemist who discovered the inert gaseous elements in air, was born in Glasgow, Scot., on Oct. 2, 1852. From 1866 to 1870 he studied in his native city. He then went to Heidelberg and studied under Robert Wilhelm von Bunsen and in 1871 went to work under R. Fittig at Tiibingen. In 1872 he became assistant in the Young laboratory of technical chemistry at Anderson's college, Glasgow. He received his Ph.D. from Tiibingen in 1873 and from 1874 was tutorial assistant in the university. In 1880 he was appointed to the chair of chemistry at University college, Bristol, and made principal in the following year. In 1887 he succeeded A. W. Williamson as professor at University college, London, a position from which he resigned in 1913. He was awarded the Davy medal of the Royal society in 1895 and the Nobel prize for chemistry in 1904. He mas made a knight commander of the Bath in 1902. He died at High Wycombe, Buckinghamshire, on July 23, 1916.

Ramsay's earliest investigations covered a wide field—from a new bismuth mineral to the physiological action of certain alkaloids —in the course of which he showed that the alkaloids are related to pyridine. which he synthesized from acetylene and prussic acid in 1876. Later he specialized definitely in inorganic and physical chemistry. With Sidney Young (1857–1937) and others he investigated the critical state, the relationship between vapour pressure and temperature and other properties of liquids (Ramsay-Young rule). In 1887 he found that absolutely dry ammonia and hydrogen chloride do not combine.

With J. Shields (1869–1920) he verified the Eotvos law of the constancy of the rate of change of molecular surface energy with temperature, and obtained evidence concerning the molecular complexity of certain liquids. In 1892 Lord Rayleigh asked for suggestions from chemists to account for the difference between the densities of chemical and atmospheric nitrogen, and Ramsay became interested in the problem. He at once predicted that an unknown heavy gas was present. Rayleigh preferred to believe that a heavy modification of nitrogen, analogous to ozone, was the disturbing factor. Ramsay devised methods for removing oxygen and nitrogen completely from air and found that there was present in addition a small quantity of a hitherto unknown gas. In hug. 1894 Ramsay and Rayleigh announced the discovery of this new gas, afterward called argon, present to the extent of almost 1% in the atmosphere. Its presence had been indicated as early as 1785 by Henry Cavendish (*q.v.*). The high density of this gas accounted for the atmospheric nitrogen having a greater density than the chemical variety. In 1895, while searching for new sources of argon, Ramsay heated the mineral cleveite with acid and obtained a gas which gave a spectrum identical with that of helium, detected in the sun by Sir J. N. Lockyer and Sir E. Frankland in 1368. In this way helium was first obtained, but it was later found to be present in the air to the extent of about 1 part in 250,000.

Both helium and argon were found to be absolutely inactive chemically and so were called the inert gases. They fitted into the periodic system although no provision had been made for chemically inactive elements. Furthermore, a study of their position in the periodic table led to the belief that at least three more such gases should exist. Ramsay, with M. Travers, found them in 1898 in the liquid air residues from which oxygen and nitrogen had been removed; they were called neon. krypton and xenon and mere found to be present in the air only to an extremely minute extent (*e.g.,* xenon, 1 part in 170,000,000). Ramsay next turned to radioactivity, since he noted the association of helium with radioactive minerals. With F. Soddy (*q.v.*) he found in 1903 that helium was continuously produced as a disintegration product of radium emanation. This discovery led to the transmutation theory and its important consequences. In 1910 Ramsay obtained a small quantity of radium. and with Whytlaw Gray he was able, as a result of a wonderful piece of experimental work, to determine the density, and incidentally the atomic weight, of about one three-millionth part of a cubic inch of radium emanation. The atomic weight showed that this gas was the last of the inert-gas series. It was called niton and is now mainly known as radon (*q.v.*) or emanation. Ramsay thus has the unique fame of discovering a whole family of new elements.

Ramsay's works include: *A System of Chemistry* (1891); *The Gases of the Atmosphere* (1896; 4th ed., 1915); *Modern Chemistry,* 2 vol. (1901); *Essays Biographical and Chemical* (1909); *Life and Letters of Joseph Black* (1918); *Elements and Electrons* (1913); *Introduction to the Study of Physical Chemistry* (1904).

Bibliography.—Sir William Tilden, *Sir William Ramsay* (1918), *Famous Chemists* (1921); obituary notice, *Proceedings Royal Soc.* (1916–17); R. B. Moone, *Journal of the Franklin Institute (1918).*

(R. E. O.)

RAMSBOTTOM, an urban district in the Rossendale parliamentary division of Lancashire, Eng., 11 mi. S.S.W. of Burnley by road. Pop. (1951) 14,589. Area 14.9 sq.mi. It includes the villages of Holcombe, Edenfield. Shuttleworth, Summerseat. Stubbins and Holcombe Brook. The main industries are textile spinning and printing, weaving, bleaching and dyeing, papermaking and engineering. Moorland uplands surround developed areas. The name is said to mean "wild garlic valley."

RAMSDEN, JESSE (1735–1800), English astronomical instrument maker, whose celebrated five-foot vertical circle, made for the observatory at Palermo, Italy (1789), quickened the tendency of divided circles to supersede quadrants in observatories toward the end of the 18th century.

He was born at Salterhebble near Halifax, Yorkshire, probably on Oct. 6, 1735. After serving his apprenticeship with a cloth-worker in Halifax, he went in 1755 to London, where in 1758 he was apprenticed to a mathematical instrument maker. About four years afterward he started his own business and secured a great reputation with his products. He died at Brighton on Nov. 5, 1800. Ramsden specialized in divided circles; the Palermo vertical circle was used by the monk-astronomer G. Piazzi in constructing his well-known catalogue of stars.

RAMSEY, a market town and urban district of Huntingdonshire (and in the parliamentary division of that county), Eng., lying on the southwestern border of the Fens, 13 mi. N.N.E. of Huntingdon by road. Pop. (1951) 5,770. Area 25.0 sq.mi. The town came into existence as a result of the founding of the Benedictine abbey in A.D. 969 by Duke Ailwyn, who bore the strange title *Totius Angliae Aldermanus* ("Alderman of all England"). A charter of King Edgar granted lands and privileges for the foundation. Ramsey abbey is one of the most historical features in the Fens. It was a "mitred" abbey; *i.e.,* its abbot was entitled to a seat in parliament. It was granted special privileges and freedom from ecclesiastical and secular control and was a seat of learning long before Oxford and Cambridge. Its library of Hebrew books was famous. After the Dissolution its demesnes were granted to Sir Richard Cromwell and the buildings fell into ruins, loads of stones going to Cambridge for Gonville and Caius. King's and Trinity colleges. Subsequently a new building was erected on the site. Of the ancient Benedictine abbey the only remains are a part of a gateway, now restored (National Trust), a lodge and some buttresses, while broken stone arches and walls remain of the conventual buildings in the basement. A statue supposedly of Ailwyn, once in the abbey, has been placed in the gatehouse.

The church of St. Thomas a Becket is transitional and has a Norman east end. The tower was built in 1672 of stone from the abbey. An oak lectern, dating from the 15th century, carries a chained copy, in a brass binding. of Dean Thomas Comber's (1645–99) book on the Common Prayer and a black-letter copy of Erasmus' paraphrase of the New Testament. There are many interesting tombs in the churchyard, and the church register contains entries relating to the Cromwell family. who moved to Ramsey from Huntingdon and owned the abbey estates until the year 1674.

Ramsey has a market for agricultural produce, potatoes being the chief product of the district, and Ramsey mere, now drained, forms excellent wheat land.

RAMSGATE, a municipal borough, holiday resort, seaport and limb of the Cinque Port of Sandwich, in the Isle of Thanet parliamentary division of Kent, Eng., 18 mi. N.N.E. of Canterbury by road. Pop. (1961) 36,906. Area 5.7 sq.mi. Ramsgate was originally a small fishing hamlet and is mentioned in a charter of Charles II as being under the jurisdiction of Sandwich, of which town Ramsgate became a limb or liberty within the confederation of the Cinque Ports in the reign of Henry VII. From that time Ramsgate developed as a seaport. The present harbour, on which George IV conferred the royal style or title, was built in the mid-18th century, and from that time substantial trade was developed with Baltic and other continental countries. Ramsgate became noted as a health resort in the middle of the Victorian era and is now one of the most popular seaside holiday towns on the coast of Kent. During World Wars I and II the Royal harbour was used as a naval base and some 83,000 troops were landed there at the time of the Dunkirk evacuation (1940). The port has good facilities for commercial traffic and is a centre for motor cruisers and yachts. Promenades and gardens have been constructed along the cliffs rising on either side of the harbour, and attractions for the visitor are numerous, including great sandy beaches. The development of the Kent coalfield during the 20th century brought additional trade to Ramsgate, the nearest pits being Betteshanger and Chislet about 10 mi. away. Small light industrial factories have been established in and near the town. Ramsgate has many historical associations. Cliffsend on the western extremity of the borough is the reputed landing place of Hengest and Horsa in A.D. 449 and of St. Augustine in A.D. 597. At Pegwell bay rests the "Hugin," replica of a Viking ship rowed over from Denmark in 1949 manned by 32 Danish oarsmen. St. Laurence church dates from early Norman times. A. W. Pugin is buried in the Roman Catholic church of St. Augustine, which he built. The town possesses a well-known boys' school (St. Lawrence college) and two grammar schools. Charter flights are available at the municipal airport.

RAMUS, PETRUS, or PIERRE DE LA RAMÉE (1515–1572), French humanist who was noted for his attacks against Aristotle, was born at the village of Cuth in Picardy in 1515, a member of a noble but impoverished family. Having gained admission, in a menial capacity, to the college of Kavarre, he worked with his hands by day and carried on his studies at night. The reaction against scholasticism was still in full tide, and Ramus outdid his predecessors in the impetuosity of his revolt. On the occasion of taking his degree (1536) he took as his thesis "Everything that Aristotle taught is false." In 1543 he published *Aristotelicae Animadversiones* and *Dialecticae Partitiones,* the former a criticism on the old logic and the latter a new textbook of the science. What are substantially fresh editions of the *Partitiones* appeared in 1547 as *Institutiones Dialecticae* and in 1548 as *Scholae Dialecticae;* his *Dialectique* (1555), a French version of his system, is the earliest work on the subject in French. Meanwhile, Ramus had opened courses of lectures, but was interdicted (1544) on the ground of undermining the foundations of philosophy and religion. The decree against him was presently canceled, and in 1551 Henry II made him professor of philosophy and rhetoric at the Collège de France. But in 1561 he embraced Protestantism, and was compelled to flee from Paris, and in 1568 from France. He returned before the massacre of St. Bartholomew (1572), of which he was one of the victims.

The logic of Ramus enjoyed a great celebrity for a time, and there existed a school of Ramists boasting numerous adherents in France, Germany and Holland. There is even a little treatise from the hand of Milton, published two years before his death, called *Artis Logicae Plenior Institutio ad Petri Rami Methodum concinnata.*

RAMUSIO, GIAN BATTISTA (1485–1557), geographer, was born at Treviso in 1485 (June 20), the son of Paolo the Elder (c. 1443–1506). Gian Battista was educated at Venice and at Padua and entered the public service (1505), becoming in 1515 secretary of the senate and in 1533 secretary of the Council of Ten. He served the republic in various missions to foreign states, *e.g.,* Rome, Switzerland and France. He died on July 10, 1557.

Ramusio had witnessed from his boyhood the unrolling of that great series of discoveries by Portugal and Spain in East and West, and geography was his chief study and delight. It appears from a letter addressed to him by his friend Andrea Navagero, that as early as 1523 the preparation of material for his great work, *Navigation; e Viaggi,* had already begun. The task had been suggested by Girolamo Fracastoro, his lifelong friend. Among Ramusio's correspondents were Cardinal Pietro Bembo, Damiano de Goez and Sebastian Cabot; among lesser lights, Vettor Fausto, Daniel Barbaro, Paolo Manuzio, Andrea Navagero, the cardinals Gasparo Contarini and Gregorio Cortese, and the printer Tommaso Giunti, editor after Ramusio's death of the *Navigationi.*

Two volumes only of the *Navigationi e Viaggi* were published during his lifetime, vol. i. in 1550, vol. iii. in 1556; vol. ii. did not appear till 1559, two years after his death. Ramusio had intended to publish a fourth volume, containing, as he mentions himself, documents relating to the Andes, and, as appears from one of the prefaces of Giunti, others relating to explorations towards the Antarctic. Ramusio ransacked Italy and the Spanish peninsula for contributions, and translated them when needful into the racy Italian of his day. The invaluable travels of Barbosa and Pigafetta's account of Magellan's voyage were not publicly known in complete form till the present century. Of two important articles at least the originals have never been otherwise printed or discovered; one of these is the *Summary of all the Kingdoms, Cities, and Nations from the Red Sea to China,* a work translated from the Portuguese, and dating apparently from about 1535; the other, the remarkable Ramusian redaction of Marco Polo (*q.v.*). The *Prefatione, Espositione* and *Dichiarazione,* which precede this version of Marco Polo's book, are the best and amplest examples of Ramusio's own style.

There were several editions of the *Navigationi e Viaggi,* and its bibliography is extremely complicated and the contents of the editions vary. It must suffice here to say that a set of Ramusio, to be as complete as possible, should embrace—for vol. i., 1563 or any subsequent edition; for vol. ii., 1583 or 1606; for vol. iii., 1606.

Besides the circumstances to be gathered from the *Navigationi* regarding the Ramusio family, see the *Iscrizioni Venete* of Emanuele Cigogna. There is also in the British Museum *Monografia letta il 14 Marzo 1883 . . .* by Guglielmo Carradori (Rimini, 1883); but little has been found in this.

RAMUZ, CHARLES FERDINAND (1878–1947), French-Swiss author, born at Cully, in the canton of Vaud. In the opening years of the 20th century he gained a well-merited reputation in a restricted circle; but nearly 25 years were to pass before proper appreciation was accorded by foreign critics to a writer of rare talent with a purely original style owing nothing to the "Latin" and "Classical" tradition. In his numerous works (including *Aline, Samuel Belet, Aimé Pache, Le Règne de l'esprit malin, La Guérison des maladies, Passage du poète, La Beauté sur la Terre* and *The End of All Men,* etc.), Ramuz gave, with broad and simple strokes, a picture of primitive human sentiments in language, the rhythm and phrasing of which intimately recall a definite district — namely, the Leman basin above Lausanne—a narrow strip of vineyard country backed by mountains and looking out over the Rhone and the luminous expanse of Lake Geneva. Though his outlook on the world and mankind was restricted to and conditioned by the influences of this district, Ramuz was the very opposite of a regionalist. In a country where so many others abused the facile picturesque and used "local colour" without distinction, his originality was the more striking. No one approached him in his humble self-subjection to the spirit of the country; he was completely under the spell of nature seen at close quarters. His own thoughts and aspirations were expressed in his characters; nevertheless his work is a most varied and representative picture gallery of a well-defined race, universal in its appeal though in appearance exclusively *Vaudois.* He died on May 23, 1947, in Lausanne. (C. CL.)

RANADE, MAHADEO GOVIND (1842–1901), Indian lawyer, reformer and author, was born on Jan. 18, 1842, at Niphad, in Nasik district, of a Chitpavan Brahman family. When his father was minister at Kolhapur he attended the Anglovernacular school in that town. He joined the Elphinstone institute in Bombay at the age of 14 and was one of the first graduates of the Bombay university, taking the B.A. in 1862 and the LL.B. in 1866. Having entered government service he became presidency magistrate and then fourth judge of the small cause court at Bombay in 1871, first-class subjudge at Poona in 1873 and judge of the Poona small cause court in 1884, after which, as special judge under the Deccan Agriculturists' Relief act from 1887. he came into close contact with the difficulties of the agrarian classes.

In 1886 he was a member of the finance committee appointed to report on the expenditure, both imperial and provincial, with a view to retrenchment. This service won him the decoration of C.I.E. He became a member of the legislative council of Bombay in 1885 and occupied that position until raised to the high court in 1893. Being an energetic social reformer, he directed his efforts against infant marriages, the shaving of widows, the heavy cost of marriages and other social functions and the caste restrictions on travelling abroad.

He strenuously advocated widow remarriage and female education. He was the founder of the social conference movement, which he supported till his death. In the political sphere he iounded the Poona Sarvajanik Sabha. He was also one of the originators of the Indian National Congress.

In Bombay university. where he held the offices of syndic and dean in arts, he displayed much organizing power and great intimacy with the needs of the student class. Himself a thorough Marathi scholar, he encouraged the translation of standard English works and tried, with some success, to introduce vernacular languages into the university curriculum. He joined with his friends Atmaram Pandurang, Bal Mangesh Wagle and Vaman Abaji Modak in founding a new sect in Bombay known as the Parthana Samaj. This community resembles, in all essential points, the Brahma Samaj of Bengal. He died on Jan. 17, 1901.

RANCÉ, ARMAND JEAN LE BOUTHILLIER DE (1626–1700), founder of the Trappist Cistercians. He was ordained in 1651 and embarked on the ambitious and worldly career of a court abbe' in the days of Louis XIV. But after a few years he underwent a complete change, and in 1662 he retired to his abbey of La Trappe, of which he became regular abbot in 1664 and introduced an austere reform. *(See* TRAPPISTS.) The best-known episode of his subsequent life was the "contestation" with Mabillon on the lawfulness of monks' devoting themselves to study, which De Rancé denied. He resigned his abbacy in 1695, because of declining health. and died in 1700.

RANCHI, a city and district of the Chota Nagpur division of Bihar, India. The city, which is situated about 2,100 ft. above sea level, is the headquarters of the division and the district. Pop. (1951) 106,849.

The town contains a cantonment, a radium institute and two mental hospitals, one for patients from the whole of northern India, the other, which can accommodate a total of 1,378 patients, for patients from Bengal as well as Bihar and Orissa.

The DISTRICT OF RANCHI, formerly called Lohardaga after the town which was its headquarters, has an area of 7,015 sq.mi. and a population (1951) of 1,861,207. It consists of two tablelands, of which the higher rises to about 2,000 ft. The whole area is broken by hills and undulations, nhich are terraced for rice. The steep slopes are covered with forest, where wild animals still abound. The principal rivers in the district are the Subarnarekha and the North and South Koel.

Rice is the staple crop; some tea is also cultivated. The only industry on a large scale is the manufacture of shellac. Myrobalans are also exported. Deposits of bauxite have been found and await exploitation. There are two sanatoria for tuberculous patients in the district.

Ranchi is connected with the town of Purulia and the main system of the Eastern railway by a narrow-gauge railway, which was extended through the district to Lohardaga. The most numerous and characteristic races are the aboriginal Mundas and Oraon.

There has been a steady increase in the Christian population, which in 1951 was 422,030.

RAND, a Dutch word, in use in South Africa, meaning rim, edge, ridge of hills; specifically, it is an abbreviated form of Witwatersrand, an elevated ridge in the southern part of the Transvaal, forming the water parting between the Vaal river and the Olifants river.

The Rand is famous for its auriferous reefs ***(see*** GOLD), and the nord is often used as a synonym for the extensive gold mining industry of this area, or for Johannesburg (*q.v.*), the city which the industry created.

RANDALL, JAMES RYDER (1839–1908), U.S. journalist and poet, best known as author of the lyrics of "Maryland! My Maryland!" was born in Baltimore. Md., on Jan. 1, 1839. Educated at Georgetown college, Washington, D.C., he became professor of English literature at Poydras college at Pointe-Coupée, La., in 1860 where he was when the Civil War broke out.

The attack made by citizens of Baltimore upon Massachusetts and Pennsylvania troops as they passed through the city was the occasion of his writing "Maryland! My Maryland!" first published in the *New Orleans Delta,* April 1861. First sung by Hetty Cary to the classic melody of "Lauriger Horatius," it became a rallying song of the Confederacy and later a national favourite. After the war Randall became associate editor of the *Augusta* (Ga.) *Constitutionalist.* He was later Washington correspondent for a number of southern papers. He died in Augusta on Jan. 14, 1908. His *Poems* were published posthumously in 1910.

RANDALL, SAMUEL JACKSON (1828–1890), American politician, was born in Philadelphia, Pa., on Oct. 10, 1828. He was educated in the public schools and in the University academy, Philadelphia. In 1858–59 he was a Democratic member of the state senate. During the Civil War he served in the Union army, rising to the rank of captain and playing an important part in the Gettysburg campaign. From 1863 until his death he was a Democratic representative in congress. During the session of 1874–75 he first gained a national reputation by the masterful manner in which he prevented the Republican majority from passing the force bill or Federal Election law. Under his leadership discipline and party harmony were established among the Democrats for the first time after the Civil War. He was speaker of the house from Dec. 1876 to March 1881, during a period marked by rancorous debates concerning the disputed Hayes-Tilden presidential election. He was noted for his work as chairman of the committee on appropriations and as a member of the committee on banking currency and retrenchment. He was a leader of the Protectionist wing of the party. He died in Washington. D.C.. on April 13, 1890.

RANDAZZO, a town of Sicily, in the province oi Catania, at the north foot of Mt. Etna, 43 mi. N.W. of Catania by rail and 26 mi. direct. Pop. (1951) 12,526. Remains of architecture of the 13th and 14th centuries include three Norman churches and some palaces. The former contain some fine sculptures and goldsmith's work, while the Museo Vagliasindi has interesting objects from a Greek necropolis in the neighbourhood. Randazzo is the nearest town to the summit of Etna (9 mi.).

RANDERS, a town of Denmark, capital of the *amt* (county) of its name in Jutland, on the Gudenaa at the point where it begins to widen into Randers fiord, an inlet of the Kattegat. Pop. (1955) 41,720. Randers is best known in history as the scene of the assassination of Count Gerhard by Niels Ebbesin in 1340. Though a place of considerable antiquity—being mentioned in 1086 as the meeting place of insurgents against Canute IV—Randers has few remains of old buildings and bears the stamp of a compact, modern manufacturing town that owes its importance to its distilleries, manufactories of gloves, railway carriages, etc. St. Marten's church dates from the 14th century. The high school is housed in a medieval monastery. The town is 15 mi. from the open Kattegat and the harbour is 1 j ft. deep.

RANDOLPH, EDMUND (JENNINGS) (1753–1813), U.S. statesman, was born on Xug. 10, 1753, at Tazewell hall, Williamsburg, Va., the family seat of his grandfather, Sir John Randolph (1693–1737), and his father, John Randolph (1727–84), who (like his uncle Peyton Randolph) were king's attorneys for

Virginia. Edmund graduated from the College of William and Mary and studied law with his father, who felt bound by his oath to the king and went to England in 1775. In Aug.–Oct. 1775 Edmund was aide-de-camp to Washington. In 1776 he was a member of the Virginia convention and was on its committee to draft a constitution. In the same year he became the first attorney general of the state (serving until 1786). He served in the Continental Congress in 1779 and again in 1780–82. He had a large private practice, including much legal business for Washington. In 1786 he was a delegate to the Annapolis convention and in 1787–88 was governor of Virginia. He was a delegate to the constitutional convention of 1787, and on May 29 presented the "Virginia plan" (sometimes called the "Randolph plan"). In the convention Randolph advocated a strongly centralized government, the prohibition of the importation of slaves, and a plural executive, suggesting that there should be three executives from different parts of the country, and refused to sign the constitution because too much power over commerce was granted to a mere majority in congress and because no provision was made for a second convention to act after the present instrument had been referred to the states. In Oct. 1787 he published an attack on the constitution; but in the Virginia convention he urged its ratification, arguing that it was too late to attempt to amend it without endangering the union, and thinking that Virginia's assent would be that of the necessary ninth state. In 1788 he refused re-election as governor and entered the house of delegates to work on the revision and codification of the state laws (published in 1794).

Service in Cabinet.—In Sept. 1789 he was appointed by President Washington first attorney general of the United States. He worked for a revision of Ellsworth's judiciary act of 1789, and especially to relieve justices of the supreme court of the duties of circuit judges, and advocated a federal code; in 1791 he considered Hamilton's scheme for a national bank unconstitutional; and in 1792–93, in the case *Chisolm* v. *Georgia* before the supreme court, argued that a state might be sued by a citizen of another state.

On Jan. 2, 1794, he succeeded Thomas Jefferson as secretary of state. In 1795 he wrote 13 letters (signed "Germanicus") defending the president in his attack on the American Jacobin or democratic societies. He was the only cabinet member who opposed the ratification of the Jay treaty. Before it was ratified the delicate task of keeping up friendly diplomatic relations with France fell to him. Home dispatches of the French minister, Joseph Fauchet, intercepted by a British man-of-war and sent to the British minister to the United States, accused Randolph of asking for money from France to influence the administration against Great Britain. Although this charge was demonstrably false, Randolph when confronted with it immediately resigned, and subsequently secured a retraction from Fauchet; he published *A Vindication of Mr. Randolph's Resignation* (1795) and *Political Truth, or Animadversions on the Past and Present State of Public Affairs* (1796). He died at Carter hall, Millwood, Clarke county, Va., on Sept. 12, 1813.

RANDOLPH, JOHN, of Roanoke (1773–1833), U.S. statesman and orator, was born at Cawsons, Va., on June 2, 1773. Through his father, John Randolph, and his mother, Frances Bland, he was related to the Randolphs of Turkey Island and the Blands of Westover, two of the most conspicuous families of colonial Virginia; and, through an ancestress, Jane Bolling, he was a descendant of the Indian princess Pocahontas. He received his collegiate education at Princeton, Columbia and William and Mary colleges. In 1799 he was elected to the house of representatives, after a historic debate with Patrick Henry. In the house, his rise was so rapid that, after the election of Jefferson to the presidency in 1801, he was made chairman of the house committee on ways and means and became the leader of the house Republicans. Soon, however, he drifted away from Jefferson and lost both chairmanship and leadership. Afterward he was, for many years, a mere free-lance, but in 1820 his resolute resistance to the Missouri Compromise made him again a truly powerful figure in the house. After his first election in 1799 he was re-elected to the house every two years until 1829, except in 1813, when his opposition to the War of 1812 resulted in his defeat by John W. Eppes, and in 1817, when he declined to be a candidate. After re-election to the house in 1825, he was elected to the U.S. senate, but he was defeated for re-election by John Tyler. In 1807 he was the foreman of the grand jury which indicted Aaron Burr for treason, and he was a prominent member of the famous Virginia constitutional convention of 1829–30. In 1830 he was sent by Andrew Jackson on a special mission to Russia. In the succeeding year he returned and later denounced, in a series of speeches, the nullification proclamation of Andrew Jackson. He died at Philadelphia on May 24, 1833. Randolph was a passionate partisan of state sovereignty and, therefore, opposed to a national bank, protection and federal internal improvements and interference with slavery; but he disliked slavery and freed his slaves by his will.

At the time of the Missouri Compromise, his influence was so great that Henry Clay afterward declared in a speech: "His acts came near shaking this Union to the centre, and desolating this fair land." After his return to the house in 1827, it was again so great that the failure of John Quincy Adams to be re-elected to the presidency was largely due to it.

One of the most brilliant and disinterested, though by no means one of the most useful, of American public men, he was a captivating talker, a delightful letter writer, a scholar and a devotee of the horse, the dog and the gun. (W. C. Be.; X.)

RANDOLPH, PEYTON (1721–1775), U.S. politician, was born at Tazewell hall, Williamsburg, Va., in 1721, a son of Sir John Randolph (1693–1737), the king's attorney for Virginia. He graduated at the College of William and Mary, studied law at the Inner Temple, London, and in 1748 was appointed the king's attorney for Virginia. Randolph wrote the address of remonstrance to the king on behalf of the burgesses against the suggested stamp duties in 1764. His policy was conservative and moderate, and in May 1765 he opposed Patrick Henry's radical "Stamp Act resolutions." In 1766 he resigned as king's attorney and was succeeded by his brother John (1727–84). In 1769 he acted as moderator of the privately convened assembly which entered into the nonimportation agreement, and in May 1773 he became chairman of the first Virginia intercolonial committee of correspondence. He presided over the provincial convention of Aug. 1774, was a member of the first Continental Congress, of which he was president from Sept. 5 to Oct. 22, 1774, and was re-elected to congress in March 1775. Randolph died of apoplexy in Philadelphia on Oct. 22, 1775.

RANDOLPH, THOMAS (1523–1590), English diplomatist, son of Avery Randolph, a Kentish gentleman, was educated at Christ Church, Oxford, and in 1549 became principal of Pembroke college, Oxford, then known as Broadgates hall. During the reign of Mary, Randolph, who was a zealous Protestant, sought refuge in Paris, where he cultivated the society of scholars. Returning to England after the accession of Elizabeth I, he was employed as a confidential diplomatic agent of the English queen in Scotland. Randolph's dispatches from Scotland between 1560 and 1586 supply important material for the history of the political intrigues of that period.

In 1568 Randolph undertook a mission to Russia which resulted in the concession by Ivan the Terrible of certain privileges to English merchants; in 1570 he returned to Scotland. After missions to France in 1573 and 1576, and Scotland in 1578, Randolph returned in Jan. 1581 to Scotland, where the earl of Morton, the regent, had been arrested a few days previously. Randolph, acting on Elizabeth's instructions, intrigued with Angus and the Douglases in favour of a plot to seize the person of the young King James and to save Morton by laying violent hands on the earl of Lennox. Douglas of Whittingham made revelations which imperilled Randolph, who withdrew to Berwick before the execution of Morton in June 1581.

In 1586, when he next visited Scotland, Randolph helped to arrange a treaty between England and Scotland. He was master of the posts from about 1566 until his death, holding this office jointly with that of a chamberlain of the exchequer. He died in

London in June 1590.

RANDOLPH, THOMAS (1605–1635), English poet and dramatist whose talent lacked time to mature, was born on June 15, 1605, at Newnham-cum-Badby, Northamptonshire, and educated at Westminster school and Trinity college, Cambridge, where he was elected to a fellowship in 1629. Both at Westminster and Cambridge he earned a high reputation for English and Latin verse, and Ben Jonson adopted him as one of his "sons." Of his three poems to Jonson, one renders thanks for his "adoption," while another answers Jonson's despondent ode on the failure of *The New Inn*. He died at Blatherwick in March 1635.

Randolph published *Aristippus* and *The Conceited Pedler* (1631), two dramas for performance at Cambridge, *The Jealous Lovers* (1632), a comedy, and verses in various collections. A posthumous collection of his poems (1638) included two other plays, *The Muses Looking-Glass* (performed 1630) and *Amyntas,* a pastoral drama (probably acted 1631). *Hey for Honesty,* a comedy adapted from *The Plutus* of Aristophanes, was published in 1651 with a number of contemporary allusions inserted by the editor. Randolph had a real lyrical gift and some dramatic ability; his early death robbed 17th-century England of an accomplished and genial poet.

The Poetical and Dramatic Works were edited by W. C. Hazlitt, 2 vol. (1875); *The Poems and Amyntas* by J. J. Parry (1917); and *The Poems* by G. Thorn-Drury (1929).

See G C Moore Smith, *Thomas Randolph* (1927); *S* **A** and *D R.* Tannenbaum, *Thomas Randolph* (1947). (*V.* DE S. P.)

RANELAGH, formerly a resort by the river Thames in Chelsea, London, England. About 1690 land lying east of Chelsea hospital and bordering the river was acquired by Richard, Viscount Ranelagh, later earl of Ranelagh. He built a mansion and laid out gardens. which in 1742 were thronn open as a proprietary place of entertainment. A building called the Rotunda was erected for concerts, and the gardens became a resort of fashionable society. By the close of the 18th century Ranelagh was ceasing to attract, and in 1803 the Rotunda was closed. The buildings were removed, and the grounds passed to Chelsea hospital.

RANGABÉ, ALEXANDROS-RIZOS (1810–1892), Greek poet, archaeologist and statesman. born at Constantinople in 1810, was the son of Jean-Rizos Rangabé, a celebrated poet and scholar. In 1829 Alexandros entered the ranks of the Bavarian army, but after the establishment of the Greek republic he returned to his native country where he became successively minister of education (1833) and director of the royal printing press (1841). In 1844 he became professor of archaeology at the University of Athens, and for the next 12 years. in company with C. Bursian, he investigated the ruins of the temple of Juno, near Argos, bringing to light many statues and bas-reliefs and discovering the entire formation of the building. He died at Athens on Jan. 28, 1892.

Rangabé advocated a revival of the ancient Greek language and wrote poetry and dramas in Greek, including *Phrosyne, The Vigil* and *The Thtrty Tyrants*. He also wrote various archaeological uorks in French, notably *Antiquités helléniques* (1842–55) and *Antiquités troyennes* (1874).

RANGE (IN AGRICULTURE) refers to extensive areas of more or less "natural" grasslands. The vegetation of ranges may include tall grass prairies, steppe, desert shrub, savanna, woodland, chaparral, tundra or forest, the only criterion being that there be enough grass in the vegetation to be profitably grazed. The true tall grass prairies such as those of the North American midwest, the Ukraine, parts of Hungary and Argentina are usually too well suited to cultivated crops to be left in range. Ranges are more generally confined to areas of marginal or submarginal farming or to areas entirely unsuited to cultivation.

Range Formation. — The naturalness of range vegetation is a matter of degree. In much of the coast and foothill ranges of California the original, largely perennial grassland has been almost completely replaced by an introduced annual Mediterranean flora. These areas are called annual range perhaps because the replacement of one vegetation by another was not intentional even though brought about by the activities of man and his livestock. Extensive areas of forest have been converted to grassland by fire or cutting or both. In other areas, selective cutting and good forest management have opened up stands of timber permitting an increase of grass for grazing purposes. Good forest management and good range management are often complementary rather than competitive. Few, if any. ranges are totally uninfluenced by man or his livestock. They are natural only in the sense that they are not artificially established by cultural means.

Fire is a natural feature of grassland vegetation, whether set by man or other agencies. The elimination of fire may be considered a disturbance which in desert shrub, savanna or woodland vegetation frequently invites the dominance of trees and shrubs to the near exclusion of the grass. Effective fires are prevented primarily by heavy grazing which removes most of the combustible material. They are also reduced in frequency by precautions against the setting of fires.

The use of fire as a management practice is common in many parts of the world, but is frequently ineffective in the control of woody vegetation because of heavy grazing. Satisfactory burns usually require deferment for a growing season to accumulate combustible material, and the value of the unused grass must be weighed against the expected value from brush control.

Management Practices. — Some of the most important range management practices are given below. (1) Proper stocking. An adequate surplus of grass must always be left at the end of the grazing season to protect the soil and to supply food reserves for the next season's growth. (2) Uniform grazing. Livestock graze more closely near water, salt, feeding areas, fence corners and other places where animals concentrate. They graze the steep parts of the range much less than the flats. Some corrective measures are: cross fencing into smaller pastures, placing salt in little used parts of the range, developing more watering and salting places, herding with greater care, etc. (3) Deferment. Ranges may be deferred early in the season to protect the grass during a period when it is using up food reserves; they may be deferred late in the season to allow the grass to recover from grazing and store food reserves; they may be deferred for an entire season for burning or to permit seed production in order to improve the vigour and density of the stand. (4) Control of undesirable plants. This may be accomplished by manipulation of livestock to either graze hard or rest at critical times or by selective herbicides, fire or mechanical treatments such as mowing, beating, root plowing, etc. (5) Encouragement of desirable plants. This is usually done by livestock manipulation or burning, but in special cases overseeding and/or fertilizing result in substantial improvements. (6) Proper seasonal use. High mountain ranges can be used only in summer, annual ranges are most productive in spring and many desert ranges are best used in winter. In order to use many ranges at the proper time, livestock must often be trailed or trucked considerable distances. (7) Pest and game control. In order to obtain maximum yields, animals that compete with livestock for forage must be controlled as well as parasites that attack livestock.

Overgrazing. — The most pernicious and chronic problem in the management of ranges is overgrazing. Too heavy use of the vegetation reduces production of forage, exposes the soil to sealing. baking and erosion, reduces the infiltration of water and the effectiveness of precipitation, increases runoff and flood hazards and induces changes in the botanical composition of the vegetation. These changes invariably involve an increase in unpalatable, woody, thorny or poisonous plants and a decrease in the more palatable and desirable species.

Overstocking and the fire control that goes with it have resulted in an alarming increase in woody vegetation in the savanna, woodland, chaparral and desert shrub areas of the world. Overstocking has practically denuded vast areas of rangeland in nearly every continent and the degeneration of range condition is one of the most serious problems in agriculture.

Stockmen and technicians alike have consistently overestimated the capacity of ranges to produce. One must become resigned to low yields per acre, and ranges can be profitably used only because the forage is cheap. As soon as elaborate management practices are required as correctives for bad management, the range forage is no longer cheap and its use often becomes unprofitable.

See also GRASS AND GRASSLAND. (J. R. HN.)

RANGE FINDERS. Range finders are used to establish surveys and maps, to enable the accurate direction of gun, rocket and missile fire, to test and study air vehicle characteristics and to determine the lens focus setting for cameras. Triangulation methods have long been used for the determination of ranges, and precise optical methods have been devised for this purpose.

With the development of pulse-time techniques for use with radio equipment, a new series of instruments evolved for the determination of range. (See RADAR.) The development of radio ranging at the beginning of World War II became an important factor in naval gunnery and anti-aircraft fire; large optical range finders formerly indispensable in the direction of such fire assumed a secondary or stand-by role. Optical range finders have the advantages of high resolution, compact size, relatively simple maintenance and accuracy at short ranges, but they are unreliable during bad visibility conditions and at long ranges, require a relatively long time to make the range determination and, for most purposes, are useless at night. Radio range finders consist of a highly complex electrical network which requires large electrical power supplies and constant attendance by highly trained technicians.

Basically, an optical range finder is a triangulation device with which two angles and the included base are measured to determine the range to the target situated at the apex of the triangle so formed. The most accurate ranging is accomplished by: (1) a two-station system of triangulation in which the base line 'is long and the optical stations are separated by distances of several hundred yards or many miles; (2) the short base monostatic range finder, a one-station system of triangulation which is a self-contained optical system; its accuracy depends on the precise mounting of its optics on an optical bar. The two-station system suffers from the difficulty of establishing time coincidence when measuring ranges to moving or intermittent targets, the complex communication network required to co-ordinate the ranging, and the difficulty of insuring that the two stations are set on a common target and the lengthy process of calculating the range. The one-station system, at the expense of accuracy, avoids these difficulties.

Two-Station System.—The two-station system of triangulation has undergone a high degree of development throughout recorded history beginning, perhaps, with the attempts of the Egyptians who were required to re-establish property lines after the annual inundation of the Nile. In modern times, the development of the optical theodolite resulted in highly precise measurements. The theodolite is used to measure angles—measurements which, in order to minimize operators' errors, are averaged from a number of readings in order to determine the true angle. By United States coast and geodetic procedure an angle is turned 16 times in a first order survey, 4 times in a second order survey, and twice in a third order survey. The accuracy of the distances so measured must not have an error exceeding 1 in 25,000 in a first order survey, 1 in 10,000 in a second order survey, and 1 in 5,000 in a third order survey. This precision is possible only because the targets are fixed and easily identifiable from each other.

In many situations, especially in military usage, the targets are either moving or intermittent, as in the determination of the ranges to vehicles or gun flashes. In such cases, a reading can be taken only once and the two base angle readings must be taken simultaneously. An elaborate communication network between the stations must be set up and timing coincidence must be established. One military system consists of a shutter assembly which is attached to the objective of a sighting telescope. A network of these instruments is established by survey with the shutters connected over communication wires so that the shutters can be simultaneously opened or closed electrically from a central control station. This system is particularly useful in spotting muzzle flashes from artillery fire. When an observer notes a muzzle flash through his telescope he closes the shutters, thus establishing time coincidence. The operalors then take a reading of the bearing of their sighting telescope and relay the bearing position to the central control station where a range plot is made.

For proof-testing and in checking the accuracy of anti-aircraft fire, a more elaborate network is established by using phototheodolites. A phototheodolite, as shown in fig. 1, consists of a camera with a long focal length lens mounted on a theodolite base. The theodolite is turned by a hand wheel or synchronous motor directed by an operator, who sights through a telescope which is fixed to the theodolite base. Time coincidence among the phototheodolite stations is established by a signal which is transmitted over a communication system. Time markers are actuated to give an indication printed on the film; the signal may also operate the shutter. It is possible to operate the phototheodolites over base lines as long as 1j mi. The camera, usually a 3j-mm. movie type, takes a picture of the target being tracked by the operator and prints fiducial marks. or reference points. which establish the zero position on the film, as well as pictures indicating the position of the theodolite base in both azimuth and elevation. The angular errors in tracking are reduced by developing the film and making corrections to the indicated azimuth and elevation readings by applying tracking corrections determined from the measured position of the target with respect to the fiducial marks. By

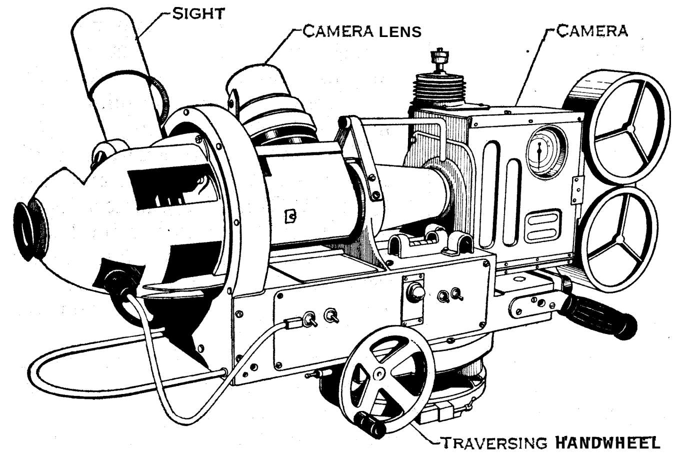


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FIG. 1—PHOTOTHEODOLITE

averaging measurements made by a system of four or five phototheodolites, it is possible to obtain range accuracies of 1 in 10,000 at ranges less than 10 000 yd.

Short Base Range Finders.—Attempts mere made as early as 1770 to couple two theodolites closely on a short base line to circumvent communication difficulties in military range finding. Georg Friedrich Brander in 1781 built a range finder for one operator and Alexander James Adie (1860) constructed a split coincidence range finder Archibald Barr and William Stroud in England culminated a rapid development of range finders in 1888 nhen they brought out their coincidence range finder a prototype of modern instruments. Later, in 1893 the Carl Zeiss firm in Germany huilt a stereoscopic range finder The Germans continued to favour the stereoscopic type made by both Zeiss and Carl Goerz; the British favoured coincidence types U S manufacturers, Bnusch and Lomb Eastman Kodak and Keuffel and Esser. continued to make hoth types Prior to and during World War II. developments in military range finders were concerned largely nith refinements of these two designs.

In the years following World War II, military developments begun during the war culminated in the perfection of both coincidence and stereoscopic range finders in tanks. In most instances, the range finder nas coupled to the tank cannon so that aiming and ranging pointed the cannon automatically in the proper direction and at the proper elevation for the target range and projectile in use. (See Tank Range Finders below.)

Coincidence and Stereoscopic Range Finders.—In the development of the modern range finder there was considerable controversy concerning the comparative effectiveness of the coincidence and stereoscopic range finders. The general advantage of one over the other had not been proved by mid-20th century. The two appear similar except that usually the coincidence type has a single eyepiece as compared with two in the stereoscopic type. Fig. 3 and 5 illustrate the schematic arrangement of the commonly used coincidence and stereoscopic range finders. Monostatic range finders are built. self-contained, with tno optical extended "arms" which define the base length. The outer case usually contains windows, the optical square and the eyepieces. An inner "optical bar." insulated from temperature differentials and vibrations, contains the objectives, deviation prism and the reticles. As the field of view is small, the range finder is mounted on bearings and must be rotated to follow the target. The range operator who observes the images formed by the two objectives adjusts the range drum to establish coincidence or stereoscopic contact; the range can then be read from the drum. Monostatic range finders having a base length of one-half yard to a yard are portable and used by armies in the field; they are accurate to several thousand yards. Larger range finders having base lengths of $4\frac{1}{2}$ ft. to 40 ft. are used to measure ranges up to 20 mi. to adjust naval and anti-aircraft fire.

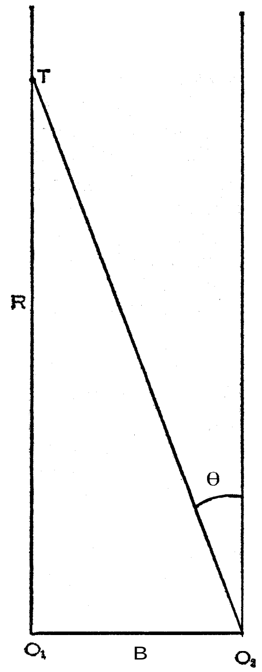

FIG 2

The fundamental equation for the range finder can be stated simply from fig. 2. At O_1 is a right angle and at O_2 is an angle θ which gives the bearing to the target. As this angle is always very small, the range is given as $R = B/\theta$ (approximately), where B is the base separation.

Assuming ideal conditions. the accuracy of optical range finders diminishes as the distance between observer and target increases. Standard formulas show that the theoretical range error varies as the square of the distance. In this respect optical instruments differ from radio range finders, which determine distance by measuring the time required for radio waves to travel from the range finder to the target and back again. Because the speed of radio waves is high and substantially constant, the range error is largely independent of distance.

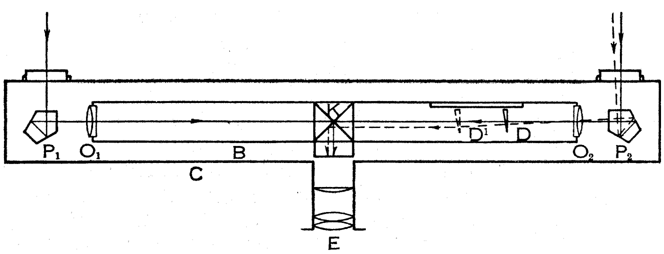

FIG. 3 — COINCIDENCE RANGE FINDER

Construction.—The two ends of the base line are defined by the optical square which changes the incoming light path at the two arms of the range finder by 90°. A penta prism P, as shown in fig. 3, is ideally suited for the purpose since it has the characteristic of changing the light path through a constant fixed angle independently of the incident angle. The prism has its two reflecting surfaces 45° to each other. In larger range finders it is necessary to use mirror surfaces M as reflecting surfaces: as shown in fig. 5, for it is impossible to obtain satisfactory prisms in the larger sizes. The choice of penta prisms or mirrors depends on the size of range finders and not on the type.

In order to effect coincidence or establish .stereoscopic contact it is necessary to displace the image which is formed through one arm of the range finder. This can be accomplished by movement of one of several optical components. To accomplish the displacement in military instruments it proved most suitable to use a sliding lens compensator or deviation prisms; two types of deviation prisms were found most useful. One type consists of a low power prism placed in the converging beam of one arm of the range finder (fig. 3), which, if displaced to the position indicated by the dotted line, results in a corresponding displacement of the image formed from that arm. The prism must be placed in the converging beam. A calibrated scale and indicator coupled to the prism indicate the range. The second type of deviation prism device, known as a diasporameter, consists of two low power prisms placed in the parallel beam ahead of one objective lens. When the

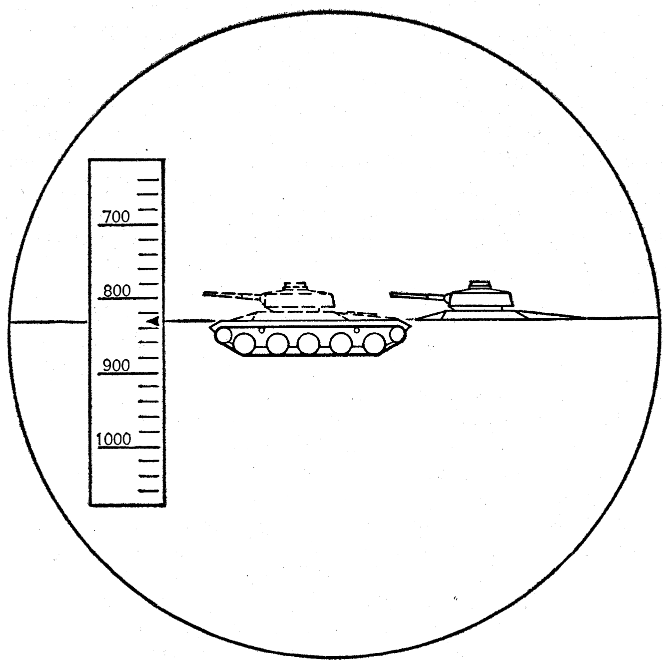

FIG. 4 — FIELD OF COINCIDENCE RANGE FINDER

bases of the prisms are vertical and opposed, the deviation caused by one prism is cancelled by the deviation from the other. If the prisms are rotated in opposite directions about the optical axis, the vertical displacements still will cancel. but the horizontal displacements introduced by the rotation will add. The result will be a horizontal displacement of the image.

The sliding lens compensator consists of two low power lenses, one convex and one concave, placed in the parallel beam ahead of one objective lens, as indicated in D, fig. 5. When both lenses are centred on the optical axis of the range finder, no deviation is introduced. If one lens is moved horizontally, a corresponding deviation of the image will result, because the off-axis section of the lens then in use introduces a convergence of light rays toward the displaced axis of this lens.

The range finder includes a telescope not only for the purpose of forming an image from the radiation arriving at the penta prisms but also to aid the operator in seeing objects at a distance. The difierence in the two types of range finders is apparent in the telescopic system. The two objectives of the coincidence range finder form an image in a common focal plane which may be viewed by either a single or a binocular eyepiece. In a stereoscopic range finder two complete telescopes are used with their own objectives and eyepieces. Stereoscopic contact is established physiologically by the operator.

The coincidence in a range finder is achieved by melding the images from the two arms by a combination of prisms. In simpler types of range finders half-silvered mirrors may be used; in more precise instruments the prism combination becomes complex to achieve the proper presentation. In fig. 3 the prism is only indicated; actually it is made up of a combination of roof prisms. The prism combination may be so constructed that not only the fields from the two arms are shown but also, as indicated in fig. 4, a scale indication of the range is made. As shown in fig. 4, the target may be presented as a split image with the field divided in the centre. Adjustment of the range drum shifts one field until coincidence is established as shown by the dotted line in the figure. Other presentations might be used: as a superimposed image as shown in fig. 7; as a double image one above the other; or as a double image with one inverted. The split image adjustment is particularly effective when definite vertical lines are visible on the target; the invert double image is effectivewith targets where

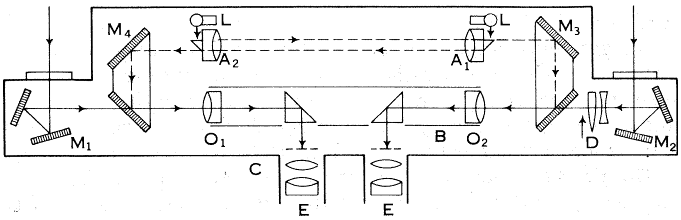

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FIG. 5— STEREOSCOPIC RANGE FINDER WITH AUTOCOLLIMATOR

the sense of symmetry aids in the adjustment. In using the split image the fineness of the dividing line is important; for precise instruments, a satisfactory line can only be produced by coincidence prisms. In order to insure the optimum performance an adjustment to correct the relative location of the two target images must be provided so that upon adjustment the images match in the field. This is done with a "halving adjustment." The adjustment may be effected by rotating a parallel plate in the converging beam of one of the arms.

The two telescopes of a stereoscopic range finder have reticles marked with a single mark or a "picket" of spaced marks. The marks are so placed that, when they are viewed by the two eyes of the observer, the marks are fused and appear to float in space because of the stereoscopic perception of the observer. If the image of the target is positioned on the reticle with the proper spacing, the target will be seen stereoscopically in three dimensions. The effect may be altered by displacing the image on the reticle and objects will appear to approach or recede. By means of the deviation prisms the target may be displaced and stereoscopic contact is established when the target appears to be at the same position in depth as the reticle spot. The reticle spot, known as the wandermark, may have various shapes such as a circle, a line or a diamond. Under adverse lighting conditions it is advantageous to illuminate the wandermark so that a spot of light appears in the field. If the picket of wandermarks as shown in fig. 6 is used, the spacing of pickets on each reticle is such as to form a series of lines which in the field of view apparently recede into space. It may be that such an arrangement is helpful in correcting the range drum reading on targets when there is not time to establish stereoscopic contact with the central wandermark.

A large variety of novel presentation arrangements have been made by U.S. range finder makers in order to improve the stereoscopic range finder. One arrangement worthy of note, the pseudo-stereoscopic range finder has, in addition to the normal field, a second crossed field produced from opposite objectives so that a double image of the target is produced. As the adjustment for stereoscopic contact is made the two images appear to move, one moving forward toward the wandermark and the other moving away from the observer toward the wandermark.

As the range finder is a precise optical instrument, it is subject not only to the shifting of its parts because of temperature changes, vibration and shock, but is also subject to the idiosyncrasies of the operator. For these reasons it must be calibrated often in use and when operators are changed. The most effective adjustment is to range on an object at infinity such as the moon or stars. Lacking these a "lath" is used for small range finders which consists of a board having two marks spaced in accordance with the dimensions of the optical separation of the instrument. This board when viewed through the range finder has the appearance of being at infinity.

Large stereoscopic range finders often contain a built-in autocollimator to eliminate the need for frequent. calibration. The autocollimator, shown in fig. 5, consists of two identical lenses A, which are engraved with marks and illuminated through small prisms. The mark on lens A_2 is at the focus of lens A, and is projected by the Porro reflector M_3 to the objective O_2 and thus to the operator's right eye. The mark on lens A_1 is similarly projected to the operator's left eye. The marks appear as an object at fixed depth, because each lens is a target for the other; an accidental shift of one lens produces equal shifts in both images and no change in the apparent depth of the mark. Range measurements are made by manipulating the deviation device until the image of a target is brought to the same apparent depth as the mark. Thus, range measurements are unaffected by misalignment of any optical element in the instrument, because the light rays from the target and the reference marks are combined, and any shifting of parts in the two telescopes has equal effects on the images of the target and the mark.

Height Finders.—When ranging on air targets, the range finder determines the slant range. Often the altitude or vertical component to the target is required. This, a function of the elevation angle and the slant range, may be computed mechanically by a system of cams.

Photographic Range Finders.—With the development of press photography and the interest in the candid camera: rapid adjustment of the camera focus became important. A range finder made by the Kalart company, permitting the rapid and accurate focusing of the lens! is shown in figure 7. Photographic range finders are invariably of the coincidence type and may be of either the split image or superposition of image type. They may be coupled directly to the camera through a mechanical linkage or they may be separate and give a range scale reading. An attachment is also available that projects a spot of light which, under unfavourable lighting conditions, forms a target reflected from the subject which can easily be brought into coincidence in the range finder. A number of range finders made b~ various camera manufacturers have appeared on the market. These, although simple in construction, may have various complexities. (See Coincidence and Stereoscopic *Range Finders* above.)

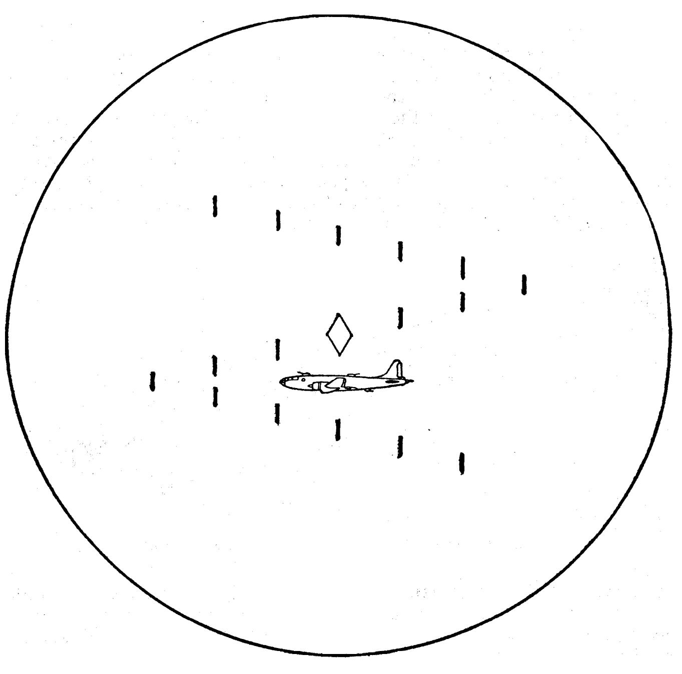

FIG. 6—FIELD OF STEREOSCOPIC RANGE FINDER

Eastman Kodak company marketed split image coincidence finders, one type with a split image coincidence prism and adjusted by moving one objective. Zeiss made a range finder having an adjustment by a diasporameter. The Leica range finder is similar to that shown in fig. 7.

Camera range finders have base lines which may be an inch and a half long to about four inches. That the instrument must be carefully made can be understood. as a movement of 3° in the mirror corresponds to a change in the setting of the range finder from three and one-half feet to infinity.

Tank Range Finders.— Range finders for use in tanks were developed in Germany and the United States during World War II to increase the accuracy of gun fire at long range. The stereoscopic range finder was used to avoid the double or split image required in coincidence instruments, and thus permit clear observation of the target during firing.

One U.S. instrument, which was produced in quantity starting in 1948, had a 60 in. base length and seven-power magnification. A later model with a 79 in. base length and 10-power magnification (shown in fig. 8) also was produced. This range finder was accurate within 40 yd. at 2,000 yd., which is equivalent to a vertical error on the target of only 15 in., for typical tank ammunition.

Special tank turret shapes are required to house and protect the range finder, and the instrument must be carefully designed and mounted to withstand the ballistic impact shocks encountered by tanks in combat. To retain accuracy under these severe conditions and to eliminate the need for frequent calibration, tank range finders contain autocollimators, as shown in fig. 5.

A ballistic computer is used in conjunction with the range finder to reduce the time required to fire the tank gun and to utilize the

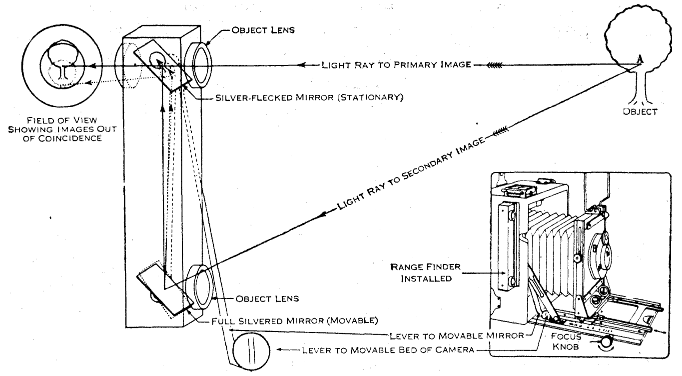

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FIG. 7— PHOTOGRAPHIC RANGE FINDER COUPLED TO CAMERA

accuracy of the range finder effectively. The range setting of the deviation device is converted by the computer into the angle at which the gun must be aimed above the target to compensate for the effect of gravity on the shell. If the range finder is used as the gun sight, the computer is built into the range finder, and points the gun at the required angle above the target when the range finder is aimed at the target. If a separate instrument, such as a periscope, is used to aim the gun, the computer is a separate instrument, and is connected either electrically or mechanically to the range finder and the periscope; however, its function and purpose are the same.

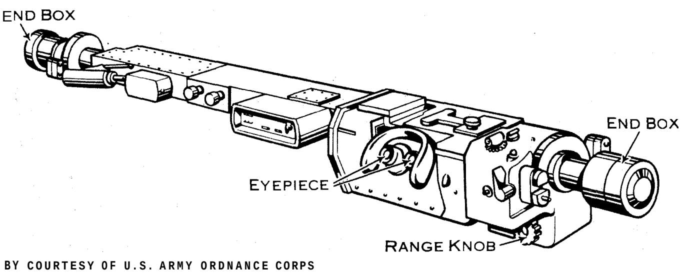

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FIG. 8—STEREOSCOPIC TANK RANGE FINDER

Stadiometric Ranging.— The determination of distances by stadia rods has long been used in survey work. The method depends upon solving the triangle established by the angle subtended at the observer's position by an object of known size to determine the range to the object. In surveying procedure a stadia rod having markings with known spacings is observed through a theodolite and standard tables give the range to the rod. A range finder using similar principles is used for military purposes. It consists of a telescope or binoculars having either a lattice of horizontal markings, or a single mark or pattern of adjustable size. By observing the image of a man, or a vehicle of known size, superimposed on the reticle the angle subtended by the object is determined. Inasmuch as aircraft have well-known dimensions, the stadiometric device is used for a simple ranging device to determine ranges to aircraft.

BIBLIOGRAPHY.—Sir R. T. Glazebrook (ed.), *Dictionary of Applied Physics*, vol. iv (1922–23); Donald H. Jacobs, *Fundamentals of Optical Engineering* (1943); Keith Henney and Beverly Dudley (eds.), *Handbook of Photography* (1939). (H. J. ML.; N. SN.; W. T. AL.)

RANGER, in U.S. military usage, a soldier specially trained to act in small groups which make rapid surprise raids on enemy territory; the corresponding British term is commando (*q.v.*). In the U.S. ranger has also been the designation for the Texas state constabulary and for national park supervisors and forest wardens.

Ranger units originated during the French and Indian War (1754–63), when the British formed special units of expert woodsmen and marksmen to range the forests on scouting, screening and harassing missions. Notable among these was Rogers' rangers, a battalion commanded by Maj. Robert Rogers (*q.v.*).

During the American Revolution both British and American forces employed rangers. At that time infantry tactics were based on the volley fire of close-ranked infantry of the line. Each regiment also contained a light infantry company, often armed with rifles rather than the muskets of line companies, for employment in advance of the main force or on its flank. These companies were sometimes detached from their parent units and grouped to fight as a body. This led to the formation of entire regiments of light infantry. sometimes referred to as rifle corps or rangers. Among American units of this type were Daniel Morgan's Virginia rangers and Thomas Knowlton's Connecticut rangers. Similar British forces were recruited from loyalists, notably Maj. John Butler's battalion (Butler's rangers), formed to operate in conjunction with Indians, and the Queen's rangers.

The term "ranger" recurred in U.S. military usage when on Jan. 12, 1812, congress authorized enlistment of six companies of these troops for service on the frontier. The *Army Register* of May 1, 1813, lists 12 companies of rangers among the units of the army. In 1832, the force authorized for the Black Hawk War included 600 mounted rangers. This first suggestion of combining the functions of rangers and cavalry was an outgrowth of changed tactical needs; the tide of settle'ment having moved beyond the eastern forests, military operations were now in more open terrain, where mounted forces had superior mobility.

The concept of ranger-cavalry was reinforced by the experience of the Republic of Texas, which recruited mounted ranger companies to protect its outlying areas against Indians and Mexicans. During the Mexican War companies of Texas rangers were formed into regiments and mustered into federal service. They operated both as conventional cavalry and as rangers, on scouting, patrolling and raiding duty. Their detached duty, independent attitude and distinctive appearance probably provided an initial basis for the association of the term "ranger" with irregular, paramilitary forces.

During the Civil War, both Union and Confederate organizations adopted "ranger" as part of their unit designations without reference to their actual military character and employment. However, true ranger units played a significant part in Confederate operations. Partly because of the type of service it performed and partly, no doubt, because of its state origin, the 8th Texas cavalry was known as Terry's Texas rangers. The concept of rangers as irregular forces was given impetus when the Confederate congress passed the Partisan Ranger act in 1862. Partisan rangers were entitled to reimbursement for equipment which they captured—an attempt to apply the law of maritime prize to land warfare. The best-known leader and foremost exponent of ranger operations in the Civil War was a Confederate, Col. John S. Mosby (*q.v.*).

Ranger units reappeared in U.S. military organization in World War II, when six ranger battalions were formed, five serving in the European-African-middle eastern theatre and one in the Pacific theatre. Composed of specially trained and conditioned men, these units made sudden, hard-hitting raids behind enemy lines, carrying out demolition and intelligence missions. The lessons of this experience led to the formation in 1950 of the air-borne ranger infantry company as an integral part of each U.S. infantry division. Six such companies were eventually employed in the Korean war. In 1951, however, it was decided that concentration of these trained men in special units was less desirable than spreading them through conventional units, where a larger number of soldiers would have the benefit of learning the combat techniques in which the rangers were especially skilled. Thereafter the U.S. army continued to conduct special ranger-training for individuals but maintained no ranger units:

The Texas rangers, after their federal service in the Mexican War, served as a state constabulary organized along military lines, maintaining law and order against Indians, bandits and other lawless elements. As local government became more effective the need for such a force declined. In 1901 it was reorganized as a state law-enforcement agency. In 1935 the Texas rangers were merged with the state highway patrol under the department of public safety.

In the national park service, the U.S. department of the interior established in 1916 a force of national park rangers, 1%-hosefunctions include protection and conservation of forests and wildlife in the national parks, enforcement of park regulations (for which they have police power) and assistance to visitors.

Similar functions with respect to the national forests were assigned to the forest rangers of the forest service, established in 1905 as an agency of the U.S. department of agriculture. Forest rangers are particularly noted for their activities in the prevention and fighting of forest fires.

BIBLIOGRAPHY.—James J. Altieri, *Darby's Rangers* (1945); V. C. Jones. *Ranger Mosby* (1944); V. C. Jones, *Gray Ghosts and Rebel Raiders* (1956); Burt G. Loescher, *The History of Rogers' Rangers* (1946); U.S. Army, *Army Lineage Book*, vol. ii, *Infantry* (1953); W. P. Webb, *The Texas Rangers* (1935). (J. B. B. T.)

RANGOON, the capital of Burma, situated on the left bank of the Hlaing or Rangoon river, 21 mi. from the sea, in 16° 47′ N. lat. and 96° 13′ E. long. In 1880 the city was detached from the main district, called Hanthawaddy, and formed into a separate district, with an area of 19 sq.mi. This was continually increased; the census area of Rangoon town district in 1931 was 77 sq.mi. The population was 501,219 in 1941 and 737,079 in 1953. On Aug. 1. 1926, the district became part of the Pegu division. From a comparatively insignificant place, Rangoon rose in less than half a century to be the third seaport in India, being surpassed only by Calcutta and Bombay in the volume of its trade. During the busy season of rice export, which lasts from the end of December to the middle of May, the pool forming the port of Rangoon presents almost as crowded a scene as the Hooghly at Calcutta. Rangoon has the double advantage of standing near the sea and being in easy communication with a great river navigable for 900 mi. behind it. It is, in addition: the centre of the Burmese railway system. In the broad and deep river is concentrated the whole of the rich trade of the delta of the Irrawaddy. A great part of the river frontage is occupied with rice mills. teak wharves and similar buildings. Because of the need for wharfage accommodation. the majority of the mills were removed to the opposite or Dalla shore of the Rangoon river, or along the banks of the Pegu river east of Rangoon.

Architecture and History.— The city is dominated by the great golden pile of the Shwe Dagon pagoda, the centre of Burmese religious life. Rising to a height of 368 ft., this magnificent building stands on an eminence itself 168 ft. above the level of the city. It is covered with pure gold from base to summit, and once in every generation this gold is renewed by public subscription. The pagoda is a solid stupa of brick. in the form of a cone. raised over a relic chamber; and the place of worship is the surrounding platform with a perimeter of nearly 1,400 ft.

Though traditionally a site of great sanctity. Rangoon owes its first importance to its rebuilding in 1753 by Alompra, the founder of the Burmese monarchy, who gave it the name of Yan Kon, "the end of strife." The modern Burmese designation of the town is Yangon. The city was taken by the British on the outbreak of the first Burmese War in 1824, but was subsequently restored. It was captured a second time in 1852 and passed with the province of Pegu into the hands of the British. It was destroyed by fire in 1850, and serious conflagrations occurred again in 1853 and 1855.

Administration and Improvements.— Until 1874, when the modern municipality was constituted, the administration was in the hands of the local government, which devoted itself to raising the centre of the town above the river level, providing land fit for building purposes from the original swamp, which was flooded at spring tides, and making roads, bridges, culverts and surface drains. In 1892 the sewage system was introduced, and Rangoon developed an excellent drainage system. The water supply. drawn at first from the Victoria lake, j mi. distant. was later drawn from a large reservoir lake 17 mi. distant. and from the Pegu Yoma water scheme completed in 1941. The city proper of Rangoon with the Kemmendine suburb is laid out on the block system. each block being 800 by 860 ft., intersected with regular streets. Rangoon has many fine public buildings.

There are two large maidans. or commons, which are used as military parade grounds and for sport, the larger being used as golf links. There are also spacious and well-kept zoological gardens. botanical gardens and a well-kept garden in the cantonments under the pagoda. Beyond these lie the Royal lake and Dalhousie park, with 160 ac. of water and well laid out and well timbered park land. There are two cathedrals. Church of England and Roman Catholic, a Presbyterian church and churches of most denominations with services in English. Burmese and the principal Indian languages. Buddhists. Hindus, Moslems, Parsees, Armenians and Jews all own lands and pagodas, temples, mosques, churches and synagogues.

The chief educational institution is the University of Rangoon, constituted in 1920. It formerly included the university college, Judson (American Baptist mission) college, the medical college and the teachers' training college in Rangoon, together with the agricultural college and an intermediate college at Mandalay, but it abandoned the collegiate system in favour of the unitary principle. The greater part of the university occupies magnificent buildings, erected bet een 192; and 1930 on a site overlooking Victoria lake; but some of its buildings suffered severe damage by air bombardment in 1945. By 1950 the total number of students was about 4.000.

Rangoon has several hotels, a number of cinemas, the largest of which are used fór stage plays by traveling companies, fine shops and a number of clubs, notably the Pegu, Orient, Golf and Boat clubs. The European residences are mainly on the outskirts of the city to the northwest in what is called the cantonments. At Mingaladon is one of the finest 18-hole golf courses in the east. The development of Rangoon was placed in the hands of the Rangoon Development trust, which administered the Rangoon government estate on behalf of the government. The trust developed the land, then handing over the completed roads, etc., for maintenance by the Rangoon corporation. A race course at Kyaikkasan was completed in 1926.

The affairs of the port were placed under the administration of the Rangoon port commissioners. Rangoon handles about 85% of the total trade of the province. Rangoon town is the business centre of Burma, but the rice milling (at Dalla), oil refining (at Syriam) and teak working, which form the staple industries, are carried on outside the town proper. The chief exports of Rangoon are rice, bran and pollard, mineral oils. timber, oil cake, pulse, lead, zinc ore. wax candles, cotton. oilseed and tobacco.

Before World War II most of the labour in the port and the town was immigrant Indian labour; much of the skilled labour, especially in building trades. had been supplied by Chinese. The trading and clerical communities were also mainly Indian. Rangoon was thus by no means a typical Burmese city; in 1931 out of a population of 400,415 there were only 121,998 Burmese, compared with 140,458 Hindus. 57.535 Moslems, 30.000 Christians (mainly Europeans, Anglo-Indians and Indians', and 30,626 Chinese. As a result of the Japanese invasion of Burma in 1941–42 the Indian and European populations were much reduced, and the attainment of independence by Burma in 1948 caused a second exodus by many who had returned after the mar.

BIBLIOGRAPHY.—*Administration Report of the Commissioners for the Port of Rangoon* (annual); *Report of the Rangoon Development Trust* (annual); *Report on the Municipal Administration of the City of Rangoon; B. R.* Pearn, *History of Rangoon* (1939).

RANGPUR, a municipal town and district in East Pakistan.

The town is situated on the little river Ghaghat. Pop. (1951) 31,759. It is a long straggling town, with a railway station at one end and the public offices 3 mi. away at the other.

RANGPUR DISTRICT, with an area of 3,699 sq.mi. and a population (1951) of 2,929,466, is one vast plain. The greater part of it, particularly toward the east, is inundated during the rains, and the remainder is traversed by a network of streams. The river system is constituted by the Brahmaputra and its tributaries, chief of which are the Tista, Dharla, Sankosh and Dudhkumar. About three-fourths of the district is under continuous cultivation. The staple crops are rice, oilseeds, jute and tobacco. The district is well served by railways. Saidpur (pop. [1951] 61,369), with the workshops of the metre-gauge system of the East Bengal state railway, is an important railway town.

RANJIT SINGH, MAHARAJA (1780–1839), Indian ruler, who was known as the "Lion of the Punjab," was born on Nov. 2, 1780, the son of Sirdar Mahan Singh, whom he succeeded in 1792 as head of the Sukarchakia branch of the Sikh confederacy. He was by birth only one of many Sikh barons, and rose rapidly entirely by force of character and will.

At the age of 20 he obtained from Zaman Shah, the king of Afghanistan, a grant of Lahore, which he seized by force of arms in 1799. He attacked and annexed Amritsar in 1802, thus becoming master of the two Sikh capitals. When Jaswant Rao Holkar took refuge in the Punjab in 1805, Ranjit Singh made a treaty with the British, excluding Holkar from his territory. Shortly afterward acute difficulties arose between him and the British as to the Cis-Sutlej portion of the Punjab. Ranjit Singh aspired to weld all of the Punjab into a single Sikh empire, while the British claimed the territory south of the Sutlej by right of conquest from the Marathas. The difference proceeded almost to the point of war, but at the last Ranjit Singh yielded. In 1808 Charles Metcalfe was sent to settle this question and a treaty was concluded at Amritsar on April 15, 1809.

The maharaja organized a powerful force, which was trained by French and Italian officers such as Generals Ventura, Jean François Allard and Paolo di Bartolomeo Avitabile, and thus forged the formidable fighting instrument of the Khalsa army, which afterward gave the British their hardest battles in India in the two Sikh wars. In 1810 he captured Multan after many assaults and a long siege; by 1820 he had consolidated the whole of the Punjab between the Sutlej and the Indus under his dominion. It was not until 1834, five years before his death, that Peshawar passed into Sikh hands. Though he disapproved of Lord Auckland's policy of substituting Shah Shuja for Dost Mohammed, he supported the British in their advance on Afghanistan. He died of paralysis on June 27, 1839. *See* also PUNJAB: *History*.

RANJITSINHJI, KUMAR SHRI (1872–1933), maharajah of Nawanagar, was born at Sarodar in Kathiawar, India, on Sept. 10, 1872. By birth a Rajput, he was educated first at Rajkumar college, Rajkot, and afterward at Trinity college. Cambridge. He soon won a high place in English cricket. From 1895 to 1904 he played for Sussex and was captain from 1899 to 1903; his last appearance was in 1920. He went to Australia with A. E. Stoddart's team in 1897–98 and took a team to the United States in 1899. He made in all 14 scores of more than 200 and in 1900 made more than 3,000 runs for an average of 87 and more than 200 five times. His greatest feat was at Hove against Middlesex. On the last day of the match, on a bad wicket, he made 202, when Vine (17) was the only other man on the side to get into double figures. In 1907 he succeeded his cousin as chief of the state of Nawanagar and proved an enlightened ruler. He provided troops for the Allies in World War I and himself served at the front. He died on April 2, 1933.

See Roland Wild, *The Biography of Colonel His Highness Shri Sir Ranjitsinhji* (1934).

RANK, OTTO (1884–1939), Austrian psychologist, was one of the earliest and most influential adherents of the psychoanalytic school. He was born in Vienna on April 22, 1884, and took his doctorate in *Germanistik* at the University of Vienna in 1912. While most of Freud's other disciples devoted themselves primarily to clinical applications, Rank applied his principles to the study of mythology, literature and art. His first important work was *Der Künstler* (1907; later expanded and rewritten under the title of *Art and Artist*, Eng. trans. by C. F. Atkinson, 1932); it invoked the Freudian theory of dream mechanisms to explain the mental processes of the artist. His two best-known publications, *Der Mythus von der Geburt des Helden* (1909; Eng. trans., *The Myth of the Birth of the Hero*, 1914) and *Das Inzest-Motiv in Dichtung und Sage* ("The Incest-Motive in Poetry and Legend," 1912), attempted to show how the so-called Oedipus complex supplied an abundance of themes and motives for poetry and myth.

Rank was editor of *Imago* and *Internationale Zeitschrift fur Psychoanalyse*, the first European journals on psychoanalysis. from 1912 to 1924; in 1919 he founded the Internationale Psychoanalytische Verlag, of which he was director until 1924. Freud endorsed and freely quoted Rank's earlier contributions, but violently opposed the more original theories developed in Rank's last important book, *Das Trauma der Geburt* (1924; Eng. trans., *The Trauma of Birth*, 1929). Consequently they parted company. After leaving Vienna in 1924 Rank divided most of his time between Paris and the United States, being engaged chiefly in teaching and in psychotherapeutic work. In 1936 he finally settled in New York city. There he sought to modify the Freudian theory, which had developed under the social conditions formerly prevailing in Vienna, and to adapt it to the contemporary needs of an industrial society, like that in the United States. He died on Oct. 31, 1939, five weeks after Freud. (CY. B.)

RANKE, LEOPOLD VON (1795–1886), German historian, who is generally regarded as the first of modern historians, was born on Dec. 20 or 21, 1795, at Wiehe, in Thuringia. He studied classics and theology at Halle and Berlin. In 1818 he began to teach history in a school at Frankfurt-on-Oder, thereby entering the service of the Prussian government.

With the scholar's dislike of textbooks, he rapidly acquired a thorough knowledge of the ancient historians, quickly passed on to medieval times and determined to make a study of universal history. At Frankfurt he wrote his first work, *History of the Latin and Teutonic Nations, 1494–1514* (1824; Eng. trans., 1887 and 1909), which included a critical dissertation on the historians of this period *(Zur Kritik neuerer Geschichtschreiber)*. exposing the untrust orthiness of much traditional history. This dissertation was as important for modern history as the criticai work of B. G. Niebuhr had been in ancient history. A copy of the book was sent to the Prussian minister of education K. A. Kamptz, and Ranke was appointed supernumerary professor in the University of Berlin, and began his 50-year connection with that university. His *Fürsten und Volker von Südeuropa im 16 und 17 Jahrhundert* ("Princes and Peoples of Southern Europe in the 16th and 17th Centuries"; 1827) was based on the study of manuscript records in the Berlin library. In later editions the book was called *Die Osmanen und die spanische Monarchie* ("The Ottomans and the Spanish Monarchy").

The Prussian government now provided him with means to prosecute his researches abroad. He visited Vienna. where the friendship of Friedrich von Gentz and the protection of Metternich opened to him the Venetian archives, of which many were preserved in that city—then a virgin field. He wrote a short book on the history of the Serbian revolution (1829; Eng. trans. by A. Kerr, 1847), afterward expanded into *Serbien* und *die Tiirkei im 19 Jahrhundert* (1879) from material supplied to him by Wuk Stephanovich. a Serbian who had himself been witness of the scenes he related. He spent three years (1828–31) in Italy. The recommendations of Metternich opened to him almost every library except the Vatican.

For a time Ranke was editor of a periodical in which Friedrich Perthes sought to defend the Prussian government against the democratic press. He failed; men desired not the scientific treatment of politics, but satire and invective. He earned the hatred and suspicion of the liberals and did not satisfy the Prussian conservatives, and after four years the *Historisch-Polifische Zeitschrift* came to an end. Two-thirds of the matter had been contributed by the editor, and the two stout volumes in which the numbers were collected contained the best political thought which had for long appeared in Germany. For Ranke the failure was not to be regretted; the rest of his life was to be wholly devoted to history proper. *Ecclesiastical and Political History of the Popes During the 16th and 17th Centuries* (3 vol.. 1834–36, and many other editions; Eng. trans. by S. Austin, 1840, and others), in form as in matter one of the greatest of his works, contains the results of his studies in Italy. The English translation by Mrs. Austin was the occasion of one of Macaulay's most brilliant essays. Before it was completed Ranke had already begun the researches for the second of his masterpieces, his *History of the Reformation in Germany* (Eng. trans. by S. Austin, 1845–47), a necessary pendant to his book on the popes. In 1837 he became full professor at Berlin; in 1841 Frederick William IV appointed him Prussian historiographer. In this capacity he wrote the *Neun Bücher preussischer Geschichte* (1847–48), a work on Prussian history which makes severe demands on the attention of the reader—he is the "Dryasdust" of Carlyle's *Frederick;* but in it he laid the foundation for the modern appreciation of the founders of the Prussian state. The 9 books were subsequently. expanded to 12 (1874). His *Civil Wars and Monnrchy in France in the 16th and 17th Centuries* (Eng. trans., 2 vol., 1852) was followed by his *History of England* (Eng. trans.. 6 vol.. 1875). This, the longest of his works, lacked something of the freshness of his earlier books; he was over 70 when it was completed, and he was never quite at home in dealing with the foundations of English public life. In his 81st year he began to write the *Weltgeschichte* ("Universal History"; 9 vol., 1883–88). Drawing on the knowledge accumulated during 60 years, he had brought it down to the end of the 15th century before his death in Berlin on May 23, 1886.

Ranke's other writings include biographies of Frederick the Great and Frederick William IV for the *Allgemeine Deutsche Biographie.* In addition to those previously mentioned, works translated into English include *Ferdinand I and Maximilian II of Austria; State of Germany After the Reformation,* by Lady Duff Gordon (1853); *Memoirs of the House of Brandenburg and History of Prussia During the 17th and 18th Centuries,* by Sir Alexander and Lady Duff Gordon (1849). A collected edition of Ranke's works in 54 volumes was issued at Leipzig (1868–90), but this does not contain the *Weltgeschichte.*

Ranke's wide reputation was due, in part, to his success as a teacher. In his more private classes, where he dealt with the technical work of a historian, he trained generations of scholars. No one since C. G. Heyne has had so great an influence on German academic life, and for a whole generation the Berlin school had no rival. Ranke's example and training has made it impossible for anyone to attempt to write modern history except on the "narratives of eye-witnesses and the most genuine immediate documents" preserved in the archives. He was determined never to allow himself to be misled, in his search for truth, by those theories and prejudices by which nearly every other historian was influenced—Hegelianism, liberalism, romanticism, religious and patriotic prejudice. For details of Ranke's life and work. *see* his own *Zur eigenen Lebensgeschichte,* ed. by A. Dove (1890).

BIBLIOGRAPHY.—E. Guglia, *Leopold von Rankes Leben und Werke* (1893); M. Ritter, *Leopold von Ranke* (1895); H F. Helmolt, *L. Rankes Leben und Wirken* (1921); H. Oncken, *Aus Rankes Frühzeit* (1922).

RANKINE, WILLIAM JOHN MACQUORN (1820–1872), Scottish engineer and physicist, was born at Edinburgh on July 5, 1820, and completed his education in its university. He was trained as an engineer under Sir J. B. Macneill, working chiefly on surveys, harbours and railroads, and was appointed in 1855 to the chair of civil engineering in Glasgow. He was the earliest of the three founders of thermodynamics (*q.v.*) on the bases laid by Sadi Carnot and J. P. Joule respectively, and the author of the first formal treatise on the subject; 150 scientific papers are credited to him in the Royal society's *Catalogue.* The more important of these were collected and reprinted in *Rankine's Scientific Papers* (1881), which contains a memoir of the author by P. G. Tait. Rankine died at Glasgow on Dec. 24, 1872.

RANSOM, JOHN CROWE (1888–), U.S. poet and critic, was born on April 30, 1888, in Pulaski, Tenn. Graduated from Vanderbilt university, Nashville, Tenn., in 1909 and from Oxford, where he was a Rhodes scholar, in 1913, he taught English at Vanderbilt from 1914 to 1937, when he went to Kenyon college, Gambier, O., as professor of poetry and editor of the *Kenyon Review.*

From 1922 to 1925, Ransom and his pupils—Donald Davidson, Allen Tate, Merrill Moore and Robert Penn Warren—published a magazine of their own verse called *The Fugitive.* The same group (excepting Moore), joined by others at Vanderbilt, published *I'll Take My Stand* (1930), which criticized current notions of industrial progress. Ransom turned to literary criticism in *The World's Body* (1938) and *The New Criticism* (1941), the latter of which gave the name to the critical school that is concerned with the close reading of poetical texts. Ransom's poems. collected in *Chills and Fever* (1924), *Two Gentlemen in Bonds* (1926) and *Selected Poems* (1945), are remarkable for their wit and irony, their understatement and their southern urbanity. (R. St.)

RANSOM, the price for which a captive in war redeemed his life or his freedom. a town secured immunity from sack and a ship was repurchased from its captors. The customs of feudal warfare recognized that captives of knightly rank had the right of buying their liberty from their captors. It was the duty of a feudal tenant to contribute toward his lord's ransom, and a king would often show his appreciation of a knight's services by redeeming him from captivity. The practice introduced a commercial element into medieval warfare, which became very prominent in the Hundred Years' War between England and France and in the internal wars of Italy in the 15th century. In the former war, the ransom paid by John, king of France. and David II, king of Scotland. sensibly relieved the finances of Edward III's administration and at an earlier date the ransom paid by Richard I to the emperor led to the introduction of new financial devices which are important in the history of English taxation.

RANTERS, an antinomian and spiritualistic English sect in the time of the Commonwealth. which may be described as the dregs of the Seeker movement. Their central idea was pantheistic. *See* Rufus M Jones, *Studies in Mystical Religion,* ch. 19 (1909).

RANTOUL, a village of Illinois, U.S., in Champaign county, was incorporated in 1869 and named for Robert Rantoul, an early member of the board of directors of Illinois Central railroad. Located about 15 mi. N.E. of Champaign in the grand prairie of east central Illinois, the village originally had an agricultural economy. Chanute air force base, adjacent to Rantoul, was built in 1917 and has been permanent since 1921. Building and maintenance of the base provided new and varied opportunities for employment to local people. School-building programs received federal aid; churches and recreational facilities were also provided. Residential development, largely to accommodate air force personnel, contributed to changing this rural community into an urban one.

For comparative population figures *see* table in ILLINOIS: *Population.* (T. J. T.)

RANUNCULACEAE, a plant family of the order Ranales that includes many familiar and ornamental flowers. There are 30 genera with about 700 species in temperate and cold regions, especially in the northern hemisphere. The family contains many well-known forms, such as buttercup, larkspur, anemone, columbine, clematis, marsh marigold, peony, etc. In North America there are about 25 genera, in Great Britain 12. The plants are dicotyledons (*i.e.,* with two seed leaves), and the family retains many of the primitive characters of the extinct ancestors of the higher dicotyledons and monocotyledons. Most of the plants are herbs (rarely woody vines, as in some species of *Clematis)* with alternate leaves (opposite in *Clematis)* usually without stipules. The flowers, which show considerable variation in the number and development of parts, are characterized by free hypogynous sepals and petals, numerous free stamens, usually many free one-chambered carpels and small seeds containing a minute straight embryo embedded in a copious endosperm. The parts of the flower commonly are arranged spirally on a convex receptacle. The fruit is one-seeded (an achene) or many-seeded (a follicle) or rarely, as in *Actaea,* a berry.

The family falls into well-defined tribes distinguished by characters of the flower and fruit.

Tribe I, Paeonieae (peonies). are mostly herbs with deeply cut leaves and large solitary showy flowers in which the parts are arranged spirally, the sepals, generally five in number. passing gradually into the large coloured petals. There are two to five free carpels which bear a double row of ovules along the suture. There are no special stalked nectaries, but nectar is secreted by a ringlike swelling around the bases of the carpels. The pistils become fleshy in the fruit and each dehisces along the suture. There are only three genera; the largest, *Paeonia,* occurs in Europe, temperate Asia and western North America. *P. officinalis* is the common peony; P. *suffruticosa* is the tree peony, native to China. This tribe possibly constitutes a separate family.

Tribe II, Helleboreae, are almost exclusively north temperate or subarctic. The leaves may be entire or nearly so, as in *Caltha,* but more often palmately divided as in hellebore, aconite (monkshood) and larkspur. The flowers are solitary *(Eranthis)* or in cymes or racemes, and are radially symmetrical as in *Caltha* (marsh marigold), *Trollius* (globeflower), *Helleborus* (hellebore), *Aquilegia* (columbine) or sometimes bilaterally symmetrical as in *Aconitum* (aconite) and *Delphinium* (larkspur). The carpels. generally three to five in number, form in the fruit many-seeded follicles. except in *Actaea* (baneberry), where the single carpel develops into a many-seeded berry, and in *Nigella,* where the five carpels coalesce, forming a five-chambered ovary. The sepals are usually five and are white or brightly coloured. Thus in *Caltha* and *Trollius* the sepals form a brilliant golden-yellow globe, and in *Eranthis* a pale-yellow star; in *Nigella* they are blue or yellow. In *Helleborus* the greenish sepals persist until the fruit is ripe. *Aconitum* and *Delphinium* differ in the bilaterally symmetrical development of the sepals. the posterior one being distinguished from the remaining four by its helmet shape (*Aconitum*) or by its spur *(Delphinium).* In *Trollius* the petals are long and narrow with a honey-secreting pit at the base; in *Nigella* and *Helleborus* they form short-stalked pitchers; in *Aquilegia* they are large and coloured with a showy, petallike upper portion and a long basal spur in the tip of which is the nectary. In *Delphinium* they are also spurred. and in *Aconitum* they form a spurlike sac on a long stalk. The parts of the flower usually are arranged in a spiral (acyclic), but are sometimes hemicyclic. the perianth forming a whorl as in winter aconite; rarely is the flower cyclic. as in *Aquilegia,* in which case the parts throughout are arranged in alternating whorls. In *Caltha,* where there are no petals, nectar is secreted in two shallow depressions situated on the side of each carpel. Monkshood is a source of medicinal febrifuges.

Tribe III, Anemoneae, are chiefly temperate, arctic and alpine herbs. They differ from the two preceding tribes in the usually numerous carpels, each with only one ovule, forming achenes. The subgenus *Bntrachium* of the genus *Ranunculus* (*q.v.*) contains aquatic plants with submerged or floating stems and leaves. The flowers are solitary as in *Anemone pulsatilla* (pasqueflower), cymose as in species of *Ranunculus,* or in racemes or panicles as in *Thalictrum.* The parts are arranged spirally throughout as in *Myosurus* (mousetail). where the very numerous carpels are borne on a much-elongated receptacle, or the perianth appears whorled as in *Anemone* and *Ranunculus.* In *Anemone* and *Thalictrum* there is only one series of perianth parts, and these are petaloid and attractive in *Anemone,* in which nectar is secreted by modified stamens. In *Anemone nemorosa* (European wood anemone), there is no nectar and the flower is visited by insects for pollen; in *Tkalictrum* the perianth is greenish or slightly coloured, and the flower is wind-pollinated (*T. minus*) or visited for its pollen. On the petal of *Ranunculus* there is a basal nectary usually covered by a scale. In *Anemone* the achenes bear the persistent naked or bearded style which aids in dissemination; the same purpose is served by the prickles on the achenes of *Ranunculus arvensis. Clematis* (*q.v.*) is characterized by its shrubby. often climbing habit. opposite leaves and the valvate (not imbricate as in the rest of the family) estivation of the sepals. The fruit consists of numerous achenes prolonged into the long feathery style. whence the popular name of the British species, old-man's-beard (*Clematis vitalba).*

See also ACONITE; ADONIS; ANEMONE; BANEBERRY; CIMICIFUGA; CLEMATIS; COLUMBINE; HELLEBORE; LARKSPUR; RANUNCULUS, etc.

BIBLIOGRAPHY.—L. Benson, *Plant Classification* (1957); A. Engler and K. Prantl, *Die natürlichen Pflanzenfamilien* (1887–1908); G. H. M. Lawrence, *Taxonomy of Vascular Plants* (1951). (L. BN.)

RANUNCULUS, familiarly known as buttercup, or crowfoot, a characteristic genus of the botanical family Ranunculaceae (*q.v.*). The Latin name, which means a little frog or tadpole (diminutive of *rana,* frog), was also given to a medicinal plant, which has been identified by some with the crowfoot. The members of the genus *Ranunculus* are more or less acrid herbs, sometimes with fleshy root fibres. or with the base of the stem dilated into a kind of tuber *(R. bulbosus).* They have tufted or alternate leaves. dilated into a sheath at the base, and generally, but not universally, deeply divided above. The flowers are solitary, or in loose cymes, and are remarkable for the number and separation of their parts. Thus there are five sepals, as many petals. and numerous spirally arranged stamens and carpels. The petals have a little nectary or honey gland at the base. The fruit is a head of achenes — dry, one-seeded fruits.

RUTHERFORD PLATT

RANUNCULUS, COMMONLY KNOWN AS BUTTERCUP OR CROWFOOT. PETALS AND SEPALS HAVE BEEN REMOVED FROM FLOWER AT LEFT SHOWING THE PISTIL AND STAMENS

The genus contains a large number of species (about 250) and occurs in most temperate countries in the northern and southern hemispheres, extending into arctic and antarctic regions, and appearing on the higher mountains in the tropics. Inclusive of the water buttercups, 100 native species of *Ranunculus* occur in North America, widely distributed throughout the continent. Representative species are *R. septentrionalis, R. abortivus* and *R. recurvatus,* of the eastern states. and R. *californicus* of the Pacific coast. About 15 species are found in Great Britain. *R. acris, R. repens* and *R. bulbosus* are the common buttercups. *R. arvensis,* which is found in European cornfields, has smaller pale-yellow flowers and the achenes covered with stout spines.

R. lingua and *R. flammula,* the spearwort, grow in marshes, ditches and wet places. *R. ficaria* is the pilewort or lesser celandine, an early spring flower in European pastures and waste places, characterized by having heart-shaped entire leaves and clusters of club-shaped roots.

The section *Batrachium* comprises the water buttercups, denizens of pools and streams, some of which vary greatly in the character of the foliage according to whether it is submerged. floating or aerial, and when submerged varying in accordance with the depth and strength of the current.

The ranunculus of the florist is a cultivated form of *R. asiaticus,* a native of the eastern Mediterranean Levant region, remarkable for the range of colour of the flowers (yellow to purplish black) and for the regularity with which the stamens and pistils are replaced by petals forming double flowers.

RANVIER, LOUIS ANTOINE (1835–1922), French histologist, a master of technical methods and a true scientist, one of the great French biologists; was born on Oct. 2, 1835, at Lyons. He began his medical studies in Lyons and worked in the hospitals there under such well-known clinicians as Charles Jacques Bouchard and Raphael Lépine. He was nominated interne in the Paris hospitals in 1860 and graduated M.D. five years later, presenting a thesis on the development and diseases of bone. By this time he had formed a close friendship with Andre Victor Cornil (1837–1908), with whom he shared an intense interest in the rapidly developing science of histology. The two friends opened a private laboratory where they gave special courses for students. Cornil soon obtained academic promotion, and Ranvier, having attracted the attention of Claude Bernard, was appointed his assistant in 1867. In 1869–76 Cornil and Ranvier brought out their *Manuel d'histologie pathologique*, a revelation to their contemporaries and one of the landmarks in 19th-century medicine. In 1872 a special histological laboratory was opened for Ranvier at the Collkge de France, and in 1875 he became the first occupant of the chair of general anatomy.

Apart from the *Manuel* Ranvier's most important published works were his *Traité technique d'histologie* (1875 ff.), *Leçons sur l'histologie du système nerveux* (1878) and *Leçons d'anatomie générale, faites au Collège de France* (1880–81). He also wrote many papers and edited seven volumes of the *Travaux* of his laboratory (1874–88). His own researches were concerned particularly with the histology of nerve fibres, the regeneration of nerves, the bipolar nature of ganglionic cells and the minute structure of the skin, conjunctival tissue and cornea. In 1878 he first described the constrictions seen in medullated nerve fibres which are known as the nodes of Ranvier. He was elected a member of the Académie de Médecine (1880) and of the Institut (1887). During his pioneer researches Ranvier had many pupils and disciples, but in the period 1880–85 the interest aroused by Louis Pasteur's discoveries in bacteriology led to a decline in histological studies. Ranvier's laboratory was no longer frequented, his courses lapsed and he made few further contributions to science. Thereafter he spent most of his time on an ancestral estate at Vendrages (Loire), to which he finally retired *c.* 1900, occupying himself with country pursuits. He never married, and in his later years was a solitary figure. He died on March 22, 1922, leaving part of his fortune to the town of Roanne for the erection of a sanatorium for tuberculosis. (W. J. Bp.)

RAOUL DE CAMBRAI, the name of a French *chanson de geste.* The existing romance is a 13th-century recension of a poem by a trouvkre of Laon called Bertholais, who professed to have witnessed the events he described. Raoul de Cambrai, the posthumous son of Raoul Taillefer, count of Cambrai. by his wife Alais, sister of King Louis (d'Outre-Mer), demanded the fief of Vermandois, which was the natural inheritance of the four sons of Herbert, lord of Vermandois. On King Louis's refusal, he proceeded to war. Bernier, a grandson of Count Herbert. eventually slew Raoul, but in his turn was slain, after an apparent reconciliation. Flodoard *(Annales, Anno* 943) states that Count Herbert died in that year, and was buried by his sons at St. Quentin; that when they learned that Raoul, son of Raoul de Gouy, was about to invade their father's territory, they attacked him and put him to death.

RAOULT, FRANÇOIS MARIE (1830–1901), French chemist, best known in connection with work on solutions (*q.v.*), was born at Fournes, Nord, on May 10, 1830. In 1862, after holding various teaching posts, he became professor of chemistry in the *lycée* at Sens. In 1867 he was put in charge of the chemistry classes at Grenoble, and three years later he succeeded to the chair of chemistry, which he held until his death on April 1, 1901. In his doctoral research on the heat of reaction and electromotive force of galvanic cells, he made the important observation that the two did not correspond on the theory that heat is a measure of affinity.

One of his most important contributions was the discovery that the freezing point depression of aqueous solutions is proportional to the solute mole fraction. His most valuable finding (Raoult's law) was the discovery that the vapour pressure of the solvent in a solution is proportional to the mole fraction of the solvent. Raoult's law has been of fundamental importance in the development of the theory of solutions. (N. H. N.)

RAPALLO, a seaport and winter resort of Liguria, Italy, in the province of Genova. Pop. (1951) 11,455. It occupies a beautiful and ell-sheltered situation on the east side of the Gulf of Rapallo, 18½ mi. E. by S. from Genoa by rail. The bridge, known as "Hannibal's Bridge," is medieval. To the south lies the small seaport of Portofino (the Roman *Portus Delphini*) under the southeast extremity of the promontory of Portofino (2,001 ft.) crowned by the remains of a castle. On the way from S. Margherita to Portofino is the suppressed monastery of Cervara, in which Francis I of France was confined after the battle of Pavia on his way to Madrid. At all these places are beautiful villas.

On the south side of the promontory is the small village of S. Fruttuoso. with the tombs of some of the Doria family of Genoa (1275–1305).

RAPALLO, TREATY OF (April 16, 1922). During the conferenceof Genoa *(see* GENOA, CONFERENCE OF), at which it was designed to consider the economic relations of the participating powers with Soviet Russia, the Soviet delegates showed no desire to resume relations with the Allied and Associated powers, but to the consternation of the latter signed an agreement with Germany, after secret negotiations. The treaty was initialled on April 16, 1922 by Georghy V. Chicherin and Walther Rathenau. Germany and Russia renounced reciprocally all claims to war indemnities of any sort, including payment for the maintenance of prisoners of war. Germany renounced any compensation for losses incurred by German subjects in consequence of Russian socialization of private property "provided that the Soviet Government does not satisfy similar claims of other states." Diplomatic and consular relations were resumed, the principle of the most-favoured nation was to be mutually applied, with a Russian reservation in favour of states formerly belonging to the Russian empire. Economic relations were to be regulated "with mutual feelings of goodwill." The main result of the Rapallo treaty, secret at that time, was that Germany was able to produce in Russia new prototypes of arms forbidden by the treaty of Versailles.

RAPE, one of the six administrative divisions of the county of Sussex, Eng., with their centres at Chichester, Arundel, Bramber, Lewes, Pevensey and Hastings. Rapes were probably established soon after the settlement and are first mentioned in Domesday Book. Their boundaries ran roughly parallel from north to south and each rape contained a river, a castle and a forest.

RAPE, various plants of the genus *Brassica* (mustard family, Cruciferae), the source of oil-yielding rape seed. Most of the cultivated varieties appear to belong either to *Brassica napus* or *B. campestris.* Both may be grown as annuals or biennials, depending upon the variety and the time of sowing. *B. napus* is a much-branched, glaucous plant growing to 3½ ft. tall, with lobed or toothed, succulent leaves, yellow flowers and elongate narrow pods. *B. campestris* is similar, but it is more weedy, its leaves are less succulent and the plant is less glaucous. Leading producers of rape seed are China, India, Pakistan, Japan, Sweden, France and the U.S.S.R. Some rape is grown for seed in Canada, but in the United States the plant is used mainly as a forage and green manure crop. Oils derived from the various kinds of rape seed are closely similar and are used mainly as edible oil and in lubricants. (J. W. Tt.)

RAPE, in law, is the crime committed by a man in obtaining unlawful carnal knowledge of a woman, without her consent, by fear, force or fraud. **A** husband cannot commit rape upon his wife unless she is legally separated from him.

A felony at common law, rape was reduced in England to a misdemeanour in 1275, but in 1285 was again declared a felony, with benefit of clergy, and so remained until 1575, when the punishment was made more severe. It became a capital offense by the Offences Against the Person act, 1861, and is now punishable with imprisonment for life. The law of England regards as immaterial whether the woman is chaste or unchaste, married or single. The offense is complete if consent is extorted by threats of death or immediate bodily harm, by fraud or by false pretenses or personating the woman's husband.

In the United States the elements of the crime under statute are similar to those at common law. The age when effective consent can be given by the woman has commonly been set by the various states between 14 and 18 years. Want of age on the part of the man is not a defense, as at common law, but simply presumptive evidence of lack of physical capacity. Many states require the testimony of the woman to be corroborated by other evidence as well as requiring the prosecution to be initiated within a year or less after the commission of the offense. The punishment is imprisonment, though a few southern states prescribe death as the penalty. (P. E. L.)

RAPE OIL, an important fatty oil, known also as "sweet oil," either expressed or extracted from the crushed seeds of cultivated varieties of the cruciferous genus *Brassica*. Under the names rape oil. rapeseed oil and colza oil (*q.v.*) are included the produce of several varieties of B *napus* and *B. campestris*. Summer rape. an annual variety of *B. napus*, is an important oilseed crop in Europe while varieties of *B. campestris* are grown in India and China. *(See* RAPE)

The oil yielded by these seeds is, in physical and chemical properties, practically the same, the range of fluctuations not being greater than would be found in the oil of any specific seed under similar varying conditions of production; the winter varieties of all the seeds are more productive than the summer varieties. Newly pressed rape oil has a dark sherry colour with. at first. scarcely any perceptible smell; but after resting a short time the oil deposits an abundant mucilaginous slime, and by taking up oxygen it acquires a peculiar disagreeable odour and an acrid taste. Refined by the ordinary processes *(see* OILS. FATS AND WAXES), the oil assumes a clear golden-yellow colour. In specific gravity it ranges between 0.9112 and 0.9117 (ra) and from 0.9127 to 0.9136 (refined); the solidifying point is from −4° to −6° C.

The principal uses of rape oil are for lubrication and lighting; but after the introduction of mineral oils for both these purposes the importance of rape considerably decreased. It is but little employed in soapmaking, as it saponifies aith difficulty and yields only an indifferent product. In Germany it is very considerably used as a salad oil under the name of *Schmalzöl*, being for that purpose freed from its biting taste by being mixed with starch, heated until the starch is carbonized and filtered after the oil has cooled. The offensive taste of rape oil may also be removed by treatment uith a small proportion of sweet spirits of nitre (nitrous ether). In Indonesia rape oil and its equivalents. known under various names, are the most important of oils for native use. They are largely consumed as food instead of ghee under the name of *metah* or sweet oil. but for all other purposes the same substance is known as *kurwah* or bitter oil It is preferred for the preparation of curries and other hot dishes. Rape oil is the subject of extensive adulteration. principally with the cheaper hemp oil, rosin oil and mineral oils These sophistications can be most conveniently detected first by taste and next by saponification, rosin oil and mineral oil remaining unsaponified. hemp oil giving a greenish soap and rape oil yielding a soap with a yellow tinge.

Rape oil and the other cruciferous oils are characterized by the presence of the unsaturated fatty acid erucic acid, $C_{21}H_{41}COOH$, the identification of which affords a means of detecting rape oil in admixture with other oils. Lead plaster boiled in rape oil dissolves, and, sulfide of lead being formed, the oil becomes brown or black. Other lead compounds give the same black coloration from the formation of sulfide.

See E W Eckey, ***Vegetable*** *Fats and Oils* (1954).

RAPHAEL (meaning "God heals"), in the Old Testament Apocryphal Book of Tobit (*q.v.*), the name of the angel who in human disguise and under the name of Azarias ("Yahweh helps") accompanied Tobias in his adventurous journey and conquered the demon Asmodaeus. He is said to be "one of the seven holy angels [archangels] which present the prayers of the saints and go in before the glory of the Holy One." In the Book of Enoch (ch. 20) Raphael is "the angel of the spirits of men," and it is his business to "heal the earth which the angels have defiled."

RAPHAEL (RAFFAELLO SANTI or SANZIO) (1483–1520), one of the greatest Italian painters of the Renaissance, was born in Urbino, the son of Giovanni Santi. His birth, probably on April 6, 1483. took place in a house which still contains a fresco of the "Madonna and Child" that is either by his father or is a very early work of his own Giovanni Santi was not a very good painter as may be seen from his surviving works such as the "Madonna and Child With Saints" (1489, Urbino gallery). but he presumably gave Raphael his first grounding as a painter. He died in 1494, and, as Raphael's mother had already died.in 1491, parental influence can have counted for little. What was far more important was Urbino itself, for this little hill town was one of the most civilized in Europe in the 15th century, under its Duke Federigo da Montefeltro and his son and successor Guidobaldo. The palace is one of the masterpieces of Italian architecture; Piero della Francesca had worked in Urbino in the 1460s and 1470s; Bramante was a citizen and was later to play a major part in Raphael's career; and Baldassare Castiglione. the arbiter of manners and author of *The Courtier*, was an Urbinate. The latter was to become a friend of Raphael, ahose portrait of him (1516, Louvre, Paris) is one of the first modern portraits—a study of character distinct from that accumulation of details which the 15th century had regarded as essential to portraiture.

Earliest Works.—Raphael's earliest years are still obscure. He is first recorded on Dec. 10, 1500, when he shared in a commission for a "St. Nicholas," completed on Sept. 13, 1501, which is now lost but is known in part through drawings. Extant works which are probably of this very early period include the large "Mond Crucifixion" (National gallery. London) and the two tiny panels of the "Knight's Dream" (also National gallery) and the "Three Graces" (Chantilly. France). Before this time he had almost certainly assisted Perugino in his frescoes in the Sala del Cambio at Perugia. and for the next few years the influence of Perugino was dominant; indeed. Raphael might well have settled down to succeed to Perugino's business had it not been for his visit to Florence which fertilized his imagination. The figure of Fortitude in the Sala del Cambio is usually agreed to be by Raphael's hand. but here, of course, he was merely executing Perugino's cartoon. Between 1501 and 1503 Raphael was commissioned to paint an "Assumption" for the nuns of Monteluce, but the picture (now in the Vatican gallery) was actually finished after his death by his pupils. The earliest surviving work by him that is completely certain is the "Sposalizio." or "Marriage of the Virgin." which is signed and dated 1504 (Brera gallery, Milan). The types are markedly Peruginesque and the composition derives from Perugino's "Christ Giving the Keys to St. Peter" (Sistine chapel. Vatican) and from another "Sposalizio" attributed to Perugino now in the museum at Caen. France. It has. however, been suggested that the Caen picture derives rather from Raphael; what is certain is that the Brera "Sposalizio" is no more than an improved Perugino and falls short of the great masterpieces Raphael was to paint no more than five years later.

Florentine Period.—Probably late in 1504 Raphael went to Florence and this date marks the first decisive phase in his career. By 1505 he was once again in Perugia. where he was commissioned to paint a fresco in S. Severo; this seems to have been still unfinished at his death and was completed by his former master Perugino. who outlived him. Nevertheless, the upper part of the fresco contains the germ of his first great Roman work. the "Disputà" Probably immediately after he received this commission Raphael returned to Florence, where he set himself to relearn his whole art under the influence of the two greatest living artists, Leonardo da Vinci and Michelangelo, both then in Florence. Also, he became friendly uith Fra Bartolommeo (*q.v*), but here the influence was mutual. A series of Madonna compositions (Florence, Paris, Vienna. Washington, D.C.. and elsewhere) shows Raphael learning the Florentine method of building up his composition in depth with pyramidal figure masses, uith figures grouped as a single unit yet each retaining its own individuality of character and shape. This new sense of unity in composition and the suppression of inessentials he owed mainly to Leonardo. in particular to his "Madonna and Child and St Anne" cartoons. To Leonardo he also owed a new sense of softness in modeling and skill in chiaroscuro. shown in his portraits of Angelo and Maddalena Doni (Pitti, Florence), in which he adapted the model provided by Leonardo's "Mona Lisa." To counterbalance any tendency to imitate the slightly overripe quality of Leonardo's modeling. Raphael made a profound study of Michelangelo's cartoon of the "Battle of Cascina," with its stress on dramatic action and expressive anatomy. The "Ansidei Madonna" (c. 1506, National gallery, London) shows something of both these influences, but the full impact of Michelangelo on Raphael at this date is best seen in the "Borghese Entombment" (1507, Borghese gallery, Rome), painted for Atalanta Baglione of Perugia in memory of her murdered and murderous son. It contains several more or less direct quotations from Michelangelo and there can be no doubt that in it and other works of the same period Raphael set himself deliberately to learn from Michelangelo the expressive possibilities of human anatomy.

Roman Period.—On April 21, 1508, Raphael was still in Florence, as we know from a letter of that date, and the "Cowper Madonna" (National Gallery of Art, Washington, D.C.) is signed and dated 1508 and must therefore be one of his last Florentine works. Traditionally it was Bramante who summoned him to Rome, since he was distantly related to Raphael and knew that there were good commissions to be had from his own splendid patron, Pope Julius II. The tradition is the more likely to be correct in that Raphael was still virtually an unknown provincial painter. by no means yet the third member of the Leonardo-Michelangelo-Raphael triumvirate that springs automatically to the mind. He was still only in his middle zos, but he was soon to receive a commission from the irascible but extremely discerning pope that placed him practically on a level with Michelangelo. Raphael was certainly at work in the Vatican by Jan. 13, 1509, and on Oct. 4 of that year he was granted a papal sinecure, presumably in payment for work done in the Stanze (Italian, "rooms").

The *Stanze*.—Julius II, who detested the memory of his predecessor Alexander VI, refused to use the Borgia apartments and, as a consequence of his remodeling of the Vatican palace, Bramante built the Cortile di S. Damaso, later to be completed by Raphael and decorated by his pupils under the name of "Raphael's Loggie." As his first great work for the pope. Raphael was commissioned to paint a cycle of frescoes in a series of medium-sized rooms known simply as the Stanze. The Stanza della Segnatura and Stanza d'Eliodoro are practically entirely decorated by Raphael himself; the Stanza dell' Incendio, though designed by Raphael, was largely executed by his numerous assistants and pupils; the last and largest of the apartments, the Sala di Costantino, was hardly even designed by Raphael, and was not finished until about four years after his death.

The main themes of the Stanze are fairly simple and easily grasped, but the details of the iconography have never been completely worked out since no two scholars are satisfied with the same interpretations. It is highly probable that there was a written "program" for the series as a whole and perhaps also for each fresco, but it has not survived and the two most important questions are left unanswered: to what extent was it imposed on Raphael by the pope or his advisers, and to what extent was each and every detail of each fresco charged nith a meaning that had been worked out in advance? When Raphael arrived in Rome he was young, almost unknown. and certainly not particularly well educated in the humanist sense; yet long before he died he was famous not only as a painter but also as a scholar and was clearly on easy and familiar terms with the papal court in general. The most likely reason for this is that he had shown himself the ideal humanist artist; that is, he was able to devise great works of art which at the same time were heavily charged with allegorical or symbolic meaning. One example will perhaps make this clear. The figures of Plato and Aristotle in the fresco known as the "School of Athens"—the identity of these two figures is shown by the books they hold—are not only exactly right from the formal point of view, as two contrasted figures set in the optical centre of the composition, but also the simplest and most telling visual symbols of the two contrasted philosophies. Plato is a grave old man, pointing upward as though to emphasize the heavenly origin of those Ideas which are the basis of his philosophy; Aristotle, a much younger and more vigorous man, gestures in a decisive and forthright way toward the earth as an expression of his unidealistic philosophy.

The four Stanze consist of a single enfilade of rooms, the first three (in the order in which the visitor sees them) being those of the Fire in the Borgo (dell' Incendio), of the Tribunal (della Segnatura) and of Heliodorus (d'Eliodoro). Each of these is about 30 ft. by 25 ft. in size, but the last and largest room, the Sala di Costantino, is about 30 ft. by 45 ft. It communicates directly with the Loggie di Raffaello.

The first to be painted was the Stanza della Segnatura, frescoed bet een 1509 and 1511. It seems to have been used for the sittings of a legal tribunal, and its title implies that important state documents were signed or sealed in it. The ceiling is decorated with four roundels and four rectangular panels in imitation of mosaics, representing Theology, Justice, Philosophy and Poetry (in the roundels), and Adam and Eve, the Judgment of Solomon, Astronomy and Apollo and Marsyas (in the rectangles). The four main fresco fields are occupied by the "Disputi" and the "School of Athens" on the larger walls and "Parnassus" and the "Cardinal Virtues" on the smaller. The two latter have subsidiary scenes representing "Augustus Preventing the Burning of the Aeneid," "Alexander the Great Depositing the Homeric Books in the Tomb of Achilles," and "Justinian Receiving the Pandects" and "Gregory IX Approving the Decretals." As the principal theme of the room is the scope of human knowledge, the main walls are given up to the contrasted representations of secular knowledge and theology—the so-called "School of Athens" and the so-called "Disputi." Presumably neither name was used by kaphael, but the "Disputi" is referred to by G. Vasari as showing "an infinite number of saints, who write down the Mass and hold dispute about the Host which is on the altar . . ." This should not be understood as meaning a dispute in the ordinary English sense of the term, but rather a medieval disputation or philosophical discussion.

It is clear that both the "Disputi" and the "School of Athens" are intended as allegories in a very general sense, and many of the highly involved "explanations" which have been propounded are no more than misplaced ingenuity. The "Disputi" is, in fact, no more than a general symbolic representation of the church on earth and in heaven, for the centre of the composition is the monstrance on the altar, with the heavenly host and the representatives of the church on earth both converging on it. At the same time the Host in the monstrance is the lowest part of the vertical axis which consists of the figures of God the Father, Christ and the Holy Spirit, again a simple piece of symbolism. The upper part of the composition is very reminiscent of the fresco in S. Severo in Perugia, with its row of saints seated on rather solid clouds. but the lower part is more freely handled. The device of the steps, which serve to lead the eye into the picture space, and the railing at the left, balancing the awkward shape made by the door cutting into the fresco field at the right, both prove Raphael's extraordinary powers as a composer. It is very likely that this was the first time he had worked on so large a scale (something like 24 ft. across), and it is nothing short of astounding that he was able to compose the "School of Athens," one of the most subtle arrangements of a large number of figures ever painted, as his second attempt on this scale.

The "School of Athens" is perhaps the most famous of all his frescoes. as the "Sistine Madonna" is the most famous of all his Madonnas. It differs from the "Disputà" in that the symbolism is less obvious and the intention vaguer, for it represents a number of the more famous classical philosophers in a splendid basilica—based on Bramante's design for the new St. Peter's—which, in a general way, symbolizes both the dignity of philosophical enquiry and the secular nature of the subject.

At about the same time, probably in 1511, Raphael also painted a more secular subject still, the "Triumph of Galatea" in the Villa Farnesina, Rome, for the Sienese banker Agostino Chigi, for whom he was later to decorate the Chigi chapel in Sta. Maria del Popolo. The Stanza della Segnatura was completed in 1511 and Raphael began to work on the next Stanza, that of Heliodorus, in 1512, completing it in 1514. The whole character of the Stanza d'Eliodoro is entirely different from that of the Stanza della Segnatura. The generalized allegories of the "School of Athens" or the "Disputi" give way to representations of specific events, all miraculous, which, since they represent the direct interventions of God on behalf of His chosen people, had a political intention in the 16th century. The four principal subjects are: "The Expulsion of Heliodorus From the Temple," "The Miracle at Bolsena." "The Liberation of St. Peter" and "Attila the Hun Turned Back From Rome." Raphael's original patron, Julius II, died in 1513 and was succeeded by Leo X (elected March 11, 1513); as both the "Expulsion" and the "Miracle at Bolsena" (which is dated 1512) contain superb portraits of Julius II while the Leo I who is shown meeting Attila has the features of Leo X, these frescoes can be closely dated. The Stanza takes its name from the fresco of "Heliodorus Expelled From the Temple of Jerusalem" and "compassed in darkness" (II Macc. 3), which had a contemporary allusion to the efforts of Julius against the French and in support of the temporal power. The fresco of the "Mass at Bolsena" records a miracle that took place in 1263, when a priest who doubted the reality of transubstantiation found the Host bleeding in his hands; the Feast of Corpus Domini was instituted as a result (1264), and Julius' own devotion to the Sacrament is probably the principal reason for the choice of this subject. The composition is one of Raphael's most accomplished, since the shape to be filled is exceedingly awkward and asymmetrical, and the celebrated group of the Swiss guards at the lower right is introduced to fill the space where it was necessary to paint a continuation of the real architecture.

In all these miraculous themes the colours are much deeper and more Venetian in feeling than the colour schemes in the earlier room, the "Liberation of St. Peter" providing a particularly notable example of the new interest in colour and light since it is a night scene and contains three separate lighting effects—moonlight, the torch carried by the soldier and the supernatural light emanating from the angel. It is usually thought that the presence in Rome

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"SISTINE MADONNA" BY RAPHAEL. IN THE DRESDEN GALLERY, DRESDEN, GERMANY

at this time of Sebastiano del Piombo may have been responsible for this marked Venetian influence on Raphael, but it is also certain that Michelangelo's Sistine ceiling was unveiled while the room was in progress; yet a renewed influence of Michelangelo is not noticeable until somewhat later, most clearly in the frescoes of "Isaiah" (c. 1512, S. Agostino, Rome) and the "Sibyls" in Sta. Maria della Pace, of about 1514.

The most important other work undertaken by Raphael at this period was probably the "Sistine Madonna" (Dresden gallery), which has always been one of his most famous paintings, although its early history is unknown. The most likely explanation for its existence is that it was painted to be carried in the funeral procession of Julius II in 1513 and that it subsequently came into the possession of the monks at Piacenza who owned it before its transfer to Dresden. By 1513 Raphael was one of the most celebrated of living artists and already employed a large studio of assistants and pupils, so that it is extremely unlikely that an obscure community of monks could have commissioned a large altarpiece from him (or have got delivery if they had commissioned it).

Immediately after completing the Stanza d'Eliodoro, Raphael began work on the third Stanza, which is first in order of visiting. The Stanza dell' Incendio was begun in 1514 and completed by 1517, but the proportion of it executed by assistants is much higher than was the case in the first two rooms. Nevertheless, it must be stressed that Raphael was responsible for the decoration as a whole. The reason for this delegation of the execution is twofold: St. Peter's and the Tapestry cartoons. In August, 1514, Raphael succeeded Bramante as chief architect of the new St. Peter's, and, although he built very little of it, the administrative responsibility for the greatest work in Christendom must have been considerable. The first payment for the cartoons was made on June 15, 1515, so it is probable that this new commission had been occupying much of Raphael's attention, rather than the frescoes in the Stanza dell' Incendio. The last and largest of the Stanze, the Sala di Costantino, was commissioned in 1517 but was finished only in 1524, four years after Raphael's death.

The Tapestry Cartoons.—Leo X commissioned a set of tapestries to hang below the 15th-century fresco cycle on the walls of the Sistine chapel. Almost certainly there were 10 (10 tapestries are preserved in the Vatican museum), but a contemporary, probably by a slip of the pen, mentions 16. Seven of the original cartoons still exist in the British royal collection (on permanent loan to the Victoria and Albert museum, London) and other sets of the tapestries, woven at various times from the cartoons, exist elsewhere. The seven cartoons represent "Christ's Charge to Peter," "The Miraculous Draught of Fishes," "The Death of Ananias," "The Healing of the Lame Man," "The Blinding of Elymas," "The Sacrifice at Lystra" and "St. Paul Preaching at Athens"; the other three tapestries, for which no cartoons exist, are "The Conversion of St. Paul," "St. Paul in Prison" and "The Stoning of St. Stephen." The last payment was made in Dec. 1516, when the cartoons must have been sent to Brussels, where the tapestries were woven. Seven were finished by Christmas 1519 and were exhibited in the Sistine chapel, when an eyewitness wrote that "by universal consent there is nothing more beautiful in the world." They were woven by the low-warp (*basse-lisse*) method which involves reversal of the designs, so that the designer has to remember to depict right-handed actions as taking place with the left—a point which was not invariably borne in mind in the cartoons (see A. P. Oppé, "Right and Left in Raphael's Cartoons." in Journal of the *Warburg* and Courtauld Institutes, vol. vii, pp. 82 ff., 1944). It is now generally agreed that Raphael actually drew much more in the cartoons himself than was previously allowed to be the case. but the use which has been made of them and the fragile nature of the medium (size colour on paper) have combined to damage them severely in many parts. Nevertheless, the amount of damage and repainting is relatively unimportant for it cannot be too strongly emphasized that they could have been executed entirely by assistants and then completely repainted without losing their importance and value, for they are supreme examples of the art of composition. It is hardly an exaggeration to say that the normal western conception of the apostles as grave. bearded men in togas derives very largely from the visual images created by Raphael in these works. There has been a great deal of discussion about the way the tapestries were originally arranged. (For a later hypothesis *see* J. White and J. Shearman in *The Art Bulletin*, xl, pp. 194–222, 299–323, 1958).

By April 19, 1516, Raphael had completed the portrait of Count Castiglione, his fellow townsman and the leading authority of the day on polite behaviour. It is indicative that Raphael should have been on terms of intimate friendship with him and also with A. Navagero and other poets and at least two princes of the church, Cardinals Bembo and Bibbiena. For the latter he decorated a bathroom in his suite in the Vatican. It is in a private part of the palace and is now much damaged, but it is of interest since the decorative motifs are based on those in the newly discovered Golden House of Nero, from which the type of decoration known as "grotesque" is derived. Similar motifs were used by members of Raphael's studio, notably by Giovanni da Udine, in the stucco decorations at the Villa Madama and elsewhere. Raphael now occupied a position held by no other artist of modern times (not even Michelangelo is quite comparable), on terms of friendship with the pope and the whole Curia and with almost every prince in Christendom intriguing to obtain a work by his hand; almost over night. the whole social position of the artist was thus revolutionized by the three great artists of the Renaissance, Leonardo, Michelangelo and Raphael. During all this time he was busy on innumerable enterprises, most of which were actually executed by his army of pupils and assistants: the remainder of the Stanza dell' Incendio, the numerous small biblical scenes in the Loggie of the Vatican (works which deserve more study than they tend to get), the sculpture and mosaics of the Chigi chapel and the work on the new St. Peter's as well as other architectural works—he designed S. Eligio degli Orefici and the Vidoni-Caffarelli and Branconio dell' Aquila palaces in Rome as well as the Palazzo Pandolfini in Florence—and the duties involved in his conservatorship of the antiquities of Rome. By employing Marcantonio Raimondi, Raphael ensured the spread of his designs all over the civilized world! for this excellent engraver produced numerous plates from designs made specially by Raphael for the purpose of spreading his ideas.

The Last Works.— A letter from Leonardo Sellaio to Michelangelo at Carrara on Jan. 19, 1517, gives the first indication of what was to become Raphael's last masterpiece, the "Transfiguration," now in the Vatican. Cardinal de' Medici (later Pope Clement VII) commissioned two enormous altarpieces for his cathedral at Narbonne in France; one was Sebastiano del Piombo's "Raising of Lazarus" (now in the National gallery, London) and the other was Raphael's "Transfiguration," unfinished at his death and never sent to Narbonne. In fact, the "Transfiguration" was not begun until 1518 and must therefore be considered along with the "Holy Family of Francis I" and "St. Michael Vanquishing Satan" (both dated 1518 and in the Louvre, Paris), both of which were destined for presentation'to Francis I of France by Leo X. All three pictures were major commissions and any new or unusual features in them are therefore extremely unlikely to be due to pupils or assistants working unsupervised; at the very least, Raphael must have approved any innovations. It is necessary, indeed, to stress this point and also to refer to the series of superb drawings for individual figures in the "Transfiguration," for there is a tendency to write off the last works, and especially the "Transfiguration," as by Giulio Romano, Gianfrancesco Penni and other pupils. Vasari noted, of the "Holy Family of Francis I," that the execution was almost entirely by Giulio Romano, and the "Transfiguration" was certainly completed after Raphael's death; yet Vasari stresses that much of it was in fact painted "with his own hand." There is every reason to suppose that the design is his, and it is in the design that the innovations are chiefly visible. The tendency in all these late works is toward a crowding together of the figures which had hitherto been lucidly arranged in accordance with the classical canons Raphael himself had done so much to impose. At the same time there is a feeling of violence and tension which is not entirely due to the demands of the subject. Indeed, one might argue that the subject was adapted to satisfy a desire to depict a scene of violence, since the boy possessed of a devil is the next stage in the Biblical narrative (Matt. 17). In short, it may be held that Raphael was the first Mannerist.

On Good Friday, April 6, 1520, after an illness lasting a week, Raphael died. He was buried in the Pantheon and his grave is marked by a slab with a commemorative epitaph by Cardinal Bembo. At the head of the bier the unfinished "Transfiguration" stood as his memorial, perhaps the first of what would have been a series of new works in the middle period which Raphael never lived to achieve. He died at 37, when most great artists are approaching their first maturity. *See* also PAINTING: *Raphael.*

BIBLIOGRAPHY.—G. Vasari, *Life*, vol. iv of Gaston de Vere's Eng. trans. (1913). V. Golzio, *Raffaello* (1936) is the most important source book. A. P. Oppe, *Raphael* (1909); G. Gronau, *Raffael* (1930); O. Fischel, "Santi, Raffaello" (with a complete bibliography) in Thieme-Becker, *Allgemeines Lexikon der bildenden Künstler*, vol. xxix (1935), *Raphaels Zeichnungen* (1913–41), *Raphael* (1948); J. W. Pope-Hennessy, *The Raphael Cartoons* (1950); E. Camesasca, *Tutta la pittura di Raffaello*, 2 vol. (1956), and (ed.), *Raffaello Sanzio, tutti gli scritti* (1956). For good sets of plates *see* especially W. Suida, *Raphael* (1941); O. Fischel, *Raphael*, cited above. (P. J. MY.)

RAPID CITY, a city of South Dakota, U.S., and the county seat of Pennington county, is the western gateway to the Black hills (*q.v.*). Located 3,200 ft. above sea level on Rapid creek, from which it derived its name, it was settled in 1876 during the days of the Black hills gold rush, and was incorporated in 1878.

Millions of tourists have been attracted by the beauty of the Black hills, with nearby Mt. Rushmore, Crazy Horse mountain and Custer National park being of particular interest. Although it is located in what is basically an agricultural and grazing area, Rapid City's industries range from lumber. millwork and building materials to Black hills gold jewelry. In addition, gold, silver, beryllium, feldspar, gypsum, mica. uranium and other minerals are mined and processed in the area. Rapid City is the site of the state-owned cement plant. the Sioux Indian sanatorium, the South Dakota School of Mines (established 1885) and Ellsworth air force base. For comparative population figures *see* table in SOUTH DAKOTA: *Population.* (C. J. P.)

RAPIER: *see* FENCING; SWORD.

RARE EARTHS, in chemistry the name originally given to a group of metallic oxides since they resemble the substances then known as earths (lime, magnesia, etc.). The corresponding elements comprising this group are unique in that they are so similar in chemical properties that they can be separated from one another only by taking advantage of the slight differences in their properties. Since there was no place for these elements in the older periodic tables they were grouped in the space allotted to lanthanum.

With a modern understanding of atomic structure it is now recognized that the rare earths include the elements with atomic numbers 58 to 71 and are now placed in a special group in the periodic table. The work of H. G.-J. Moseley (1913) definitely established the maximum number of rare earths and set up procedures by which their purity and existence could be determined. The theories of Niels Bohr and subsequent workers have shown that the electron structure of the trivalent rare-earth ions is: $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$, $4s^2$, $4p^6$, $4d^{10}$, $4f^x$, $5s^2$, $5p^6$. The neutral atoms contain three extra electrons which distribute themselves between the $6s$, $5d$ and $4f$ subshells. These three electrons, however, are removed to the negative ions in the rare-earth trivalent compounds and do not take a direct part in the electronic configuration of the rare-earth ions. The completed subshells produce diamagnetism in the rare earths. The true rare-earth group arises from the filling in of the $4f$ subshell and since this subshell can contain from 1 to 14 electrons there are only 14 true rare earths. These electrons give rise to the paramagnetic properties of the ions.

Since the rare-earth elements have the same configuration of outer electrons and since it is these electrons which mainly determine chemical properties, the elements are very similar chemically and physically. The relatively small progressive changes in the properties of these elements with the addition of $4f$ electrons make them particularly useful for testing various theories of matter such as the relation of the solid state to atomic structure. In fact, their properties are so similar that suggested procedures for the separation of isotopes are often first tested with the rare earths. Lanthanum (57), yttrium (39) and scandium (21) have similar external atomic structures and always occur in mixtures of the rare earths. Hence, lanthanum and yttrium, and sometimes scandium, are also included in discussions-of the rare earths and with the possible exception of scandium are never found free from the rare earths.

The principal source of the rare earths is the mineral monazite found as an alluvial sand in India, Brazil and Idaho. This material is es-

TABLE I.—*Properties* of the Rare-Earth Ions and Salts

Atomic number	Name	Symbol	Atomic weight	4f electrons	Effective Bohr magneton numbers	Colours of trivalent ions
57	Lanthanum	La	138.92	0	0.00	Colourless
58	Cerium	Ce	140.13	1	2.56	Colourless
59	Praseodymium	Pr	140.92	2	3.62	Yellow-green
60	Neodymium	Nd	144.27	3	3.68	Red-violet
62	Samarium	Sm	150.43	5	1.55–1.65	Pale yellow
63	Europium	Eu	152.0	6	3.40–3.51	Paie pink
64	Gadolinium	Gd	157.26	7	7.94	Colourless
65	Terbium	Tb	158.93	8	9.7	Very pale pink
66	Dysprosium . .	Dy	162.46	9	10.6	Pale yellow-green
67	Holmium	Ho	164.94	10	10.6	Brownish-yellow
68	Erbium	Er	167.2	11	9.6	Rose
69	Thulium	Tm	169.4	12	7.6	Pale green
70	Ytterbium.	Yb	173.04	13	4.5	Colourless
71	Lutetium	Lu	174.99	14	0.00	Colourless
21	Scandium	Sc	45.10	0	..	Colourless
39	Yttrium	Y	88.92	0	..	Colourless

Adapted from various sources, especially D. M. Yost, H. Russell and C. S. Garner, 1944.

sentially a complex phosphate. Other important mineral sources are gadolinite (a silicate found in Norway, Sweden, Colorado and Texas), fergusonite (a columbate and tantalate found in Norway, Texas and Australia), samarskite (a tantalate and uranate found in the Urals and North Carolina), xenotime (a phosphate found in Brazil and Norway), yttrocerite (a fluoride found in Scandinavia), cerite (a basic silicate found in Sweden) and allanite (a silicate found in Greenland and Scandinavia). The relative abundance of these elements in the earth's crust is summarized in Table III. It will be noted that the elements with even atomic numbers are much more abundant than those with odd atomic numbers. Contrary to the earlier ideas, these elements are not so rare as the name implies; for example, cerium is more common than cadmium, tin, mercury, antimony, molybdenum, silver, tungsten, bismuth, gold or platinum. The rare earths, however, are widely distributed in low concentration and are so difficult to separate from one another that, with the exception of cerium, lanthanum and neodymium, they were not available for commercial distribution until after 1946.

Methods for separating the mixed rare earths from their ores vary with the type of ore. Prior to 1945, with the exceptions of certain rare earths such as cerium, europium, samarium and ytterbium which can have valencies different from three, the individual rare earths were separated from one another by laborious processes such as fractional crystallization, fractional decomposition, etc. Since these procedures had to be repeated thousands of times, only a few chemists had the patience to devote the required time to this routine work. Hence, only limited amounts of the scarcer rare earths were prepared in the pure state. In order to carry out these processes it was convenient to place the elements in subgroups such as the ceria group (j7 to 64) and the yttria group (64 to 71); another classification introduces the terbia group (63 to 65). Such groups are arbitrary since there are no clear-cut separations between successive members of the series; they are based on the solubility relationships of various compounds of the elements. The solubilities of some of the rare-earth trivalent compounds are summarized in Table II.

Some of the rare earths are always found among the fission products of plutonium, thorium and uranium, and a number of new radioactive isotopes of the rare earths have been obtained from this source. In addition, it is now possible to make artificial radioactive isotopes of any of the rare earths and a large number have been identified. For details concerning these isotopes see the article on RADIOACTIVITY, ARTIFICIAL. In 1945 a rapid method for separating the rare earths was developed in connection with the atomic bomb research program. The procedure involves the use of adsorption columns of organic resins and subsequent elution with complexing agents such as citric acid. The separations are based on the slight differences in the equilibrium constants. It is expected that, by use of such procedures, the pure rare-earth metals eventually will become more available and less expensive for detailed scientific studies and possible industrial uses.

TABLE 11.—Solubilities of Several Rare-Earth *Trivalent Compounds*

Compound	Cerium group (57–62)	Yttrium group (63–71)
Carbonates	Insoluble in water and in $(NH_4)_2CO_3$ solution	Insoluble in water; soluble in $(NH_4)_2CO_3$ solution
Hydroxides . . .	Somewhat soluble in water	Slightly soluble in water
Fluorides. . . .	Insoluble in water	Insoluble in water
Formates. . . .	Slightly soluble in water	Moderately soluble in water
Nitrates	Soluble in water; less soluble in HNO_3	Soluble in water; less soluble in HNO_3
Basic nitrates. . .	Moderately soluble in water	Slightly soluble in water
Double nitrates (*e.g.*, $Mg_3R_2(NO_3)_{12}.24H_2O$)	Easily crystallized	Not easily crystallized
Oxalates. . . .	Very insoluble in water and in $(NH_4)_2C_2O_4$ solution	Very insoluble in water, soluble in $(NH_4)_2C_2O_4$ solution
Phosphates	Insoluble in water	Insoluble in water
Potassium sulphates ($K_3R(SO_4)_3$) . .	insoluble in K_2SO_4 solution	Soluble in K_2SO_4 solution

From D. M. Yost, H. Russell and C. S. Garner, 1944.

The common valence of the rare-earth elements is three and many of them possess no other valence in their compounds. Since their chemical properties differ so slightly from member to member, the customary methods of qualitative analysis for these elements are of no real value. All accurate analyses for their purity are therefore based on their physical properties. The five general criteria available are: average atomic weight, magnetic susceptibilities, absorption spectra, X-ray spectra and arc spectra. Several of these properties are listed in Table I.

In Table III are listed some of the physical properties of the rare-earth elements as known at mid-20th century. Since the pure rare earths have been so difficult to obtain, many of the properties and

TABLE 111.—Physical Properties and Abundance of the Rare-Earth Elements

Atomic number	Symbol	Density	Melting point, °C.	Electrode potentials E^0(ox) (volts)	Atomic radius co-ordination no. 12 (Å)	% in earth's crust x 10^5
57	La	(α)6.194 (β)6.180	820–850	+2.37	(α)1.870 (β)1.872	7
58	Ce	(α)6.78 (β)6.810	770–800	2.0	(α)1.81 (β)1.817	31
59	Pr	(α)6.776 (β)6.805	940–960	2.0	(α)1.824 (β)1.821	5
60	Nd	(α)7.004	800–900	2.0	(α)1.818	18
62	Sm	6.93	1,350	2.0	..	7
63	Eu	5.244	1,100–1,200	1.9	2.042	0.2
64	Gd	7 948	..	1.9	1.794	7
65	Tb	8.332	..	1.9	1.773	1
66	Dy	8.562	..	1.9	1.769	7
67	Ho	8.764	..	1.9	1.759	1.2
68	Er	9.164	1,250 (?)	1.8	1.748	6
69	Tm	9.346	..	1.8	1.742	1
70	Yb	7.010	1,800 (*c.*)	1.8	1.933	7
71	Lu	9.740		1.7	1.737	1.5
39	Y	4.34			1.814	..

Adapted from D. M. Yost, H. Russell and C. S. Garner, 1944.

physical constants of the elements are probably inaccurate and may be altered considerably as better data become available through the use of new methods for their separation and purification. The metallic elements can be produced by electrolysis of the molten salts (such as the chloride or fluoride) or by chemical reduction of the oxides or halides by means of the alkali or alkaline-earth metals. All of them except promethium, formerly called illinium, have been produced in small amounts by the above methods, but in many cases the salt was not pure and most of them undoubtedly contained various amounts of the neighbouring rare-earth metals in solid solution.

As was so well stated by J. W. Mellor: "A large proportion of unconfirmed discoveries belongs to the rare earth series, and this may be taken as a tribute to the difficulties attending their isolation." A brief chronological summary of the isolation of the various rare earths follows. In 1794 J. Gadolin separated a new rare earth, yttria, from a black mineral found in Ytterby, Swed. In 1803 J. J. Berzelius, M. H. Klaproth and W. Hisinger independently found ceria in a mineral from the Bastnäs mine in Sweden. C. G. Mosander, in 1839, showed that ceria also contained a new oxide, lanthana; in 1842 he found didymia in the lanthana fraction. In 1843 he found that yttria contained terbia (called erbia since 1860) and erbia (called terbia since 1877). Erbia was subsequently found to contain ytterbia (J. C. G. de Marignac, 1878), holmia (J. L. Soret, 1878) and thulia (P. T. Cleve, 1879). In 1879 L. de Boisbaudran claimed the discovery of a new element in didymia which he called samarium, and in 1880 De Marignac found another element in samarium which he later called gadolinium. In 1885 C. A. von Welsbach split didymia into praseodymium and neodymium and in 1886 J. de Boisbaudran obtained dysprosia from holmia. In 1901 E. Demarçay separated europia from samaria and in 1907 G. Urbain found lutetia in ytterbia. In 1926 B. S. Hopkins announced the discovery of element 61 which he named illinium In the same year J. C. Corke, C. James and H. C. Fogg obtained 61 independently and measured the lines of its X-ray spectrum. This discovery was challenged. (See PROMETHIUM.)

BIBLIOGRAPHY.—For details of extraction, separation and properties of the individual members of the group. J. N. Friend (ed), Text-book of Inorganic Chemistry, vol iv (1914, etc.); B S. Hopkins, Chapters in the Chemistry of the Less Familiar Elements, vol. i (1940); S. I.

Levy, *The Rare Earths* (1924); J. W. Mellor, *A Comprehensive Treatise on Inorganic and Theoretical Chemistry,* vol. v (1924); D. M. Yost, Horace Russell, Jr., and Clifford S. Garner, *The Rare-Earth Elements and Their Compounds* (1947). (F. H. Sp.)

RASH, a breaking out of the skin. The term rash was originally descriptive of certain skin diseases in which dandrufflike scales and some degree of redness were prominent features. The term is now commonly used with much less specificity, referring to various skin abnormalities in which the affected skin may be red, swollen, have scales or small blisters. Hence, breaking out of the skin such as that occurring in measles, dandruff conditions of the scalp, hives and diseases characterized by small blisters (*e.g.,* "prickly heat rash" or "poison ivy rash") are examples of diverse skin eruptions that are known as rashes. Generally excluded from the category of rashes are fleshy growths (*e.g.,* warts, moles or tumours) and acute mechanical, thermal or corrosive chemical injuries.

The generally broad meaning of "rash" that has developed through its popular use excludes it from use in strict medical terminology. See also Skin Diseases. (E. J. V. S.)

RASHI (1040–1105), Jewish scholar, called "the Commentator," was born at Troyes. Fr., in 1040 and died there in 1105. His real name was Rabbi Solomon (Shelomoh) ben Isaac, his nickname being derived from the initial letters of those words. Little is known about his life, though many legends have gathered around it. He is known to have worked at Worms, as a young man, under Jacob ben Yaqar, and at Mainz under Isaac ben Judah, perhaps combining at the same time the functions of teacher and student. He returned at the age of 25 to Troyes, which under his guidance became a recognized centre of Jewish learning. There he acted as rabbi and judge, and he and his family worked in the vineyards. His learning and character raised him to a position of high respect among the Jewries of Europe, though Spain and the east were long outside the range of his influence. As was said of him soon after his death: "His lips were the seat of wisdom, and thanks to him the Law, which he examined and interpreted, has come to life again." The latter part of his life was saddened by the massacres in the Rhineland at the time of the first crusade.

Besides minor works, including a recension of the prayer book, Rashi wrote two great commentaries on the whole of the Hebrew Bible and on about 30 treatises of the Talmud. His commentary on the Pentateuch, in particular, has been printed in hundreds of editions and is still to Jews the most beloved of all commentaries on the Mosaic books. More than a hundred supercommentaries have been written on it. Rashi's influence in Christian circles was great, especially because of the use made of the commentary by Nicholas of Lyra (*q.v.*), who in his turn was one of the main sources of Luther's version. More important was his commentary on the Talmud, which is nearly the definitive interpretation.

Bibliography.—M. Liber, *Rashi* (1906); American Academy for Jewish Research, *Rashi Anniversary Volume* (1941); M. Waxman, *A History of Jewish Literature,* vol. i (1930).

RASHID AL-DIN FADLULLAH (1247–1318), Persian statesman and historian, author of a universal history, *Jami al-tawarikh,* belonged to a Jewish family of Hamadan but was converted to Islam, and as a physician joined the court of the Mongol ruler of Persia, Abaqa-khan (1265–1282). He became vizier to Ghazan-khan in 1298 and served under his successor Uljaytu. Accused by his rivals of having poisoned his sovereign, he was put to death by Uljaytu's son Abu Sa'id.

Rashid al-Din's history covers a vast field even outside the Moslem world. His sources of information for Mongolia and China were high officials of the Mongol empire and the Mongol records, for India a Buddhist from Kashmir, for the popes and emperors a Catholic monk, etc. There are important chapters describing the social and economic conditions of the Islamic countries under Ghazan-khan (1295–1304) and the reforms introduced by this ruler on the advice of the author himself. Rashid al-Din uses a great number of Mongol and Turkish terms but his style is lucid and matter-of-fact.

The important parts of Rashid al-Din's history were published by E. Quatremère (1936), I. M. Berezin (1858–1888), E. Blochet (1911), K. Jahn (1940), Ali-zade (1958), A. Atesh (1957). The parts on the Mongolian tribes, on Jenghiz-khan and on Ghazan-khan appeared in a new Russian translation (1946–52). Rashid's interesting correspondence with his sons and dependents was published by M. Shafi (1947). (V. F. M.)

RASHTRAKUTA, an Indian dynasty which ruled in the Deccan (*q.v.*) from about A.D. 754 to 973. The Rashtrakuta or Ratta clan are supposed to have held power during the historical blank before the 6th century, but they came to the front in A.D. 754 when Dantidurga overthrew the Chalukya dynasty and made himself ruler of the Deccan. He was succeeded by his uncle Krishna I (c. 768), who completed his conquests and whose reign is memorable for the Kailasa, the rock-cut temple at Ellora. His grandson Govinda III (793–814) extended the power of the family from the Vindhya mountains and Malwa on the north to Kanchi on the south. The reign of Krishna III (939–968) was remarkable for a war with the Cholas, in which the Chola king was killed on the field of battle in 949. The last of the Rashtrakuta kings was Karka II, overthronn by the Chalukyas in 973.

RASIN, ALOIS (1867–1923), Czechoslovak statesman, was born at Nechanice. While a university student he took an active part in politics, and his abilities as an orator, journalist and organizer brought him into the forefront of the Czech progressive movement. After serving a prison sentence for anti-Austrian activities, he gained a prominent position in the Czech Liberal ("Young Czech") party. During the anti-Czech persecution in the World War I period, Rasin was arrested, charged with treason and condemned to death. The sentence, however, was not carried out, and after the accession of the emperor Charles I, Rasin, with other political prisoners, was amnestied. He then took part. as a member of the National committee, in the preparations for the revolutionary coup of 1918. In the first Czechoslovak government he became finance minister. In Jan. 1923 he was attacked by a demented youth and died of his injuries on Feb. 16. 1923.

RASK, RASMUS CHRISTIAN (1787–1832), Danish philologist. a founder of the science of comparative linguistics, mas born at Brandekilde, Fiinen, on Nov. 22, 1787. He studied at Copenhagen, and was appointed assistant keeper of the university library in 1808 and later professor of literary history. Rask was one of the first to recognize that the Celtic languages are Indo-European; he anticipated Grimm in the formulation of the first Germanic consonant shift; and De Saussure in his realization of the function and character of minimal speech-sounds (the phoneme). He wrote grammars of Icelandic, Old Norse, Old English, Spanish, Frisian and Itaiian; treatises on Jewish, and on Egyptian chronology; edited parts of the *Edda;* and published innumerable papers on linguistic and literary topics. He also brought out the Icelandic Lexicon (1814) of Bjorn Haldorson.

Rask was the first president of the Icelandic Literary society; but in 1816 he left Denmark to prosecute inquiries into the languages of the east and collect manuscripts for the university library at Copenhagen. From Stockholm he went to St. Petersburg, thence through Tatary into Persia, and resided for some time at Tabriz, Tehran, Persepolis and Shiraz. From Persia he went to India and Ceylon. Rask returned to Copenhagen in May 1823, bringing a considerable number of oriental manuscripts, Persian, Zend, Pali, Sinhalese and others, with which he enriched the collections of the Danish capital. He died at Copenhagen on Nov. 14, 1832.

Bibliography.—See his collected essays, *Samlade Afhandlinger, 3* vol. (1834–38); selected essays, *Udvalgte Ajhandlinger,* ed. *by L.* Hjelmslev (1932); Otto Jespersen, *Rasmus Rask* i *hundreddret efter hans Hovedværk* (1918). (J. Wh.)

RASMUSSEN, KNUD JOHAN VICTOR (1879–1933), Danish polar explorer and ethnologist who possessed an unsurpassed ability to win the confidence and understand the character of the Eskimo, was born at Jakobshavn, Greenland, on June 7, 1879. His maternal grandmother was a Greenlander (*i.e.,* of mixed race), and he acquired a thorough mastery of the Eskimo language. After studies at Copenhagen university and a visit to Lapland (1901), he accompanied L. Mylius-Erichsen to northwest Greenland in 1902–04, where he wintered with the most northerly

Eskimo tribe in the world (the Polar Eskimo). He was in west Greenland in 1905 to study the possibilities of introducing reindeer husbandry, but spent the next two years with the Polar Eskimo, and in 1910 established, with the aid of privately contributed means, the permanent station at Thule. The object was to provide a trading centre for the population, a base for expeditions and a foundation for the raising of the Polar Eskimo's spiritual, cultural and material level. In 1912 Rasmussen led the first Thule expedition. With three companions he traveled with dog sledges across the Greenland ice sheet from Thule to the northeast coast and back, making valuable geographical discoveries. The second Thule expedition (1916-18) surveyed the north coast of Greenland under very hard conditions. Rasmussen did not personally accompany the third Thule expedition; the fourth (1919) was his journey to Angmagssalik in east Greenland to collect Eskimo tales. The fifth Thule expedition (1921-24) was Rasmussen's greatest. After investigations in northeast Canada, Rasmussen, with two Eskimos, accomplished the longest dog-sledge journey ever made, across the American arctic. He left Danish Island on March 11, 1923, and reached Point Barrow on May 23, 1924. He made a scientific study of every Eskimo tribe, tracing their migration routes and showing the basic unity of their cultures. The sixth and seventh Thule expeditions made cartographic, archaeological and ethnographical studies in southeast Greenland. He died on Dec. 21, 1933, in Gentofte, Denmark.

A brilliant expedition leader, Rasmussen inspired an extraordinary devotion in his companions. Probably no polar explorer has so much used the services of the Eskimo, while he was himself a superb dog-sledge driver. His rich literary production embraces travel descriptions and translations of Eskimo mythology and songs, as well as strictly scientific works, including *Grønland Langs Polhavet* (1919; Eng. trans. *Greenland by the Polar Sea*, 1921) and *Across Arctic America* (1927). (P. A. B. G.)

RASPBERRY (genus *Rubus*), an old and well-known fruit-bearing bush, mentioned by Pliny as a wild fruit. John Parkinson (*Paradisus*, 1629) speaks of red, white and thornless varieties of raspberries, and their culture began about this time. Raspberry bushes bear juicy red or black (rarely orange, amber or pale yellow) berries which separate from the core that remains on the plant; in blackberries, the core is a part of the fruit.

ROCHE

BLACK RASPBERRIES (RUBUS OCCIDENTALIS)

Distribution. — The raspberry section of *Rubus* probably evolved in eastern Asia, where there are more than 200 species known.

In Great Britain and throughout Europe only one species, *R. idaeus*, is known, from which the European cultivated varieties are derived. In the United States and Canada, three species (*R. strigosus*, the red raspberry; *R. occidentalis*, the eastern black raspberry; and *R. leucodermis*, the western black raspberry) are found. American red varieties are derived from *R. strigosus* and hybrids of it with *R. idaeus*. They are much hardier and less prickly than European varieties. Black varieties came from *R. occidentalis;* purple varieties are hybrids of the black and red. Related edible berries, often called raspberries, are the two flowering raspberries of northern American woodlands, *Rubus odoratus* and *R. parviflorus;* the Rocky mountain flowering raspberry, R. *deliciosus;* and the salmonberry, *R. spectabilis*, of the Pacific northwest. Three other raspberries are grown for their fruit in other parts of the world—the Andes black raspberry, *R. glaucus*, in northern South America and Central America; the southern Asian black raspberry, *R. niveus;* and the wineberry, R. *phoenicolasius*, introduced from northeastern Asia. R. *kuntzeanus* from China has been hybridized with the Cuthbert to give the Van Fleet, and *R. biflorus*, also from China, has been hybridized with Latham to give the Dixie, both adapted to southern U.S.

Acreage and Varieties. — In Great Britain about 10,000 ac. of red raspberries are cultivated. The Blairgowrie district is the centre of production in Scotland; Kent. the eastern counties and Worcestershire are important centres in England. Raspberries are sometimes grown in mixed plantings with other fruit, the plants being set at 18-in. intervals in rows 6 or 7 ft. apart. Lloyd George is a leading variety, having very large berries that are excellent for canning and jam. Red Cross, Pynes Royal and Malling Promise are other good varieties.

The acreage of raspberries in the United States is about 20,000. Black raspberries are nearly as important as red; the acreage of purple varieties is small. Important raspberry sections are western Maryland, southern New Jersey, the Hudson river valley, western New York, western Michigan, near Minneapolis, Minn., the Puyallup valley of Washington, and the Willamette valley of Oregon. Few plantings in the United States, except in the Hudson river valley, are mixed with other fruits. Good red varieties are Willamette, Canby and Washington, in the Pacific northwest; Sunrise, for early, and Latham, for late, for eastern states; and Taylor and Milton, in New York and New England. Cumberland is the chief black variety. In eastern Canada, Viking and Newman red varieties are widely grown. Sodus and Marion are desirable purple varieties. September and Durham are red sorts that also bear fruit on the young canes in late summer and fall.

Propagation. — Red raspberries are propagated by suckers from the roots of the parent plant. Root cuttings about three inches long are also used for rapid increase of new varieties. Black and purple varieties have arched canes and are propagated by tip layers, the tips of the shoots being buried about two inches deep in August and the rooted tips being dug in early spring. Leaf-bud cuttings may be used for the rapid propagation of new black varieties. Red raspberries are usually planted 2½ ft. apart, the black and purple about 4 ft. apart in rows 6 to 9 ft. distant. Shoots are produced in spring and summer that bear fruit the following year and then die. These old canes are cut away each year just after the harvest to make room for the new shoots. The new shoots of the black varieties are tipped or cut off at 12 in. to induce branching; those of the purple at 18 to 24 in. The branches are shortened the following winter to about 8 in. for the black and 12 in. for the purple. The canes of the red raspberries are either not pruned or are shortened to 3 to 5½ ft., depending on the variety and vigour. However, surplus suckers should be cut away early in the summer, leaving seven or eight of the strongest canes per plant or per 30 in. of row. The stouter the canes of both black and red varieties, the more productive they are. Stakes or trellises are commonly used to support the canes of the red raspberry. Two-wire trellises with a wire on each side of the row about 3 ft. high or with one wire above the other at 30 in. and 54 in. are common.

Virus diseases, leaf spot, anthracnose, crown gall, wilt and orange rust are serious diseases, while the red spider mite, crown borer and fruit worms are serious insect pests.

See also FRUIT FARMING.

See U.S. Department of Agriculture *Farmers' Bulletin* 887 *(1948)*. (G. M. D.)

RASPE, RUDOLF ERICH (1737–1794), the original author of the *Adventures of Baron Munchausen* (see MUNCHAUSEN), was born in Hanover in 1737, and studied at Göttingen and Leipzig. In 1767 he was appointed professor in Cassel, and subsequently librarian. In 1775 he went to Italy to buy curios for the landgrave of Hesse, to whom he was keeper of the gems, and sold the landgrave's valuables for his own profit. On orders being issued for his arrest, he decamped to England. Later, he found a patron in Sir John Sinclair of Ulbster, whom he deceived by pretending to discover valuable and workable veins on his estates; but Raspe had "salted" the ground himself, and on the verge of exposure he absconded. He betook himself to Ireland, and died at Muckross in 1794. His authorship of *Munchausen* was only revealed in 1824, by the biographer of its translator Bürger.

RASPUTIN, GREGORY EFIMOVITCH (1871–1916), Russian monk, was born in 1871 in the village of Pokrovskoe, near Tyumen, in the province of Tobolsk, Siberia. In 1904 Rasputin left his family and devoted himself to religious exercises, declaring to his people that he was inspired by God. His passionate nature, his great physical strength and the superstitious atmosphere in which he had been brought up, gave an unexpected direction to his religious exaltation. He adopted the views of the sect known under the name of "Khlysty," the leading idea of whose teaching was that salvation could be achieved only by repentance.

"Sin in order that you may obtain forgiveness"—was the practical rule which he drew from this doctrine. "A particle of the Supreme Being is incarnated in me"—he told his hearers. "Only through me you can hope to be saved; and the manner of your salvation is this: you must be united with me in soul and body. The virtue that goes out from me is the source of light, the destruction of sin" (E. J. Dillon, *The Eclipse of Russia).* This extravagant and dangerous teaching, which resulted in practice in the wildest orgies, not only created for Rasputin immense popularity and the reputation of a holy man among his fellow-peasants. but opened before him the doors of some of the most fashionable Russian houses and even those of the Imperial palace. Looking for new experiences Rasputin left his native village, and made long pilgrimages to various holy places, and even went to Mount Athos and Jerusalem. He spent some time in different monasteries and applied himself to the study of holy books.

In 1907, during a stay in St. Petersburg (Leningrad), Rasputin was introduced to the archimandrite Feofan, rector of the theological academy and confessor to the empress, who took an interest in the story of his conversion. The archimandrite, with the assistance of the grand duchesses Militza and Anastasia, presented Rasputin at court, and he produced a deep impression on the empress and emperor. The mystic atmosphere which always prevailed at the Russian court and the constant fear for the health of the tsarevich created a favourable background for the appearance of such a man. The eventual improvement in the health of the grand duke Alexis procured for Rasputin a commanding influence over the empress.

For some time Rasputin was satisfied by his social success, and at first he did not interfere in politics. But his activity was felt in church questions. His friendship with the famous monk, Heliodor, and the bishop of Saratov, Hermogen, which resulted in a complete rupture between them and in a series of scandals, had a painful echo in the country. The appointment of Varnava, an illiterate peasant and a friend of Rasputin, to be bishop of Tobolsk in 1911, and the servility with which the Holy Synod followed the wishes of the favourite, provoked a strong opposition among all classes of society. An unsuccessful attempt to kill him, made by a certain Guseva in 1914, incited by the monk Heliodor, only strengthened his influence. No important nomination was made without his approval, and the most unexpected people rose to the highest offices as the result of his influence. Rasputin was too ignorant to have any opinion on political questions: he was in most cases a mere instrument of the reactionaries. At length a small group of men of the highest social position, which included the grand duke Dimitri Pavlovich, Prince Yussupoff and Purichkevich determined to end the empire of Rasputin. He was invited to a supper at the Yussupoff palace on Dec. 16 (O S.; 29 N.S.), 1916, and shot dead, after an attempt at poisoning him with a strong dose of potassium cyanide mixed with wine had not produced the desired effect.

RASTELL (or RASTALL), **JOHN** *(c.* 1475–1536), an English printer and author, belonged to a Coventry family, and was educated for the law. He began his printing business some time before 1516, for in his preface to the undated *Liber Assisarum* he announced the forthcoming publication of Sir A. Fitzherbert's *Abbreviamentum librorum legum Anglorum,* dated 1516. In that year he undertook an expedition to America, but got no further than Ireland when his sailors left him. Among the works issued from the "sygne of the meremayd at Powlysgate," where he lived and worked from 1520 onwards, are *The* XII. *Mery Gestys of the Wydow Edyth* (152j), and *A Dyaloge of Syr Thomas More* (1529). The last of his dated publications was *Fabyl's Ghoste* (1533), a poem. In 1530 he wrote, in defence of the Roman doctrine of Purgatory, *A New Boke of Purgatory* (1530), dialogues on the subject between "Comyngs and Almayn a Christen man, and one Gyngemyn a Turke." This was answered by John Frith in *A Disputacion of Purgatorie.* Rastell replied with an *Apology against John Fryth,* also answered by the latter. Rastell had married, at some time before 1504, Elizabeth, sister of Sir Thomas More, with whose Catholic theology and political views he was in sympathy. More had begun the controversy with John Frith, and Rastell joined him in attacking the Protestant writer, who, says Foxe *(Actes and Monuments,* ed. G. Townsend, vol. v. p. 9), did so "overthrow and confound" his adversaries that he converted Rastell to his side. Separated from his Catholic friends, Rastell does not seem to have been fully trusted by the opposite party, for in a letter to Cromwell, written probably in 1536, he says that he had spent his time in upholding the king's cause and opposing the pope, with the result that he had iost both his printing business and his legal practice, and was reduced to poverty. He was imprisoned in 1536, perhaps because he had written against the payment of tithes. He probably died in prison, and his will was proved on July 18, 1536.

Rastell's best-known work is *The Pastyme of People, the Chronycles of dyvers Realmys and most specially of the Realme of England* (1529), a chronicle dealing with English history from the earliest times to the reign of Richard III., ed. T. F. Dibdin (1811). His *Expositiones terminorum legum Angliae* (in French, trans. into English, 1527; reprinted 1629, 1636, 1641, etc., as *Les Termes de la Ley*), and *The Abbreviacion of Statutis* (1519), of which 1j editions appeared before 1625, are the best known of his legal works.

To Rastell is generally attributed the morality play, *A new Interlude and a Mery of the 1111 Elements (c.* 1519). The fullest details available on John Rastell's life are in A. W. Reed, *Early Tudor Drama* (1926). For the books issued from his press *see* a catalogue by R. Proctor, in *Hand-Lists of English Printers* (Bibliographical Soc., 1896).

RASTELL, WILLIAM *(c.* 1508–156j), English printer and judge, son of the preceding, was born in London about 1508. At the age of 17 he went to the university of Oxford, but did not take a degree, being probably called home to superintend his father's business. The first work which bears his own imprint was *A Dyaloge of Sir Thomas More* (1531), a reprint of the edition published by his father in 1529. He also brought out a few law-books, some interludes ascribed to John Heywood *(q.v.),* an edition of *Fabyan's Cronycle* (1533), and *The Apologye* (1533) and *The Supplycacyon of Soulys* of his uncle Sir Thomas More. He became a student at Lincoln's Inn on Sept. 12, 1532, and gave up the printing business two years later. In 1547 he was appointed reader. On account of his Catholic convictions he left England for Louvain; but upon the accession of Mary he returned, and was made serjeant-at-law and treasurer of Lincoln's Inn in 1jj5. His patent as judge of the Queen's Bench was granted on Oct. 27, 1558. Rastell continued on the bench until 1562, when he retired to Louvain where he died on Aug. 27, 1565.

It is difficult to distinguish between the books written by William and those by his father. The following are believed to be his: *A Colleccion of all the Statutes* (1559), *A Table collected of the Yeares of the Kynges of Englande* (1561), both frequently reprinted with continuations, and *A Colleccion of Entrees,* **of** *Declarations, etc.* (1566), also frequently reprinted.

RAT, probably in its original sense the designation of the rodent known as the black rat *(Rattus rattus),* but also applied to the brown or Norway rat *(R. norvegicus),* and in a wider sense to all the larger representatives of the family Muridae.

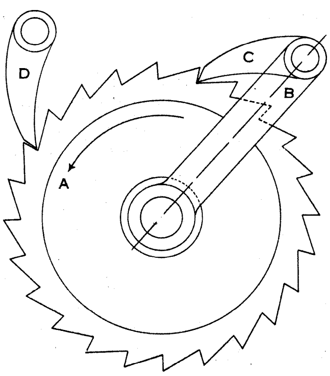
ABOVE: BLACK RAT (RATTUS RATTUS); BELOW: BROWN RAT (R. NORVEGICUS)

Rats have more rows of scales on the tail (reaching to 210 or more) than mice, in which the number does not exceed 180. For the distinctive characteristics of the family Muridae *see* RODENTIA. Of the two species the brown or Norway rat *(R. norvegicus)* is distinguished by its large size, brownish gray colour, short tail and ears, stout skull, and the possession of from 10 to 12 teats. It is fierce and cunning, and overcomes all allied species with which it is brought in contact. Its original home would seem to have been some part of Central

Asia. Thence it has spread over much of the world, driving out the house-haunting species everywhere, as it has in England all but exterminated the black rat. The brown rat migrated westward from Central Asia early in the 18th century, and is believed to have first reached Great Britain about 1730. The black rat (R. *rattus*) is smaller in size than the brown rat, with longer ears and tail. It is typically glossy black in colour, but brownish varieties, which may be distinguished readily from the brown rat, are common, especially in southern lands. It frequents ships and on them has reached most parts of the world. It is more common and more \vide-spread in the tropics than the brown rat, which in these climes is often restricted to the coast or to ports. This long-tailed rat, originally a native of southern Asia, first penetrated to all parts of the world, in many places nearly exterminating the indigenous rats. After this followed the advance of the more powerful brown rat. The black rat first reached Europe in the 13th century. The Isle of Dogs and Yarmouth in Norfolk are chief English strongholds of the black rat. It is this species that is the chief disseminator of bubonic plague. Both species agree in their predaceous habits, omnivorous diet and great fecundity. They bear, four or five times in the year, from four to ten blind and naked young, which are in their turn able to breed at an age of about six months; the time of gestation being about 20 days.

See J. Millais, "True Position of *Mus* rattus and its Allies," Zoologist (June 1905); M. Hinton, "Rats and Mice . . . ," Brit. Mus. Pamphlets; U S Fish and Wildlife Service, *Wild* Life Circular 6 (1941).

RATCHET AND PAWL is an important mechanical device in many machines and appliances, enabling a movement to be effected in one direction but not in the opposite direction. The mechanism is used to lock a part so that it cannot slip or reverse, to hold a load as in a winch or to give a positive feed. Ratchets may be straight or curved, the majority being circular. In fig. 1, motion of the arm (B) in the direction of the arrow rotates the wheel **(A).** When the arm (B) reverses, supplementary pawl (D) prevents backward motion of the wheel, providing the typical intermittent motion in one direction for the wheel.



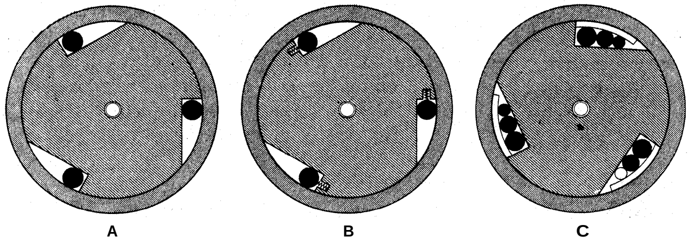
FROM C W HAM E J CRANE AND W L ROGERS 'MECHANICS OF MACHINERY. REPRODUCED BY PERMISSION OF MCGRAW HILL BOOK CO

FIG. 1.—SIMPLE RATCHET AND PAWL

(A) ratchet wheel, (B) oscillating lever carrying (C) driving pawl; (D) supplementary pawl prevents backward motion of the wheel

Slack in the engagement of the teeth may be reduced by using smaller teeth, additional stationary pawls or by using the silent (free-wheeling) ratchet (fig. 2). A variety of constructions employ balls, rollers or eccentrically pivoted pa ls to wedge in tapered slots and provide silent smooth, slack-free motion in one direction.

Various drives and brake mechanisms are made safe by ratchet devices, the ship's capstan being one of the oldest examples. Screwdrivers and wrenches are operated by ratchet for access in difficult situations, or to help the worker in manipulative power. Braces and metal drills are actuated by ratchets when it is not possible to make the complete revolution of a handle. So also are jack screws for lifting loads rapidly. Many counting devices are based on the use of ratchets. Ratchet feed, by which an arm holding the pawl is moved, thus moving a ratchet wheel and a feed screw, is utilized in many types of machines and is usually automatic in action. For example, the workpiece table on a shaper may be moved sideways a small space for each stroke of the cutting tool, a movement which will provide a complete traverse of the surface of the piece being machined. (F. J. B.)



FROM J. H. BILLINGS, "APPLIED KINEMATICS," D. VAN NOSTRAND COMPANY, INC., PRINCETON, N.J. (1953)

FIG. 2.— THREESILENT OR FREE-WHEELING RATCHETS

Counterclockwise rotation of inner driving member turns outer drlven member by wedging action of balls: (A) basic single-ball mechanism; (B) basic type with springs to insure positive wedging in any starting position; (C) multiple-ball type with lining protecting driven member

RATE. In England the term is specially applied to the levying of public money contributions for local purposes, as distinguished from the taxes raised for what are treated as general state purposes. By the Rating and Valuation acts of 1925 and 1928 the English system of rating has been amended and the law partially consolidated as also for Scotland by the Rating act, 1926, and the Rating (Scotland) Amendment act, 1928. In the United States the term rate does not signify a form of taxation, but is used to indicate the assessment percentage. *See* further POOR LAW; TAXATION; TAXATION, LOCAL.

RATEL or HONEY BADGER, the name of certain Indian and African small clumsy-looking creatures of the size and appearance of badgers, representing the genus Mellivora in the family Mustelidae (see CARNIVORE). Only one living species of ratel is known (Mellivora *capensis*), represented by several races in various parts of Africa, south of the Sahara and in India. Ratels are normally black with whitish crown and grizzled back, a style of coloration that is found also in the grison (*q.v.*). Pure-black individuals are known. The body is stout and thickly built; the legs are short and strong and armed (especially the anterior pair) with long curved claws; the tail is short; and the ears are reduced to rudiments. The Indian ratel is found throughout India, chiefly in hilly districts, but also in the north of India in alluvial plains. It lives usually in pairs; eats rats, birds, frogs, white ants and various insects. Like its Cape congener it occasionally partakes of honey and is often destructive to poultry. In confinement the Indian ratel becomes tame and even playful. (J. E. HL.)

RATEL, OR HONEY BADGER (MELLIVORA CAPENSIS)

RATHENAU, WALTHER (1867–1922), German statesman, industrialist and philosophical writer, was born in Berlin on Sept. 29, 1867. His father was Emil Rathenau, who became a pioneer of the modern power industry by acquiring Thomas A. Edison's European patent rights and founding the 'Allgemeine Elektrizitats-Gesellschaft. Having completed an academic curriculum in philosophy, physics, chemistry and engineering, Walther Rathenau successively filled responsible positions in various industrial enterprises, and in 1899 entered the service of the Allgemeine Elektrizitats-Gesellschaft. Although he had always been interested in public affairs, it was not until the beginning of World War I that he became a public figure.

The cause of Rathenau's prominence was the fact that, almost alone among German industrialists, he realized in the early days of the war the dependence of the German war effort on the supply and prudent management of raw materials. His proposal to organize a special board of the war ministry for this purpose was accepted, and he was put in charge, directing this vital work until the spring of 1915. Then he returned to business activity and writing; his best-known book, Von kommenden *Dingen* (1917; Eng. trans. by Eden and Cedar Paul, In Days to Come), was produced during this period.

Rathenau's knowledge of the world outside Germany, and his genuine love for peace, co-existed in his mind with strong national feelings. In Oct. 1918, in despair over the Gernian armistice request, which he correctly interpreted as in effect an act of unconditional surrender, he proposed in vain a *levée* en masse of the German people. In his economic views, Rathenau held an intermediate position between capitalism and democratic socialism; after the revolution of 1918, he founded with others the middle-class Democratic party, but he tried to keep that party in a relationship of co-operation with the Social Democrats, despite his critical view of many of their policies. In his book Die neue Wirtschaft, he supported the idea of industrial self-government with the participation of employees and effective state control rather than universal nationalization.

Rathenau was one of relatively few Germans who combined democratic convictions and a strong belief in international conciliation with economic experience and knowledge of foreign countries. In 1921 Joseph Wirth, who had just formed a cabinet, appointed Rathenau minister of reconstruction, a position involving responsibility for important aspects of reparation policy; later he exchanged this portfolio for that of foreign affairs. As one of his first achievements, Rathenau negotiated an agreement with France on German deliveries in kind for the reconstruction of French war-devastated areas. Rathenau believed that a practicable settlement of the reparations issue could best be obtained as part of a European reconstruction scheme, in which the economic rehabilitation of Russia would have to play a vital role. He induced Lloyd George to make this idea the core of the British proposal at the international conference at Cannes (Jan. 1922). No progress was made, however, either at Cannes or at the subsequent conference of Genoa. To forestall an Allied understanding with Russia at Germany's expense, Wirth decided to conclude a German agreement with the Russians for the mutual cancellation of all claims (the Rapallo treaty) and Rathenau reluctantly agreed. Through the Rapallo treaty, Germany for the first time after its defeat asserted its position as an independent agent in international affairs. The treaty antagonized the Allies; its wisdom has remained a matter of controversy.

Even among the conservatives, some leaders had a great deal of personal admiration for Rathenau, though others attacked him nith bitterness. For the extreme nationalists Rathenau was the symbol of everything they hated, especially because he was a Jew. On June 24, 1922, some young nationalist fanatics shot Rathenau to death on his way to his office. His assassination initiated the disintegration of the Wirth cabinet and the sequence of events that led to the French occupation of the Ruhr.

Rathenau's collected works (5 vol.) were published in 1918. Of his later writings, the most important are: Die neue Wirtschaft (1918); Kritik der dreifachen *Revolution* (1919); Die neue Gesellschaft (1919. Eng. trans., The New Soczety, 1921).

See Harry Kessler, *Walther Rathenau, sein Leben und sein Werk* (1928), Eng. trans., *Walther Rathenau* (1929). (*C.* L.)

RATHENOW, a town in the district of Potsdam, Germany, on the Havel, 45 mi. W.N.W. of Berlin. Pop. (1950) 29.353. Rathenow was incorporated as a town in 1295. In 1394 it was taken and partly destroyed by the archbishop of Magdeburg. It suffered much from the ravages of the Thirty Years' War. The Protestant church of St. Mary and St. Andrew, originally a basilica, was transformed to the Gothic style in 1517–89.

RATIBOR (Polish Raciborz), formerly a town of Germany, in the Prussian province of Silesia, situated on the left bank of the Oder at the point where the river becomes navigable, 97 mi. S.E. of Breslau by rail. on the main line to Oderberg. Pop. (1950) 26,400. Ratibor, which received municipal privileges in 1217, was formerly the capital of an independent duchy, 380 sq.mi. in extent, which existed from 1288 to 1532, and afterward passed successively into the hands of Austria and Prussia. In 1821 a small mediate principality was formed and was conferred upon the landgrave of Hesse-Rotenburg, as compensation for some Hessian territory absorbed by Prussia. In the partition of Upper Silesia between Germany and Poland in 1921 (see SILESIA) Ratibor was retained by Germany; after 1945 it became part of Opole province, Poland.

RATICHIUS (RATKE. RATICH), **WOLFGANG** (1571–1635), German educator, an early experimenter in education, was born at Wilster, Schleswig-Holstein, on Oct. 18, 1571. He devised a method for the rapid teaching of Latin by basing the work upon the learner's native language. He taught in a dozen different places, trying various methods, but his most consistent work was done in Kothen, where he established a school in which there were also classes for girls. Ratichius' "experiments" were not important in themselves, as he had little idea of proper method. His chief influence upon education was through the borrowing from him by many other men (notably Comenius) who were university students during the feu years that Ratichius' activities and ideas were being discussed. Ratichius died at Erfurt on April 27, 1635.

See J. Lattmann, *Ratichius und die Ratichaner* (1898); *K.* Setler, *Das pädagogische System des Wolfgang Ratkes* (1931). (L. CE.)

RATIOCINATION, a term used in logic and psychology for those processes by which the mind proceeds from general to particular truths. The steps involved in ratiocination may perhaps be most clearly seen in the form of reasoning followed in the syllogism (*q.v*).

RATIONALISM is that system of philosophical belief which asserts that human reason unaided is competent to attain objective truth. In its basic form it is an epistemological doctrine in which reason is contrasted with sense-experience, ahich is held to be unnecessary. or even a hindrance, to the attainment of truth. The inspiration of rationalism has always been mathematics, and rationalists have stressed the superiority of the deductive over all other methods in point of certainty. They attach a peculiar value to the capacity to recognize necessary connections between abstract ideas or concepts (*e.g.,* the connection between being a Euclidean triangle and having angles equal to 180°). Euclid's Elements presents the ideal to which rationalists hold that all human thinking should conform.

According to the extreme rationalist doctrine all the truths of physical science and even history could in principle be discovered by pure thinking and set forth as the consequences of self-evident premises.

Few rationalists, however, have been so extreme, and we may distinguish in different philosophers different degrees of rationalism. Locke, for example, is a rationalist in the weakest sense, holding that the materials of human knowledge (ideas) are supplied by sense-experience or introspection, but that knowledge consists in seeing necessary connections between them, which is the function of reason (Essay Concerning Human *Understanding*). Most philosophers who are called rationalists have also maintained that the materials of knowledge are derived. not from experience, but from the reason itself; *i.e.,* they are innate ideas.

Ethical rationalism is the application of epistemological rationalism to the field of morals. The primary moral ideas (good, duty) are held to be innate and the first principles of morals (*e.g.,* the Golden Rule) self-evident. It is further claimed that the possession of reason provides an adequate motive for moral conduct In ethical rationalism, reason is generally contrasted with feeling or moral sense.

Theological rationalism asserts the claims of reason against those of revelation or authority. The fundamental principles of religion are held to be innate or self-evident and revelation unnecessary. Theological rationalism thus stresses the importance of natural as opposed to revealed religion. By an easy extension of meaning, the word "rationalism" then came to signify a skeptical or antireligious attitude. This is the most common use of the word in the 19th and in the 20th centuries. Rationalism is conceived as the ally of liberalism in the struggle against religious intolerance (see W. E H. Lecky, History of the Rise and *Influence* of the Spirit of Rationalism in Europe, 2 vol., 1910 or alternatively as the enemy of religion (see J. F. Hurst, History of Rationalism, 1865). It thus came to be connected, somewhat paradoxically, with empiricism (*q.v.*), the antithesis of epistemological rationalism.

EPISTEMOLOGICAL RATIONALISM

Epistemological rationalism was first explicitly formulated by Plato. According to him there is a system of eternal necessary truths accessible to the human reason apart from sense-experience (Republic, vi and vii) and his theory of learning as recollection, developed in the *Meno* and in the Phaedo, is the first form of the doctrine of innate ideas. The typical innate ideas are mathematical concepts such as equality, which, he holds, are not perfectly exemplified in the material world (Phaedo).

In later antiquity and in the middle ages, wherever Platonism is influential, we have implicit epistemological rationalism (*e.g.*, in the Neoplatonists, in St. Augustine, in Boethius and in St. Anselm). but it is subordinated to the dominant ethical and theological interests. Medieval theological rationalism, however, makes one important contribution to epistemological rationalism. This is the ontological argument of St. Anselm, in which he seeks to prove that the existence of God follows from His essence, and thus to provide a connection between the abstract system of innate ideas and the actual world. (See ANSELM, SAINT; THEISM.) When rationalism became self-conscious at the Renaissance, both Kepler and Descartes felt the need for this connection, and both use the idea of God, Descartes deliberately reviving Anselm's ontological argument.

Epistemological rationalism reached its highest development in the 17th century under the double impetus of the revival of Platonism and the development of mathematical physics by Kepler, Copernicus, Galileo and Descartes. The new science rests on the basis of mathematics, and it recognizes as clear and distinct only what can be expressed in mathematical form. All scientific truth is derived from certain axioms and principles which can be comprehended by reason as universal and necessary. Thus, according to Galileo, "Truth is written in the great book of Nature, but only he can read it who can decipher the letters in which it is written." These letters, however, are the terms of mathematics, especially of geometry: the concepts of the straight line, the circle, the sphere, etc. None of these concepts is derived from experience; the mind rather takes them "from itself" in order to apply them to sense-perceptions. In the same way, Kepler considers number and magnitude as innate ideas not drawn from experience but required for the scientific investigation of nature (see E. Cassirer, Das *Erkenntnisproblem*, 3rd ed., i, pp. 328 ff., 1922; and E. A. Burtt, *Metaphysical* Foundations of Modern Physical Science, ch. ii and iii, 1925).

Descartes enlarges this view by setting forth a system of universal concepts of reason which are obtained by analysis of certain fundamental — logical and mathematical — relationships and which can be applied to all empirical data. These concepts are valid, not only for the actual world, but for all possible worlds, so that, in understanding by means of them every effect from its cause, we can obtain a priori knowledge of the universe as a whole. As instances of such fundamental concepts, Descartes cites primarily the concept of being, then the ideas of number and time and of space, figure and motion.

As physics thus becomes a purely deductive science, epistemological rationalism has to draw, as was said above, on theological rationalism for support. The innate ideas are within the mind, and sense-experience constitutes no proof of the reality of the external world (Descartes, Meditation *I*). We can, therefore, get outside the system of our own ideas only by proving the existence of reality external to us. This demands the idea of a Necessary Being, that is, God. But in order to show the applicability of the system, something must also be known of the nature of God. Descartes states that He is veracious; *i.e.*, that He will not allow us to be deceived in our clear and distinct thinking. The world is, therefore, constructed on the plan according to which we think. It is the construction of an infinite intellect. The applicability of pure mathematics is assured because nature itself is the product of a divine mathematics: Cum Deus calculat, *fit* mundus.

Leibniz' system may be regarded as the crowning achievement of epistemological rationalism. He attempts to deduce from fundamental laws of logic the basic propositions of his system, which are so repugnant to common sense that only a boundless confidence in the powers of pure reason could recommend them. The universe is said to consist of an infinite number of spiritual substances (monads), each regarding the whole from a distinct point of view and with a specific degree of confusion. The human mind occupies an intermediate position in the hierarchy of monads, its perceptions being clear in comparison with those of animals but still involving a great degree of confusion, of which the spatio-temporal and qualitative appearance of things is the product. This confusion also accounts for the fact that the truths of science and history, although logically necessary, cannot be known a priori by human beings.

The gap between truths of reason and truths of fact remains unbridgeable by the human mind. The aim of human science must, however, be to order knowledge so that it approximates as far as possible to the ideal deductive system (see L. Couturat. La *Logique* de Leibniz, especially ch. vi, 1901; and B. Russell, *A* Critical Exposition of the Philosophy of Leibniz, 2nd ed., 1937).

Leibniz attempted to lay the foundation for this in the grandiose scheme of his *characteristica* universalis, which was to give a catalogue of primary simple ideas together with a method by which all truths, however complex, could be exhibited as combinations of them. This project of Leibniz inspired later development in symbolic logic and investigation of the foundations of mathematics, particularly the work of Gottlob Frege, Giuseppe Peano, Bertrand Russell and A. N. Whitehead, in which it is sought to reduce all mathematics to logic. In the 18th century, however, the immediate outcome of the Leibnizian subordination of empirical to rational knowledge was the philosophy of Christian Wolff (1679–1754), who produced the voluminous system now chiefly remarkable as being the form of rationalism in which Kant was reared. Epistemological rationalism was meanwhile subject to attack from the British empiricists, especially Locke and Hume, who stressed the necessity for empirical data in the acquisition of scientific knowledge.

Immanuel Kant (*q.v.*), aroused by Hume from the "dogmatic slumber" induced by Wolff, attempted to combine rationalism and empiricism into a single system, the "critical philosophy." He adheres, however, to the rationalist position in stressing the importance of the a priori element in knowledge; and the "pure forms of intuition" and the "categories," in so far as they belong to the mind, have something of the nature of innate ideas But he differs from preceding rationalists in holding that, because of their nature, we cannot know that the pure forms of intuition (space and time) or the categories (cause, substance, etc.) apply to reality as such (the thing-in-itself). In short, according to Kant, rationalism provides a satisfactory basis for science only if we adopt skepticism as regards metaphysics. The a priori truths of reason apply only to things as they appear to us (phenomena), and reason is inadequate to solve the metaphysical problems of God, freedom and immortality (*Kritik* der *reinen* Vernunft, preface to 2nd ed., 1787). It is Kant who provides the classical refutation of the ontological argument (*op. cit.*, "Dialektik").

Hegelianism, in spite of the slogan "The Real is the Rational and the Rational is the Real," is only apparently a return to rationalism, being opposed to the mathematical method and inspiration which provide the keynote of classical rationalism. In fact it may be said that epistemological rationalism has not survived Hume's devastating criticism (Treatise of Human Nature, book i). Even the milder Kantian form was subject to severe criticism in the 20th century by the logical positivists, whose conventionalist theory of a priori truth challenges the basic rationalist claim to insight into objective necessary connection.

But however unacceptable as a complete theory of knowledge, rationalism as an attitude has been and still is an inspiration in science. It is the rationalist spirit which urges us to approach nature as masters rather than as pupils and to construct bold hypotheses and verify them later.

Some eminent 20th-century physicists have even put forward deductive systems entirely in the spirit of Leibniz: for example, A. Eddington in his Philosophy of Physical Science (1939) and E. A. Milne in his Modern Cosmology and the Christian Idea of God (1952).

ETHICAL RATIONALISM

Ethical rationalism was also first developed by Plato, partly under the inspiration of the Socratic dictum "Virtue is knowledge." In the Republic the reasoning element of the human soul both recognizes what is right and good and is itself the spring of action which prompts moral conduct. The Stoics, however, among the philosophers of the ancient world, developed the form of ethical rationalism which was most influential in later times. Although they rejected the theory of innate ideas, they held that there is in every man a spark of the divine reason which is sufficient, properly used, to discover the universally binding rules of conduct. On these rules positive law is properly based. Thus the Stoic doctrine gives rise to the theory of natural lam and natural right. It was popularized by Cicero, whose writings were later extremely influential (De *Republica,* iii; De Legibus, i).

As did epistemological rationalism, ethical rationalism underwent a considerable revival at the Renaissance, when it also had great influence on political theory. The first clear statement that the rules of conduct discovered by reason are independent of the commands of God was made by Hugo Grotius (De Jure belli et *pacis,* Prolegomena § 11). Ethical rationalism had a considerable vogue in the 17th and 18th centuries, especially in England, where it was developed by Lord Herbert of Cherbury, by Samuel Clarke, by John Balguy, by William Wollaston and by Richard Price.

The ethical systems of Spinoza and Kant have moreover considerable affinities with rationalism: Spinoza's is even developed in the mathematico-deductive form (*Ethica, ordine geometrico* demonstrata) in close connection with his metaphysics and theory of knowledge, though it depends in fact on certain empirical propositions concerning the nature of man; and Kant holds that the form of the moral law, the categorical imperative, is purely a priori, though it provides not a premiss from which we may deduce our duties but a test that enables us to discern the moral character of any proposed course of action.

The classical criticism of ethical rationalism is to be found in Hume's Treatise, books ii and iii. A modified form of rationalism was developed in the 20th century under the name "intuitionism" (W. D. Ross, Foundations of Ethics, 1939).

THEOLOGICAL RATIONALISM

The question "Is theological truth discoverable by reason or solely by revelation?" could arise only in the context of religions such as Judaism, Christianity and Islam. The relations between revelation and reason were much debated in the middle ages. E. Gilson (Reason and Revelation in the Middle Ages, 1939) distinguishes two positions which may be called rationalist as distinct from the antirationalist view that reason is totally unable to grasp religious truth. The less extreme position is the Augustinian, namely that, once revelation is accepted, its content may be grasped by the intellect; this is adopted by St. Anselm, who sums it up in the phrase credo *ut intelligam,* "I believe in order that I may understand." The complete rationalist position, which makes revelation unnecessary at least for the philosopher, was worked out by Averroes in Moslem Spain and adopted by his Christian followers.

Rationalism in theology developed rapidly after the Reformation. A clear statement of the position is given by Lord Herbert of Cherbury in De *Veritate* and De Religione *gentilium.* Leibniz' introduction to the *Théodicée* shows that the word "rational" had already come into use in this context. The position was further developed in the 18th century by the English deists, by the French *philosophes* (*e.g.* Voltaire and Condorcet) and by the German theologians called rationalists (particularly S. J. Baumgarten and J. S. Semler, who were influenced both by Wolffian rationalism and by biblical criticism). (See ENLIGHTENMENT.)

By the end of the 19th century rationalism had become a frankly antireligious movement, often combined with empiricism and materialism and identified with practically atheistic forms of agnosticism (*q.v.*): see for example J. McCabe, Biographical Dictionary of Modern Rationalists (1920) and *A* Rationalist Encyclopaedia (1948). (M. KE.)

RATIONING, a term of military origin, meaning apportionment to each member of a group of his due share of supplies, was first applied to the nation-wide distribution of food in World War I. During World War II it was practised not only by belligerent governments but also in neutral countries faced with shortages and high prices.

Rationing of consumers is carried out by supplying them with a card or booklet containing numbered and dated sections which have to be presented for cancellation or surrender when a purchase is made. Separate cards with detachable coupons may be issued, like the bread cards first used in Berlin, Germany, in the winter of 1914; or a number of cards with different colouring or pattern may be bound together in a single ration book, like that first introduced in Great Britain in July 1918. The issue of ration books and identity cards from the same office is helpful for checking fraud and recording movements of the population.

Out of straight rationing of a single commodity there was developed in World War II a new "points" system of rationing for a group of articles such as clothing and footwear or miscellaneous groceries. Distinction may be drawn between rationing based on tying consumers to a particular shop, in which case retailers receive buying permits corresponding with the number of their registered customers and have no need to detach coupons; and the alternative system whereby customers are free to buy at any shop, and retailers replenish their stocks against the surrender of coupons collected. The former system was applied in Great Britain to meat, bacon, sugar, fats, milk and eggs; the latter to clothing. motor vehicle fuels and soap, and among foods to tea, chocolate and sugar confectionery and miscellaneous groceries.

German and Continental **Rationing.**—When bread rationing was first introduced in Berlin a few months after the outbreak of World War I, it was wrongly interpreted abroad as a sign of serious shortage rather than as a precautionary measure designed to prevent maldistribution. From the outset the German system embodied the principle of differential rations. Manual workers, later divided into light, heavy and very heavy workers, received more than the normal consumer; children under ten years, less. Rationing was administered by local authorities, who enjoyed more independence than in World War II and sometimes competed with one another for supplies. Co-ordination of supply and distribution by state-controlled war companies was never complete, and this opened the door to illicit trade. Evasion of the regulations from 1917 onward grew to such an extent that maldistribution of food was one of the chief factors in the collapse of the home front in 1918.

Before the outbreak of World War II thorough preparations had been made for rationing as an integral part of war economy. The reich food estate (Reiclzsnaehrstand) had already established centralized control over food supplies and distribution, and disciplinary action reduced illicit trade to the minimum. Rationing of bread, flour, sugar, meat and fats was introduced in Sept. 1939 and continued at a fairly adequate level until 1944. Further refinements were made in the system of differential rations to cover special categories of consumer and different age groups.

Rationing in occupied countries followed the German pattern but varied widely in efficiency and adequacy. Administration was left largely to local officials,and passive resistance by producers, traders and consumers led to an extensive black market.

Great Britain.—Rationing was unknown in Great Britain until toward the end of World War I. In Aug. 1914 a royal commission on sugar supplies had been set up to undertake bulk buying. Toward the end of 1916 sugar supplies fell short of demand, and distributors were allotted only half of their 1915 supplies. Retailers were left to share this out among their customers as best they could, but queues formed and discontent grew. After some months of hesitation the cabinet decided in June 1917 to introduce the first rationing scheme under which householders were invited to register with a particular shop, and retailers received supplies of sugar equal to the rations of their registered customers. One thousand eight hundred food control committees were appointed by local authorities to exercise powers delegated by the food controller. A local rationing scheme for meat and fats in London and the home counties, covering about 10,000,000 people, came into force on Feb. 25, 1918, as a result of which queues largely disappeared. On April 7 a national rationing scheme for meat was started, and on July 14 the whole population received ration books with separate cards for meat, fats, sugar and lard. By May 1919 rationing by coupons was abolished, and sugar registration ended in Nov. 1920. Rationing had lasted for little more than two years.

By contrast in World War II rationing started early in 1940 and was not ended until July 1954. Ration books, which had been printed in 1938, were issued by post from local food offices to every individual on the basis of a special census conducted for national registration on Sept. 29, 1939. Five types of ration books were issued: for children under 5, children 5 to 18, normal adults, travellers and seamen. Emergency cards valid for one week were issued to new arrivals or persons who had lost their books. Straight rationing, which entitled consumers to a fixed weekly amount of each food, was applied in 1940 to meat, bacon, sugar, fats and tea. In 1941 cheese and preserves were added, and milk and eggs came under a scheme of priority rationing. On Dec. 1, 1941, a new system of points rationing was put into force for miscellaneous groceries, under which each consumer received a number of points to spend in each four-week period on any food in the group, each food being given a points price varying according to the expected demand in relation to the supply; thus canned salmon and dried fruits had a high points price, and cereal foods, a low price. This system was adopted after the successful introduction of points rationing for clothing and footwear. In June 1941 everyone had been given a coupon currency of 66 points, roughly corresponding to 66% of prewar average consumption. Later the figure was reduced to 48 a year. Point prices for clothing were based on the amount of cloth used, but other garments mere pointed to equate demand roughly to estimated supply. Rationing of expenditure by value coupons was rejected on the ground that it would have concentrated demand too much on the cheaper goods.

Soap rationing was introduced early in 1942 on the basis of 16 oz. per four weeks for hard soap. Chocolate and sugar confectionery were first rationed in July 1942 under what was called the personal points scheme; distribution to retailers was based on coupons collected without consumer registration. Other foods subject to controlled distribution rather than strict rationing included milk, eggs, oranges and fish. Milk went first to priority consumers — mothers and children up to 5 years old were guaranteed a ration of seven pints a week; children of 5 to 18 years, three and one-half pints; and schools, hospitals and invalids also had priority supplies. The rest of the public got what was left with no definite guarantee of supply, the usual amount being two pints a week in the minter and three to four in the spring. Consumers were tied to one dairyman who received his share of the available supplies according to the number of priority and nonpriority customers registered with him. Controlled distribution of shell eggs started in June 1941. Mothers and infants received priority supplies, and ordinary consumers got allocations as and when supplies permitted, varying from one a month in the winter to two or more a week in the spring. Up to the end of 1944 nonpriority consumers received an average'of 30 eggs a year, which was about one-fifth of prewar consumption. In June 1942 dried eggs, supplied by the United States under lend-lease, were distributed in packets containing an amount equivalent to 12 eggs at the rate of one packet or more per eight weeks; but later priority supplies were allotted to infants and nursing mothers, and the balance went on points. Oranges when available were sold to holders of children's ration books before other customers could be served. It was found impracticable to ration fish, but supplies to retailers were distributed as fairly as possible. Bread, flour and potatoes never had to be rationed during World War II. Bread and flour rationing was introduced in July 1946 and lasted for two years; potatoes were rationed in 1947–48 when a poor potato harvest synchronized with world shortage of wheat.

In contrast with rationing schemes on the continent, differential rations for special categories of workers were kept to the minimum, and coupons did not have to be surrendered for meals in restaurants. The general principle was that everyone should be free to take meals out as a supplement to domestic rations, and caterers received an allocation of rationed foods on the basis of the number of meals served.

Food rationing in Great Britain, which ended with the decontrol of meat and bacon on July 3. 1954, was made easier by the fact that half the total food supply was imported and also by the willing co-operation of food traders and the public. There was general assent to the principle of fair shares which, though it involved some levelling down in the consumption of the majority, also allowed some levelling up of the diet of the poorest by means of food subsidies and welfare food schemes.

BIBLIOGRAPHY.—W H. Beveridge, *British Food Control* (New Haven, Conn., 1928); League of Nations, *Wartime Rationing and Consumption* (New York, 1942; London, 1943) and *Food Rationing and Supply 1943–44* (New York, London. 1944); *How Britain Was Fed in War Time* (H.M S.O., London, 1945); R. J. Hammond, *Food*, vol. i, *Growth of Policy* (H M S O., London, New York, 1951), vol. ii, *Studies in Administration and Control* (1956). (E. M. H. L.)

United States. — Rationing in the U.S. was an emergency measure accompanying major warfare. Recognized as necessary, rationing nevertheless was adopted with reluctance and abandoned with alacrity. Idealistic self-restraint was the principal recourse of the U.S. during World War I although wheat flour and sugar supplies were eventually controlled by the Food administration headed by Herbert Hoover, to ensure maximum use of food supplies for wartime needs. Disappearing quickly after the Armistice, controls did not appear again until after the attack on Pearl Harbor, Dec. 7, 1941, when it became clear that extraordinary efforts would be needed to fight and win a two-continent war. An Office of Price Administration (OPA) was created April 11, 1941, by executive order to prevent "price spiraling, rising costs of living, profiteering, and inflation." Signing of the Emergency Price Control act on Jan. 30, 1942, gave OPA specific authority to enforce its orders. Leon Henderson, Prentiss Brown and Chester Bowles served successively as OPA administrators.

Although OPA had an army of paid officials, much of the burden of making thankless but necessary daily decisions fell on unpaid local citizens, serving on community ration boards. Their task was not eased by the presence of three antagonistic forces: shortages of goods; government-regulated price ceilings; and war-swollen incomes. The prices of some luxury goods were raised artificially by high federal excise taxes; typewriters, jewelry and luggage continued to bear such federal levies long after the war. OPA rationed some commodities according to individual need, while other items were to be equally available to all. Basic raw materials were controlled at first through priorities and, after mid-1943, by allocations. The change became necessary when the word priority lost its meaning in the light of exhausted supplies Government allocations under a Production Requirements plan and later a Controlled Materials plan were ways of dividing total supplies among essential users

Consumer rationing was handled by several methods. In point rationing, a consumer could select from items in specific groups. Thus small red stamps could be surrendered for meat, butter, fats, cheese, canned milk and canned fish. Blue stamps were used for canned fruits, vegetables and related items. Stamps were good for stated periods. Certificate rationing involved the use of certificates obtainable by those who could prove special need for tires, motor vehicles and similar products.

Ration coupons came to comprise a sort of currency. They passed successively from consumer to retailer to wholesaler to producer to ration authorities. After 1943 a ration banking plan facilitated co-operation by commercial users by permitting depositing of ration currency in banks and drawing on one's existing balance by check. Simplification and refinement in administration came in 1944.

Tires were rationed almost immediately, and sugar was rationed after the first general consumer registration, May 4–7, 1942. Gasoline was rationed first in the east, then throughout the country. Automobile owners with special needs established them with ration boards and were provided with additional rations; many others switched to buses, joined car pools or relearned the joys of walking. Meats, canned goods, butter and other foods eventually joined sugar on rationed lists. Clothing, other than shoes, was unrationed through the war, but scarcities developed, especially after demobilization of uniformed personnel. Fuel oil was rationed in some sections

Rationing was broadened in 1943, and eased briefly in 1944 when key victories seemed to warrant it. Immediately after the Japanese surrender in Aug 1945, most items were released from controls. Sugar and tires, the first to be listed, were the last to be decontrolled OPA ceased May 31, 1947, having lingered on chiefly to handle rent control and to perform final administrative acts.

The very nature of rationing could not but make it unpopular. Yet it performed the task assigned to it. Persons in the U S remained well nourished The black market was kept to a reasonable minimum, in part because OPA in its lifetime instituted over 280,000 enforcement orders against violators of price, rent and rationing regulations, winning 95% of its court cases

There was never any general desire to make rationing a permanent part of the American scene Rapid removal of controls was acclaimed, although in 1945–46 temporary scarcities and a 23% rise in prices indicated that supply had not satisfied pent-up demands.

The Korean War did not bring with it the comprehensive rationing procedures of World War II. An Office of Price Stabilization enforced a limited program of production, wage and price controls. Chrome and other strategic materials were regulated, and the quality of appliances and motor car bumpers suffered for a time.

There was evidence during and after the Korean War that leaders hoped, by planning and stockpiling of critical raw materials, to increase national self-sufficiency in the future. The report of the Materials Policy commission, Resources for Freedom, 5 vol., (Washington, D.C., 1952), was an important step. An indication that future rationing, if any, might vary from the patterns of earlier years could be found in the continuing farm surpluses and in constantly expanding industrial facilities. (See also WAR CONTROL OF FOOD.) (V. D. B.)

RAT KANGAROO or POTOROO, any member of the diprotodont marsupial subfamily Potoroinae (see MARSUPIALIA). None of them exceeds a rabbit in size. They inhabit Australia and Tasmania, are nocturnal and feed on leaves, roots and bulbs, which latter they dig up with their forepaws. About ten species are known. The members of the type genus (Potorous) run, rather than leap, and do not use the hind feet for kicking. In the genus Betfongia the tail is prehensile. (See KANGAROO.)

RATLAM, formerly a princely state within the Central India agency, from 1948 a district of Madhya Bharat, India—the maharaja (a Rathor Rajput of the Jodhpur family) ceasing to rule actively. Madhya Bharat became part of Madhya Pradesh Nov. 1, 1956. Area 1,727 sq.mi.; pop. (1961) 484,006. Chief town, Ratlam (pop.. 1951, 63,403).

RATNAGIRI, a town and district of the Bombay Koukan division of Bombay state, India. The town is on the coast 136 mi. S. of Bombay. Pop. (1951) 27,082. There is no railway, but there is steamer connection with Bombay.

The DISTRICT OF RATNAGIRI has an area of 5.013 sq.mi. It forms a strip between the Western Ghats and the sea. Nearly all the fertile land lies on the banks of the streams which intersect the country. Ratnagiri (pop. [1961] 1,824,343) formed part of the dominions of the Peshwa and was annexed by the British in 1818 on the overthrow of Baji Rao. The district is known for supplying men of outstanding quality to the Bombay police, to the army and to the intelligentsia.

RATNAPURA (*i.e.*, "the City of Gems"), the chief town in the province of Sabaragamuwa, Ceylon. It is the centre of a long-established industry in digging for precious stones—rubies, sapphires, cat's-eyes, etc. There are important tea and rubber plantations in the district, and rice and fruit are cultivated. The town has good rail and road connections with Colombo. Pop. of town (1953) 16.598; of district 421,555.

RATTAZZI, URBANO (1808–1873), Italian statesman, was born on June 29, 1808. at Alessandria. and from 1838 practised at the bar. In 1848 he was sent to the chamber of deputies in Turin as deputy of his native town. For a short time he held the portfolio of public instruction; afterward, in the Gioberti cabinet, he became minister of the interior. and on the retirement of Gioberti in 1849 he became practically the head of the government. The defeat at h'ovara compelled the resignation of Rattazzi in March 1849. His election as president of the chamber in 1852 was one of the earliest results of the so-called *connubio* with Cavour; *i.e.,* the union of the moderate men of the right and of the left. Rattazzi resigned in 1858, but again entered the cabinet under La Marmora in 1859 as minister of the interior. He again retired in Jan. 1860. He was entrusted with the formation of a new ministry in March 1862, but his policy of repression toward Garibaldi at Aspromonte led to his fall in December. He was again prime minister in 1867, from April to October. He died at Frosinone on June 5, 1873.

RATTLESNAKE, any snake of the genera Sistrurus and Crotalus, American pit vipers with the tail terminating in a rattle. The "pit" characteristic of these snakes is a deep depression on each side of the snout between eye and nostril. (See PIT VIPER.) The rattle is developed as a modification of the single scale that covers the tip of the tail; instead of being a simple. conical sheath, as in ordinary snakes, it has two ringlike constrictions so that it resembles three hollow bulbs, gradually diminishing in size and each one opening into its neighbour; the largest is also open at its free end, where the tail enters. All snakes shed the horny, epidermal covering of their scales periodically, a new one forming beneath the old one before the latter is sloughed; when, however, the new covering of the end of the tail is developed in the rattlesnakes, the middle ring of the new segment develops within the basal segment of the old rattle and. though the rest of the old skin is sloughed, the old tail sheath remains loosely fitting over the new one but prevented from slipping off by its shape. Thus, newly born rattlesnakes have no rattle but with each succeeding moult a joint is added; the older joints, however, gradually wear away and are lost so that the number of joints on the rattle is not a criterion of a snake's age unless the rattle is complete with the original terminal button.

The characteristic noise is produced by rapid vibration of the whole tail, when the loosely fitting horny shells produce a shrill sound, which may be audible 20 yd. away. The majority of the species are dwellers of the plains and open spaces and it has been suggested that the development of the rattle was to give a warning audible at a distance, to keep the snake from being trodden upon by hoofed animals, or from molestation by carnivores.

The venom of the rattlesnakes is of the same general type as that of other pit vipers and all of the larger species inject sufficient venom to kill a man. They are, however, not easily provoked and mill usually endeavour to escape or, if cornered, to frighten the aggressor by rattling and puffing themselves out as much as possible. In all species the eggs are retained within the body of the mother until the young are ready to emerge.

Sistrurus, with three species, is confined to the United States, southern Ontario and Mexico. *Sistrurus* may be distinguished from *Crotalus* by the presence of large, regularly arranged shields on the top of the head; all of the forms are small. Crotalus, with small irregular scales on the top of the head, contains about 20 species, most of which occur in North and Central America. The largest and most dangerous species is the eastern diamondback (C. adamanteus) which reaches a length of about eight feet; it is confined to the southeastern U.S. Other well-known species are the prairie rattler (C. *confluentus*), which occurs all over the great plains from Canada to Texas. the timber rattlesnake (C. *horridus*) of the eastern United States and C. *terrificus,* which ranges from Mexico to the Argentine and is the only representative of the genus in South America. The sidewinder (C. cerastes) is a small, desert-dwelling form from southwestern h'orth America and is characterized by the development of a blunt, hornlike process above each eye. (K. P. S.)

RATZENHOFER, GUSTAV (1842–1904), Austrian sociologist and army offickr, who conceived of society as a universe of conflicting ethnic groups, was born in Vienna on July 4, 1842. Ratzenhofer became a cadet at the age of 17 and rose rapidly in the military. Already a voracious reader, he had more opportunity for study when he became director of the army archives in 1878. After subsequent service as chief of the general staff of an army, in 1898 he became field marshal and president of the supreme military court of Vienna.

Intellectually and professionally a tough self-made man, Ratzenhofer was naturally inclined to apply Darwin's biological theory of the struggle for existence and survival of the fittest to human society. Thus he joined the ranks of the social Darwinists who carried Darwin's theory of biological evolution of organisms into sociology by explaining the origin of ever larger social groups as a gradual development from less complex groups in conflict. Ratzenhofer, following his fellow Austrian, L. Gumplowicz, chose racial groups as the units for analysis. As might be expected from a sociologist at the top of the military hierarchy, Ratzenhofer believed that political science must rule society. He thought sociology could engineer the human species to even higher forms of social association. See his three volumes *Wesen* und *Zweck* der Politik, *als* Theil der Sociologie und Grundlage der *Staatswissenschaften* (1893).

See Robert Schmid, "Gustav Ratzenhofer: Sociological Positivism and the Theory of Social Interests" in An Introduction to the History of Sociology, ed. by H. E. Barnes, with bibliography (1948). The life of Ratzenhofer is given in his posthumous work, Sociologie (1908), ed. by his son. (H. S.; X.)

RAU, KARL HEINRICH (1792–1870), German political economist, was born on Nov. 29, 1792, at Erlangen, where he studied at the university, of which he subsequently became a professor (1818). In 1822 he was called to the chair of political economy at Heidelberg where the rest of his life was spent in teaching and research. He took some part, however, in public affairs. In 1837 he was nominated a member of the first chamber of the duchy of Baden; in 1845 he became a privy councilor; and in 1851 he was one of the commissioners sent to England on the part of the *Zollverein* to study the Industrial exhibition. A result of this mission was his account of the agricultural implements exhibited at London (*Die landwirthschaftlichen Geräthe der Londoner Ausstellung,* 1853). He was elected a corresponding member of the French institute in 1856. He died at Heidelberg on March 18, 1870.

His principal work is the *Lehrbuch der politischen Ökonomie* (1826–37), an encyclopaedia of the economic knowledge of his time, written with a special view to the guidance of practical men. The three volumes are respectively occupied with (1) political economy, properly so called, or the theory of wealth; (2) public administration science (*Volkswirtschaftpolitik*); and (3) finance. The two last he recognizes as admitting of variations in accordance with the special circumstances of different countries, while the first is more akin to the exact sciences, and is in many respects capable of being treated, or at least illustrated, mathematically. This threefold division marks his close relation to the older German cameralistic writers. The book passed through many editions; in that of 1870 by Adolf Wagner it was transformed into a new book.

RAU, SIR (BENEGAL) NARSING (Narsinga) (1887–1953), Indian lawyer, diplomat and administrator, who helped draft the Indian constitution of 1950, was born in Mangalore on Feb. 26, 1887. Graduate of the universities of Madras and Cambridge, he entered the Indian civil service in 1910 where he achieved distinction as a jurist by his revision of the entire Indian statute book (1935–37). He served as a judge of the high court of Calcutta (1939–44). As the pre-eminent jurist of India he became constitutional adviser to the constituent assembly (1946–49); also for Burma in 1947 in drafting its constitution. His writings on Indian law include a noted study on constitutional precedents as well as articles on human rights in India.

Rau headed the Indian delegation at several sessions of the United Nations general assembly and was permanent representative of India to the United Nations from 1949 to 1951. He served as vice-chairman of the International Law commission, and in 1951 was elected a judge of the International Court of Justice at The Hague. He died on Nov. 29, 1953, in Zürich, Switz.

(Or. S.)

RAUSCHENBUSCH, WALTER (1861–1918), U.S. clergyman, professor of theology and social reformer, a leader of the Social Gospel movement, was born in Rochester, N.Y., Oct. 4, 1861, the son of a Lutheran missionary among German immigrants in the United States who had become a Baptist and had been engaged to train a German-speaking ministry at the Rochester Theological seminary. After graduating from the Rochester Free academy, Rauschenbusch studied for four years in Germany and then returned to Rochester in 1883, taking simultaneously his final year at the University of Rochester (B.A., 1884) and his first year at the theological seminary. On June 1, 1886, following the completion of his theological studies, he became minister of the Second German Baptist church in New York city. There he was awakened to the social problem by the personal distress he encountered in a depressed neighbourhood and by the influence of Henry George's campaign for mayor. An even more important influence was exerted by two other young Baptist preachers, Leighton Williams and Nathaniel Schmidt. The three young men formed themselves into a Society of Jesus, which was later to be expanded into the influential Brotherhood of the Kingdom. *For the Right,* a monthly periodical published "in the interests of the working people," was launched in Nov. 1889 in an effort to reach the labouring classes and to aid in the formulation of a Christian Socialist program. Publication ceased in March 1891 when Rauschenbusch left for a year's study in Germany. In 1897 he was called to the faculty of the Rochester Theological seminary and in 1902 was installed as professor of church history. The publication of *Christianity and the Social Crisis* (1907) won him national acclaim as the major spokesman of the social gospel. He died, saddened by World War I, on July 25, 1918.

Rauschenbusch always regarded himself as an evangelist, seeking to win men to a "new birth" in Christ and to put them to work in the interests of his kingdom. He seized upon the "kingdom of God" as the only concept adequate to induce repentance and to harness the impulses of new spiritual life. He had little patience with contemporary optimistic views of human nature. "Ethically," he said, "man sags downward by nature. It is ever easy to follow temptation and hard to resist it. The way that leads to destruction is always broad and its asphalt pavement is kept in perfect order, with toboggan slides at either side for those who prefer a steeper grade." Among his other important writings are *Prayers for the Social Awakening* (1910), *Christianizing the Social Order* (1912) and *A Theology for the Social Gospel* (1917). *See* also Christian Socialism.

See D. R. Sharpe, *Walter Rauschenbusch* (1942). (W. S. H.)

RAVAILLAC, FRANÇOIS (1578–1610), the assassin of Henry IV of France, was born near Angoulême. He began life as a *valet de chambre*, but afterward became a lawyer and schoolteacher. He failed to obtain admission either to the recently founded order of Feuillants or to the Society of Jesus. Rumours that the king was intending to make war upon the pope suggested to him the idea of assassination, which he carried out on May 14, 1610. He was executed on May 27, 1610.

RAVAISSON-MOLLIEN, JEAN GASPARD FÉLIX, commonly known as Félix Ravaisson (1813–1900), French philosopher and connoisseur, was born at Namur on Oct. 23, 1813. A protégé of the comte de Salvandy, minister of education, he was taken from a teaching post in Rennes to be inspector general of public libraries (1839–45, 1846–53). Under Napoleon III he was made inspector general of higher education, a title which he retained till 1888, though from 1870 he was curator of antiquities in the Louvre. He died in Paris on May 18, 1900.

His major philosophical works are: *Essai sur la métaphysique d'Aristote,* 2 vol. (1837–46); *De l'habitude* (1838; new ed., 1927); and *La Philosophie en France au XIX^{e} siècle* (1868; 3rd ed., 1889). As a philosopher Ravaisson belonged to the school of Victor Cousin, with whom, however, he was at issue on many important points. The act of consciousness, according to him, is the basis of all knowledge. His influence was extensive in the Latin Catholic world, where it did much to prepare for Bergsonism.

See his *Testament philosophique et fragments,* ed. by Charles Devivaise (1933); also J. Dopp, *Félix Ravaisson: la formation de sa pensée d'après des documents inédits* (1933).

RAVEL, MAURICE (1875–1937), French musical composer, was born at Ciboure, near St. Jean de Luz, Basses-Pyrénées, March 7, 1875. He was the most outstanding figure in modern French music. More than that, he held an assured place in that line of composers, beginning with the *clavecinistes* of the 17th century, who had so powerful an influence on French instrumental music. Educated at the Conservatoire de Paris, where his master in composition was Gabriel Fauré, Ravel won the second prix de Rome for composition in 1901. But he was not awarded the grand prix de Rome, and the judges were severely criticized for thus refusing to recognize his talent; the resignation of F. C. T. Dubois from the directorship of the Conservatoire was in fact attributed to this cause. When Ravel's piano pieces began to be known, notably *Pavane pour une infante défunte* and *Jeux d'eau,* played in Paris by Ricardo Viñes in 1902, a comparison was made between him and C. A. Debussy, whose *Pelléas et Mélisande* (Opéra-Comique, 1902) was then arousing heated controversy.

It is true that such diverse minds as Fauré, A. E. Chabrier and Erik Satie exercised an influence on Ravel during his formative years, but his personality showed itself from the first. This personality became more clearly defined in his subsequent works, which included the *String Quartet in F,* the three *Schéhérazade* melodies for voice and orchestra or piano (both 1903); the

Histoires *naturelles* (1906); Introduction et allegro (septet for harp, strings, flute and clarinet) and the *Rapsodie espagnole* for orchestra (1907). For the piano he wrote Miroirs and *Sonatine* (1905); *Gaspard* de la *nuit* (3 pieces) (1909); Ma mkre *l'Oye* (suite of five pieces) (1908); and Valses nobles et sentimentales (1911). The last two of these are best known in England as orchestrated by the composer.

However daring Ravel's harmony may appear, he was never experimental. He had an unerring sense of direction and knew where he was going, even if he sometimes seemed to watch himself going there with a smile of amusement. The cynical wit of his one-act opera, *L'heure* espagnole (Opéra-Comique, 1911), and the conscious pose of the ballet *Daphnis* et Chlot (choreography by Michel Fokine and produced by Sergei Diaghilev, 1912), emphasize in different ways the detached attitude of Ravel toward his art. His later works include a sonata for violin and violoncello, and a trio for piano and strings (1915); La Valse for orchestra (1920) and Tzigane, for violin and piano (1924).

(H. C. C.)

BIBLIOGRAPHY.—Roland Manuel, *Maurice Ravel et son oeuvre* (1914), *L'Oeuvre de Maurice Ravel* (1921); A. Coeuray, *La musique française moderne* (1922); G. Dyson, *The New Music* (1926); C. Gray, *A Survev of Contempovary Music* (1924).

RAVELLO, a village of Campania, Italy, in Salerno province, 3 mi. N N.E. of Amalfi, 1,227 ft. above sea level. It commands a magnificent view, especially from the Belvedere of Cimbrone. Pop. (1957 est.) 2,566 (commune). The history of Ravello begins in the 9th century. In the 11th it was called Rebellum, because it rebelled against Amalfi; in the 13th, at the height of its prosperity, it had 36,000 inhabitants. The Palazzo Rufolo, begun in the 11th century, has two lofty towers and beautiful Saracenic decoration in the courtyard. The former cathedral of S. Pantaleo has a good campanile, fine bronze doors by Barisanus of Trani (1179) and two pulpits in Cosmatesque work. The larger, supported by six columns resting on the backs of lions, was made in 1272 by Nicolaus of Foggia; the bust over the entrance may be a portrait of Sigilgaita Rufolo, or may symbolize the church. The smaller (*c.* 1130) has curious representations of Jonah and the whale. The parish church of S. Giovanni in Toro contains a splendid pulpit in Cosmatesque work, supported on four pillars, and the crypt some 14th-century frescoes. S. Maria Immacolata is another Romanesque church.

RAVEN, the largest bird of the order Passeres, and a member of the Corvidae. Quick-sighted, sagacious and bold, the raven preys on the spoils of fishers and hunters, also on weakly animals among flocks and herds. A sentiment of veneration or superstition has often been attached to it. Superstition has been generally succeeded by persecution, which in many districts has led to extirpation.

The raven breeds early in the year, in England resorting to its nest, which is usually an ancient structure, toward the end of January. Therein are laid from five to seven eggs of the common corvine coloration (*see* CROW), and the young are hatched before the end of February. The young have bright crimson throats. In more northern countries the breeding season is naturally delayed, but everywhere this species is almost, if not quite, the earliest breeder. The raven measures about 26 in. in length and has an expanse of wing exceeding a yard. It is entirely black, the feathers having a purple iridescence. The common raven (*Corvus* corax) inhabits the whole of Europe, northern Asia and northern America. In Africa its place is taken by allied species, one of which (*Corvus umbrinus*) has a brown neck; farther south are species whose plumage is varied with white.

RAVEN-HILL, LEONARD (1867–1942), English artist and illustrator, was born on March 10, 1867. He studied art at the Lambeth school and afterward in Paris under A. W. Bouguereau and Aim6 Morot. He began to exhibit at the Salon in 1887 and at the Royal Academy in 1889. In 1893 he founded, with Arnold Golsworthy, the humorous and artistic monthly the *Butterfly* (1893–94, revived in 1899–1900). He contributed to many illustrated magazines and was with Punch from 1896 until his retirement in 1935. He illustrated Sir Walter Besant's East London (1901) and J. H. Harris's Cornish Saints and Sinners. His impressions of his visit to India on the occasion of the tour of the prince and princess of Wales appeared as An Indian Sketch-Book (1903); other published sketchbooks include Our Battalion (1902) and The *Promenaders* (1894). He died March 31, 1942.

RAVENNA, a city and archiepiscopal see of Emilia-Romagna, Italy, capital of the province of Ravenna, in a marshy plain 13 ft. above sea level, 6 mi. from the sea and 45 mi. by rail east of Bologna. Pop. (1957 est.) 102,897 (commune)—a considerable increase, as the population of 1881 was only 34,270 (commune). The town is a centre for agriculture, which has been much favoured by extensive drainage and reclamation works. There is also a sugar factory at Classe. The town is connected with the sea by the Corsini canal. Ravenna has railway communication with Bologna (via Castel Bolognese), Ferrara and Rimini, and by steam tram with Forlì. Though the external aspect of the town is not striking, no other in the world offers so many and such splendid examples of the ecclesiastical architecture of the centuries from the 5th to the 8th. The style is commonly called Byzantine, but the colonnades and the mosaics are not so much Byzantine as representative of early Christian art generally.

The cathedral of Ravenna, built by S. Ursus in 370–390, which had a nave and four aisles, was destroyed in 1734–44, only the (inaccessible) crypt and the round campanile remaining from the earlier structure; there are fragments of reliefs from a pulpit erected by Archbishop Agnellus (556–569) in the interior. The present cathedral contains several early Christian marble sarcophagi, a silver cross of the 11th century and the throne of the Archbishop Maximian (546–552), adorned with reliefs in ivory.

The period from the transference of the imperial residence to Ravenna to the death of Valentinian III (404–455) was the first period of great building activity in Ravenna, when the archiepiscopal see of Ravenna attained great importance. It was to it that is owed the erection of the Basilica Petriana at Classe (396–425), which has entirely disappeared, of the churches of S. Giovanni Evangelista (425), of S. Agata (425–432), of the chapel of S. Pier Crisologo (433–449), of the mausoleum of Galla Placidia (440), the church of S. Pier Maggiore (now S. Francesco) (433–58), baptistery of Neon (449–458), S. Giovanni Battista and S. Croce.

S. Giovanni Evangelista, erected by Galla Placidia in fulfilment of a vow made on her voyage from Constantinople, has been entirely rebuilt, though the columns are ancient. The Gothic portal is fine, and the church contains a mosaic pavement of 1213 with representations of the 4th crusade and some frescoes by Giotto, painted during a visit to Dante between 1317 and 1320. S. Agata was almost entirely rebuilt in 1476–94. The chapel of S. Pier Crisologo in the archiepiscopal palace preserves its original mosaics; so also does the mausoleum of Galla Placidia (SS. Nazario e Celso), a small structure in the form of a Latin cross with a dome (in which, as in the baptistery of Neon, the old cathedral, etc., the constructional use of amphorae is noteworthy), with a plain brick exterior, and rich mosaics on a dark blue ground.

S. Francesco has been modernized, except for the crypt and campanile (10th century). The baptistery adjacent to the cathedral was either originally part of the Roman baths, converted to a Christian baptistery by the Archbishop Neon (449–452), or a Christian building dating from before A.D. 396. It is an octagon, with a dome; in the interior are two arcades one above the other. The mosaics of the 5th century, in the dome, are the earliest and perhaps the finest at Ravenna.

Of S. Giovanni Battista, also erected in this period, hardly anything remains after the restoration of 1683, and S. Croce has been overtaken by a similar fate. Honorius and Galla Placidia built a palace about A.D. 402, remains of which have been found under S. Croce.

The reign of Theodoric (493–526) marks another era of magnificence. In the eastern part of the city he built for himself a large palace. There still remains fronting the Corso Garibaldi a high wall built of square Roman bricks, with pillars and arched recesses in the upper portion, which goes by the name of Palazzo di Teodorico, but is a guardhouse erected by the exarchs, recent explorations having made it clear that it was an addition to the palace, while mosaic pavements and a court once surrounded by colonnades and really belonging to the latter were found behind S. Apollinare Nuovo and the so-called Palazzo at a lower level and a different orientation. (See Ghirardini in Monumenti *dei Lincei,* xxiv, 737–838.) A mosaic in the church of S. Apollinare Nuovo gives some faint idea of the palace. The massive mausoleum of Theodoric stands still perfect outside the walls near the northeast corner of the city. It is circular internally and decagonal externally, in two stories, built of marble blocks, and surmounted by an enormous monolith, brought from the quarries of Istria and weighing more than 300 tons. It has been converted into a church dedicated to the Virgin.

S. Apollinare Nuovo, the most important basilica in the town, was built by Theodoric to be the largest of Arian churches. The exterior is uninteresting, and the church lost both atrium and apse in the 16th century. The interior has 24 columns of marble, with almost uniform capitals. The walls of the nave are adorned with mosaics of the 6th century; the scenes from the New Testament above the windows date from the time of Theodoric.

The campanile (850–878) is circular and has perhaps the earliest example of the use of disks of coloured majolica as a decoration. This, like the other campanili of Ravenna, is later than the church to which it belongs Those of the cathedral of S. Apollinare in Classe, S. Maria Maggiore and S. Agata, also circular, probably belong also to the 9th century, while the two square campanili of S. Giovanni Evangelista and S. Francesco probably belong to the 10th century The other churches erected by Theodoric are: S. Teodoro (or S Spirito), erected by Theodoric for the Arian bishops. but entirely modified; the baptistery of this church (afterward the oratory of S. Maria in Cosmedin), formed out of the octagonal hall of a Roman bath, with mosaics of the 6th century; S. Maria Maggiore. founded by the Archbishop Ecclesius (521–534), but almost entirely rebuilt; and S Vittore. which has suffered a similar fate. To the same period probably belong a few columns of the so-called Basilica of Heracles in the Piazza Vittorio Emanuele, with capitals like those of S. Apollinare in Classe.

The impulse given by Theodoric was continued by his successors, and during the regency of Amalasuntha and the reigns of Theodatus and Vitiges (526–539), S. Vitale and S. Apollinare in Classe were constructed by Julius Argentarius contemporaneously with S Lorenzo in Milan and the cathedral of Parenzo—also S. Michele in Africisco, little of the original structure of which now exists; the apse mosaic is in the Berlin museum. The former, well restored by Ricci (except for the dome with its baroque frescoes which has not been altered), is a regular octagon. with a vestibule, originally flanked by two towers on the west, a choir added on the east. triangular outside and circular within; it is surrounded within by two galleries interrupted at the presbytery, and supported by eight large pillars. the intervals between which are occupied by open exedrae The mosaics of the choir (547) are due to Justinian, and, though inferior in style, are remarkable for their splendour of colouring and the gorgeous dresses of the persons represented. and also for their historical interest, especially the scenes representing the emperor and the empress Theodora presenting offerings The marble screens of the altar are wonderfully finely carved The marble mosaic pavement (11th century) is very effective. Remains of the original marble mall lining and stucco decoration also exist.

The architecture of S Vitale according to Rivoira, was inspired not hy Byzantium. where similar churches — S. Sofia and SS. Sergio and Bacco — are slightly later in date. but by the churches of Salonica (AD. 495), while the plan is derived from a Christian baptistery, or from such a building as the so-called temple of Minerva Medica at Rome

It has been ascertained that a 5th century building already occupied the site.

S Apollinare in Classe, erected at the same time outside the walls of Classis, and now standing by itself in the lonely marshes, is the. largest basilica existing at Ravenna. It has a nave and aisles with a closed vestibule on the west, and a fine round campanile of the 9th (?) century. The exterior brick walls are divided by shallow arches and pilasters, as in other churches of Ravenna. It has 24 columns of Carystian (cipollino) marble, with capitals probably of Byzantine work with swelling acanthus leaves; but the rest of the church is the work of native architects. The lofty presbytery and the crypt under it belong to the 12th century. The walls of the interior were stripped of their marble panelling by Sigismondo Malatesta in 1449, for the adornment of his church at Rimini. The apse has mosaics of the 6th and 7th centuries. The 18th-century series of portraits of the archbishops of Ravenna is no doubt copied from an earlier original. There are a number of fine carved sarcophagi in the church (5th to 8th century). The building activity of the Gothic kings was continued by Justinian, to whose time we owe the completion of S. Vitale and S. Apollinare in Classe, and some of the mosaics in S. Apollinare Nuovo.

The buildings of a subsequent period are of minor importance, but the Basilica of S. Maria in Portofuori near the ancient harbour (1096 seqq.), a basilica with open roof, with frescoes by masters of the Rimini school, may be noticed. The campanile dates from 1173–87. The tomb of Dante, who died at Ravenna in 1321, is close to S. Francesco; it is a square domed structure, with a relief by Pietro Lombardo (1483) representing the poet, and a sarcophagus below, in an urn within which lie the poet's remains. Close by is a small court with early Christian sarcophagi, containing the remains of the Braccioforte family. The important museum near S. Vitale has Roman and Byzantine antiquities. inscriptions. sculptures, jewelry, etc. The library has rare manuscripts (including the best extant manuscript of Aristophanes) and incunabula. The Accademia has pictures by local masters.

In the Piazza Vittorio Emanuele are two granite columns erected by the Venetians in 1483. The cloisters of S. Maria di Porto, erected in the town in the 16th century (because of malaria, as in the case of those of Classe), and of S. Vitale are pleasing 16th-century structures. The 15th-century castle in the northeast corner of the town erected by the Venetians is a picturesque brick building. The walls, 3 mi. long, which still surround the town. were also built by them.

History.—Strabo mentions a tradition that Ravenna was founded by Thessalians, who afterward called in the Umbrians and left the city to them. About 191 B.C., by the conquest of the Boii, the whole of this region passed definitely under the dominion of Rome. Under Augustus it rose into importance, when it was made the station for the fleet on "the upper sea." Two hundred and fifty ships could ride at anchor in its harbour. At the same time Augustus conducted a branch of the Po (the fossa Augusta) through the city into the sea. It also became important for the export of timber from the Alps. Strabo gives a description which corresponds closely with modern Venice.

On the other hand, good water was proverbially difficult to obtain at Ravenna—dearer than wine. says Martial. Trajan, however, built an aqueduct nearly 20 mi. long, which was restored by Theodoric in 503. Of this some traces still exist in the bed of the Ronco above Ravenna. Flies and frogs were also complained of. and Sidonius, writing in the 5th century, complains bitterly of the "feculent gruel" (cloacalis *puls*) which filled the canals of the city and gave forth fetid odours when stirred by the poles of the bargemen. The port of Ravenna. situated about three miles from the city, was named Classis. A long line of houses called Caesarea connected it with Ravenna, and in process of time there was such a continuous series of buildings that the three towns seemed like one. It had large gilds of fabri (smiths and carpenters) and *centonarii* (firemen).

A prehistoric station was found in 1894 at S. Zaccaria near Ravenna, belonging to a Terramare. Of Roman Ravenna nothing remains above ground. It was connected with Ariminum, 33 mi. to the south, by the coast road, the Via Popilia, which ran on north to Hatria. and joined the road between Patavium and Altinum at Ad Portum.

Early in the 5th century, Honorius, alarmed by the progress of Alaric in the north of Italy, transferred his court there. From this date (404) to the fall of the Western Empire in 476 Ravenna was the chief residence of the Roman emperors. There Stilicho was slain; there Honorius and his sister Placidia caressed and quarrelled; there Valentinian III spent the greater part of his life; there Majorian was proclaimed; there the little Romulus donned his purple robe; there in the pinewoods outside the city his uncle Paulus received his decisive defeat from Odoacer. The great pinewoods to the east of the city, which is still one of the great glories of Ravenna, must therefore have been in existence in the 5th century. Odoacer made Ravenna his chief residence. Theodoric's siege of Ravenna lasted for three years (489–492); ten days after his entry into the city he slew his rival at a banquet in the palace of the Laurel Grove (March 15, 493). Ravenna was also Theodoric's chief residence (493–526).

In 535 Justinian sent an army to destroy the Gothic monarchy and restore Italy to the empire. The Goths at length, weary of the feebleness of Vitiges, offered to transfer their allegiance to Belisarius on condition of his assuming the diadem of the Western Empire. Belisarius dallied with the proposal until he had obtained an entrance within the walls of the capital, and proclaimed his inviolable fidelity to Justinian (539). Under the rule of Narses and his successors, the exarchs, Ravenna was the seat of Byzantine dominion in Italy. In 728 the Lombard king Luitprand took and destroyed the suburb Classis; about 752 the city itself fell into the hands of his successor. Aistulf, from whom a few years later it was wrested by Pippin, king of the Franks.

It formed part of the Frankish king's donation to the pope in the middle of the 8th century, though the archbishops, as a fact, retained almost independent power. It was an independent republic, generally taking the Guelph side in the 13th century, subject to rulers of the house of Polentani in the 14th, Venetian in the 15th (1441) and papal again in the 16th. St. Romuald and St. Peter Damian were both natives of Ravenna. From this time (1509) down to 1860, except for the interruptions caused by the wars of the French Revolution, Ravenna continued subject to the papal see and was governed by a cardinal legate. In 1849 Garibaldi's wife, Anita, who had accompanied him on his retreat from Rome, succumbed to fatigue in the marshes near Ravenna.

Charles the Great carried off the brazen statue of Theodoric and the marble columns of his palace to his own palace at Aix-la-Chapelle. Lord Byron resided at Ravenna for 18 months in 1820–21, attracted by the charms of the Countess Guiccioli.

BIBLIOGRAPHY.—The most important authority for the history of Ravenna is Bishop Agnellus, who wrote, about 840, the *Liber Pontificalis Ecclesiae Ravennatis* The best edition is that by Holder-Egger in the *Monumenta Germaniae Historica* (1878) *See* G T Rivoira. *Lombardic Architecture* (London, 1910); C Ricci, *Ravenna* (Bergamo, 1902), *Ravenna* (London, 1913); E Hutton, *The Story of Ravenna* (London, 1926). To the careful restorations of Ricci the buildings of Ravenna owe much. (T. H.; T. A.)

BATTLE OF 1512

This battle, one of the principal events of the long Italian wars of Charles VIII. Louis XII and Francis I of France, is, like Marignan (*q.v.*), interesting in a tactical sense, from the fact that the feudalism of the past and the expert soldiership of the future were strangely mingled. It arose out of the attempt of the Spanish and Italian forces to relieve Ravenna, besieged by Gaston de Foix, duke of Nemours. The most celebrated captains of these wars were present on either side—under Gaston de Foix were Bayard. Yves d'Allègre, La Palisse; and under Cardona, the Spanish viceroy of Naples, Pedro Navarro. the great engineer, and Pescara. the originator of the Spanish tactical system. After some preliminary manoeuvres the two armies drew up face to face on the left bank of the Roneo. the Spanish left and the French right resting on this river. The Spaniards Mere entrenched with their heavy artillery distributed along the front, but, thanks to Navarro, they had a more mobile artillery in the shape of 200 *arquebuses à croc* mounted in groups upon carts, after the German fashion. The battle opened with a prolonged cannonade from the Spanish lines. For three hours the professional regiments of all sorts in the French lines rivalled one another in enduring the fire unmoved, the forerunners of the military systems of to-day, landsknechts, Picardie and Piedmont, showing the feudal gendarmerie that they too were men of honour. There was no lying down. The captains placed themselves in the front, and in the centre 38 out of 40 of them were struck down. Molart and Empser, drinking each other's health in the midst of the cannonade, were killed by the same shot. Sheltered behind the entrenchments, the Spaniards scarcely suffered, for they were lithe active troops accustomed to lie down and spring up from the ground. But after three hours, Pescara's light horse having meantime been driven in by the superior light horse of the enemy, the artillery-loving duke of Ferrara conceived the brilliant plan of taking his mobile field guns to the extreme right of the enemy. This he did, and so came in sight of the prone masses of the Spaniards. Disciplined troops as they were. they resisted the temptation to escape Ferrara's fire by breaking out to the front; but the whole Spanish line was *enfiladed,* and on the left of it the papal troops, who were by no means of the same quality. filled up the ditch in front of their breastworks and charged forward, followed by all the gendarmerie. Once in the plain they were charged by the French gendarmes under Gaston himself. as well as by the landsknechts, and driven back. The advantage of position being thus lost, the Spanish infantry rose and flung itself on the attackers; the landsknechts and the French bands were disordered by the fury of the counterstroke, being unaccustomed to deal with the swift, leaping and crouching attack of swordsmen with bucklers. But La Palisse's reserve wheeled in upon the rear of the Spaniards, and they retreated to the entrenchments as fast as they had advanced. The papal infantry, the gendarmes and the light horse had already vanished from the field in disorder; but the Spanish regulars were of different mettle, and it was only after a long struggle that the landsknechts and the French bands broke into the trenches. The conflict continued, but at last La Palisse. with all the gendarmerie still in hand, rode completely around the entrenchments and charged the Spaniards' rear again. This was the end, but the remnant of the Spanish infantry retreated in order along the river causeway, keeping the pursuers at bay with their arquebuses. Gaston de Foix, recklessly charging into the midst of them, was killed.

RAVENNA, EXARCHATE OF, or exarchate of Italy, created by the emperor Maurice (582–602) as a new administrative province to comprise the Byzantine dominions in Italy after the Lombard invasion; it is first mentioned in 584. Soon after, it came to form part of the new system of "themes" established along the frontiers of the empire by Heraclius and his successors. At the beginning of the 7th century, the exarchate included Istria, maritime Venetia, Emilia with Ravenna, the Pentapolis, *i.e.,* the coast from Rimini to south of Ancona with the hinterland, Calabria (then the name of the "heel" of Italy). Bruttium (the "toe" of Italv. called Calabria from the late 7th century), Naples with southern Campania, Rome with northern Campania and-southern Tuscany, Perugia and Liguria

The territory of Ravenna was also called, in a limited sense, the exarchate of Ravenna. It was under the direct administration of the exarch. while the other Byzantine possessions in Italy were governed. under his authority, by dukes or *magistri militum;* below them there were tribunes in charge of towns and castles. The internal organization of the exarchate, like that of the themes, was marked by the combination of military and civil powers in the same hands. The exarch, first created as the military governor of Byzantine Italy. thus soon displaced the existing head of the civil administration, the prefect of Italy, whose office seems to have disappeared about the middle of the 7th century. Sicily formed a separate province directly dependent on Constantinople, although the exarch exercised some control over it during that century; Corsica and Sardinia were placed under the exarchate of Carthage.

During the 7th century, the Byzantines suffered further losses; by the middle of the century. Liguria had fallen to the Lombard kings; by the end of it, nearly the whole of Calabria (*i.e.,* the southeast of Italy) had been conquered by the Lombard dukes of Benevento. In 726 a revolt broke out in the exarchate which seriously threatened the Byzantine government; although primarily caused by the iconoclastic policy of Leo III, it was also due to dissatisfaction with the Byzantine administration. After the suppression of the revolt, or after 750, the south Italian dominions were separated from the exarchate and incorporated in the theme of Sicily. The pope. who had played a leading part in the revolt, was gradually becoming the virtual ruler of Rome and its duchy. King Liutprand took advantage of the difficult situation of the Byzantines and extended his power at their expense. After a brief respite, Aistulf continued this policy of conquest; in *c.* 751 he finally took Ravenna, after its territory (the exarchate in the limited sense) had already been conquered In northern Italy, Istria and maritime Venetia alone remained Byzantine. Subsequent Frankish intervention (*see* ITALY: *History*) made a recovery of the lost dominions impossible; the exarchate in the limited sense and the Pentapolis passed, together with the duchy of Rome, under papal rule.

The Byzantine possessions in southern Italy saw a temporary revival toward the end of the 9th century; in view of the Arab conquest of Sicily, they were then reorganized in the new themes of Longobardia and Calabria. Venice, nominally under Constantinople, became practically independent under its dukes (doges); and this also happened in some of the southern territories, as at Naples. The development toward local and regional autonomy had already started before the downfall of the exarchate, and had undoubtedly contributed to it. Imperial officials became landowners, and local landowners entered the imperial administration. The tribunate tended to become hereditary in the landowning class; the dukes of Venice were elected by the population from the time of the revolt of 726.

BIBLIOGRAPHY.—C. Diehl, *Etudes sur Padministration byzantine dans l'exarchat de Ravenne (568–751)* (Paris, *1888)*; L. M. Hartmann, *Untersuchungen zur Geschichte der byzantinischen Verwaltung in Italien (540–750)* (Leipzig, 1889), *Geschichte Italiens* im *Mittelalter,* vol ii (Leipzig, 1903). (N. R.)

RAVENSBURG, a town in the state of Württemberg-Hohenzollern, Ger., on the Schussen, 12 mi. N. of Friedrichshafen on Lake Constance. Pop. (1959 est.) 30,822. Ravensburg was founded in the 11th century by the Guelphs, and in their castle on the Veitsburg, Henry the Lion was born. In 1180 the town passed to the Hohenstaufens, and a century later it became a free town of the empire. It was ceded to Württemberg in 1810. It retains its walls and nine towers and its 15th-century town hall.

RAVENSCROFT, THOMAS (c. 1590–*c.* 1633), English composer and musical editor, received his B.Mus. at Cambridge in 1607 and in 1618–22 was music master at Christ's hospital. He is best known by his *The Whole Booke of Psalmes* (1621), *48* of the 100 harmonizations being his own. His other works, the first three of which show his appreciation of popular and humorous poems, are *Pammelia,* including 100 rounds and catches (1609); *Deuteromelia,* a collection of 31 items, including "Three Blind Mice" (1609); *Melismata,* a collection of 21 items, chiefly short madrigals (1611); and *A Briefe Discourse of the True (but Neglected) use of Charact'ring the Degrees, by their Perfection, Imperfection and Diminution in Measurable Musicke,* etc. (1614).

RAVI, one of the "Five Rivers" of the Punjab. It rises in the Kulu subdivision of Kangra district, Punjab (India), and flows through Chamba, the isolated northern division of Himachal Pradesh. Turning southwest it briefly enters Jammu (Kashmir), traverses the Gurdaspur district (Punjab, India), then forms the India-Pakistan frontier before finally crossing into the Pakistan province of Punjab about 1j mi. N.E. of Lahore, within a mile of which it later passes. Flowing across the Punjab plains, it finally falls into the Chenab about 10 mi. S. of Ahmadpur after a course of about 450 mi. Its water is used for the irrigation of the Bari *doab.* The Cpper Bari *doab* canal (1859), with headworks at Madhupur on the Indian side of the frontier, serves about 1,177,000 ac. and the Loner Bari *doab* canal (completed 1917), with headworks on the left bank of the Ravi at Balloki, about 345,000 ac. The waters of the Ravi are supplemented for the irrigation of the lower *doab* by canals leading from the Jhelum and the upper Chenab. The Sidhnai canal, beginning about 10 mi. above the Chenab junction, was frequently dry in winter until the construction of the Haveli canal (1939), delivering water to the Ravi from the Trimmu barrage at the Chenab-Jhelum confluence. (T. HER.)

RAWALPINDI, interim capital of Pakistan, cantonment and a district and division of West Pakistan. The town, which is 20 mi. E.S.E. of Peshawar and 160 mi. N.W. of Lahore, had a population in 1961 of 340,175 (including cantonment, 142,805). It was formerly the largest military station in India and the key to the British system of defense on the northwest frontier. It is the starting point of the road to the hill station of Murree and of the route into Kashmir. The seat of government was moved there from Karachi in Oct. 1959, and it was proclaimed the capital on Aug. 2, 1960, pending completion of construction of a new capital, Islamabad, near Rawalpindi. Besides the locomotive works of the North-Western railway there are gasworks, a tent factory, an iron foundry, an oil refinery and a brewery. To the northwest lie the ruins of the ancient city of Taxila, an important seat of learning in the 4th century B.C.

RAWALPINDI DISTRICT (area 2,022 sq.mi.; pop. [1961] 1,137,085) contains the Murree hills. In ancient times it formed part of Gandhara and was included in the Persian empire of the Achaemenidae.

RAWALPINDI DIVISION (area 11,206 sq.mi.; pop. [1961] 3,979,139) contains Rawalpindi, Jhelum, Gujrat and Shahpur districts.

RAWANDIS, a Persian sect (from Rawand, a town near Isfahan). Its origin is unknown, but its members held ultra-Shi'ah doctrines (*see* ISLAM). They maintained that the spirit that was in Jesus was in Ali, then in the imams one after the other to Ibrahim ibn Mohammed, and that thus these were divine. They believed in metempsychosis, or the transmigration of souls, and asserted that the lord who fed them and gave them drink was Mansur. In 759 they came to the palace of Mansur in Hashimiya and began to hail him as lord. The caliph, however, secured their chiefs and threw them into prison.

RAWLINS, a city of south central Wyoming, U.S., 163 mi. N.W. of Cheyenne; the seat of Carbon county. It was founded in 1868 when the Union Pacific railway arrived. The town was first named Rawlins Springs for U.S. Army Gen. John A. Rawlins, who had discovered a pleasant spring of fresh water at that point in 1867, but the word "Springs" was soon dropped. Rawlins was incorporated as a city in 1886.

The Cnion Pacific railway company has always been a principal employer. Quite early Rawlins also became known as a cattle and sheep centre. It is also a centre for antelope hunting and in the 1950s became an important shipping point for uranium ore from the Gas Hills area to the north. The state penitentiary is located at the north edge of Rawlins and an oil refinery is 6 mi. away at Sinclair. For comparative population figures *see* table in WYOMING: *Population.* (T. A. LN.)

RAWLINSON, SIR HENRY CRESWICKE (1810–1895), English soldier and orientalist, was born at Chadlington, Oxfordshire, on April 11, 1810. In 1827 he went to India as cadet under the East India company; and after six years as a subaltern he was sent to Persia in company with other English officers to reorganize the shah's troops. He became interested in the hitherto undeciphered cuneiform character. In two years he transcribed as much as he was able of the great cuneiform inscription at Bisitun (*q.v.*), but the friction between the Persian court and the British government ended in the departure of the British officers. He became political agent at Kandahar in 1840. Then, at his own desire, he was sent as political agent to Turkish Arabia; thus he was enabled to settle in Baghdad, where he devoted much time to his cuneiform studies. He was then able to make a complete transcript of the Bisitun inscription, which he deciphered and interpreted. During two years' leave in England (1849–51) he prepared a memoir on the Bisitun inscription. He disposed of his valuable collection of Babylonian, Sabaean and Sassanian antiquities to the trustees of the British Museum, who made him a grant to enable him to carry on the Assyrian and Babylonian excavations initiated by Sir Austen Layard. In 1851 he returned to Baghdad. In 1855 he resigned his post in the East India company and he received the K.C.B. and crown directorship of the East India company. The remaining 40 years of his life were mainly spent in London. In 1858 he was appointed a member of the first India council, but resigned in 1859 on being sent to Persia as envoy extraordinary and minister plenipotentiary. The latter post he held only for a year. Rawlinson rejoined the council of India in 1868, and continued to serve upon it until his death. He was a strong advocate of the forward policy in Afghanistan. He died in London on March 5, 1895.

His published works include four volumes of cuneiform inscriptions, published under his direction between 1870 and 1884 by the trustees oi the British museum; *The Persian Cuneiform Inscription at Behistun* (1846–51) and *Outline of the History of Assyria* (1852), both reprinted irom the Asiatic Society's journals; *A Commentary on the Cuneiform Inscriptions of Babylon and Assyria* (1850); *Notes on the Early History of Babylonia* (1854); *England and Russia in the East* (1875). He contributed to the *Encyclopædia Britannica* (9th ed.) the articles BAGHDAD; EUPHRATES; KURDISTAN; and several other articles dealing with the east; and assisted in editing a translation of Herodotus by his brother, Canon George Rawlinson (1812–1902).

See G. Rawlinson, *Memoir of Henry Creswicke Rawlinson* (1898).

RAWLINSON, HENRY SEYMOUR RAWLINSON, 1ST BARON (1864–1925), British soldier, was born on Feb. 20, 1864. son of Maj. Gen. Sir Henry Rawlinson. Bart. He joined the army in 1884 and a year later became aide-de-camp to Sir Frederick Roberts in India on whose staff he served intermittently for some years. He took part in the Burma operations in 1886–87 and on the Nile in 1898; he had succeeded to the baronetcy in 1891. He served throughout the South African War (1899–1902). Some months after his return to England he became commandant of the staff college and from 1910 to May 1914 commanded the 3rd division. Gen. Rawlinson was in charge of the forces sent to assist Antwerp in 1914, and took part in the first battles of Ypres and in the Neuve Chapelle and the Loos offensives. He commanded the 4th army during the battle of the Somme (1916), achieving important successes. At the end of 1917 he was transferred temporarily to the command of the 2nd army during Gen. Plumer's absence in Italy, and in February and March 1918 he acted for some weeks as British representative on the Supreme War council. Resuming his command of the 4th army in April, his troops on Aug. 8. in conjunction with the French. attacked the enemy near Xmiens and gained a signal victory. which heralded the general advance of the Allies. After World War I he was raised to the peerage as Baron Rawlinson of Trent and received a grant of £30,000. In the latter part of 1919 he was sent to north Russia to conduct the withdrawal of the Allies from Archangel and Murmansk, and on his return he commanded at Aldershot for a year. At the end of 1920 he went to India as commander in chief. He died at Delhi on March 28. 192j.

See Sir F. Maurice, *Life of General Lord Rawlinson of Trent, from his Journals and Letters (1928).*

RAWMARSH, an urban district in the Rother valley parliamentary division of the West Riding of Yorkshire. Eng., about 2 mi. N. of Rotherham. Pop. (1961) 19,603. Area 4.1 sq.mi. Rawmarsh has three collieries, a large ironworks, steel rolling mills, and an 11-in continuous bar mill of advanced design.

RAW MATERIALS: *see* NATURAL RESOURCES.

RAWTENSTALL, a municipal borough (1891) in the Kossendale parliamentary division of Lancashire, Eng., 17 mi. N. of Manchester by road Pop (1951) 25,437. Area 14.9 sq mi. Rantenstall manufactures cotton, felt, shoes. etc. There is an art gallery and museum. which has a collection of footwear.

RAY (WRAY), **JOHN** (1627–1705), English naturalist, famous for his systems of natural classification, was born at Black Notley, Essex. on Nov. 29. 1627. He graduated B.A. from Cambridge in 1647/48 and in 1649 secured a fellowship at Trinity college, obtaining his M.A. degree in 1651. He resigned his fellowship in 1662 because he could not subscribe to the Act of Uniformity. He devoted himself to science, aided through the generosity of Francis Willughby (*q.v.*), with whom Ray agreed to work on a survey and classification of plants and animals. They made several botanical tours in Britain and, from 1663 to 1666, traveled in Europe. In 1667 Ray mas elected a fellow of the Royal society. Willughby died in 1672, leaving Ray an annuity for life. Subsequently Ray published (1673) an account of their European travels. Ray died at Black Notley on Jan. 17. 1705.

Ray's system of plant classification, which greatly influenced the development of systematic botany, appeared in the *Methodus plantarum nova* (1682) and, in final form, in *Methodus plantarum emendata* (1703). Ray was the first to distinguish (1682) the divisions that he later (1703) called "Monocotyledones" and "Dicotyledones" (from cotyledon, a seed leaf; *see* PLANTS AND PLANT SCIENCE; ANGIOSPERMS), both fundamental in modern classifications though altered in content from Ray's concept. His *Catalogus plantarum circa Cantabrigium* (1660) was the first flora of Cambridgeshire, and his *Catalogus plantarum Angliae* (1670; 2nd ed.. 1677) and *Synopsis methodica stirpium Britannicarum* (1690; 2nd ed.. 1696). the former arranged alphabetically and the latter according to his classification system, were the first floras of Britain. The *Historia plantarum* (1686–1704) described all known plants and arranged them in his system. The book's introductory essays, surveying botanical knowledge, formed the most complete treatise that had appeared on plants in general. Ray was the first to attempt to define what constitutes species.

Ray's zoological works were characterized by Georges Cuvier as "the basis of all modern zoology." The "foundation of scientific ornithology" (A. Newton) was laid in the *Francisci Willughbeii . . . ornithologiae libri tres* (1676), amplified and edited by Ray from the incomplete manuscript left by Willughby. The classification, which was for the most part followed later by Linnaeus, appears to have been of Ray's devising. The bases for the natural classification of fishes were laid in *Francisci Willughbeii . . . historia piscium* (1686). wherein the major share of the work was apparently that of Ray. This work greatly influenced Peter Artedi, whose arrangement of fishes was adopted by Linnaeus. The earliest classification of animals based upon anatomical characters was that in Ray's *Synopsis methodica animalium* (1693). He maintained Aristotle's great divisions, animals with blood (*i e.*, vertebrates) and those "without" blood (*i.e.*, invertebrates). In the former he laid the basis for Linnaeus' first four classes. Ray also issued a preliminary *Methodus insectorurn* in 1705 and his *Historia insectorum*, incomplete when he died, was published in 1713 as it stood and without figures. Ray's system of insects, following Jan Swammerdam, was based upon metamorphosis (*q.v.*).

Ray also wrote *A Collection of English Proverbs* (1670; reissued 1855 and 1875) and *A Collection of English Words* (1674; reissued 1874).

The Ray society, for the publication of works on natural history, was founded in his honour in 1844.

BIBLIOGRAPHY.—C. E. Raven, John *Ray*, 2nd ed. (1950); G. Keynes, *John Ray, a Bibliography* (1951); *E.* Lankester (ed), *Memorials of John Ray* (1846), with *a* listing of Ray's works. (J. W. TT.)

RAY, a common name loosely applied to any of the numerous cartilaginous fishes (class Chondrichthyes) of the order Batoidei, distinguished from the related modern sharks by a flattened body, which has the five gill openings and the mouth generally located entirely on the undersurface, and by the greatly enlarged pectoral fins, which extend forward along the sides of the head above the gill openings. Rays are well fitted by their structure for life at the bottom of the sea. On the upper surface of the head, behind the eyes, are large holes leading to the pharynx; these are termed spiracles and serve for the intake of water for respiration. Most bear young live, but the skates (family Rajidae) have eggs enclosed in oblong horny cases similar to those of dogfishes. As in the sharks, the males have the posterior edges of the pelvic fins modified to form copulatory organs. For a detailed discussion of the anatomy and relationships in cartilaginous fishes *see* CHONDRICHTHYES.

The rays (Batoidei) may be broken down into the following special groups: electric rays (family Torpedinidae), guitarfishes (Rhinobatidae). sawfishes (Pristidae). skates (Rajidae), stingrays (Dasyatidae), eagle rays (Myliobatidae), mantas, including the devil rays (Mobulidae).

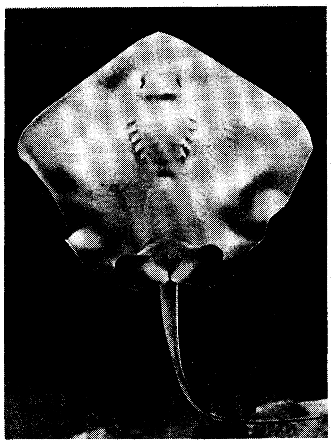
Electric Rays.—The electric rays form an isolated family distinguished by large paired electric organs formed of vertical hexagonal columns. between the pectoral fins and the head. and capable of giving powerful shocks either for defensive purposes or to kill prey. The electric rays have a smooth and naked skin; the head and trunk with the pectoral fins form a circular disc: the tail is short and stout. About 20 species are known from warm seas. some reaching a weight of 200 lb. One representative species is the torpedo *(Torpedo nobiliana),* which occurs from North Carolina to Nova Scotia and from tropical west Africa to Scotland. Another is *Torpedo californica,* which occurs along the

Pacific coast of the United States from central California northward.

Nonelectric Rays.——The other rays, without electric organs, generally have a rough skin, often bearing strong spines. The most sharklike are the guitarfishes (Rhinobatidae) of which about 20 species are known from tropical and subtropical seas; in most of them the pectoral fins are relatively small and the trunk passes gradually into the tail. The sawfishes, or sawrays (Pristis), differ from them in that the snout is produced into a long blade armed with a series of strong teeth on each side; five species are known from warm seas, frequenting sandy shores and estuaries.

The American sawfish (Pristis *pectinatus*) is common in the Gulf of Mexico, about the West Indies and occasionally is found on the Atlantic coast as far north as New Jersey. Small ones are excellent food. Some attain a length of 20 ft.; such large specimens are dangerous, the saw being a formidable weapon.

In the skates the large pectoral fins extend to the snout and backward stopping abruptly at the base of the slender tail. Numerous species of the cosmopolitan genus Raja are known, some living at considerable depths; some species reach a weight of 500 lb. These rays swim by undulating or flapping movements of the pectoral fins: their teeth are small and blunt in some species, pointed in others. Skates have two small dorsal fins on the rear part of the tail; they lack a distinct tail fin and also the long, slender recumbent barbed spine that characterizes the tail of stingrays. Their food consists of mollusks, crustaceans and fishes. Skates produce large, oblong eggs with dark, leathery shells having a tendril at each corner by which they become fastened to seaweed or other objects. The largest western Atlantic species is the Barndoor skate (*Raja* laevis), which is said to reach a length of six feet. Its European counterpart is R. *batis*. A Pacific American species, the California skate (*Raja inornata*), which occurs from San Diego to the Strait of Juan de Fuca, is probably the principal species of commerce in the northeastern Pacific. Around 80,000 tons of skates are caught annually in trawls, traps and beach seines and on hook and line. The largest quantities are landed in Japan, France, Great Britain and Spain. The pectoral fins are cut off and used as food.



BY COURTESY OF MIAMI SEAQUARIUM

UNDERSIDE OF SOUTHERN STINGRAY (DASYATIS AMERICANA), FAMILY DASYATIDAE

The remaining rays are collectively termed "whip-tailed," the tail being long and slender and usually having a barbed spine connected with a poison gland; this spine is capable of inflicting serious wounds and is a dangerous weapon when the tail is lashed. All the whip-tailed rays are inhabitants of warm seas, except a few kinds of stingray in the rivers of South America. In the stingrays (Trygon, etc.), as in most of the rays previously described, the teeth are numerous, small and blunt; in the eagle rays (*Myliobatis*) the teeth are relatively few in number, hexagonal, forming a flat pavement, and in the spotted eagle rays (Aetobatus) are reduced to a single series of broad flat teeth used to crush the shells of mollusks.

The largest rays are the devil rays, Manta and *Mobula*, which may measure 20 ft. across the disc. Unlike other whip-tailed rays. they lack the tail spine. Also the anterior ends of the pectoral fins are free and project forward; when rolled up, the edges look like a pair of horns, but when unrolled. they meet below the mouth to form a scoop. Devil rays have been observed pursuing small fishes and scooping them into their mouths.

(C. T. R.; L. A. WD.)

RAYAH, the name given to the subjects of a Mohammedan ruler; in later usage, to all who pay the poll tax levied on unbelievers (Arabic ra'iyah, "flock").

Five classes of rayahs existed under Turkish rule until the system was destroyed by the revolution follo ing World War I. These were: (1) the Greek, or *Roum* milleti; (2) the Armenian, or *Ermeni milleti;* (3) the Catholic Armenians, or *Ermeni* gatoliki *milleti;* (4) the Latin Christians. or Roum gatoliki nzilleti; and (5) the Jews, or Yahoudi milleti.

The name rayah was most commonly used of the peasants, but did not apply to the agricultural populations.

The same term ("ryot") was applied in India to peasants or landholding tenants.

RAYBURN, SAM (SAMUEL TALIAFERRO) (1882–1961), U.S. political leader who served as speaker of the U.S. house of representatives for 17 years, was born in Roane county, Tenn., Jan. 6, 1882. His family, of predominantly Scottish origin, moved to Texas in 1887, and there Rayburn grew up on a 40-ac. farm. He worked his way through East Texas State college at Commerce, taught school, and became a lawyer. He served in the Texas house of representatives for six years (1907–1913) and in 1911 was elected speaker. In 1912 he was elected to the U.S. house of representatives and served there continuously for 48 years and 8 months, a record tenure. He was elected to congress 25 consecutive times.

Energetic, studious, ambitious and affable, Rayburn quickly became influential behind the scenes in government and party politics. As chairman of the powerful congressional committee on interstate and foreign commerce (1931–37), he was a major architect of the New Deal. As a member of the house of representatives he was coauthor of six important laws — Railroad Holding Company act, "Truth-in-Securities" act, Securities Exchange act, Federal Communications act, Rural Electrification act, and the most bitterly contested of all New Deal laws, the Public Utility Holding Company act.

Rayburn was elected Democratic leader of the house of representatives in 1937 and became speaker of the house on Sept. 16, 1940. He held the latter office for 17 years, exceeding by a wide margin the record set by Henry Clay in the first quarter of the 19th century. Noted for his tart common sense, honesty and unflagging patriotism, he was a trusted adviser to Presidents Roosevelt, Truman, Eisenhower and Kennedy. A dedicated party man who described himself as a Democrat "without prefix, without suffix, and without apology," Rayburn was often called "Mr. Democrat." He was permanent chairman of the Democratic national conventions in 1948, 1952 and 1956. After winning the battle in 1961 to enlarge the house committee on rules — the hardest internal house struggle in 50 years — Rayburn's health failed quickly. Before congress adjourned, he went home to Bonham, Tex., where he died on Nov. 16, 1961. (L. B. J.)

RAYLEIGH, JOHN WILLIAM STRUTT, 3RD BARON (1842–1919), British physicist, was awarded the Nobel prize for physics in 1904 for his discovery (1894) of the inert elementary gas, argon, in collaboration with Sir William Ramsay. He was born near Maldon, Essex, on Nov. 12, 1842, and educated at Trinity college, Cambridge, where he graduated senior wrangler (1865). As successor to James Clerk Maxwell he was head of the Cavendish laboratory at Cambridge from 1879 to 1884, and in 1887 he became professor of natural philosophy in the Royal Institution of Great Britain. Elected (1873) a fellow of the Royal society, he was president from 1905 to 1908. He was an original recipient of the order of merit (1902) and a privy councilor (1905). His researches ranged over almost the whole field of physics, including sound, wave theory, optics, colour vision, electrodynamics, electromagnetism, the scattering of light, hydrodynamics, the flow of liquids, capillarity, viscosity, the density of gases, photography and elasticity as well as electrical measurements and standards. His researches on sound were embodied in his Theory of Sound, 2 vol. (1877–78), and his other extensive studies in physics appeared in his Scientific Papers, 6 vol. (1899–1920). Re died on June 30, 1919, at Witham, Essex. (D. McK.)

RAYMOND, HENRY JARVIS (1820–1869), the first editor of the New *York Times,* who did much to elevate the style and tone of newspapers in his day. Born near the village of Lima, Livingston county, N.Y., Jan. 24, 1820, and graduated from the University of Vermont (Burlington) in 1840, he taught, acted as correspondent for various papers, assisted Horace Greeley (*q.v.*) on the *New Yorker* and the *Tribune* and served on the *Courier and Enquirer* before he obtained backing for a venture of his own. The first issue of the *New York Times* appeared Sept. 18, 1851. Of this journal Raymond was editor and chief proprietor until his death. Raymond was a member of the New York assembly in 1850 and speaker in 1851 and again in 1862. He supported the views of the radical antislavery wing of the Whig party in the north. His nomination over Greeley on the Whig ticket for lieutenant governor and his election in 1854 led to the final dissolution of the famous political alliance of Seward, Weed and Greeley. He took a prominent part in the formation of the Republican party. and drafted the famous "Address to the People" adopted by the Republican convention that met in Pittsburgh, Pa., in Feb. 1856. He was a member of the national house of representatives in 1865–67. He retired from public life in 1867 and devoted his time to newspaper work until his death in New York city, June 18, 1869. He published several books, including a biography of Abraham Lincoln, which in substance originally appeared as *A History of the Administration of President Lincoln* (1864) and which with additions was republished under varying titles.

See A. Maverick, *Henry J. Raymond and the New York Press for Thirty Years* (1870); F. Brown, *Raymond* of *The Times* (1951).

RAYMOND, ROBERT RAYMOND, 1ST BARON (1673–1733), a great English judge, who became lord chief justice, was born on Dec. 20, 1673, the son of Sir Thomas Raymond. a judge under Charles II. He entered Gray's Inn in 1682 and was called to the bar in 1697. He soon acquired an extensive common-law practice, and in 1710 became solicitor general and member of parliament for Lymington, Hampshire, and was knighted. He lost office with the accession of George I in 1714, but by 1720 his Jacobite sympathies had been sufficiently forgiven for Lord Stanhope to make him attorney general. His position was uneasy. however, and in 1724 he surprisingly became a mere puisne judge of the king's bench. He at once displayed judicial powers of the highest order, and this, coupled with Walpole's admiration, led to his appointment as one of the lords commissioners of the great seal on Lord Macclesfield's disgrace in 1725. In the same year he succeeded Sir John Pratt as lord chief justice of the king's bench, an office which he held until his death on March 18, 1733; he had become a peer in 1731. Lord Raymond was a great judge, especially in criminal matters, and his reports, covering nearly 40 years, have a high reputation.

See Lord Campbell, *Lives of the Chief Justices* (1858).

(R. E. MY.)

RAYMUND (1099–1149), prince of Antioch, called RAYMUND OF POITOU, was the son of William VII, count of Poitiers (William IX of Aquitaine), and Philippa of Toulouse. On the death of Bohemund II of Antioch, the principality devolved upon his daughter. Constance, a child of less than ten years of age (1130). Fulk, king of Jerusalem and, as such, guardian of Antioch, sent envoys to England to offer her hand to Raymund, who was then at the court of Henry I. Raymund reached Antioch in 1135, where he was married to Constance. As prince of Antioch he faced no easy task Alice, the mother of Constance, uho had expected Raymund to marry her. was hostile to him. The atabeg Zengi, now firmly established in both Mosul and Aleppo, was beginning to extend his possessions at the expense of Antioch. while the eastern emperor. John II Comnenus. was preparing to enforce his claims to suzerainty over the city. In 1137 Raymund was forced to do homage to the emperor, and even to promise to cede his principality as soon as he was recompensed by a new fief. which John promised to carve for him in the Mohammedan territory to the east of Antioch. The expedition of 1138, in which Raymund joined with John and which was to conquer this territory, failed. The emperor made a solemn entry into Antioch, but the city was never handed over to him, and at his death in 1143 he still did not control the principality. Zengi's conquest of Edessa in 1144 and the subsequent collapse of that Frankish county further weakened Raymund's position. He was forced to visit Constantinople and to renew his oath of homage to Manuel I Comnenus. In 1149 he fell in battle against Nureddin, Zengi's successor.

(R C SMA.)

RAYMUND IV (c. 1042–1105), count of Toulouse, called also RAYMUND OF SAINT-GILLES (from his original countship), leader of the Provencal contingent on the first crusade, was the younger son of Pons, count of Toulouse (died 1061). Raymund became marquis of Provence by his marriage to his first cousin the heiress (1066); but this marriage was condemned by the church, and their son Bertrand held to be a bastard Raymund's second marriage (1080) was with Matilda of Sicily, niece of Robert Guiscard, his third (1094) with Elvira, daughter of Alphonso VI of Castile. In 1093, on the death of his brother Count William IV (with whom he had divided the paternal heritage), Raymund succeeded to the whole countship of Toulouse.

Having previously fought against the Moors in Spain, Raymund was the first of the princes of the west to take the cross after Pope Urban's sermon at Clermont. The oldest and the richest of the crusading princes, the count of Toulouse started, in Oct. 1096, with a large company, which included his wife. his son and Adhemar of Monteil, the papal legate. His march lay by Ragusa and Scutari to Durazzo, whence he struck eastward. along the route also used by Bohemund, to Constantinople. At the end of April 1097 he was with difficulty induced to take a somewhat negative oath of fealty to Alexius. He was present at Nicaea and Dorylaeum; but he first showed his hand in Oct. 1097, when. as the army neared Antioch and a rumour was spread that Antioch had been deserted by the Turks, he sent a detachment in advance to occupy the city—an action which presaged his future difficulties with Bohemund (*q.v.*), the would-be prince of Antioch.

In the siege of Antioch (which was far from having been deserted) Raymund played his part. When the city was taken by Bohemund (June 1098), the count garrisoned the palace of the amir Yagi Sian and the tower over the Bridge gate. He lay ill during the second siege of Antioch by Kerbogha; but in his camp a great spiritualistic activity culminated in the discovery of the Holy Lance by the Provençals. The miracle stimulated the crusaders to defeat Kerbogha; the Lance itself, discovered by the Provencals and carried thenceforward by their count, became a valuable asset in Raymund's favour. A struggle arose between the Provencals and the Normans, partly with regard to the genuineness of the Lance and partly with regard to the possession of Antioch. Raymund moved southward in the autumn of 1098 to the siege of Marra, leaving a detachment of his troops in Antioch. With Bohemund left in Antioch. with the Holy Lance to give him prestige and with the wealth which he had at his disposal, the count of Toulouse began to figure as the leader of the crusade. But he delayed the advance to Jerusalem to besiege Arca with the intention of founding a principality to check the extension of Bohemund's kingdom. A wave of indignation in the ranks and the inducements which the amir of Tripoli offered to the other princes forced Raymund to desist from the siege (May 1098) and to march southward to Jerusalem. Bohemund meanwhile had expelled Raymund's men from Antioch. Raymund took part in the storming of Jerusalem, but he hampered Godfrey in the campaigns which followed.

Raymund had come to the east with the intention of founding a principality. During the crusade his ambition had been thwarted at Antioch, Marra. Arca, Jerusalem and Ascalon. He then decided to advance his interests by upholding Byzantine claims in Syria. In Sept. 1099 he joined forces with the Greek garrison of Laodicea. then besieged by Bohemund. From Laodicea he went to Constantinople, where he fraternized with Alexius, the great enemy of Bohemund Joining in the ill-fated crusade which followed the first, he escaped from the debacle and returned to Constantinople. In 1102 he went by sea from Constantinople to Antioch, where he was imprisoned by Tancred, regent of Antioch during the captivity of Bohemund. and dismissed only upon promising not to attempt any conquests in the country between Antioch and Acre. He broke his promise, attacking and capturing Tortosa and beginning to build a castle on the Mons Peregrinus for the reduction of Tripoli, of which he is recognized as the first count (Raymund I). In this policy he was aided by Alexius. In 1105 Raymund died. He was succeeded by his nephew William who, in 1109, with the aid of Baldwin I, captured the town and definitely established the county of Tripoli. William was ousted in the same year by Raymund's eldest son Bertrand, and the county continued in the possession of his house during the 12th century. After partition between Bertrand and Alphonse (*q.v.*; Raymund's son by his third marriage), the county of Toulouse was united under Alphonse alone on Bertrand's death in 1112.

RAYMUND **III** (d. 1187), count of Tripoli, was the most famous of the descendants of Raymund IV of Toulouse (reckoned as Raymund I of Tripoli), a great-grandson of his eldest son Bertrand and son of Raymund II and Hodierna, a daughter of Baldwin II of Jerusalem. He became count of Tripoli in 1152, on the assassination of his father. He was captured by Nureddin in 1164 and was released in 1172 after a captivity of eight years. In 1174 he claimed the regency on behalf of Baldwin IV (*q.v.*) (at once a minor and a leper) in virtue of his close relationship, and the claim was acknowledged. After two years the regency passed successively to the two husbands of Sibyl, the king's sister and heiress; but Raymund, who had married the heiress of the county of Tiberias, continued to figure in the affairs of the kingdom. His great ability procured him enemies; for two years, 1180–82, they induced Baldwin IV to exclude Raymund from his territories. But as Saladin grew more threatening, Raymund grew more indispensable; and in 1184, when Guy of Lusignan, Sibyl's second husband, had proved his incapacity, Raymund became regent for Baldwin V, on condition that, if the king died before his majority, his successor should be determined by the great powers of the west. Raymund conducted the regency with skill, securing a truce from Saladin in 1185; but when Baldwin V died, in 1186, the supporters of Guy of Lusignan had him crowned, in defiance of the stipulation under which Raymund had become regent. Raymund, left in isolation. retired to Tiberias and negotiated a truce for himself with Saladin. His ambiguous position led contemporaries to accuse him of treasonable correspondence with Saladin; but his loyalty to the Christian cause was nobly shown in 1187, when he reconciled himself to Guy and aided him in the battle of Hattin, which was engaged, however, against his earnest advice. He escaped from the battle wounded and ultimately retired to Tripoli, where he died. With the growth of faction which marked the reign of Baldwin IV. Raymund emerged as leader of the native baronage against the "court" party that included the Lusignans, the Courtenays and Raynald of Châtillon. He was the most able statesman among'the Syrian Franks and might well have saved the Latin kingdom from its destruction by Saladin. (R. C. SMA.)

END OF VOLUME EIGHTEEN

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